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[Teorìâ ta Metodika Fìzičnogo Vihovannâ]

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ORIGINAL SCIENTIFIC ARTICLE

PHYSICAL ACTIVITY FOR OSTEOARTHRITIS: A CROSS SECTIONAL STUDY

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Background. Physical activity is a fundamental and proactive form of conservative treatment for persons with knee osteoarthritis.

Study purpose. This study aims to investigate risk variables for individuals in Indonesia who had knee osteoarthritis (OA).

Materials and methods. This study's cross-sectional study design employed an observational analytical approach. The samples obtained using Slovin's formula contained as many as 66 respondents. The study's dependent variables were the primary and secondary types of knee OA.

Results. The study's dependent variables were the primary and secondary forms of knee OA. 43 patients experienced the primary knee OA, while 23 experienced the secondary OA. The logistic regression test used age (p=0.011), gender (p=0.021), body mass index (p=0.027), history of knee injury (p=0.001), hypertension (p=0.023), hypercholesterolemia (p=0.112), and physical activity (p=0.004) as independent variables. These variables also met the criteria to be incorporated into the multivariate analysis with a p value less than 0.25. The biggest risk factor for knee OA was found to be age (OR=1.923; p=0.011; p=0.011). Knee OA is significantly influenced by age, gender, BMI, a history of knee injuries, and physical activity.

Conclusions. Increased physical activity is necessary for those with knee osteoarthritis. Patients with knee osteoarthritis should be treated by healthcare professionals who are aware of their physical activity habits, especially those at risk.

Keywords: osteoarthritis, physical activity, rehabilitation, pain.

Introduction

A chronic degenerative joint condition that affects the articular cartilage is osteoarthritis (OA). Because of the constant pressure over many years, this condition, which is directly associated to aging, is most commonly found in the joints of the knees, hips, fingers, and lumbar vertebrae (Kesehatan et al., 2019).

According to WHO data, there are 9.6% more males than women with OA than are over 60 years old (Charlesworth et al., 2019). In patients aged 40 to 60 years in Indonesia, the prevalence of knee OA is established by radiological examination and is 15.5% in males and 12.7% in women (Kesehatan et al., 2019). An average prevalence of joint illness of 24.7% was determined by Indonesian Basic Health Research (Riskesdas) data in 2019 from respondent interviews with a sample of 722,329 people aged 15 from each province in Indonesia. Around 27% of the population in East Java Province suffers from OA, which is a rather significant prevalence (Kesehatan et al., 2019).

Although the exact etiology of OA is unknown, a number of risk factors can lead to the disease. You can divide these risk factors into non-modifiable and modifiable categories. Age, gender, physical disability/body imbalance, trauma history, and ethnicity are risk factors that cannot be changed. Osteoarthritis typically affects elderly people and is more prevalent in women (Derwich et al., 2020). Body mass index (BMI), diabetes, hypercholesterolemia, hypertension, and smoking are the risk factors that can be changed. Review articles on obesity and osteoarthritis by Bestwick-Stevenson et al. (2021) came to the conclusion that obesity is a modifiable risk factor that has the strongest correlation with the development of knee OA.

The World Health Organization (WHO) claims that both industrialized and developing nations are susceptible to the impairment caused by OA. Knee and hip osteoarthritis is the 11th most prevalent form of disability worldwide (Choi et al., 2019). One of the causes of disability is mechanical and chemical injury, which is one of the etiologies for defective cartilage metabolism and damage to proteoglycans. An key contributor to joint inflammation, chondrocyte destruction, and pain is assumed to be mechanical and chemical insult, which induces the development of aberrant molecules and cartilage breakdown products in the synovial fluid of the joint (Abramoff & Caldera, 2020). Patients with knee OA will have continuous and escalating discomfort near the knee joint. If you engage in knee-taxing activities like walking, climbing and descending stairs, or prolonged standing, the discomfort will worsen. These conditions range in severity from minor to so severe that the sufferer is unable to walk (Zeng et al., 2021). In order to lessen pain, patients with knee OA will restrict knee joint mobility. Long-term immobilization of the knee joint muscles causes weakening and even atrophy. This will affect the victim's socioeconomic circumstances (Whittaker et al., 2021).

The results of the history, physical examination, and radiographic examination are used to make the diagnosis of osteoarthritis. Patients with osteoarthritis of the knee typically report long-standing pain complaints, but the condition progresses slowly (Ghouri & Conaghan, 2021). Physical examination revealed that the knee joint had little range of motion. An osteophyte picture in the knee joint was found aberrant during a radiological evaluation using an X-ray of the knee joint. However, joint radiographs taken early in the disease are frequently normal (Blanco et al., 2021).

Joint function has not been able to return to normal following pharmacological treatment for OA. Non-steroidal anti-inflammatory medicines (NSAIDs), for example, are used in pharmacological therapy to alleviate OA symptoms such pain and swelling (Astephen Wilson & Kobsar, 2021). Additionally, hyaluronic acid molecules used in intra-articular injection therapy only served to improve the suppleness and viscosity of joints rather than changing illness (Boer et al., 2021). Intra-articular injections and the use of NSAIDs have not yet significantly improved outcomes. Surgery is another option for treatment, although the outcomes are also unsatisfactory. Surgery can only effectively reduce discomfort; it cannot significantly enhance joint function (Cao et al., 2021). Therefore, a primary goal in reducing disability from OA is the recognition of risk factors in attempts to prevent OA. According to studies on 30 people with knee osteoarthritis in Yogyakarta, it is possible to significantly slow the course of knee OA by decreasing weight, performing regular knee exercises, and taking medication on a regular basis (Rohmansyah et al., 2021). The purpose of this study was to investigation risk factors for patients in Indonesia with osteoarthritis (OA) of the knee joint will be analyzed.

Materials and methods

Design

Analytic observational methodology and a cross-sectional design were employed in this study. This study was carried out in the provincial hospital's orthopedic polyclinic, medical records department, and each respondent's residence.

Study participants

There were 127 individuals with knee osteoarthritis who received care at provincial hospitals in the most recent six months, from 1 December 2018 to 30 May 2019. All OA patients who met the inclusion criteria and gave their informed agreement to participate in the study made up the sample for this investigation. Patients with knee osteoarthritis in a provincial hospital who agreed to participate in the trial were the only inclusion criteria.

Patients with osteoarthritis affecting joints other than the knee, gout, rheumatoid arthritis, systemic lupus erythematosus (SLE), and rheumatic fever, patients with a history of patellar fractures, femur fractures, and tibia fractures, and patients with incomplete medical records were all excluded from this study. The Slovin algorithm was used to determine the sample size (Arikunto, 2017), yielding 56 responses.

$n=N/(1+Ne^2)$

Information:

N: number of samples

n: total population

e: fault tolerance limit

Measurement

Blood sugar and cholesterol levels

If the respondent doesn't know their blood sugar and cholesterol history, the technique of measuring those values will be used. Sitting down, respondents underwent a physical examination. Install a glucose or cholesterol chip and prepare the tool in an ignitable state. In the lancet pen, get a sterile needle ready. Aseptic protocols should be followed on the region where the droplets will be collected and an alcohol swab should be prepared. In the ring or middle finger's palm, place the pen lancet. The examiner uses the examination chip to take blood samples from the respondent and measure their cholesterol and blood sugar levels. A single exam will be used to measure both cholesterol and blood sugar levels. Milligrams per deciliter of blood (mg/dl) are the units used to measure blood sugar and cholesterol levels.

Physical activity assessment

A Baecke physical activity questionnaire was used in this interview-based study. The physical activity questionnaire is broken down into three categories: activities done while at work or connected to work, activities done in free time or away from work, and activities done while participating in sports. The findings of the assessment of physical activity can be divided into three levels, namely low, moderate, and heavy activities, based on the Baecke index score (Sadeghisani et al., 2016), mild activity (score 5.6), such as sweeping the floor, washing the dishes or clothing, sitting and watching television, usually involves little effort and has no noticeable effects on respiration or endurance. Moderate exercise (score 5.6-7.9) that calls for sustained or intensive effort as well as flexible muscular action, such as jogging, table tennis, swimming, cycling, and brisk walking. Running, playing soccer, doing

aerobics, and self-defense are examples of strenuous activity (score > 7.9) that typically relates to sports and calls for strength and perspiration (Sadeghisani et al., 2016).

Statistical analysis

Using the Excel 2020 application, data were gathered and processed. Univariate and bivariate analyses of the data were performed. Descriptive statistics are used in univariate analysis to identify the sample identification (age, gender, occupation), body mass index (BMI), history of disease or injury, smoking habits, and physical activity, as well as other aspects of the data. Due to the fact that the data utilized in this study are nominal data with non-parametric statistics and a significance threshold of $p<0.05$, bivariate analysis is employed to determine the relationship between the dependent variable and the independent variable. Because the used dependent variable was dichotomous/had two categories, the independent variables were not interval or ratio data, and they were not regularly distributed/non-parametric statistics, multivariate testing using logistic regression was performed to determine the most significant variable. Utilizing statistical analysis software throughout the entire data processing and analysis process.

Results

Primary and secondary osteoarthritis of the knee are the two classifications. 43 primary OA and 23 secondary OA were found in the study's 66 samples of knee OA. With a sample size of 51 patients, the age group with the highest prevalence of knee OA was 41–61, whereas the group with the lowest prevalence was 21–40, represented by 15 patients. There were 17 patients with male sexual orientation and 49 patients with female sexual orientation.

The majority of patients with knee OA, or 23 individuals, work as housewives. The remaining patients are traders, laborers/farmers, public servants, retirees, and entrepreneurs.

With 28 patients, the overweight category (BMI 25–29.9 kg/m2) had the highest BMI. In contrast, 8 patients fell into the underweight BMI category (18.5 kg/m^2), which had the lowest percentage. 18 patients in 66 samples of osteoarthritis patients had a history of knee injury, while 48 patients had no such history. There were 10 patients with OA in their families and 56 individuals without OA in their families.

In 29 patients with knee OA, hypertension and a history of hypertension were present. While there were 47 patients who had no history of hypertension. 53 patients had no history of diabetes, compared to 13 patients who both had diabetes and that history. Thirteen patients had both hypercholesterolemia and a history of it, compared to 53 patients who had no such history. In the non-smoking category, 42 patients had the greatest smoking habit. The examination of the level of physical activity revealed that there are 33 persons who engage in moderate physical activity, 26 who engage in severe physical activity, and 7 who engage in light physical activity.

The independent variables used in the logistic regression test were age ($p = 0.011$), gender ($p = 0.021$), body mass index ($p = 0.027$), history of knee injury ($p = 0.001$), hypertension ($p = 0.023$), hypercholesterolemia ($p = 0.112$), and physical activity ($p = 0.004$). These variables also met the criteria to be included in the multivariate analysis with a p value of less than 0.25.

Table 1. Risk factor for OA

Variable	OA primary	OA secondary	p value
Age			
21-30	2	5	0.021
31-40	3	5	
41-50	10	2	
50-60	14	8	
61 and above	14	3	
Gender			
Women	35	14	0.011
Man	8	9	
BMI			
Underweight	3	5	0.034
Normal	6	8	
Overweight	20	8	
Obesity	18	7	
History of knee injury			
Yes	7	11	0.001
Not	37	11	
Physical Activity			
Light activity	4	3	0.005
Moderate activity	16	17	
Strenuous activity	22	4	
Family history of OA			
Yes	6	4	0.635
Not	36	20	
Hypertension			
Yes	20	9	0.312
Not	28	19	
DM			
Yes	9	4	0.247
Not	34	20	
Hypercholesterolemia			
Yes	9	4	0.113
Not	36	21	
Smoking habit			
Do not smoke	31	11	0.412
Light smoker	2	3	
Medium smoker	6	6	
Heavy smoker	4	5	
Work			
Trader	9	4	0.284
Farm workers	11	7	
Civil Apparatus	2	1	
Retired	1	2	
Self-employed	3	4	
Housewife	17	5	

Table 2. All variables are entered into the model

Variable	p value	OR
Age	0.011*	1.923
Gender	0.023*	1.136
BMI	0.023*	1.952
History of knee injury	0.001*	0.042
Physical activity	0.004*	3.729
History of OA	0.673	0.032
Hypertension	0.214*	0.783
Diabetes mellitus	0.238*	1.054
Hypercholesterolemia	0.112*	1.832
Smoking habits	0.424	3.837
Occupation	0.372	3.657

Discussion

Age and knee OA were shown to be significantly correlated in this study (p = 0.005). The percentage of women with OA rises with age, according to research by Nelligan et al. (2019) among 422 women aged 30 to 60. Age was discovered to be strongly related to knee OA (Ghouri & Conaghan, 2021).

Osteoarthritis is a degenerative joint condition that affects the elderly in particular. When a person reaches age 45, they are considered old (Kesehatan et al., 2019). Age-related changes in collagen and a decline in the production of proteoglycans make bones and joints less elastic and more prone to damage (Abramoff & Caldera, 2020). Age-related hormonal changes raise the risk of knee OA, particularly in women following menopause. This implies that hormones play a role in the etiology of OA (Dantas et al., 2021).

According to the study's findings, there is a statistically significant link between gender and knee OA (p = 0.021). Studies showed that women had a noticeably higher incidence of knee OA (Aubourg et al., 2022). As they approach menopause, older women will see a decline in estrogen levels as well as other bodily processes. One of the hormone estrogen's tasks is to aid in the production of chondrocytes, or cartilage cells, which are found in the bone matrix. Because chondrocyte synthesis is affected by estrogen hormone levels, the production of collagen and proteoglycans is also affected. Additionally, as a person ages, lysosomal activity increases, which is why OA affects women more frequently than men (Bierma-Zeinstra et al., 2020).

The results of this study revealed a significant association between BMI and knee OA (p=0.027). This is consistent with the findings of Batushansky et al. (2022) who observed that all 65 respondents with knee OA weighed more than their optimal body weight, and the majority were slightly obese or overweight by 20–40% of their body weight. ideal. Degeneration will be accelerated by excess body weight, especially in the joints that support the weight. Half of the body weight is supported by the knee joint when someone is walking. As a result, carrying more weight doubles the load placed on the knee joint while walking, which can lead to knee OA (Batushansky et al., 2022).

A history of knee injuries and knee OA were shown to be significantly correlated in this study (p=0.001). According to a study by Kolasinski et al. (2020) women with knee OA were more likely to have a history of prior knee injuries than women without such a history. This demonstrates that knee trauma or injury is a factor that affects the prevalence of knee OA. Mechanical injury, which is thought to be a significant factor in stimulating the formation of abnormal molecules and cartilage degradation products in the synovial fluid of the joint, can be brought on by knee injuries such as meniscus tears, ligament instability, intra-articular fractures, or joint dislocation. This causes chondrocyte destruction, joint discomfort, and joint inflammation. This causes chondrocyte destruction, joint discomfort, and joint inflammation (Charlier et al., 2019).

Physical activity and knee OA were shown to be significantly correlated in this study (p=0.004). This is consistent with studies by Sun et al. (2019), which found that middle-aged women and men who engage in vigorous physical activity run the risk of injuring their knees and developing osteoarthritis. OA may be exacerbated by excessive body weight and repetitive joint activity. In persons who are predisposed to OA, repeated impact loads can be a site-defining factor and may be linked to the onset and severity of OA (Block et al., 2022).

According to this study, there was no connection between a family history of OA and knee OA (p=0.542). The findings of this study differ from those of O'Neill & Felson's (2018) study, which found that family history of OA significantly affects the incidence of knee OA (OR: 1.78). This might be as a result of the small sample size and population in the study, which was only carried out at one healthcare agency.

According to this study, there was no discernible link between hypertension and knee OA (p = 0.203). The findings of this study differ from those of O'Neill & Felson's (2018) study, which discovered that individuals with OA were more likely to develop hypertension than the general population (40%vs25%). This may be the result of the responders to this study having hypertension that was sufficiently under control to prevent blood vessel constriction. Uncontrolled hypertension causes blood vessel constriction and subchondral ischemia, which, according to Vina & Kwoh (2018), can cause OA. This kind of subchondral ischemia can encourage bone remodeling and hinder the metabolism of nutrition and gas exchange between articular cartilage and bone.

Diabetes mellitus and knee OA were shown to have no meaningful link in this study (p=0.279). This study is consistent with previous research O'Neill & Felson's (2018) the non-diabetic group had a higher prevalence of knee OA, both in men and women, according to a study using a sample of 3428 adults aged 40 to 74. This may be brought on by the fact that just one examination is performed to measure blood glucose levels, and that the test utilized is a random blood glucose assay (GDA), which is not the ideal test for doing so. HbA1C testing is the procedure that provides the best baseline for managing diabetes (Abramoff & Caldera, 2020). Additionally, diabetes respondents did not report having significant hyperglycemia, which can result in consequences such diabetic neuropathy.

According to this study, there is no connection between hypercholesterolemia and knee OA (p=0.107). The findings of the study by Choi et al. (2019) which indicated that only 27.6% of patients with a history of dyslipidemia had knee OA, also found the same conclusion. Choi et al. (2019) claim that an accumulation of cholesterol can lead to a disruption in the metabolism of cholesterol secretion in degenerative articular cells and result in the onset of OA. This is because the respondents' hypercholesterolemia is under good control, preventing an excessive buildup of cholesterol in the cartilage. In the end, there won't be any disruptions to the metabolism of cholesterol excretion in degenerative articular cells, which won't lead to the onset of OA.

The findings demonstrated that smokers had a lower prevalence of OA than non-smokers. According to this study, there was no discernible link between smoking and knee OA (p = 0.304). This may be due to the research participants' failure to boost the body's level of nicotine through cigarette usage. When the body's nicotine levels are low, osteoblasts continue to function correctly in cartilage and levels of carbon monoxide in the arteries rise, preventing damage to cartilage and normal bone resorption and osteoclast activity (Whittaker et al., 2021). Additionally, one study discovered a link between smoking history and knee OA, meaning that smoking among healthy persons without present or prior knee illness increased knee joint cartilage volume and de-

creased cartilage degradation. This is due to the nicotine in cigarettes' ability to stimulate the chondrocytes' metabolism of protein and enhance the production of glycosaminoglycans and collagen, both of which are important for maintaining joint flexibility (Zeng et al., 2021).

Limitations

This study has a number of limitations, including the fact that the variables hypertension, diabetes mellitus, and hypercholesterolemia are only divided into two categories (yes/no), which means that the study is unable to consider how seriously these conditions may affect the dependent variable. The duration, number of cigarettes smoked daily, and kind of cigarette were not assessed by the smoking habit variable, making it difficult to conduct an appropriate study of the association between smoking behavior and knee OA.

Conclusions

Patients with knee osteoarthritis had significantly lower levels of physical fitness than healthy persons, but the study should be replicated with a larger sample size because increasing physical activity is an essential objective for those with knee osteoarthritis. Our findings suggest that interventions to increase physical activity in people with knee osteoarthritis are crucial, especially for those who are older or have comorbid conditions. Clinicians should make it clear to patients that physical activity does not worsen their condition and assist them in finding activities to improve their physical fitness.

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Conflict of interest

The authors declared no potential conflicts of interest.

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ФІЗИЧНА АКТИВНІСТЬ ДЛЯ ТЕРАПІЇ ОСТЕОАРТРИТУ: ПЕРЕХРЕСНЕ ДОСЛІДЖЕННЯ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

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Історія питання. Основним і проактивним видом консервативного лікування хворих на артроз колінного суглоба є фізична активність.

Мета дослідженя. Метою цього дослідження є вивчення змінних ризику для осіб в Індонезії, які мали остеоартрит (ОА) колінного суглоба.

Матеріали та методи. За планом перехресного дослідження в цьому дослідженні використовували спостережний аналітичний підхід. Вибірки, одержані за формулою Словіна, містили 66 респондентів. Залежними змінними в цьому дослідженні були первинний і вторинний типи ОА колінного суглоба.

Результати. Залежними змінними в цьому дослідженні були первинна та вторинна форми ОА колінного суглоба. У 43 пацієнтів спостерігався первинний тип ОА колінного суглоба, а у 23 – вторинний тип ОА. Як незалежні змінні в логістичному регресивному тесті використовували вік (p=0,011), стать (p=0,021), індекс маси тіла (p=0,027), історію травм колінного суглоба (p=0,001), гіпертензію (p=0,023), гіперхолестеринемію (p = 0,112) та фізичну активність (p = 0,004). Ці змінні також відповідали критеріям для включення в багатофакторний аналіз зі значенням p, меншим за 0,25. Установлено, що найбільшим фактором ризику ОА колінного суглоба є вік (відносний ризик=1,923; p=0,011; p=0,011). ОА колінного суглоба значною мірою залежить від віку, статі, ІМТ, історії травм колінного суглоба та фізичної активності.

Висновки. Особам з остеоартритом колінного суглоба необхідна підвищена фізична активність. Пацієнтів з остеоартритом колінного суглоба, особливо тих, хто входить до групи ризику, мають лікувати медичні працівники, яким відомо про їхні звички до фізичної активності.

Ключові слова: остеоартрит, фізична активність, реабілітація, біль.

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ORIGINAL SCIENTIFIC ARTICLE

IMAGERY AND AGILITY TRAINING: HOW DO THEY AFFECT THE REACTION ABILITY OF FUTSAL GOALKEEPERS?

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Abstract

Study purpose. Goalkeepers in futsal require fast movements to anticipate the ball that is heading toward the goal. Therefore, the reaction of the goalkeeper is very necessary to improve the quality in the game.

Materials and methods. This research is experimental research conducted using factorial design research using a quantitative approach. In this research, the researchers use treatment with imagery exercises, with audiovisual and visual methods, with measuring the level of ability and agility of each sample in a group experiment. The type of instrument used to measure the ability of the goalkeeper's reaction speed in this study is the whole-body reaction test. The population in this study was high school (SMA) students who played futsal goalkeepers throughout the city of Metro, with the number of participants being 90 students of 9 high schools throughout the city of Metro. Purposive sampling technique was used so that a sample of 24 students was obtained.

Results. The results of the study prove that the significance value of imagery training is 0.001 < 0.05 which means "Ha is accepted", then there is an effect of Imagery training on the goalkeeper's reaction time. Next, the significance value of Agility training is 0.018 <0.05, which means "Ha is accepted", then there is an effect of agility training on the goalkeeper's reaction time. There is a significant difference between imagery training using audiovisual, high agility, and imagery training using audiovisual, low agility, with a significance value of 0.016. While there is no significant difference between imagery exercises using visuals, high agility and imagery exercises using visuals, low agility with a significance value of 0.395.

Conclusions. Based on the results, it can be concluded that imagery and agility exercises have a significant effect on the reaction time of goalkeepers in futsal.

Keywords: imagery training, agility training, goalkeeper reaction, futsal, sports.

Introduction

Intermittent game sport (Costa Miranda, Santos Cerqueira, & Bouzas Marins, 2020), considering that every time it is necessary to reduce the duration with high intensity. In addition, a futsal player must have high competence in terms of endurance (Naser, Ali, & Macadam, 2017a; Wibisana, 2020), and requires tactics (Miftachurochmah et al., 2021), technique, and excellent physical condition (Litardiansyah & Hariyanto, 2022). Where the intermittent nature of exercise requires the use of aerobic and anaerobic energy during training and competition (Dwi Juniarsyah, Safei, Bahri, Resmana, & Fahmi Hasan, 2021; Suryadi & Rubiyatno, 2022). In team sports, such as futsal which dominates overt motor skills, it is necessary that players constantly adapt their actions to the movements of opponents and teammates to ensure functional collective behavior (Chow, Davids, & Button, 2016), and can increase the number of needs physics and its importance (Mancha-Triguero, Martín-Encinas, & Ibáñez, 2020).

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Futsal is also considered a fast-growing game sport in the world (Lopes, Oliveira, & Ribeiro, 2020), and is becoming a popular team sport (Spyrou, Freitas, Marín-Cascales, & Alcaraz, 2020). Furthermore, in Malaysia, futsal has become one of the main sports at sports parties (Ahmad-Shushami & Abdul-Karim, 2020), not far behind in Indonesia, futsal has developed and is well known (Rayawang, SP, & Basuki, 2017; Yuniva, Andriansah, & Ikhsan, 2020; Zein et al., 2020), and are loved by almost all circles of society (Purwanto, Nugraha, Prayogha, & Syahputra, 2021; Salahuddin, Haluti, & Nurhikmah, 2021). This statement provides evidence that the game of futsal is currently undergoing major changes, this can be seen during the futsal world cup match that took place. All eyes are on the match, and of course the game technique, rules, The sport of Futsal is played by 5 players, one of which is a goalkeeper (Naser, Ali, & Macadam, 2017b), where this sport has a high intensity and intermittent, but also has a high risk of injury (Ahmad-Shushami & Abdul-Karim, 2020), and tends to cause dehydration (Zein et al., 2020). Although factors such as strength, endurance, power and balance are important in futsal (Agras, Ferragut, & Abraldes, 2016), the assessment of a futsal player must also depend on his special futsal skills such as goalkeeper. Where the position of the goalkeeper in the game of futsal is a certain position and the demands placed on quick and precise reactions are even greater. This statement is in line with (Fadi & Sutresna, 2019) who said that the futsal goalkeeper really needs a reaction in anticipation so that the ball does not go into the goal. In addition to reaction speed, explosive power (Montesano, 2016), and all speed skills in the game are also very necessary (Dragijsky et al., 2016) (Smpokos, Mourikis, & Linardakis, 2018).

A study conducted by (Hülsdünker, Strüder, & Mierau, 2018) proves that athletes have better reaction times than non-athletes, where the ability to see and hear has a relationship with reaction time test results (Atan & Akyol, 2014). There is a relationship between reaction time, movement speed and agility with fitness (Moradi & Esmaeilzadeh, 2015), because poor fitness will affect the activities to be carried out (Suryadi, 2022; Suryadi & Rubiyatno, 2022; Suryadi, Samodra, & Purnomo, 2021). A goalkeeper in a match, the reaction will be formed when making a save shot (Otte, Millar, & Klatt, 2020). Several studies have shown that reaction time and age are the main factors influencing skills (Birren & Schaie, 2005; Chang, Pan, Chen, Tsai, & Huang, 2012; Der & Deary, 2006). Furthermore, it is proven by (Moradi & Esmaeilzadeh, 2015) that the measurement of reaction time is closer to the agility variable.

Bompa & Buzzichelli (2019, 2021) say agility is a person's ability to change direction quickly, and this is a very important factor in many sports. Another study that proved reaction time in karate athletes gave accurate results with agility tests within 0.8 meters (Zemková, 2016). Research has shown that reaction time is also influenced by sleep deprivation (M. Jarraya, Jarraya, Chtourou, Souissi, & Chamari, 2013; S. Jarraya, Jarraya, Chtourou, & Souissi, 2014), fasting conditions for 14 hours and exercise (Cherif et al., 2018), and anxiety (Singh, Prakash, Punia, & Kulandaivelan, 2017). Based on this review, this illustrates that in order to get it, a goalkeeper needs to deal with two other important temporal dimensions that underlie motor skill performance including anticipation and reaction time. (Schmidt & Wrisberg, 2010; Tani, 2016). Based on this problem, the temporal coincidence that the goalkeeper is looking for in relation to the ball moving towards the goal can be preceded, so as to be able to defend the goal from attacks. A kick towards the goal that is fired from close range so that high reflex skills are needed (Scheunemann, 2012).

Various attempts were made to increase reaction time, one of which was by increasing agility and speed through high-intensity interval training (Fauzi, Wiriawan, & Khamidi, 2020), drill leader (Fantiro, 2018; Puriana, 2017). There are four aspects that need to be considered and trained including physical exercise, technical training, tactical training, and mental training (Harsono, 2015). According to (Muhammad Muhyi Faruq, 2014) physical exercise is one very important aspect, in which the physical components and classifications in men's football are strength, muscle endurance, speed, agility, flexibility, power and cardiopulmonary endurance. Next, there is a relationship between reaction speed, agility and confidence with penalty kick anticipation (Lubis, 2014). A goalkeeper will have difficulty responding to a directed ball if he does not have reaction and speed, a goalkeeper who has the ability to react quickly is an expensive plus. Reaction time is one of the important supporting elements that need to be tested for measurement (Eckner et al., 2015), especially for goalkeepers who really need a reaction (Fadi & Sutresna, 2019). Therefore, effective training is needed to increase the goalkeeper's reaction time, so this is an important point to do. Based on this statement, this study aims to prove the effect of imagery and agility training on the reaction ability of futsal goalkeepers.

Materials and methods

Participant

This study involved high school (SMA) students in the position of futsal goalkeepers in Metro City with 90 students participating, consisting of 9 High Schools in Metro City who participated in the Student Futsal League. In this study using perposive sampling technique with criteria for age 16-18 years, goalkeeper position, male students and players who have an agility ladder and agility hurdle, so that a sample of 24 students is obtained.

Data Collection Techniques and Instruments

The type of instrument used to measure the ability of the goalkeeper's reaction speed in this study was the whole body reaction test with reliability and validity coefficients of 0.93 and 0.607 according to Nurhasan (Nurhasan, 2008). To perform the whole body reaction time test, the researcher used the whole body reaction time test. This test is carried out to determine the level of whole body reaction time from all samples. This type of test consists of two types: 1) visual, namely doing tests using the sense of sight and 2) Audio, namely doing tests using the sense of hearing (Miyatake, 2012).

Prosedure

Experimental research conducted using a factorial design research design using a quantitative approach, the

approach Quantitative data uses a lot of numbers, starting from data collection, interpretation to the data, as well as appearance of the results (Sugiyono, 2019). In research this researchers use treatment (treatment) with imagery exercises with audiovisual and visual methods with level ability agility each sample to group experiment. The process of training carried out on the futsal field, imagery training using audiovisual with the procedure of students seeing training videos that have been prepared by the coach to be implemented in the field, as well as the imagery training process using visuals, students seeing pictures of exercises that have been prepared by the coach to be implemented in the futsal field.

Table 1. 2×2. Factorial Research Design

Imagery Agility	Audio visual A1	V visual A2
Tall B1	A1B1	A2B1
Low B2	A1B2	A2B2

Agility test after high and low results are grouped in both training methods, then grouped into groups exercise method. The results are taken high and low. The procedure for obtaining a high component group and a low component group in the two training methods is 27% of the total score of each group, then an order is taken from the highest score to the number of samples required and an order is taken from the lowest score to the number of samples required., the score midway between the highest and lowest scores is omitted. If the test takers are large enough, then the division of the upper and lower groups, is taken 27% of students who have high-high scores as the upper group and 27% of students who have low-low scores as the lower group.

Data Analysis

The data analysis technique used in this study is the ANOVA test, before the ANOVA test is carried out, the analysis requirements test is carried out, namely the Normality Test; and Homogeneity Test assisted using the SPSS version 23 application program and a significance level of 5%, The analysis was continued with the Least Significance Difference (LSD) test.

Result

Based on the results of the normality test, the significance value shows 0.971 and 0.946 > 0.05, thus it can be concluded that the sample comes from a normally distributed population. The results can be seen in table 2.

Table 2. Normality Test One-Sample Kolmogorov-Smirnov Test

	AV	V
N	12	12
Kolmogorov-Smirnov Z	0.488	0.525
asymp. Sig. (2-tailed)	0.971	0.946

The research hypothesis test was carried out using analytical techniques on 2×2 factorial ANOVA, the summary of which can be seen in table 3.

Table 3. 2×2 Factorial Anava Results (2 Way Analysis of Variance)

Dependent Variable: post				
Source	df	F	Sig.	Note:
Imagery Practice	1	16.603	0.001	There is a significant influence
Agility	1	6.968	0.018	There is a significant influence

Based on the results in table 3, it is known that the significance value of imagery training is 0.001 < 0.05 which means "Ha is accepted" then there is an effect of Imagery training on the goalkeeper's reaction time. Next, the significance value of Agility training is 0.018 <0.05, which means "Ha is accepted", then there is an effect of agility training on the goalkeeper's reaction time.

Based on the results of the main effect above and shows the influence of the interaction between factors or treatment of imagery training and agility then tested the simple effect with the LSD difference test statistic in table 3.

Table 4. Simple Effect Calculation Results with LSD Difference Test Statistics

Group	Average Difference	Sig	Sig	Conclusion
A1B1–A1B2	39.59	26.77	0.016	0.05	There is a significant influence
A2B1–A2B2	28.94	19.42	0.395	0.05	No significant effect

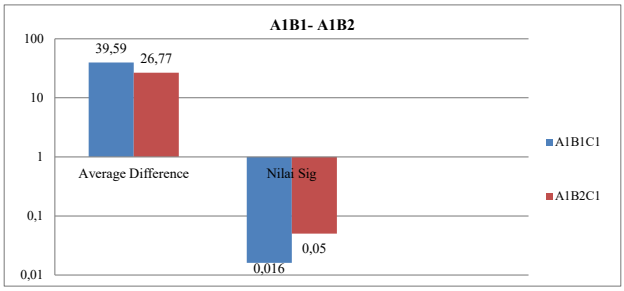

Fig. 1. Result Chart A1B1 – A1B2

The difference shows that in imagery exercises using audiovisual, high agility is obtained on average is X = 39.59 while imagery exercises using audiovisual, low agility obtained the average is X = 26.77. Where from the results of significance 0.016 < 0.05 so it can be concluded that there is a significant difference between imagery training using audiovisual, high agility and imagery training using audiovisual, low agility (fig. 1).

Imagery practice using visual, high agility the average obtained is X = 28.94 while the imagery exercise using visual, low agility is obtained on average is X = 19.42. Where from the results of significance 0.395 > 0.05 so it can be concluded that there is no significant difference between imagery

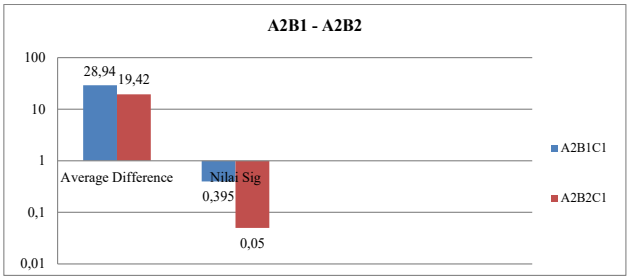

Fig. 2. Result Chart A2B1 – A2B2

training using visuals, high agility and imagery training using visuals, low agility (fig. 2).

Discussion

This study aims to prove the effect of imagery training and agility training on the reaction ability of goalkeepers in futsal, so that they can be used as training activities to increase the reaction time of goalkeepers. The results of the 2x2 factorial ANOVA test show that imagery and agility training on the goalkeeper's reaction time t count is greater than t table. In addition, the results of the significance test show that the effect is significant. Based on these results, it can be concluded that imagery and agility exercises have a significant effect on the reaction time of goalkeepers in futsal. Relevant research in basketball games proves that imagery training with a low concentration level and a high concentration level has an effect on students' lay-up abilities (Akbar, Priambodo, & Jannah, 2019), and is able to increase players' reaction time (Hariyanto, Prakosa, & Sholikhah, 2021).

Recent research has shown that by doing imagery exercises for eight weeks using video, it can significantly increase the total RMST time of soccer players, reactive agility time, passing time, and passing accuracy (Majlesi, 2021). Imagery exercise combined with physical exercise turned out to give more effective results than physical exercise alone, these results indicate a difference in the effect given (Simonsmeier, Andronie, Buecker, & Frank, 2021). This statement is also reinforced by several previous studies that suggest doing imagery exercises because they are considered effective for improving psychological skills (Cumming & Williams, 2013; Guillot & Collet, 2008). Another study was conducted on futsal goalkeepers that the speed of reaction time can be increased by using the 8-point star drill method (Fadi & Sutresna, 2019). In addition, understanding the application of providing training stimuli is also very important to improve athlete performance (Hammami et al., 2018; Lloyd et al., 2013; McNarry & Jones, 2014). Research conducted by (Frank, Bekemeier, & Menze-Sonneck, 2021) using imagery exercises during breaks between exercises turned out to provide a positive increase in the ability of higher motor skills.

Subsequent studies where doing agility exercises has an effect on foot coordination ability (Sumarsono, 2019; Sumarsono & Ramadona, 2019), dribbling results (Irfan & Umansyah, 2019; Nasuki, Kharisma, & Effendy, 2021), and has an influence on kick skills sickle using agility leader and cone drill (Dwi Lestoyono, 2020). It turns out that agility training also increases agility in the game (Anjasmara, 2021; Haryono, Amiq, & Fitriady, 2021; Wihantono, Pradipta, & Widiyatmoko, 2020). The better the athlete's agility level, the easier it is for athletes to make difficult movements, avoid injury when practicing or competing, and easy to move in various directions and quickly in anticipating the ball from the opponent (Darojat & Hariadi, 2019). The results presented by (Büchel, Gokeler, Heuvelmans, & Baumeister, 2022) show that agility performance is closely related to cognitive demands. Therefore, with the ever-increasing demands of the game, researchers are looking for ways and means, which at some level will have an impact on these motor skills as well (Obetko, Peracek, Miculic, & Babica, 2020).

Mańkowska, Poliszczuk, Poliszczuk, and Johne (2015) say the ability to perceive in basketball games affects the ability to anticipate. A study proves that the reaction of futsal goalkeepers is influenced by bouncing tennis balls against the wall (Herlambang, Rahmat, Suharto, Aprillyaningrum, & Sari, 2021), with the reaction training method, this will provide an effective increase in goalkeeper performance in a match (Hidayat, Permadi, & Hermawan, 2022). The results of this study provide evidence that the reaction of the goalkeeper is needed to improve the quality of the game. So this result also illustrates the importance of doing the right exercises so that the goalkeeper's reaction increases. In addition, by doing exercise through sports activities it makes a positive contribution to physical, emotional, and psychological well-being (Hughes et al., 2020), and can also improve health (Meo et al., 2021).

Conclusion

The results of the research above have a strong foundation regarding imagery and ability training on goalkeeper reactions, on the basis of references from previous studies that have been carried out which are listed in the discussion of results and discussion. Therefore, it can be concluded that imagery and agility exercises have a significant effect on the reaction time of goalkeepers in futsal. The results also prove that there is a significant difference between imagery training using audiovisual, high agility and imagery training using audiovisual, low agility. While there is no significant difference between imagery training using visuals, high agility and imagery training using visuals, low agility. The weakness in this study is only limited to the effect of two levels of imagery training methods, two levels of agility training, as a follow-up to this research it is advisable to examine various variables and other attribute variables that affect the reaction ability of futsal goalkeepers.

Conflict of interest

There is no conflicts of interest to declare.

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ТРЕНУВАННЯ УЯВИ ТА СПРИТНОСТІ: ЯК ВОНИ ВПЛИВАЮТЬ НА ЗДАТНІСТЬ РЕАГУВАТИ ФУТЗАЛЬНИХ ВОРОТАРІВ?

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Реферат. Стаття: 8 с., 4 табл., 2 рис., 78 джерел.

Мета дослідження. Воротарі у футзалі потребують швидких рухів, щоб передбачити м'яч, який прямує до воріт. Тому реакція воротаря дуже необхідна для підвищення якості гри.

Матеріали та методи. Це експериментальне дослідження, проведене за факторним планом із використанням кількісного підходу. У цьому дослідженні дослідники використовують режим застосування вправ на розвиток уяви, аудіовізуальних і візуальних методів, з вимірюванням рівня здатності та спритності кожної вибірки в груповому експерименті. Тип інструменту, який використовували для вимірювання здатності швидкості реакції воротаря в цьому дослідженні, це тест реакції всього тіла. Популяцію в цьому дослідженні складали учні середньої школи, які грали футзальними воротарями по всьому місту Метро; кількість учасників становила 90 учнів із 9 середніх шкіл по всьому місту Метро. Використовували метод цілеспрямованої вибірки, щоб отримати вибірку з 24 учнів.

Результати. Результати дослідження доводять, що величина значущості тренування уяви становить 0,001 < 0,05, що означає «Альтернативну гіпотезу прийнято», тобто існує вплив тренувань уяви на час реакції воротаря. Далі значення значущості тренування спритності становить 0,018 < 0,05, що означає «Альтернативну гіпотезу прийнято», тобто є вплив тренування спритності на час реакції воротаря. Існує статистично значуща різниця між тренуванням уяви з використанням аудіовізуальних засобів, високою гнучкістю, та тренуванням уяви з використанням аудіовізуальних засобів, низькою гнучкістю, із показником значущості 0,016. При цьому немає статистично значущої різниці між вправами на розвиток уяви з використанням візуальних засобів, висока спритність, і вправами на розвиток уяви з використанням візуальних засобів, низька спритність, із показником значущості 0,395.

Висновки. На підставі одержаних результатів можна зробити висновок, що вправи на розвиток уяви та спритності мають значний вплив на час реакції воротарів у футзалі.

Ключові слова: тренування уяви, тренування спритності, реакція воротаря, футзал, спорт.

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ORIGINAL SCIENTIFIC ARTICLE

EFFECT OF 8 WEEKS OF COMBINED PLYOMETRIC TRAINING ON INCREASING LOWER AND UPPER BODY MUSCLE POWER IN STUDENT VOLLEYBALL ATHLETES

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Abstract

The study purpose was to identify the effects of a combination of plyometric exercises in the increasing leg and arm power abilities of volleyball athletes.

Materials and methods. Forty students were involved in this study. They were students who were active in practicing volleyball, and then they were divided into four groups of 10 students each, namely (1) Squat thrust jumps and clap push-ups, (2) Squat thrust jumps and lateral push-ups, (3) Rope jumps and clap push-ups; and (4) Rope jumps and lateral push-ups. Then they practiced plyometrics three times a week for eight weeks. Statistical analysis used the t-test and the N-Gain Score using the Statistical Package for Social Science (SPSS) version 26 program.

Results. The results of the combination of plyometric exercises stated that it had an effect on the muscle power of both the legs and arms ($p<0.05$); then, the results showed the combination of squat thrust and lateral push-up exercises was effective in increasing the ability of leg muscle power by 84.43% while the variety of squat thrust jump exercises and clap push-ups provide effectiveness in increasing arm muscle power by 25.23%.

Conclusions. The variety of these two types of plyometric exercises was successful in helping volleyball athletes improve their vertical jump abilities. Still, from the results of this study, it was not very effective in increasing the capacity of arm muscle power.

Keywords: plyometrics, power, muscles, combined exercises.

Introduction

Volleyball is a very popular sport at this time, to become a professional player, it requires main indicators on anthropometric profiles (height and BMI) as well as physical components (leg power, speed, and agility) (Tsoukos et al., 2019), volleyball athletes also need development of explosive power exercises to support performance (Loturco et al., 2018). Athletes with low levels of performance differ significantly, with athletes from higher-ranked teams achieving better results (Pocek et al., 2021). Successful players are volleyball athletes with slimmer and taller anthropometric profiles and greater motor skills than lower-level players (Milić et al., 2017). Volleyball coaches must be observant in developing these two profiles from the start of the athlete joining the training program.

Success in attacking actions in volleyball matches is directly related to the athlete's ability to make vertical jumps (Berriel et al., 2021). Thus, players need coordinated movements of the hips, torso, shoulders, elbows, and wrist muscles to efficiently transfer their power to the ball (Baena-Raya et al., 2021). Therefore, volleyball athletes often perform jumps, moving quickly, and a combination of the two during practice and matches.

Improved spike performance is generally associated with increased motor mobilization units, increased coordination between muscles, increased nerve stimulation to agonist muscles, and increased use of SSCs (Markovic & Mikulic, 2010; Taube et al., 2012). Plyometric exercises show positive things for volleyball athletes, and practices are characterized by slow cycles of muscle-tendon shortening (SSC) or fast SSC and jumping exercises with different ground contact times (Ramirez-Campillo et al., 2020). During slow and fast SCC, the accumulation of elastic energy facilitates greater

regeneration of mechanical work, i.e., explosive forces in subsequent actions (Radnor et al., 2017).

Plyometric training is suitable for increasing vertical jumping ability (Stojanović et al., 2017), agility, and speed (Silva et al., 2019). All of these components are needed by volleyball athletes. In addition, plyometric training, combined with other typical training modalities, elicits many positive changes in healthy individuals' nervous and musculoskeletal systems, muscle function, and athletic performance (Markovic & Mikulic, 2010). In previous research, plyometric training can increase the jumping ability of young athletes (Meylan & Davide, 2009; Santos & Janeira, 2008); squat thrust and jumping rope are types of exercises that can increase speed and power (Fischetti et al., 2018).

In addition to strengthening the lower muscles, volleyball players also need to increase performance in the upper body, especially in the trapezius and pectoralis muscles (Cuckova et al., 2012). Clap push-up exercise is an exercise that can increase the activation ability of the pectoralis major, triceps brachii, and anterior deltoid muscles (Nadzalan et al., 2021). This type of plyometric exercise is highly recommended to increase strength in the upper body (Moore et al., 2011).

Many reviews have been written about the benefits of plyometric training. However, most of these reviews focus on one body part (Sole et al., 2021). This study focuses on the effect of 2 plyometric combination exercises on increasing body performance in the arms and legs. Both of these parts have contributed to the implementation of volleyball athletes in volleyball.

Materials and methods

Participants

Forty male students participated in this study. They have inclusion requirements, namely 1. Are students who are active in the activities of the volleyball branch student activity unit. 2. The age of the participants is 19-20 years. 3. Actively engage in physical activity at least three times a week. Furthermore, 40 students were divided into four experimental groups, which were differentiated based on the form of exercise given. The division is group (1) Squat thrust jump and clap push-ups; (2) squat thrust jumps and lateral push-ups, (3) rope jumps and clap push-ups; and (4) Rope jumps and lateral push-ups. Before the trial, participants were informed of the benefits and potential risks associated with the study. In addition, all signed informed consent forms according to the most recent revision of the Declaration of Helsinki.

Table 1. Demographic Characteristics

N	Body Weight	Body Height	Age
40	60-70 kg	170-180 cm	19-20 Years

Study Protocol

Forty participants will carry out combined plyometric physical training for 8 weeks (3 times a week) (Negra et al., 2020; Voisin & Scohier, 2019). All participants were divided into four groups, and each group had 10 participants; they were included in groups (1) Squat thrust jumps and clap push-ups, (2) squat thrust jump and lateral push up, (3) rope jump and clap push up; and (4) Rope jumps and lateral push-ups. Leg power was assessed using a force plate/Accu power version 1.3, and arm power was measured using a ball medicine throw test.

Statistical analysis

The mean and standard deviation were measured using descriptive statistics. Furthermore, to determine the differences in each treatment using the t-test. And to see what treatment is most effective in supporting the performance of power for both resolution and arm muscles, the NGain Score test is used. Statistical analyzes were performed using the SPSS 26 program for Windows (SPSS, Inc., Chicago, IL).

Results

Table 2 explains that the four groups provide differences after doing a combination of plyometric exercises. Squat thrust exercise gives the best results in increasing leg and arm muscle power after undergoing plyometric training for eight weeks.

Table 2. Results of Descriptive Analysis of the difference between Pre-test and post-test Power of the Muscles of the Legs and Arms

Group Treatment	N	Leg Muscle		Arm Muscle	
		Mean (Watt)	SD	Mean (Meter)	SD
Squat thrust and clap push up	10	10.10	2.60	9.92	2.70
Squat thrust and lateral push up	10	6.44	0.72	7.29	1.27
Rope jump and clap push up	10	10.02	1.70	5.06	1.92
Rope jump and lateral push up	10	5.35	1.46	5.65	2.50

Table 3 shows that the intervention of squat thrust and lateral push-up exercises gave a highly practical value of 84.43% in increasing leg muscle ability. Furthermore, the intervention of squat thrust and clay push-up exercises only provided an effective value of 45.53%. On the other hand, the combination of rope jump and lateral push-up exercises only gives a weight of 3.36%. Meanwhile, the variety of rope jump and lateral push-up exercises gave a small value of 3.36%, or it can be said that it was ineffective for leg power.

In table 4, it can be seen that the intervention of several combinations of plyometric exercises only had an impact of less than 25% on increasing the performance of arm muscle power. First, the variety of plyometric exercises in the form of squat thrusts and clap push-ups has the greatest impact, with an effect of 25.23%. Then, the combination of plyometric exercises in the form of squat thrusts and lateral push-ups has an effect of 21.66%. After that, the variety of plyometric exercises in rope jumps and clap push-ups only had an effect of 14.83%. And the combination of plyometric exercises in the form of rope jumps and lateral push-ups only had an impact of 22.18% on arm power ability.

Table 3. Of the effectiveness of the exercise on the four treatments on leg muscle power

No	Group Treatment	N	r	t	Sig.	N-Gain Score	%
1	Squat thrust and clap push up	10	0.641	-6.381	0.000	45.53	45.53 %
2	Squat thrust and lateral push up	10				84.43	84.43 %
3	Rope jump and clap push up	10				3.36	3.36 %
4	Rope jump and lateral push up	10				15.36	15.36 %

Table 4. Shows the effectiveness of exercise in 4 treatments on arm muscle power

No	Group Treatment	N	r	t	Sig.	N-Gain Score	%
1	Squat thrust and clap push up	10	0.991	-15.662	0.000	-25.23	25.23 %
2	Squat thrust and lateral push up	10				-21.66	21.66 %
3	Rope jump and clap push up	10				-14.83	14.83 %
4	Rope jump and lateral push up	10				-22.18	22.18 %

Discussion

Volleyball has immediate difference from similar sports such as basketball. This sport allows an athlete to perform explosive power in both the lower body (legs) and upper body (arms). This happens when a volleyball player hits a mass, and then the function of the leg and arm muscles both perform explosive power movements. In volleyball, the ability to jump on each player is very important to master because it is a characteristic of the volleyball game itself, especially in increasing improvement and maintaining points (Pereira et al., 2015).

After eight weeks of plyometric training with a combination of plyometric exercises, it was found that the variety of plyometric exercises using squat thrusts had more impact on the average power of volleyball athletes than the group using a variety of rope jump plyometric exercises. However, the squat thrust combination group and the rope jump combination gave the same results.

Hypertrophy of the quadriceps, Vastii, rectus femur and gluteus maximus muscles is why there is an increase in power in the supporting muscles (Ribeiro et al., 2022). In addition, squat thrust exercises also increased the quality of the vertical jump both in the single plyometric exercise group (Ramlan et al., 2018) and in combination with plyometric training (Adams et al., 1992).

This study found that plyometric exercise more effectively influenced lower body power. This is in line with previous research, which concluded that plyometric training has the potential to improve lower extremity performance (Chelly et al., 2014; Davies et al., 2015; Hrženjak et al., 2016). Therefore, plyometric training is an important component of any training program for volleyball players (Ahmadi et al., 2021).

Two volleyball players' abilities, such as spike and block, rely heavily on jumping skills. Fast and high jumps are an important requirement for every player (Loturco et al., 2017). The increased elastic characteristics of musculotendinous nerves are thought to cause increased muscle performance when jumping (Ignjatovic et al., 2012). Plyometric training can lead to neuromuscular adaptations that lead to improved jumping performance. These adaptations can include increased nerve impulses to the agonist's muscle, changes in the mechanical stiffness characteristic of muscle-tendon, changes in muscle size and/or architecture, and changes in single-fibre mechanics (de Villarreal et al., 2009; Maffiuletti et al., 2002; Thomas et al., 2009). Other possible aspects of neural adaptation to plyometric training include changes in leg muscle activation strategy (or inter-muscle coordination) during vertical jumps, particularly during the preparatory jump phase (i.e., pre-landing), and (ii) changes in the excitability of the stretch reflex (Bishop & Spencer, 2004; de Villarreal et al., 2009).

The interesting thing in this study was that the rope jump exercise treatment group did not show effectiveness in the power test results for both leg and arm muscles. This is possible because rope jump training tends to give great value to increasing agility and speed skills (Fischetti et al., 2018).

The surprising finding in this study was that the percentage of exercise effectiveness in the group did not give effective results when associated with the performance of arm muscle power. In this study, the four treatments had less than 25% practical value, so they were considered ineffective in increasing arm muscle power. In addition, clap push-ups in the study (Moore et al., 2011) gave differences from the results of the pre and post-tests in this study also made differences. Still, in the statistical analysis results, the N-Gain score had a low effectiveness value.

Research provides a new understanding of training patterns to increase power in volleyball athletes. Combining the two exercises to increase power in the upper body (arm muscles) and upper body (leg muscles) is only effective in one component, the upper body.

Conclusions

The combination of 2 types of plyometric exercises greatly impacts increasing power in the leg muscles. The variety of these two types of plyometric exercises was successful in helping volleyball athletes improve their vertical jump abilities. Still, from the results of this study, it was not very effective in increasing the capacity of arm muscle power.

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ВПЛИВ 8 ТИЖНІВ КОМБІНОВАНОГО ПЛІОМЕТРИЧНОГО ТРЕНУВАННЯ НА ЗБІЛЬШЕННЯ СИЛИ М'ЯЗІВ НИЖНЬОЇ ТА ВЕРХНЬОЇ ЧАСТИНИ ТІЛА У СТУДЕНТІВ-ВОЛЕЙБОЛІСТІВ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 6 с., 4 табл., 35 джерел.

Метою дослідження було виявити вплив комбінації пліометричних вправ на збільшення силових здібностей ніг і рук у волейболістів.

Матеріали та методи. У цьому дослідженні брали участь сорок студентів. Це були студенти, які активно займалися волейболом, їх розділили на чотири групи по 10 студентів у кожній, а саме: (1) стрибки з присіду ногами назад у положення планки й поверненням у вихідне положення зі стрибком у висоту та віджимання з оплесками, (2) стрибки з присіду ногами назад у положення планки й поверненням у вихідне положення зі стрибком у висоту та бокові віджимання, (3) стрибки зі скакалкою та віджимання з хлопками; та (4) стрибки зі скакалкою та бокові віджимання. Потім вони займалися пліометрією тричі на тиждень протягом восьми тижнів. Для статистичного аналізу використовували t-критерій Стьюдента та оцінку нормалізованого приросту за допомогою ПЗ Statistical Package for Social Science (SPSS) версії 26.

Результати. Результати комбінації пліометричних вправ свідчать про її вплив на силу м'язів як ніг, так і рук ($p<0,05$); також, результати показали, що комбінація вправ «стрибки з присіду ногами назад у положення планки й поверненням у вихідне положення зі стрибком у висоту» та «бокові віджимання» була ефективною для збільшення здатності сили м'язів ніг на 84,43%, тоді як різноманітність вправ на стрибки з присіду ногами назад у положення планки й поверненням у ви-

хідне положення зі стрибком у висоту та віджимання з оплесками забезпечує ефективність у збільшенні сили м'язів рук на 25,23%.

Висновки. Різноманітність цих двох типів пліометричних вправ успішно допомогла волейболістам покращити їхні здібності у виконанні стрибків у висоту. Проте, за результатами цього дослідження, вона не була дуже ефективною у збільшенні сили м'язів рук.

Ключові слова: пліометрія, сила, м'язи, комбіновані вправи.

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OSTEOGENIC EFFECTS OF AEROBIC BOTH SIDES UTILIZED BALL VERSUS AEROBIC STEP TRAINING IN PREMENOPAUSAL WOMEN

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Study purpose. Exercise training plays an important role in increasing bone mass. Nevertheless, the osteogenic effects of exercise training using various bench surfaces are unknown. Therefore, this study aimed to compare the osteogenic effects of exercise with a soft surface bench and an aerobic both sides utilized (BOSU) ball with those of aerobic step exercise training (STEP).

Materials and methods. Fifty-two sedentary female participants aged 30–45 years were recruited and randomly divided into three groups. Seventeen participants were in the STEP, 17 in the BOSU, and 18 in the control group. The exercise programs of the STEP and BOSU groups were designed to have the same intensity and heart rate range during each stage of the program. During training, music was used to set the tempo for workouts.

Results. After week 24, both training groups showed significant improvements in physical fitness, body composition, and body stability ($p<0.05$). Increased levels of procollagen type I N-terminal propeptide (P1NP), an osteogenesis marker, were observed in both STEP and BOSU groups. Increased bone mineral density was only seen in the BOSU group ($p<0.05$).

Conclusions. Both STEP and BOSU programs effectively improved P1NP levels, muscle strength, and postural control, but only the aerobic BOSU ball training improved bone mineral density in premenopausal women.

Keywords: bone formation, postural control, premenopause.

Introduction

There are several ways to measure bone density, including measuring procollagen type I N-terminal propeptide (P1NP) levels and quantifying bone mineral density (BMD). P1NP is a bone formation marker and predictor of BMD. Lower levels of P1NP predicted BMD loss over 12 months in patients with premenopausal systemic lupus erythematosus (Seguro et al., 2015). In addition, low levels of P1NP and BMD may predict osteoporosis (Krege et al., 2014), which increases the risk of bone fractures.

Pharmacological strategies may constitute the main treatment for osteoporosis; however, some medications cause adverse effects (McClung et al., 2013). Exercise and non-pharmacological strategies are recommended to maintain/improve bone health (Xu et al., 2016). The long-term effects of exercise include increased BMD (Park et al., 2008; von Stengel et al., 2007) and body stability in postmenopausal women (Anek et al., 2015). A recent systematic review and meta-analysis documented the benefit of life-long exercise in maintaining bone health in women (Xu et al., 2016). In premenopausal women, specific impact exercises (vertical jumps or hops) improve the BMD of the femoral neck, lumbar spine, and greater trochanter. Thus, one of the main objectives of exercise in this stage of a woman's life is to increase the peak bone mass to prevent bone loss after menopause.

Several studies have confirmed that impact exercises such as jumping and step aerobics could enhance bone mass, muscle strength, and balance stability in pre- and postmenopausal women (Anek et al., 2011; Marques et al., 2013; Sherrington et al., 2008). Exercise programs of shorter durations might increase P1NP levels before changes in BMD are observed. A study reported that a 48-week combined exercise training program enhanced body stability and BMD of the trochanter and femoral neck (Park et al., 2008). Essentially, significant changes in BMD from exercise interventions may require a long duration, while increases in P1NP levels have been observed following short

experiments (Alkahtani et al., 2019; Scott et al., 2011). Using shorter durations, Anek et al. (2011) investigated the effects of an aerobic step (STEP) program in postmenopausal women. After 12 weeks, an increase in bone formation marker (P1NP/beta-Crosslaps) levels was observed in the training group, suggesting that hard surfaces should be used in exercises for managing bone health (Anek et al., 2011).

Unstable surfaces with whole-body vibration training increased BMD in postmenopausal women (de Oliveira et al., 2019). Moreover, a recent study reported that both stable and unstable surface balance training enhanced static balance and functional ability in middle-aged women. Nevertheless, unstable balance training with an aerobic both sides utilized (BOSU) ball showed greater improvements (Nepocatych et al., 2016). BOSU ball training has two main objectives: maintaining lateral balance and timing efficiency during the ascending and descending phases of movement (Wing, 2014). The degree of ground reaction force during BOSU exercises may differ from that during the STEP program, thus promoting a more distinct effect on bone status in the long term. Interestingly, no studies have investigated its effects on bone markers. Moreover, there is a need to assess the combination of box jumping and different surfaces on bone markers; however, no studies have compared the effects of training on stable and unstable surfaces when performing box jumping on P1NP levels and BMD in premenopausal women. Therefore, the objective of this study was to investigate the effect of a 6-month exercise program, using either 1) a soft surface bench with aerobic BOSU ball training (BOSU) or 2) a hard surface (STEP), on P1NP levels, BMD, and postural control. We hypothesized that these programs would yield distinct positive effects on bone status and body stability.

Materials and methods

Study participants

This study employed an experimental research design conducted in sedentary 30–45-year-old women (n=80) based on the criteria for premenopausal women reported in a previous study (Anek et al., 2011). Activity levels were evaluated using a questionnaire, with "sedentary" defined as not meeting the minimum threshold of 75–150 min/week of moderate-to-vigorous intensity physical activity. Medical history and general qualifications were evaluated before the exercise program was selected. The selection instruments were a participant selection form, health questionnaire, and dual-energy X-ray absorptiometry (DEXA Scan, Hologic Inc., Marlborough, MA) to measure BMD. None of the participants were diagnosed with osteoporosis based on DEXA or were smokers or alcohol consumers. Those who drank tea or black coffee consumed no more than two standard cups daily (250 mL/cup). None of the participants received hormonal replacement therapy or calcium supplements, and none of the patients had a body mass index of >30 kg/m^2. The exclusion criteria were premenopausal status with heart disease, known obstructive lung disease, inability to complete the exercise program, and severe injury during training. A total of 52 participants were included in the study, with 17 participants in the STEP, 17 in the BOSU, and 18 in the CON groups (Fig. 1). After recruitment, the participants were randomized into three groups: 1) control (CON) group, 2) BOSU group, and 3) STEP group, using a Microsoft Excel random number generator program. Participants were also excluded if they dropped out or completed less than 80% of the training schedule.

The participants in the CON group were instructed to remain sedentary. The exercise training groups underwent 24-week exercise training programs involving exercising thrice weekly for 30 min a day. The BOSU and STEP group programs were divided into two phases: the intensity was 60%–70% of maximum heart rate (determined by the Tanaka equation, i.e., 208 − 0.7 × age) in phase 1 (weeks 1–4), and 70%–80% of maximum heart rate in phase 2 (weeks 5–24). In each phase, compliance with the heart rate training zone was ensured using a heart rate monitor (Polar Team 2 Pro, Polar Electro Inc., Lake Success, NY, USA) during the exercise sessions. A pilot study was conducted before the project to identify correlations between program intensity and music rhythm to achieve the same heart rate during each program stage. The heights of the STEP bench and BOSU ball were similar (15 cm). During training, music was used to set the tempo for the aerobic and BOSU training workouts. The two modes of exercise included dynamic stretching before and after training as well as warm-up and cool-down periods totaling 10 min (Fig. 2).

This study was approved by the ethics committee of the institution (No. SWUEC-440/2561E) and conducted in accordance with the guidelines of the Helsinki Declaration. Informed consent was obtained from all participants.

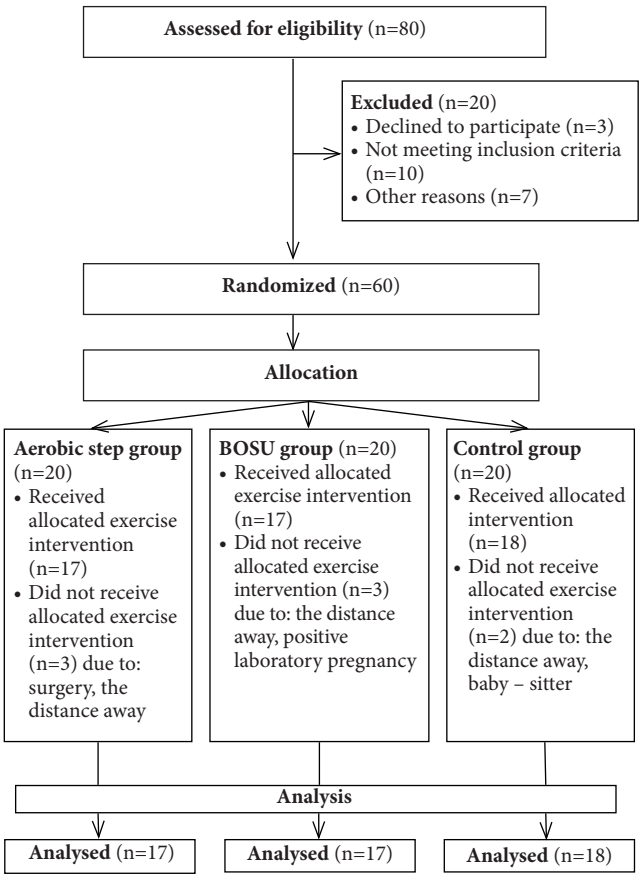

Fig. 1. CONSORT flow chart

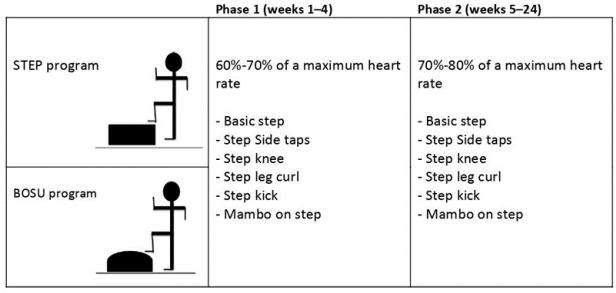

Fig. 2. STEP and BOSU programs: STEP, aerobic step exercise training; BOSU, aerobic both sides utilized ball

Study design

At baseline and after 24 weeks, the participants were evaluated for general physiological status, biochemical bone markers, BMD, physical fitness, and balance performance.

Measurements

Measurement of biochemical bone markers

Venous blood was drawn on arrival following a standard 8-h overnight fast. The P1NP level was measured using a standard procedure in the clinical laboratory (BRIA lab, Bangkok, Thailand). Blood collection was performed at the same time of day for the pre- and post-training tests to avoid diurnal changes in blood chemistry variables. Three hours after breakfast, the participants were asked to undergo body composition, BMD, balance, and physical fitness assessments.

Physical fitness measures

Body composition was evaluated using DEXA. Muscle strength measurements were obtained using a Nautilus-type weight machine (leg extension and leg curl) using the one repetition maximum (1RM) method.

Balance performance measures

The participants were tested on both hard and soft surfaces on balance plates to assess static balance ability (Leme et al., 2022) using the balance error scoring system, consisting of three stances as follows: single-leg stance (standing on the nondominant leg with hands on the hips), double-leg stance (hands on the hips), and tandem stance (dominant foot in front of the nondominant foot) in a heel-to-toe fashion. The stances were performed on hard and soft surfaces with the eyes closed, and errors were counted during each 20-s trial. An error was defined as lifting hands off the hips, opening the eyes, stepping, abducting the hip by more than 30°, or falling out of position after more than 5 s. Balance performance measures were collected by the same operator. The intra-rater reliability of measures was determined using intraclass correlation coefficients with 95% confidence intervals. The intra-rater reliability of double-leg stance on firm surface, single-leg stance on firm surface, tandem stance on firm surface, double-leg stance on foam surface, single-leg stance on foam surface, and tandem stance on foam surface was 1.00, 0.97 (0.81–0.99), 0.82 (0.31–0.95), 0.96 (0.88–0.99), 0.95 (0.86–0.98), and 0.90 (0.69–0.97), respectively.

Measurement of body composition and bone mineral density

We measured whole-body fat, muscle mass, and BMD at the lumbar spine (L1–L4) using DEXA (T-score values greater than −1) to assess body composition and BMD. BMD scans were analyzed using the World Health Organization criteria for total bone mass density. BMD measurements were expressed in g/cm2. These scores were then sex-, age-, and mean peak BMD-matched.

Statistical analysis

Data are expressed as mean ± standard deviation. All data were tested for normality. Differences among the three groups were tested using analysis of covariance and Bonferroni post hoc test. Mean values were compared before and 24 weeks after the exercise program using repeated measures analysis. A p-value of <0.05 was considered statistically significant.

Results

The mean age, anthropometrics, and body mass indexes of the participants are presented in Table 1. There were no significant differences in demographic data among the groups at baseline (p >0.05).

Table 1. Participant characteristics at baseline

Characteristic	STEP group (n = 17)	BOSU group (n = 17)	CON group (n = 18)
Age (years)	39.2±4.3	38.2±3.5	39.2±3.5
Weight (kg)	59.9±2.6	59.1±7.9	58.4±4.0
BMI (kg/m^2)	24.9±2.3	24.0±2.2	24.1±2.3
Height (cm)	160.2±5.4	159.8±4.4	157.4±3.9
SBP (mmHg)	117.1±7.1	114.7±5.7	115.3±7.0
DBP (mmHg)	75.8±9.2	75.1±7.6	77.3±6.6

Values are presented as mean ± standard deviation. CON, Control; STEP, Aerobic step exercise training; BOSU, Both sides utilized ball; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

There were no significant differences among the groups in terms of P1NP levels, BMD, muscle strength, or postural control (p >0.05).

Both exercise groups had significantly lower weight, body mass index, and heart rate at rest (p < 0.05) after the training intervention. Body composition data revealed significantly lower arm fat percentages in both exercise groups (p <0.05). At week 24, android fat percentage significantly decreased

only in the STEP group, while lean mass significantly increased only in the BOSU group ($p < 0.05$). In terms of muscle strength at week 24, both exercise training groups showed significant improvement in leg extension and leg curl measures ($p < 0.05$). Regarding the balance ability after the exercise intervention, single-leg and tandem stance had significantly lower error scoring in both exercise groups after the training, while the double-leg stance on the foam surface was significantly lower in terms of error scoring only in the BOSU group ($p < 0.05$, Table 2).

We found significantly greater P1NP levels in both exercise and training groups. However, after the training

Table 2. Response of physiological data, body composition, muscle strength, balance, PINP, and BMD

Variable	STEP group (n = 17)				BOSU group (n = 17)				CON group (n = 18)			
	Pre	Post	p^a	Effect size	Pre	Post	p^a	Effect size	Pre	Post	p^a	p^b
Physiological data												
Weight (kg)	59.9±2.6	58.7±2.9[c]	0.01	0.05	59.1±7.9	58.4±7.4[c,d]	0.01	0.03	58.4±4.0	58.5±4.0[d]	0.60	0.01
BMI (kg/m^2)	24.9±2.3	24.5±2.2[c]	0.01	0.32	24.0±2.2	23.0±1.9[d]	0.01	0.28	24.1±2.3	23.7±2.5[c]	0.90	0.01
HR Rest (bpm)	75.9±5.3	71.6±6.9[c]	0.01	0.59	74.4±5.9	70.5±6.8[c]	0.01	0.75	75.1±6.8	75.6±6.8[d]	0.24	0.01
SBP (mmHg)	117.1±7.1	115.2±9.2[c]	0.06	0.09	114.7±5.7	113.4±7.0[c]	0.08	0.13	115.3±7.0	114.5±8.2[c]	0.48	0.29
DBP (mmHg)	75.8±9.2	74.6±11.7[c]	0.21	0.19	75.1±7.6	73.9±9.1[c]	0.14	0.27	77.3±6.6	76.1±8.1[c]	0.20	0.93
Body composition data												
Body fat percentage (%)	40.2±7.1	39.4±7.3[c]	0.14	0.62	39.6±5.0	39.5±4.5[c,d]	0.62	0.59	41.3 ± 4.4	41.8±3.9[d]	0.11	0.04
Right arm fat percentage (%)	34.6±7.5	32.7±7.2[c]	0.01	0.49	35.1±6.9	33.5±6.5[c]	0.01	0.34	35.3 ± 5.6	35.3±5.3[d]	0.97	0.01
Left arm fat percentage (%)	34.7±7.5	32.7±7.2[c]	0.01	0.49	35.1±6.9	33.5±6.5[c]	0.01	0.34	35.3±5.6	35.3±5.3[d]	0.97	0.01
Right leg fat percentage (%)	42.0±7.8	41.0±7.6[c]	0.07	0.87	42.1±7.8	41.4±7.6[c,d]	0.05	0.79	44.6±4.7	45.1±4.7[d]	0.11	0.01
Left leg fat percentage (%)	41.9±7.8	41.3±3.6[c]	0.08	0.69	41.9±3.2	41.3±7.8[c]	0.05	0.69	44.6±4.7	45.1±5.5[c]	0.38	0.10
Android fat percentage (%)	44.1±9.0	41.9±9.5[c]	0.01	0.54	43.6±8.2	42.8±7.9[c,d]	0.07	0.32	43.9±4.8	44.1±4.1[d]	0.63	0.01
Gynoid fat percentage (%)	48.7±5.4	48.5±5.9[c]	0.29	0.35	48.0±3.8	47.5±3.3[c]	0.16	0.12	47.1±4.2	47.0±4.3[c]	0.87	0.50
Lean mass (kg)	34.6±3.8	33.5±3.8[c]	0.55	0.76	32.4±3.1	33.1±2.8[c]	0.02	0.67	30.1±4.2	30.1±4.5[c]	0.86	0.34
Muscle strength												
Leg extension strength (kg/bw)	62.7±12.9	66.1±14.1[c]	0.01	0.73	62.1±10.5	64.9±11.3[c]	0.01	0.59	58.4±16.1	60.0±8.3[c]	0.60	0.40
Leg curl strength (kg/bw)	40.0±7.7	41.9±9.1[c,d]	0.04	0.52	39.3±6.7	42.0±7.6[c]	0.01	0.59	37.6±6.7c	37.1±8.3[d]	0.58	0.03
Balance												
Double-leg stance on firm surface (errors)	0.0±0.0	0.0±0.0	NA	NA	0.0±0.0	0.0±0.0	NA	NA	0.0±0.0	0.0±0.0	NA	NA
Single-leg stance on firm surface (errors)	5.9±3.2	3.7±2.3[c]	0.01	0.27	4.4±2.8	2.1±2.0[c]	0.01	0.80	3.0±1.4	3.3±1.5[d]	0.21	0.01
Tandem stance on firm surface (errors)	2.2±0.8	0.6±0.7[c]	0.01	0.65	2.6±0.2	1.0±0.7[c]	0.01	0.50	1.7±0.8	1.4±0.8[d]	0.06	0.01
Double-leg stance on foam surface (errors)	0.5±0.6	0.3±0.6[c]	0.08	0.17	0.5±0.6	0.2±0.4[c]	0.02	NA	0.3±0.5	0.2±0.6[c]	0.43	0.64
Single-leg stance on foam surface (errors)	7.0±1.6	4.6±1.4[c]	0.01	0.27	6.3±2.3	3.1±1.4[c]	0.01	0.41	4.3±2.5	4.0±2.2[d]	0.38	0.01
Tandem stance on foam surface (errors)	2.4±0.9	1.2±0.8[c]	0.01	0.42	2.4±1.0	1.7±1.1[c]	0.02	NA	2.4±1.2	1.7±1.2[c]	0.11	0.41
Biochemical bone markers												
P1NP (ng/mL)	42.7±6.1	44.2±7.0[c,d]	0.01	0.14	43.0±8.1	45.9±9.5[c]	0.01	0.37	42.8±7.4	43.2±7.3[d]	0.21	0.01
Bone mineral density												
Whole-body BMD (g/cm^2)	1.19±0.09	1.20±0.07[c]	0.06	1.13	1.11±0.08	1.14±0.08[c]	0.03	0.38	1.13±0.11	1.11±0.08[d]	0.21	0.01
Lumbar spine BMD L1 (g/cm^2)	1.18±0.17	1.17±0.16[c]	0.52	0.50	1.11±0.12	1.12±0.12[c]	0.67	NA	1.15±0.11	1.12±0.10[c]	0.05	0.30
Lumbar spine BMD L2 (g/cm^2)	1.25±0.17	1.23±0.17[c]	0.14	0.47	1.16±0.14	1.17±0.14[c]	0.21	0.13	1.18±0.10	1.15±0.15[c]	0.17	0.13
Lumbar spine BMD L3 (g/cm^2)	1.26±0.14	1.26±0.13[c]	0.86	0.60	1.21±0.13	1.21±0.14[c]	0.83	0.10	1.19±0.10	1.20±0.10[c]	0.57	0.90
Lumbar spine BMD L4 (g/cm^2)	1.24±0.10	1.24±0.13[c]	0.94	1.00	1.18±0.17	1.20±0.19[c]	0.36	0.50	1.15±0.10	1.16±0.08[c]	0.54	0.84
Lumbar spine BMD L1–L4 (g/cm^2)	1.21±0.13	1.22±0.13[c]	0.55	0.67	1.18±0.14	1.18±0.15[c]	0.70	0.22	1.20±0.12	1.16±0.09[c]	0.08	0.05
Lumbar spine BMD L2–L4 (g/cm^2)	1.25±0.12	1.24±0.13[c]	0.75	0.60	1.17±0.13	1.19±0.15[c]	0.17	0.10	1.18±0.09	1.18±0.10[c]	0.47	0.63

Values are presented as mean ± standard deviation. CON, control; STEP, aerobic step exercise training; BOSU, both sides utilized ball; NA, not available; BMI, body mass index; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; P1NP, procollagen type 1 N-terminal propeptide ; BMD, bone mineral density. $p < 0.05$; [a], repeated measures analysis; [b], analysis of covariance (ANCOVA); [c,d], Different superscripts in the same row mean that the values are significantly different ($p < 0.05$) according to ANCOVA and Bonferroni post hoc test.

intervention, BMD showed significant enhancement only in the BOSU group ($p < 0.05$, Table 2). No changes in physical characteristics, postural control measures, biochemical bone formation markers, or BMD were observed in the CON group.

Discussion

The main findings of this study are that both BOSU and STEP programs enhanced physical fitness, bone status, and body stability; however, significant improvements in total BMD were observed only in the BOSU group. Our results suggest that BOSU training improves physical fitness, bone status, and body stability in premenopausal women.

Aerobic training, involving high intensity and speed, can prevent a decrease in BMD in patients with osteoporosis (Bendetti et al., 2018). The National Osteoporosis Foundation (n.d.) recommends high-impact weight-bearing training, that is, dancing, high-impact aerobic exercise, hiking, jogging/running, jumping, stair climbing, and tennis, to yield beneficial effects on bone health in women. Our training was designed according to the concept of high impact to increase gravitational and muscle forces.

STEP and BOSU training, with their ascending and descending movements, make use of gravity, which may promote improved functioning of the vestibular apparatus. The possible mechanism might be that stronger muscles and consequently better nervous system functions improve balance (Kovács et al., 2012). Regarding the time course, a previous study reported significant improvements in balance and health-related physical fitness but not in P1NP levels following a 12-week program of circuit box jumping (Anek et al., 2011). Using a longer duration (24 weeks), our results demonstrated the benefits of STEP and BOSU training on body composition and physical fitness. Moreover, increased P1NP levels in both STEP and BOSU groups were observed after 24 weeks, suggesting that exercise duration should be considered when monitoring bone status in premenopausal women.

Both muscle and gravitational forces are critical to regulating bone health, as confirmed by several studies (Kohrt et al., 1997; Nikander et al., 2005; Shackelford et al., 2004). In the present study, we used aerobic exercise with a BOSU ball and bench of a similar height. Owing to the different surfaces, there might have been distinct muscle and gravitational forces. Both programs may improve awareness of body position due to increased proprioceptive input from the muscles, tendons, and joints (Park et al., 2008) and may lead to increased body stability, with the unstable surface of the BOSU ball providing more advantage in terms of balance (as seen by the changes in double-leg stance). Our balance results are similar to those of a previous study in which a greater improvement was observed in unstable surface training (Nepocatych et al., 2016). Long-term increases in BMD were observed only in the BOSU group; however, improvement in the levels of P1NP, a bone formation marker, was observed in both STEP and BOSU groups. The mechanism is unknown but is likely due to greater changes in ground reaction force (step down to the ground from the bench), which should be confirmed by further studies. Considering the different effects on BMD between the groups, differences in mechanical loading might be one of the possible mechanisms to explain why a lower level could lower cartilage degeneration, subchondral bone remodeling, secondary inflammation, and activation of the NLRP3 inflammasome, as previously seen in a male rat model of osteoarthritis (He et al., 2020). However, it is necessary to investigate the possible underlying mechanisms of these outcomes due to the combination of box jumping and different surfaces in future studies.

Limitations

This study has some limitations. First, considering the two phases of stepping on and down to the ground surface in both groups, stepping down to the ground surface would generate a relatively higher mechanical landing impact on the foot compared with stepping onto a surface. Ground reaction force measurement should be added to further studies to verify the mechanical impacts induced by two different interventions. Second, we did not measure the BMD of the lower limbs, which would have also received mechanical impact, and did not measure multiple time points of serum bone markers and BMD. Third, we only measured P1NP levels to identify the bone formation status. Other parameters, e.g., β cross-linked C-telopeptide of type 1 collagen (β-CTX), should be added in further studies to verify coupling effects (bone formation and resorption). Lastly, the number of subjects in the control, BOSU, and STEP groups was relatively small.

Conclusions

Both STEP and BOSU training programs enhanced health-related physical fitness, body stability, and P1NP levels; however, an improvement in total BMD was only observed in the BOSU group. Therefore, we recommend our BOSU training program to improve these parameters in premenopausal women.

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Conflict of interest

Authors state no conflict of interest.

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ОСТЕОГЕННІ ЕФЕКТИ ТРЕНУВАНЬ З БАЛАНСУВАЛЬНОЮ ПЛАТФОРМОЮ ДВОБІЧНОГО ВИКОРИСТАННЯ ПОРІВНЯНО З ТРЕНУВАННЯМИ ЗІ СТЕП-ПЛАТФОРМОЮ В ЖІНОК У ПРЕМЕНОПАУЗІ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 2 табл., 2 рис., 23 джерел.

Мета дослідження. Заняття фізичними вправами відіграють важливу роль у збільшенні кісткової маси. Тим не менш, остеогенні ефекти занять фізичними вправами з використанням різних стендових поверхонь невідомі. Таким чином, метою цього дослідження було порівняти остеогенні ефекти вправ зі стендом із м'якою поверхнею та балансувальною платформою двобічного використання (BOSU) з ефектами вправ зі степ-платформою (STEP).

Матеріали та методи. Для участі в дослідженні були набрані та випадковим чином розділені на три групи 52 учасниці, які ведуть сидячий спосіб життя, віком 30–45 років. Сімнадцять учасниць тренувалися в групі STEP, 17 – у групі BOSU, а 18 – увійшли до контрольної групи. Програми вправ для груп STEP та BOSU були розроблені таким чином, щоб мати однакову інтенсивність і діапазон пульсу на кожному етапі програми. Під час занять для встановлення темпу тренувань використовували музику.

Результати. Після 24-го тижня обидві тренувальні групи показали статистично значущі покращення у фізичній підготовці, композиції тіла та стані рівноваги тіла ($p<0,05$). В обох групах STEP та BOSU спостерігалися підвищені рівні N-термінального пропептиду проколагену I типу (P1NP), маркера остеогенезу. Підвищення мінеральної щільності кісткової тканини спостерігалося лише в групі BOSU ($p<0,05$).

Висновки. Обидві програми STEP та BOSU ефективно підвищили рівні P1NP, м'язову силу та контроль постави, але лише тренування з балансувальною платформою двобічного використання BOSU покращило мінеральну щільність кісток у жінок у пременопаузі.

Ключові слова: формування кісток, контроль постави, пременопауза.

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ORIGINAL SCIENTIFIC ARTICLE

ANALYSIS OF REACTION TIME, SPLIT TIME AND FINAL TIME SWIMMING ATHLETES IN THE OLYMPIC GAMES ON 2008-2021

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Abstract

Study purpose. This research aims to evaluate and analyze the Final Time (FT), Split Time (ST), and Reaction Time (RT) records of 100-meter butterfly swimmers in four Olympic events in order to provide benchmarks and standards for the development of swimming training.

Materials and methods. This research combines quantitative and qualitative approaches. This study utilized a sample of 32 athletes ranked first through eighth who competed in the 100-meter butterfly at four Olympics: the 2008 Beijing Olympics, 2012 London Olympics, 2016 Rio Olympics, and 2021 Tokyo Olympics. It utilizes secondary data in which all time results are obtained from the website (http://www.fina.org). The descriptive statistics of mean and standard deviation were utilized for statistical analysis in this study. The Kolmogorov-Smirnov test was used to determine data normality. For comparing data between Olympiads, a one-way multi-comparison ANOVA was used to verify interactions between RT, ST, and FT across Olympiads. To determine the effect of RT and ST on FT, one-way linear regression was used with a significance level of $p<0.05$ as a standard. SPSS Inc., Chicago, IL, USA, was utilized for all analyses.

Results. ST and RT were found to influence the achievement of FT in the 100-meter butterfly stroke, and RT had an effect of 0,712 (51%), for both male and female swimmers, on the achievement of the time in the first 50 meters.

Conclusions. The conclusion is that both athletes and coaches are required to optimize the achievement of RT and ST in short-distance swimming because these two indicators play a crucial role in achieving the travel time of short-distance swimmers.

Keywords: reaction time, final time, split time, swimming.

Introduction

In every European, world and Olympic swimming championship, there is always a record-breaking swimming time for all events (Marinho et al., 2020). This is inseparable from the ingenuity of the coach in maximising every movement of the swimmers. Swimming movements have high complexity, such as when starting and turning, dolphin and hand pull (Morais, Marinho, et al., 2019; Tourny-Chollet et al., 2010).

Hand drag kinematics is another essential element of the results of butterfly stroke swimming (Strzała et al., 2017). In addition, adjustments to match distances (short, medium and long distances) are also a separate consideration for a coach in determining appropriate movements and techniques as well as pace time for each event (McGibbon et al., 2018; Menting et al., 2019; K. G. Thompson et al., 2000).

In swimming, small motion errors will cause hydrodynamic resistance (Washino et al., 2019), so coaches must pay attention to the movements' details and the energy athletes use. Coaches must use match data such as RT, ST, and FT combined with video recordings to analyse swimmer performance (Gonjo & Olstad, 2021).

A 100-meter butterfly stroke is a fast number or short distance that must be supported by several indicators such as reaction time (RT), force technique, low resistance when

entering the water, underwater glide, and underwater propulsion (Bishop et al., 2013; Potdevin et al., 2011). A coach must pay attention to long jump performance in swimming athletes to positively impact achieving reaction time(Rebutini et al., 2016).

Swimming speed can be defined as the speed at which a swimmer completes a distance and is an important variable to monitor to get better performance (Gordon et al., 2015; G. K. Thompson, 2014). Therefore, proper swimming speed is essential to avoid unwanted sudden onset of fatigue, leading to loss of strength, coordination and stroke speed (Mauger et al., 2012; Taylor et al., 2016; G. K. Thompson, 2014). Competitive and elite swimmers can constantly repeat swimming speeds under different conditions (Skorski et al., 2013, 2014).

This research aims to evaluate and analyse records of final travel time, ST, and reaction time to determine the performance developments of athletes swimming in the 100-meter butterfly at the four Olympics. The urgency in this study is that the evaluation of FT, ST and RT is critical to be applied to swimming training even though. Currently, swimming coaches do not understand the standards of swimmer success as measured by these three indicators.

Materials and methods

Study participants

In this study, the type of research used is a combination of quantitative and qualitative with descriptive methods. There were 32 athletes ranked 1-8 participating in this study. They participated in the 100-meter butterfly swimming competition at four Olympics: the 2008 Beijing Olympics, the 2012 London Olympics, the 2016 Rio Olympics, and the 2021 Tokyo Olympics.

Study design

The data source in this study uses secondary data where all travel time results, such as speed of 100 meters, every 50 meters, and RT, is taken from the website (www.fina.org, 2022) This study did not use the consent form as a sample because the data taken is secondary data validated through the official website for every Olympics.

Statistical analysis

Descriptive statistics are presented as mean and standard deviation. Data normality was performed using the Kolmogorov-Smirnov test. For comparing data between Olympiads, one-way multi-comparison ANOVA was used to verify the interaction between the different Olympiads' reaction time (RT) and final time (FT). To see the effect of RT with FT using one-way linear regression. The adopted significance level is p <0,05. All analyzes were performed using statistics for the Social Sciences software (SPSS Inc., Chicago, IL, USA).

Results

Fig. 1 describes the two normally distributed data with a probability value of more than 0.05. Furthermore, the respective averages of the reaction time for each Olympic event for both male and female athletes were stated to be different from the sig. < than 0.05 (Table 1).

Table 2 describes the average first and second ST achievements of swimmers at the Olympics in the 100-meter butterfly for both men and women. It can be seen in table 3 that the best first and second splits were during the Tokyo Olympics (men's 23.763/26.882 seconds and women's 26.255/29.886 seconds)

Table 1. Profile of the 8 Best Swimmers at Each Olympic Event

Rank	Sex	Beijing 2008	age (Years)	Height (cm)	London 2012	age (Years)	Height (cm)	Rio 2016	age (Years)	Height (cm)	Tokyo 2021	age (Years)	Height (cm)
1	Pa	MP	23	193	MP	27	193	JS	21	184	CD	24	191
	Pi	LT	23	167	DV	24	185	SS	22	182	MM	21	169
2	Pa	MC	24	197	CLC	20	189	MP	31	193	KM	21	190
	Pi	CM	22	185	LY	23	175	PO	16	186	YZ	23	176
3	Pa	AL	21	186	YK	29	197	C£	24	189	NP	20	192
	Pi	JS	21	170	AC	24	176	DV	28	185	EM	27	180
4	Pa	1C	25	193	MC	28	197	LC	30	188	AM	19	187
	Pi	ZY	24		SS	18	182	YL	27	175	TH	18	173
5	Pa	JD	21	183	SD	25	186	ZL	17	183	JM	20	
	Pi	TL	18	160	IB	22	170	RK	16	170	LH	24	187
6	Pa	TF	23	184	JV	24	ISO	MM	24	191	MT	22	
	Pi	JL	18	171	JO	24	178	EM	22	180	MW	24	180
7	Pa	AS	25	188	TM	24	180	TS	25	193	LCM	25	183
	Pi	GS	19	166	CD	23	170	JO	28	178	SS	27	182
8	Pa	RP	26	196	KC	23	195	AS	19		JM	18	
	Pi	ID	22	183	EG	20	170	XC	18	178	AS	18	182

Fig. 1. Average RT 100 meters butterfly at each Olympics

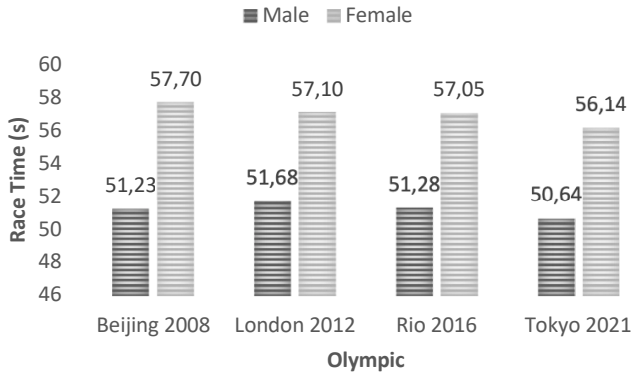

Fig. 2. The average travel time of 100 meters butterfly at each Olympics

Table 2. Details of Mean ST Records in the Four Olympics Men's and Women's Athletes

Olympic	n	Split Time 1st		Split Time 2nd	
		Mean (second)	S.Dev	Mean (second)	S.Dev
Male					
Beijing 2008	8	23.911	0.340	27.319	0.456
London 2012	8	24.077	0.299	27.545	0.517
Rio 2016	8	24.058	0.199	27.218	0.344
Tokyo 2021	8	23.763	0.377	26.882	0.444
Female					
Beijing 2008	8	27.123	0.428	30.661	0.366
London 2012	8	26.602	0.250	30.402	0.518
Rio 2016	8	26.421	0.319	30.208	0.496
Tokyo 2021	8	26.255	0.384	29.886	0.437

Table 3. Details of ST Records in the Four Men's Athlete Olympiads

No	Split Time	N	Normality	F	Sig
Male					
1	Split Time 1st	32	0.536	1.764	0.177
2	Split Time 2nd		0.547	3.061	0.044
Female					
1	Split Time 1st	32	0.007	1.190	0.331
2	Split Time 2nd		0.007	1.080	0.374

Table 3 describes only ST in male athletes normally distributed with a probability value of more than 0.05. Furthermore, only the second ST of the male athlete was stated to be different from sig. < than 0.05.

Fig. 2 explains that both data are normally distributed with a probability value of more than 0.05. Furthermore, the average travel time for each Olympic event in the 100-meter butterfly for both male and female athletes is stated to be different from the sig. < than 0.05.

Table 4 explains that in the 4 Olympics held in the 100-meter butterfly event, only the London and Tokyo Olympics had different average travel times for male athletes. In comparison, the female athletes at the Beijing 2008 and Tokyo 2021 Olympics had other has an average travel time of 100 meters in different butterfly strokes. These two groups show that the Tokyo 2021 Olympics is the best organizer on the average travel time indicator for the 100-meter butterfly.

Table 4. The results Olympics on the 100-meter butterfly event

Uji statistic	Olympiad	N	Subset for alpha = 0,05	
			1 (second)	2 (second)
Male				
	Tokyo 2021	8	50.65	
	Beijing 2008	8	51.23	51.23
Tukey HSD	Rio 2016	8	51.28	51.28
	London 2012	8		51.68
	Sig.		0.078	
Female				
	Tokyo 2021	8	56.14	
	Rio 2016	8	57.05	57.05
Tukey HSD	London 2012	8	57.10	57.10
	Beijing 2008	8		57.70
	Sig.		0.111	

Table 5. The similarity of Average Reaction Time in the Swimming Olympics Number 100 Butterfly Stroke

Uji statistic	Kejuaraan	N	Subset for alpha = 0,05	
			1 (m/s)	2 (m/s)
Male				
	Tokyo 2021	8	0.632	
	Rio 2016	8	0.68	0.68
Tukey HSD	London 2012	8		0.70
	Beijing 2008	8		0.73
	Sig.		0.128	0.069
Female				
	Tokyo 2021	8	0.67	
	London 2012	8	0.71	0.71
Tukey HSD	Rio 2016	8	0.73	0.73
	Beijing 2008	8		0.76
	Sig.		0.135	

Table 6. The effect of ST, RT on FT in all Olympic events

	R Square	F	Sig.
Male			
ST 1st vs FT Male	0.328	14.657	0.001
ST 2nd vs FT Male	0.713	74.565	0.000
RT vs FT (Male)	0.160	2.389	0.023
Female			
ST 1st vs FT Female	0.996	7806.906	0.000
ST 2nd vs FT Female	0.997	10973.351	0.000
RT vs FT (Female)	0.876	2.215	0.000

Table 7. Effect of RT on First ST

	R Square	F	Sig.
Male and Female			
RT vs Split 1st	0.712	153.013	0.000

Table 5 explains that the reaction time for the men's swimmers in the 2008 Beijing 2008, London 2012 and Tokyo 2021 Olympics was significantly different. The reaction time for the 2021 Tokyo Olympics is the fastest reaction time from the 2 previous Olympics. For female athletes, the difference in reaction time only occurred in the 2008 Beijing and 2021 Tokyo Olympics.

Table 6 explains that the two indicators, ST and RT, influence the achievement of FT in the 100-meter butterfly stroke.

Table 7 explains that the RT ability of male and female swimmers has an effect of 0.712 (51%) on achieving the first 50 meters in the 100 meters butterfly event.

Discussion

This study aims to provide benchmarks and standards in the development of swimming sports training, especially in the 100-meter butterfly stroke. This analysis is based on the two categories of ST and RT in swimmers who entered the final round at the Olympics from 2008 to 2021.

The findings in this study are that the ST travel time in the last 50 meters has differences in each Olympics. This is in accordance with the results of research (Robertson et al., 2009), which found that ST management will affect the achievement of travel time at the end of the race. The last ST 50 meters is a critical travel time for swimmers. In all Olympic events, there is a slowdown in the stroke. This causes a delay in the ST travel time due to physiological limitations of the body in supporting performance to increase speed in the last 50 meters (Morais, Barbosa, et al., 2019; Tucker et al., 2006).

The first ST speed is caused by optimal starting support, where starting ability is also supported by high leg muscle strength (Keiner et al., 2021; Thng et al., 2020). Furthermore, the body's physiological ability to maximize the energy released will also help optimize performance in maximizing all swimming movements (Barbosa et al., 2008; Nordsborg et al., 2014). Breaststroke and butterfly stroke have a higher energy expenditure value than freestyle and backstroke (Barbosa et al., 2006; Strzała et al., 2012, 2017).

This study also found that RT (RT) in every Olympics, both male and female, had different travel times. This difference indicates that every coach and athlete has set the same strategy for improving their performance when starting a swimming competition. RT achievements also relate to the final performance of swimming athletes (Everett, 2015; Lima, 2016; Seifert et al., 2011).

Previous research stated that final travel time was strongly influenced by net swimming speed, shot reaction time at the start, stroke frequency and stroke length (Markovic et al., 2014). This speed of reaction is also supported by the athlete's ability to start (Cuenca-Fernández et al., 2015; Marinho et al., 2021). Support for the quality of athletic starts is also an indicator of promoting an athlete's swimming performance (Garcia-Hermoso et al., 2013). These facts suggest that coaches should apply all the kinematic elements of the training season and try to identify optimal swimming speed (ratio of stroke speed to long stroke) for swimmers (Vasic et al., 2021).

This study also found that RT influenced the target travel time at the first ST. This study found that RT can affect the first ST by 50%. This is the same as several studies which state that optimal RT will provide a path to the swimmer's shot timing policy (da Silva et al., 2019). However, other variables also affect it, such as the force applied to the block, low resistance when entering the water, underwater slides and underwater propulsion (Bishop et al., 2013; Potdevin et al., 2011; Rebutini et al., 2016).

Viewed in this study, it can be interpreted that from the Beijing Olympics (2008) to the Tokyo Olympics, there has been a change in the reaction time performance policy strategy. The findings from this study show RT affects the attack time of the 100-meter butterfly stroke, so RT here will positively impact swimmer speed (Draheim et al., 2019).

RT itself is influenced by the athlete's ability to capture start instructions in audiovisual form. In sports, an athlete's swimming ability in receiving stimuli from the committee's instructions also determines how fast the RT gets; most of these stimuli are in the form of audiovisual. Like runners, swimmers are very good at capturing audiovisual stimuli, which will later be continued in the form of RT (Nuri et al., 2013).

Conclusions

This study concludes that the implementation of each Olympics in swimming in the 100-meter butterfly event has a different average of FT and RT in each event. Every performance of FT and RT shows changes that are getting faster in both. Furthermore, there is the influence of RT on the desire for FT; although this effect is minimal, it strongly impacts the willingness of the first ST.

Conflict of interest

Authors state no conflict of interest.

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АНАЛІЗ ЗАРЕЄСТРОВАНИХ ПОКАЗНИКІВ ЧАСУ РЕАКЦІЇ, ПРОМІЖНОГО ЧАСУ ТА КІНЦЕВОГО ЧАСУ СПОРТСМЕНІВ-ПЛАВЦІВ НА ОЛІМПІЙСЬКИХ ІГРАХ 2008-2021 РР.

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 7 табл., 2 рис., 39 джерел.

Мета дослідження. Метою цього дослідження є оцінка та аналіз зареєстрованих показників кінцевого часу (КЧ), проміжного часу (ПЧ) та часу реакції (ЧР) плавців батерфляєм на дистанції 100 метрів у чотирьох олімпійських змаганнях із метою забезпечення контрольних показників і стандартів для розвитку навчання плавання.

Матеріали та методи. Це дослідження поєднує в собі кількісний і якісний підходи. У цьому дослідженні використовували вибірку з 32 спортсменів з першої по восьму категорії, які змагалися на дистанції 100 метрів батерфляєм на чотирьох Олімпійських іграх: Олімпіаді 2008 року в Пекіні, Олімпіаді 2012 року в Лондоні, Олімпіаді 2016 року в Ріо-де-Жанейро та Олімпіаді 2021 року в Токіо. У дослідженні використовують вторинні дані, у яких усі часові результати одержані з вебсайту (http://www.fina.org). У цьому дослідженні для статистичного аналізу використовували описову статистику середнього та стандартного відхилення. Для визначення нормальності даних використовували тест Колмогорова-Смирнова. Для порівняння даних між олімпіадами використовували однофакторний дисперсійний аналіз із критерієм множинного порівняння, щоб перевірити взаємодію між ЧР, ПЧ та КЧ на олімпіадах. Для визначення впливу ЧР та ПЧ на КЧ використовували однофакторну лінійну регресію з рівнем значущості $p<0,05$ як стандартом. Для всіх аналізів використовували ПЗ SPSS Inc., Чикаго, Іллінойс, США.

Результати. Було встановлено, що ПЧ та ЧР впливають на досягнення КЧ на 100-метровій дистанції батерфляєм, а ЧР має вплив на рівні 0,712 (51%), для плавців і чоловічої, і жіночої статі, на досягнення цього часу за перші 50 метрів.

Висновки. Висновок полягає в тому, що як спортсмени, так і тренери повинні оптимізувати досягнення показників ЧР та ПЧ у плаванні на короткі дистанції, оскільки ці два показники відіграють вирішальну роль у досягненні часу загального руху плавців на короткі дистанції.

Ключові слова: час реакції, кінцевий час, проміжний час, плавання.

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ORIGINAL SCIENTIFIC ARTICLE

DIFFERENCES IN ANTHROPOMETRIC CHARACTERISTICS OF YOUTH IN FOOTBALL BETWEEN ELITE AND NON-ELITE PLAYERS

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Abstract

Study purpose. This paper is about the differences in anthropometric characteristics between elite and non-elite youth football players in the Republic of Kosovo. Therefore, our current study aims to compare the differences in anthropometric characteristics between elite and non-elite youth players. The test was conducted with 132 young football players aged 14±0.5 years.

Materials and methods. The sample was divided into two groups, namely 66 young players playing in the elite league and 66 young players playing in the non-elite league. The sample of variables consisted of 10 anthropometric measurements. The results of the measurements were analyzed using statistical procedures characterized by descriptive parameters and analysis of variance (ANOVA).

Results. The results show that the elite league players have higher values in height and body mass compared to the non-elite league players. It should be noted that the length of the left leg is also higher in the elite league players, while the waist circumference is higher in the non-elite league players. As for knee diameter, the values are identical in both groups. Subcutaneous adipose tissue is more pronounced in the non-elite group than in the elite league players. According to the analysis of variance (ANOVA), significant differences were presented only in the three variables such as the subcutaneous adipose tissue of the back, triceps and suprailiac between the elite and non-elite groups at the level ($p<0.05$), while no differences were presented in other variables. That is, between the elite and non-elite groups.

Conclusions. In summary, the elite league players had better values in the anthropometric characteristics compared to the non-elite league players.

Keywords: anthropometry, differences, football, elite, non-elite.

Introduction

Football is the most popular and widely played sport in the world in recent decades, and a body of research has focused primarily on examining the factors that influence a player's performance (Reilly et al., 2000; Brocherie et al., 2014). Anthropometric characteristics are important indicators and have the potential to influence the success of football players (Norton & Olds, 1996). A review of the literature has shown that body size, body mass and body fat percentage are among the important anthropometric characteristics that are related to performance (Norton & Olds 1996). Body mass and height, body mass index and subcutaneous fat are the most studied anthropometric measures. However, there is a need to better study the anthropometric characteristics of players, including diameter and girth (Cavia et al., 1999). Elite youth players are taller and heavier than their non-elite league peers and perform significantly better physically (Rebelo et al., 2013; Lenjani et al., 2018).

The aim of this work is to determine the anthropometric characteristics of young players playing in the elite and non-elite leagues of the Republic of Kosovo. Thus, the main objective of this study is first to determine the normative

values of anthropometric parameters for young players of this age. Therefore, the results of this research can provide useful information for experts in this field of sport. First, we assume that there will be significant differences in the anthropometric variables between the elite and non-elite group of soccer players. Second, we assume that reference values have been presented in favor of the anthropometric variables in elite league players.

Materials and methods

Study participants

This study was designed to investigate the differences in anthropometric characteristics in youth soccer between elite and non-elite players. The sample of participants included 132 teste, mainly young elite and non-elite players from the Republic of Kosovo. Young players aged (14 years ± 6) months were tested. For the purpose of the study and comparison, the players were divided into two groups: 1. the first group includes (N=66), young players playing in the elite league; and 2. the second group includes (N=66), young players playing in the non-elite league. All measurements with the players of the two groups were performed under the same conditions in a closed hall with a room at a temperature of 24°C. The measurements were taken in the morning hours from 9:00–11:00. The players wore light clothing consisting mainly of a T-shirt and sports shorts. All players tested at this age were clinically healthy and had no visible physical defects, as evidenced by their sealed notebooks at medical examination. Therefore, all subjects in this study were treated and assessed in accordance with the ethical standards of the Declaration of Helsinki. The entire study includes all players whose parents consented to participate in this research. Players were informed in advance of the protocols to be followed during the experiment.

Table 1. Characteristics of the participants (Mean ± Std. Dev.)

Characteristics	Elite (N=66)	Non-elite (N=66)
	Mean±Std.Dev.	Mean±Std.Dev.
AGE	14.3	14.4
AVIS	155.42±10.90	152.50±9.38
ATTM	45.69±10.37	45.31±11.39
ABMI	18.61±2.22	19.24±3.22

Test protocol

Length parameters, body height was measured with a stadiometer with an accuracy of up to 1 cm (SECA Germany), while leg length was measured with a short Martini anthropometer (Eurofit 1988). Body weight is estimated in light clothing and without trainers with an accuracy of up to 0.1 kg (Tanita BC530).

Body mass index (BMI) is a value derived from a person's mass (weight) and height. BMI is defined as body mass divided by the square of height and is expressed in the unit kg/m^2, which is derived from mass in kilograms and height in metres (BMI 1995).

Knee joint diameter-is measured from behind by placing the ends of the pelvimeter on both epicondyles of the knee and compressing the soft tissues. The result is read with an accuracy of 0.1 cm (Eurofit, 1988).

The subcutaneous adipose tissue on the back of the scapula, the subcutaneous adipose tissue on the lower part of the calf, the subcutaneous adipose tissue on the triceps of the upper arm and the subcutaneous adipose tissue on the suprailiac part were measured using calipers for measuring subcutaneous adipose tissue according to standard procedures (Lohman et al., 1988).

Statistical analysis

For each variable, descriptive statistics were calculated for the arithmetic mean (Mean) and standard deviation (Std.Dev). Through the analysis of variance (ANOVA) was applied for independent variables between the elite and non-elite league group at the value level < 0.005. Classification and testing of differences between these two groups of football players was carried out. Furthermore, in this case, the analysis of the data processing was carried out using the statistical software SPSS for Windows version 22.0.

Results

Table number 2 shows the results of the table of anthropometric variables among the group of elite and non-elite football players, so the data for each result will be presented separately in the presented table. Elite league players have higher height and body mass values compared to non-elite league players. It should be noted that left leg length is also higher in elite league players, while waist circumference is higher in non-elite league players. Regarding knee diameter, the values are identical in both groups. Subcutaneous adipose tissue is more pronounced in the non-elite group than in the elite league players.

Table 2. Basic indicators and differences between the elite and non-elite football groups in anthropometric variables

Indicators	Elite (N=66)	Non-elite (N=66)	ANOVA	
	Mean±Std.Dev.	Mean±Std.Dev.	F	P
VIS	155.42±10.90	152.50±9.38	2.723	0.101
DLN	94.23±7.07	92.73±7.91	1.510	0.221
ONK	44.61±4.24	45.23±4.70	0.632	0.428
TTM	45.69±10.37	45.31±11.39	0.041	0.839
BMI	18.61±2.22	19.24±3.22	1.669	0.199
DZK	9.74±0.78	9.74±0.89	0.000	0.992
KNG	6.68±3.87	9.02±6.25	6.648	0.011
KNP	14.70±4.65	16.38±6.07	3.182	0.077
KNNT	8.32±4.35	10.59±5.15	7.496	0.007
KNS	8.64±6.18	12.14±8.11	7.780	0.006

While according to the analysis of variance (ANOVA) we have significant differences between the groups are presented in elite and non-elite, the variable subcutaneous adipose tissue in the back has shown differences with a value of .011, the other variable subcutaneous adipose tissue of the triceps has shown a difference with a value of .007 and the

suprailiac subcutaneous adipose tissue variable with a value of .006. Meanwhile, the system of variables between elite and non-elite groups did not present significant differences between the groups.

Discussion

The focus of this paper is on the differences in anthropometric characteristics between elite and non-elite football players. First, we will compare our results between elite and non-elite youth football players, while we will then analyse and compare our results with those of other authors. We will present the differences in anthropometric characteristics between elite and non-elite football players and how they compare. The main results of our study on youth anthropometric characteristics in elite and non-elite football players will be analysed. Elite league players have shown higher values in height compared to non-elite league players, and elite league players also have a larger body mass. Body mass index (BMI) is higher in non-elite league players than in elite league players, and the values of players in both leagues are within the normal range. The length of the left leg is also higher in elite league players, while the waist circumference is higher in non-elite league players. As for knee diameter, the values are identical in both groups of players. Subcutaneous adipose tissue is more pronounced in the non-elite group than in the elite league players. As the research of Portuguese players of this age divided into elite and non-elite groups, also the players we tested height and body mass have shown differences between elite and non-elite league players (Rebelo et al., 2013). In fact, height has been cited as an important criterion in the selection of football players (Carling et al., 2009; Coelho et al., 2010, Gil et al., 2010), while thigh, calf and upper arm circumference are measures needed to distinguish professional athletes from the general population as well as from non-professional athletes (Fragoso et al., 2015). In this context, Le Gall et al. (2010), assessed several anthropometric variables in young football players and showed that top international athletes had above-average scores from the age of 14 years. Furthermore, Matkovic et al. (2003) found that height plays a crucial role in the selection of young football players, with tall players being preferred (Fragoso et al., 2015). When we compare the players of the Pristina, Trepça and Besa teams with our players tested in the elite and non-elite leagues, we see that we have approximate values in the indicators of subcutaneous adipose tissue (Gardasevic et al., 2020). If we compare for comparison elite league players from Macedonia have shown higher results in body mass, height and body mass index (Gontarev et al., 2016), while Greek players have shown approximate values (Michailidis et al., 2022), while games from Italy have shown lower values in these three anthropometric indicators (Rinaldo et al., 2021). Elite and non-elite games have significant values in the corats, like the players we took for the research (Bidaurrazaga-Letona et al., 2016). Also, in terms of height and body mass, elite and non-elite league players have shown significant differences among themselves (Nughes et al., 2020). In our study, elite or select league players were on average taller than their non-elite league counterparts (Nughes et al., 2020). This is consistent with previous research showing that adult players reaching higher levels of play were on average, with significant differences from non-elite league players in height and body mass (Le Gall et al., 2010). Based on the research of the authors Grendstad et al. (2019), in body height, elite players have shown better values than non-elite players, while in elite body mass, they have shown lower values, but if we compare with the players we have taken for studies, we see that the body height is the same as the study of the top author noted in the group of the elite league and the non-elite league. Subcutaneous adipose tissue in the back of the subscapula in the elite players that we took for studies showed a value of 6.68 mm while the players of a study showed a value of 8.5 mm, it should also be noted that in the triceps the difference was 0.42 in favors of our elite players. It should also be emphasized that the suprailiac in the players we have treated for studies have a higher value compared to other elite players (Bernal-Orozco et al., 2020). In this case, it should be emphasized that the subcutaneous adipose tissue was more pronounced in the elite players that we treated, than in those players that we did not have for the purpose of the experiment-study.

Conslusions

This study-research has examined the anthropometric characteristics of football players, in which differences between elite and non-elite players have been highlighted. Anthropometric characteristics body height, left leg length, waist circumference, body mass, body mass index, knee joint diameter was higher in the players of the elite group than in the non-elite group. In contrast, players of the non-elite group showed greater values in subcutaneous adipose tissue indicators. According to the analysis of variance (ANOVA), significant differences were presented only in the three variables such as the subcutaneous adipose tissue of the back, triceps and suprailiac between the elite and non-elite groups at the level ($p<0.05$), while no differences were presented in other variables. That is, between the elite and non-elite groups. These findings of this study provide reference values for elite league players that can help coaches improve performance and identify young elite players to make the most of a career in the game of football. To reach a final conclusion, this study highlights that elite and non-elite league players can improve their anthropometric characteristics and results based on the level of competition they have attended.

Conflict of interest

The authors state that there is no conflict of interests.

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ВІДМІННОСТІ В АНТРОПОМЕТРИЧНИХ ХАРАКТЕРИСТИКАХ МОЛОДІ У ФУТБОЛІ МІЖ ЕЛІТНИМИ ТА НЕЕЛІТНИМИ ГРАВЦЯМИ

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Реферат. Стаття: 5 с., 2 табл., 24 джерела.

Мета дослідження. У цій статті йдеться про відмінності в антропометричних характеристиках між елітними та неелітними юнаками-футболістами в Республіці Косово. Таким чином, метою нашого поточного дослідження є порівняння відмінностей в антропометричних характеристиках між елітними та неелітними юними гравцями. Тест проводився за участю 132 юних футболістів віком 14±0,5 року.

Матеріали та методи. Вибірку було розділено на дві групи, а саме: 66 молодих гравців, які грають в елітній лізі, і 66 молодих гравців, які грають в неелітній лізі. Вибірка змінних складалася з 10 антропометричних вимірювань. Результати вимірювань аналізували за допомогою статистичних процедур, що характеризуються описовими параметрами, та дисперсійного аналізу (ANOVA).

Результати. Результати показують, що гравці елітної ліги мають вищі показники зросту та маси тіла порівняно з гравцями неелітної ліги. Слід зазначити, що довжина лівої ноги також більша у гравців елітної ліги, а окружність талії більша у гравців неелітної ліги. Що стосується діаметра коліна, то значення в обох групах однакові. Підшкірна жирова клітковина більш виражена в неелітній групі, ніж у гравців елітної ліги. Відповідно до результатів дисперсійного аналізу (ANOVA), статистично значущі відмінності між елітною та неелітною групами були представлені лише в трьох змінних, таких як підшкірна жирова клітковина спини, трицепса та гребня клубової кістки, на рівні ($p<0,05$), тоді як в інших змінних відмінностей не було. Тобто між елітною та неелітною групами.

Висновки. Таким чином, гравці елітної ліги мали кращі значення антропометричних характеристик порівняно з гравцями неелітної ліги.

Ключові слова: антропометрія, відмінності, футбол, елітний, неелітний.

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ORIGINAL SCIENTIFIC ARTICLE

DEVELOPMENT OF KINESTHETIC MOVEMENT IDENTIFICATION INSTRUMENTS FOR BADMINTON

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Abstract

The purpose of this study was to develop an instrument to identify movements and produce recommendations for children who are predicted to be able to develop in badminton.

Materials and methods. The kind of this research is research and development consisting of (1) the Preliminary study stage, (2) the Expert validation stage, (3) the Acceptance test stage, and (4) the benefit test stage. The validation stage is carried out by three experts with assessment indicators of suitability, accuracy, convenience, and practicality. The acceptance test phase was obtained from the application of the instrument to the participants. The benefits test stage was determined by a retest test to determine the reliability of the instrument. Participants in the product trial consisted of two groups, namely the male group with 17 participants and the female group with 17 participants. The age of the participants was 6-7 years old. They were elementary school students who were in grade 2. Statistical analysis used a test-retest.

Results. The results show that the validation from badminton experts gives an assessment with a presentation of 97% in the very good category, the validation of talent identification experts is 98% in the very good category, and the validation from the coach is 97% in the very good category. For the acceptance test, 4 children (24%) in the first test were recommended, and 5 children (29%) in the second test were recommended. For girls, 2 children (12%) in the first test were recommended, and 3 children (18%) in the second test were recommended. For the reliability test, it was obtained 0.97 in the very strong category for boys and 0.91 in the very strong category for girls.

Conclusions. This instrument has been proven valid and reliable and can provide recommendations. The existence of this instrument can facilitate sports teachers and badminton coaches in identifying children's movements.

Keywords: development, kinesthetic movement, children, badminton.

Introduction

Indonesia is a reference in the development of world badminton to produce classy athletes. There have been many badminton athletes who were born and have proud achievements in international events and in the Olympic class. This success is certainly not born by itself but has a long journey. Starting from finding superior seeds in their respective regional clubs throughout Indonesia to forging talent by conducting training camps (Bradley et al., 2013). In finding the badminton trainee candidate, of course, based on the focus on inclusion (Bennie, 2021). Focusing on many factors, the point is that growth and maturity are the best concepts in understanding the identification, selection, and development of young athletes (Gonçalves et al., 2012). In Indonesia to join the training camp, the athlete must pass a screening system, including regional selection for the province and national selection for the national level. However, this is done after the trainees have acquired the skills from the existing clubs. From this information, there is an empty in method to capture the kinesthetic movement abilities of participants at the children's level, so that this void becomes the problem that arise in badminton clubs in Indonesia.

The problems are very diverse, including the difficulty of the trainer in delivering the training program due to the ability of the trained children to absorb the training programs is different (Lorio et al., 2020). This difficulty was identified from the results of interviews that have been carried out that children's abilities are different in accepting and applying

the given training program. The trainer explained that the program that provided to the trainees was a program that was developed when they received the license of level 1 trainer from the Badminton World Federation (BWF). The essence of the problem is that the trainers do not yet know the level of ability of the trainees so the ability to accept the training program is different. What is the impact of all this? 1) The children who are less able to follow the instruction in training programs will feel bored with badminton training, 2) The children who have talent will be a problem if these talents cannot be found and maximized. 3) If these talents are not channeled with a good program, they will become underachievers, namely people whose achievements are below their maximum ability. Therefore, the trainer also acts as a facilitator in determining children who have good kinesthetic movement skills (Sepdanius et al., 2018). The results of this identification are recommended in the sport of badminton.

Talent is not only based on intelligence but also accompanied by willingness and productive performance (Bailey, 2017). To realize this giftedness, appropriate interventions are needed, namely interventions in differentiated programs (Mann et al., 2017). This differentiation program which is the embodiment of sports achievement needs to be prepared from the stage of the children's age (Komaini et al., 2022). Starting from the maturation of multilateral movements, determining the right sporting tendencies and training programs that are in accordance with the child's growth and development, greatly determine the achievements of athletes at the golden age (Fischetti & Greco, 2017). However, there are still many other factors that determine the success of children in the future to achieve achievements, namely intelligence, psychological and external factors such as derivatives from parents or environmental influences (Tod, 2014). The involvement of children in sports participation is another factor in creating outstanding athletes in the future (Križ, 2020). This involvement forms social relationships that affect the child's self-perception, achievement orientation, and motivated behavior patterns.

Several studies have proven that there are three categories in predicting a person's talent, namely cognitive/psychological abilities, physical profiles, and previous performance/experiences (Johnston et al., 2018). Of the three, it was identified that there is considerable variability related to the criteria that can be seen from the criteria for tasks, rules, activities, and motor skills required in different sports (Gonçalves et al., 2012; Özmen & Aydoğmuş, 2017). The importance of selecting talented athletes is done to predict the performance of athletes who are able to carry out training activities for a long time and are continuous. Conny Semiawan states that there are two key clues in observing and interpreting giftedness: 1) Giftedness is a special and external universal trait that is inborn and is the result of the interaction of environmental influences, 2) Giftedness is also determined by the needs and tendencies of the culture in which it belongs (Vater et al., 2017). Multi-faceted conceptualizations of talent are interpreted as: 1) Innate (i.e., derived from biological elements present at birth), 2) Multidimensional (i.e., consisting of capacities from a broad range of cognitive, physical, and psychological categories), 3) Emergency (i.e. involving interactions among factors that are multiplicatively coupled), 4) Dynamic (i.e., evolve across developmental time due to interactions with the environment and random gene expression), and 5) Symbiotic (i.e., cultural and social factors will determine the highest scores of individual talents) (Baker et al., 2019). Therefore, physical and physiological growth and development in sports giftedness is closely related to sports performance (Pearson et al., 2006). Physical and physiological development can be improved over time with exercise (Chuckravanen et al., 2019). Then to support physical performance and skills when the process is running, it is determined by kinesthetic, psychological, genetic and environmental intelligence (Syväoja et al., 2021). These four indicators are very important to know in making it easier for prospective athletes to accept and apply the training program obtained so as to reduce the athlete's boredom and frustration in participating in strenuous training (Mason & Burn, 2023). Kinesthetic intelligence is closely related to a person's ability to develop movements so that they display movements that have maximum performance with different beauty from others (Koçak, 2019). There are five basic movements that need to be present to develop good kinesthetic movements, namely body coordination, agility, strength, balance, and eye coordination (Komaini et al., 2022). These five basic movements are interrelated with one another to produce efficient and effective movements. Just as agility is the result of a combination of speed, coordination, flexibility, and strength shown in badminton games (Bompa & Buzzichelli, 2015).

Materials and Methods

Study design

This kind of this research is research and development theory from Borg and Gall which has been modified into four major stages, namely (1) preliminary study stage, (2) expert validation stage, (3) acceptance test stage, and (4) benefit test stage. The validation stage was carried out by three experts, namely an expert in badminton, an expert in identifying sports talent, and a badminton coach. These experts assess the indicators of suitability, accuracy, convenience, and practicality. Five-scale assessment was used with each item and each indicator having 5 questions for the expert validation stage.

This instrument was directly applied to the participants for the acceptance test phase. Then the data obtained is converted to a scale of five except on the balance test. For balance, it must have a value of 2 from the implementation of dynamic balance for forward and backward movements (forward and backward). There are five tests in the Table: 1) Shuttlecock throw test; 2) Test catch shuttlecock; 3) Agility test (seconds); 4) Test bouncing ball (amount); 5) Balance test walking the block (forward and backward).

Table 1 above is the result of development which is arranged based on the classification of data using the interval class of values obtained. Except for the balance test, it is only determined based on being able or unable. The maximum total score that may be obtained by participants is twenty-two (22). However, what is included in the recommendation is a large value equal to 18 (≥ 18). At the trial stage, participants were asked to do the test twice. Then the first data and the second data were tested using the retest method to see the reliability of the instrument.

Table 1. Assessment scale for badminton talent identification instrument for children.

Items	Male	female	Score	Items	Male	female	Score
1) Shuttlecock Throw Test (meters)	5.7	4.1	1	3) Agility Test (seconds)	10.3	11.63	1
	5.8-6.0	4.2-4.7	2		9.5-10.2	11.05-11.62	2
	6.1-6.3	4.8-5.3	3		8.7-9.4	10.47-11.04	3
	6.4-6.6	5.4-5.9	4		7.9-8.6	9.89-10.46	4
	6.7	6	5		7,8	9.88	5
2) Test Catch Shuttlecock (Quantity)	1	1	1	4) Test Bouncing ball (amount)	10	8	1
	2	2	2		11-14	9-12	2
	3	3	3		15-18	13-16	3
	4	4	4		17-22	17-20	4
	5	5	5		23	20	5
	0	0	0	5) Balance Test walking the block (forward and backward)	Capable	Capable	1
					Not	Not	0

Participant

Participants in the product trial in this study consisted of two groups, namely the male group was 17 participants and the female group was 17 participants. The average age of participants is 6-7 years old elementary school students who are in grade 2. The reason for taking participants at this age is that participants have begun to be given an introduction to sports (Hastie et al., 2009) we examined the development of skill competence and tactical knowledge of 41 eighth-grade students (mean age 13.6 years. In addition, the school where the research was carried out had approved the implementation of the research in order to collect data.

Product Design

The product is designed based on kinesthetic motion, namely strength, body coordination, agility, eye coordination, and balance. Strength is represented by throwing the shuttlecock, body coordination is represented by catching the shuttlecock, agility is represented by agility movements, eye coordination is represented by bouncing the ball, and balance is represented by walking blocks.

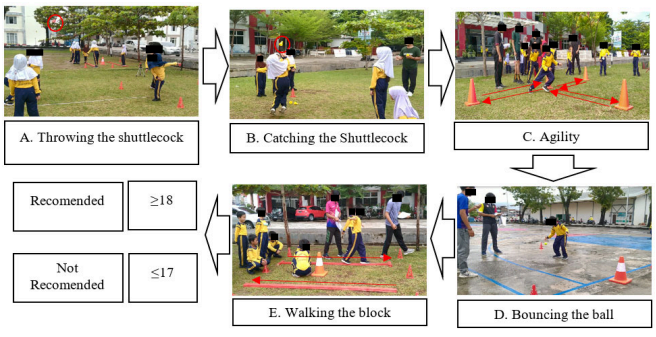

Fig. 1. The series of implementation of the kinesthetic motion test instrument for badminton
Source: Image from researcher Endang Sepdanius' private collection

Statistical Analysis

The expert validation stage uses data analysis techniques using the percentage of expert research results. For the acceptance test stage, descriptive analysis of the percentage of data obtained from the use of the instrument with the output is a recommendation for the value of the participants who have a large value equal to 18. For the usefulness test, see the results of the reliability of the instrument with the retest test

Results

Product

There are five items resulting from this development according to the kinesthetic motion for badminton, namely 1) throwing the shuttlecock, 2) catching the shuttlecock, 3) agility, 4) bouncing the ball, and 5) walking the block. The following shows the product and its implementation in Figure 1.

Figure 1 describes the sequence of implementation of the kinesthetic movement identification instrument starting from throwing the shuttlecock, then catching the shuttlecock, agility, bouncing the ball and walking the block. After the implementation, the value of the child's kinesthetic movement ability is then classified and processed to get a recommendation or not. This instrument is a battery test so it must be done sequentially. There are no rules for rest periods between test items. For the implementation and equipment needed can be seen in table 2.

Expert Validation

The following shows the validation results by badminton experts, expert in identifying sports talent and badminton coaches shown in table 3.

In table 3 it can be seen that the validators gave an assessment of which 97% of badminton experts were included in the very good category, expert in identifying sports talent rated 98% as very good and the coach assessed 97% in the very good category.

Table 2. Kinesthetic movement instrument product for badminton for children aged 6-7 years

Name	Equipment	Implementation
Throw shuttlecock	a. Shuttlecock weighing 4.74-5.50 gram b. Shuttlecock speed should be 75-79 c. 4 cones d. Meter	a. Testee stands in a circle to prepare to throw the Shuttlecock b. Testee throws Shuttlecock as far as possible c. Testee's throw is measured d. The throw is made 3 times e. The throw taken is the farthest throw
Catch shuttlecock	a. Shuttlecock weighing 4.74-5.50 gram b. Shuttlecock speed should be 75-79 c. 4 small cones	a. The tester is in the shuttlecock throwing position b. Testee is in a catch position c. The tester throws the shuttlecock at the testee with a parabolic throw d. Tester catches shuttlecock with two hands e. 5 shuttlecocks are thrown f. The points that are counted are the shuttlecocks caught
Agility	a. 4 large cones b. Stopwatch c. whistle	a. Place four cones at a distance of 2 meters from each cone as shown in Figure C. b. Testee getting ready in starting position on Cone A c. The testee starts running quickly towards cone B and then surrounds, returns to cone A then goes to cone C around, returns to cone A and goes to cone D around then finishes at cone A. d. It was done in 2 trials and the fastest time was taken
Bouncing Ball	a. 4 small cones b. Tennis ball c. stopwatch	a. The ball is in the strongest hand (right/left) b. The ball is reflected to the floor and then caught by the opposite hand. c. When caught by the opposite hand, it is counted as one. d. Done in 30 seconds.
Walking the Blockc	a. Two block boards with a length of 3 meters. The first board is 6 cm wide and the second board is 11 cm wide b. 1 large cone c. 4 small cones	a. The testee is in the starting position, on the signal forward the participant starts walking on the first available block. b. The assessment is carried out if the participant performs well without dropping one of the leg then it is considered "capable". If you drop one of your leg, it is considered "incapable". Participants must complete until the finish c. To retreat, participants start at the start and then do it backwards until they finish d. The assessment is carried out if the participant does well without dropping one leg then it is considered "Able", if dropping one leg it is considered "incapable". Participants must complete until the finish

Table 3. Questionnaire scores for the validity of kinesthetic movement by expert

Indicator	Expert		
	Badminton	Talent	Trainer
Suitability	25	24	25
Accuracy	24	24	25
Convenience	25	25	24
Practicality	23	25	23
Amount	97	98	97
Percentage	97%	98%	97%
Eligibility Level	Very good	Very good	Very good

Descriptive Data

Descriptive data obtained from participants using gifted instruments in kinesthetic movements are shown in table 4 for boys and table 5 for girls.

Based on table 4 the results of the kinesthetic movement test for boys, it was found that 4 children (24%) were given recommendations on the first test and 5 (29%) children were given recommendations on test 2.

Based on table 5 the results of the implementation of kinesthetic movement testing in girls, it was found that 2 children (12%) were given recommendations for the first test and 3 children (18%) were given recommendations for the second test.

Reliability

To determine the reliability of the instrument, a retest test was carried out to obtain the results as shown in table 6.

Based on table 6, the instrument reliability for boys was 0.97 in the "very strong" category, while the instrument reliability value for girls was 0.91 in the "very strong" category.

Discussion

The success of movement in badminton can be identified from the beginning of growth (Werkiani et al., 2012). Children with good kinesthetic movement intelligence are expected to be able to undergo training programs in badminton well (Wang, 2021; Zubir et al., 2022). Children with good kinesthetic movements are able to receive the coach's instructions to be applied in the movement of sports (Hastie et al., 2009). Kinesthetic movements that lead to badminton

Table 4. Kinesthetic movement for boys on Test 1 and Test 2

Classification	Test 1			Test 2		
	Frequency	Percentage	Information	Frequency	Percentage	Information
18	4	24%	Recommendation	5	29%	Recommendation
17	13	76%	Not	12	71%	Not
Total	17	100%		17	100%	

Table 5. Kinesthetic movement for girls on Test 1 and Test 2

Classification	Test 1			Test 2		
	Frequency	Percentage	Information	Frequency	Percentage	Information
18	2	12%	Recommendation	3	18%	Recommendation
17	15	88%	Not	14	82%	Not
Total	17	100%		17	100%	

include throwing, jumping, catching, body balance when stepping forward and backward, and body coordination (Nugroho et al., 2021). These movements if done properly and the use of appropriate sports equipment can reduce the risk of injury (Hong et al., 2014). Badminton is identical to hitting the shuttle using a racket. With a good hitting technique, it has an impact on the accuracy of the stroke and the speed of the shuttlecock (Zhu, 2013). The phase in hitting using a racket is the same as someone throwing a throw, which requires flexibility and power (Tohidin et al., 2021). By identifying the child's ability to throw well, it becomes the basis for seeing good muscle activation for children (Sakura & Ohtsuki, 2000). With this identification, it is hoped that children will be able to apply good hitting techniques while in the training process. Furthermore, children with the ability to catch objects that are above their heads are the ability to coordinate their bodies to prepare themselves to catch an object (Junaid & Fellowes, 2006). The accuracy of the body in capturing this object is a benchmark that in carrying out manipulation movements using a racket, children are able to hit the shuttlecock well. The ability to catch is not only placing the hands but also involves placing the body position at the right time which involves the coordination of all bodies to get the degree of capture (Davids et al., 2000).

Agility is also important in badminton, changing directions in the shortest possible time is the hallmark of badminton (Ooi et al., 2009; Tohidin et al., 2021). A person is forced to move the body as quickly as possible in various directions in the shortest possible time so that the body position when hitting the shuttlecock is in a ready state (Mohammadi & Fathi, 2018). The effectiveness of movement in moving determines the formation of badminton players on single or double courts (Alcock & Cable, 2009). In this movement for agility, participants must be in a balanced condition. Good balance is a picture of the body's physiology, both nerves and muscle abilities and other physical factors (De Oliveira et al., 2019). The ability of nerves to process information to keep the body in a balanced state is individualistic and not everyone has and is able to apply it well (Hrysomallis, 2011). Although this balance can be obtained through physical exercise, it is also determined by confounding factors and maturation of children and individuals (De Oliveira et al., 2019). By detecting a good balance as early as possible, we can predict children who are able to carry out motion assignments in badminton training well.

Table 6. Analysis of the test retest for boys and girls

	Male		Female	
	Test 1	Test 2	Test 1	Test 2
Min	4	7	7	11
Max	19	19	19	20
Average	12.8	13.6	14.55556	15.72222
Standard Deviation	4.89973	4.256483	2.955	2.270153
Variant	24.78333	17.98333	8.732026	5.153595
Reliability	0.97		0.91	

Conclusions

The identification of kinetic motion in children makes it possible to recommend children to engage in sports. This identification is carried out to determine the child's basic movement ability to be adapted to the basic movement in certain sports. The dominant movements in badminton include throwing, jumping, catching, body balance when stepping forward and backward, and body coordination. Based on the badminton movement, an instrument was developed to identify the basic movements that have been proven to be valid and reliable. The instrument consists of five activities, namely throwing the shuttlecock, catching the shuttlecock, agility, bouncing the ball, and walking blocks. This instrument is an answer to the current problems found by coaches in badminton clubs in identifying children's abilities. The existence of this kinesthetic movement identification instrument can make it easier for sports teachers and badminton coaches to identify children and provide recommendations. The next research is to develop instruments from the psychological aspect for badminton for children aged 6-7 years.

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Conflict of interest

The authors declare no potential conflicts of interest.

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РОЗРОБКА ІНСТРУМЕНТІВ ВИЗНАЧЕННЯ КІНЕСТЕТИЧНИХ РУХІВ ДЛЯ БАДМІНТОНУ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 5 с., 2 табл., 24 джерел.

Мета цього дослідження полягала в тому, щоб розробити інструмент для визначення рухів і надання рекомендацій для дітей, які, за прогнозами, зможуть досягти успіхів у бадмінтоні.

Матеріали та методи. Це дослідження належить до типу дослідження та розробки, яке включає (1) етап попереднього дослідження, (2) етап експертної оцінки, (3) етап приймального випробування та (4) етап перевірки переваг. Етап оцінки проводять три експерти за показниками оцінки придатності, точності, зручності та практичності. Етап приймального випробування мав місце після застосування інструменту до учасників. Етап перевірки переваг був зумовлений повторним тестом для визначення надійності інструменту. Учасники випробування продукту складалися з двох груп, а саме: чоловічої групи із 17 учасників і жіночої групи із 17 учасниць. Вік учасників становив 6-7 років. Це були учні початкової школи, які навчалися в 2 класі. Для статистичного аналізу використовували тестування з повторним тестуванням.

Результати. Результати показують, що оцінка від експертів із бадмінтону дає оцінку з представленням 97% у категорії «дуже добре», оцінка експертів із визначення талантів становить 98% у категорії «дуже добре», а оцінка від тренера становить 97% у категорії «дуже добре». Для приймального випробування було рекомендовано 4 дітей (24%) у першому тесті та 5 дітей (29%) у другому тесті. Для дівчат було рекомендовано 2 дітей (12%) у першому тесті та 3 дітей (18%) у другому тесті. Для випробування на надійність було отримано 0,97 у категорії «дуже стійкий» для хлопців і 0,91 у категорії «дуже стійкий» для дівчат.

Висновки. Цей інструмент підтвердив ефективність і надійність і може забезпечувати рекомендації. Наявність цього інструменту може допомогти вчителям фізичного виховання та тренерам із бадмінтону визначати рухи дітей.

Ключові слова: розробка, кінестетичний рух, діти, бадмінтон.

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ORIGINAL SCIENTIFIC ARTICLE

PHYSICAL EXERCISE AS A PHYSIOLOGICAL MODULATOR OF IMPROVING CARDIOVASCULAR HEALTH IN OBESE WOMEN

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Abstract

The study purpose was to analyze the effective form of physical exercise in improving cardiovascular health in obese individuals.

Materials and methods. Twenty-four (24) obese adolescents, aged 20–24 years, who met the criteria were selected as participants. The participants were divided into 3 groups, namely the control, the strength training, and the endurance training, with 8 participants in each group. Strength training was done with Machine Fitness, while endurance training used a Treadmill. Exercise was done with moderate intensity, for 35 minutes, the frequency of exercise was 3x/week, for 1 month. Heart rate and blood pressure, as parameters of heart health, were measured before and after treatment. Data analysis used the One-way ANOVA test with a significance level of 5%.

Results. The results showed that there was a significant difference in cardiovascular health between endurance and strength training ($p \leq 0.05$).

Conclusions. Based on the study results, it was shown that endurance training is a potential physiological modulator to improve cardiovascular health in obese women.

Keywords: cardiovascular health, physical exercise, obesity, blood pressure.

Introduction

Obesity is a very complex health problem (Chen et al., 2021), and is an independent factor, increasing the risk of heart disease, type 2 diabetes mellitus, and other diseases (Jamka et al., 2021). It was found that an increase in obesity was directly proportional to an increase in heart disease (Amaral, 2014), and in overweight individuals have twice the probability of developing heart disease, in obese individuals the probability rate can reach 10 times that of individuals with normal weight (Pinckard et al., 2019). However, in modern society heart disease is still considered the most common health condition (Machado et al., 2021), with its main contribution to high blood pressure (Schroeder et al., 2019), which has the highest prevalence rate (Shim & Kim, 2017). Data shows that high blood pressure reaches 29% and is predicted to continue to increase, as well as being the main risk of death (Schroeder et al., 2019). It is estimated that 25% of deaths each year are due to heart disease (Jamka et al., 2021), and the prevalence rate increases to 31% deaths every year (Brandão et al., 2022). Therefore, heart disease can be a major risk factor for increased mortality and morbidity (Pinckard et al., 2019).

Obesity is a significant contributor to an increase in heart disease, especially high blood pressure (Tayagi et al., 2020), myocardial infarction, (Almutawa et al., 2020) and coronary artery disease, (Machado et al., 2021), is also a major risk factor for death (Schroeder et al., 2019). Pharmacological approach (Zimmer et al., 2019) and an eating behavior change approach using diet in combination with medication (Shim & Kim, 2017). It has been used to treat heart disease and cardiovascular health. However, other experts stated that the approach with drugs (pharmacology) in the long term is still considered less than ideal (Almutawa et al., 2020). Meanwhile, other experts stated that the approach with physical exercise

was more appropriate and physiological to improve heart health in the long term (Ramos et al., 2019) and physical exercise is also considered an effective codulation not only for heart health, but also for improving cardiac performance (Durrani & Fatima, 2015). Physical exercise, is a modulation associated with the level of energy expenditure, decreased fat mass and increased skeletal muscle mass as well as heart muscle (Saeidi et al., 2022; Rejeki et al., 2021).

Physical exercise is very beneficial, not only for heart health but also for general health, which is believed to be an effective non-drug method of lowering and replacing drug doses (Shim & Kim, 2017), thereby so as to reduce and prevent non-communicable diseases including improving heart health (Thirupathi et al., 2021). Previous research has shown that regular physical exercise increases high-density lipoprotein (HDL), controls insulin resistance, reduces risk factors for heart disease and reduces the incidence of death (Oh et al., 2016). Physical exercise also improves weight management, preventing excessive increases in blood pressure over time (Durrani & Fatima, 2015). Adaptation response to physical exercise depends on: frequency, intensity, time, and form of exercise (Saeidi et al., 2022). Previous research suggests that forms of endurance training and strength training can be an alternative in reducing obesity and improving heart health, although resistance training is still considered more effective in improving heart health than strength training (Schroeder et al., 2019). Strength training is thought to have little effect on improving heart health (Shim & Kim, 2017). In contrast, endurance training for reducing the risk of heart disease and increasing parasympathetic activity (Grässler et al., 2021). However, the analysis of the effectiveness of power training and strength training on cardiac performance has not been widely reported. The form of endurance training is still unclear in terms of intensity and duration, compared to strength training which will also increase muscle mass and cause muscle hypertrophy (Machado et al., 2021). Therefore, this study aims to analyze the adaptive response of strength training and endurance training as a physiological modulator in improving cardiovascular health in obese adolescent womens.

Materials and Methods

Study participants

This study is an experimental study that aims to analyze differences in strength and endurance training as a physiological modulator of improving cardiovascular health in obese adolescent girls. This study involved 24 obese adolescents, female gender, age 20-24 years, body mass index (BMI) 27-35 kg/m^2, normal oxygen saturation (SpO_2). Participants were divided into 3 groups: control, strength training, and endurance training. The division of groups was done randomly, each group of 8 participants. Prior to the study all participants were given an explanation of the research problem and procedure, both written and verbal. All participants, both verbally and in writing, expressed their willingness. Likewise, participants also received an explanation of the physical exercise procedures during treatment.

This study was approved by the ethics committee of the institution and conducted in accordance with the guidelines of the Helsinki Declaration. Informed consent was obtained from all participants.

Study design

Warming up and cooling down, with static and dynamic stretching and running on a treadmill. Light intensity is used for heating and cooling. Each group started at 06.00-10.00 A.M., at the same time on different days. Strength training is done by lifting moderate intensity weights, for 35 minutes. Exercises are performed at intervals, 12 repetitions, 6 sets, with active rest between sets for 30 seconds. While endurance training was done by means of participants running on a treadmill for 35 minutes continuously, with moderate-intensity (60-70% HRmax). Exercise is done 3x/week for 4 weeks. Heart rate monitored using Polar H10. Physical exercise intervention will be temporarily stopped if physical signs are found, shortness of breath, sharply increased heart rate, dizziness and pale face.

Measurement of heart health using parameters of systolic and diastolic blood pressure and resting heart rate. Measurement of heart health was carried out before exercise and 4 weeks after the last exercise, while measurements of height and weight were carried out before exercise. Blood pressure was measured using an OMRON digital blood pressure meter.

Statistical analysis

Data analysis used the one-way ANOVA, which was followed by the Tukey's Honestly Significant Deference (HSD) post-hoc test, with a significant level of 5%.

Results

Characteristics of research participants, based on the results of descriptive statistical analysis in each group are presented in Table 1 below.

Based on the analysis of participant characteristics: resting heart rate, normal systolic and diastolic blood pressure (Table 1). The characteristics of the participants did not show any significant difference ($p \geq 0.05$). Therefore, if there is a difference in heart health, which in this study used blood pressure and heart rate parameters after exercise, it can be believed to be the effect of the intervention given for 4 weeks. The results of the analysis of physical exercise as a modulator of cardiovascular health, in reducing systolic blood pressure in each group (Figure 1).

Physical exercise as a modulator of cardiovascular health in reducing systolic blood pressure between before exercise

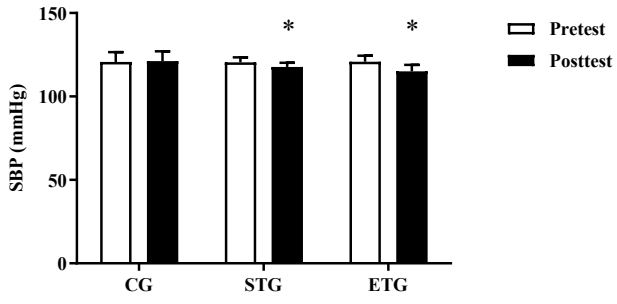

Fig. 1. Analysis of systolic blood pressure between pretest and posttest in the three groups
Description: SBP: Systolic blood pressure.
(*) Significant vs. Pretest ($p \leq 0.001$)

Table 1. Analysis of the characteristics of research participants

Parameter	CG	STG	ETG	p-value
Age, years	21.88±1.46	21.63±1.41	22.25±1.28	0.667
BH, m	1.57±0.07	1.58±0.05	1.55±0.06	0.786
BW, kg	74.37±12.32	73.63±6.78	71.41±6.07	0.588
BMI, kg/m^2	29.67±4.25	29.46±2.98	29.78±3.27	0.983
SBP, mmHg	120.13±6.29	120.25±4.33	120.63±2.67	0.976
DBP, mmHg	82.25±6.27	82.50±5.73	84.38±7.89	0.788
RHR, bpm	80.25±3.49	81.13±4.02	80.63±8.98	0.958
SpO_2, %	97.50±1.19	97.63±1.18	98.13±1.13	0.538

Description: CG: Control group; STG: Strength training group; ETG: Endurance training group. p-value obtained by using One-way ANOVA test. Data are shown with mean ± SD. BH: Body height; BW: Body weight; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; RHR: Resting heart rate; SpO_2: Oxygen saturation.

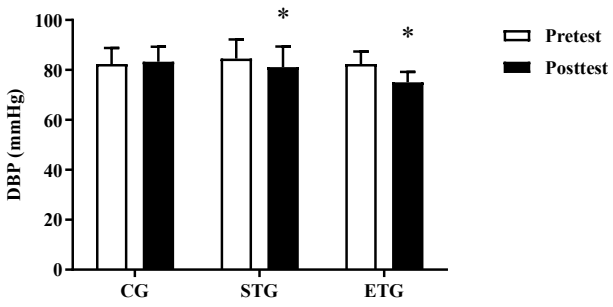

Fig. 2. Analysis of diastolic blood pressure between pretest and posttest in the three groups
Description: DBP: Diastolic blood pressure.
(*) Significant vs. Pretest ($p \leq 0.001$)

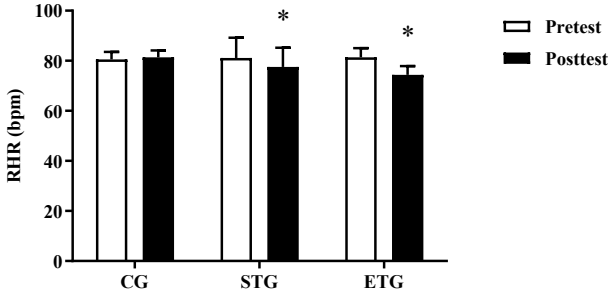

Fig. 3. Analysis of resting heart rate between pretest vs. posttest in the three groups
Description: RHR: Resting heart rate.
(*) Significant vs. Pretest ($p \leq 0.001$)

Table 2. Analysis of cardiovascular health pretest and posttest

Parameter	CG	STG	ETG	p-value
Systolic Blood Pressure (mmHg)				
Pretest	120.63±5.88	120.38±3.11	120.75±3.69	0.985
Posttest	121.13±5.94	117.63±2.56	115.00±3.96*	0.035
Delta	0.50±0.33	-2.75±1.04**	-5.75±1.75**#	0.000
Diastolic Blood Pressure (mmHg)				
Pretest	82.38±6.44	84.50±7.71	82.37±5.01	0.754
Posttest	83.25±6.04	81.13±8.24	75.00±4.17*	0.045
Delta	0.88±1.25	-3.37±1.19**	-7.38±1.92**#	0.000
Resting Heart Rate (bpm)				
Pretest	80.50±3.02	81.13±8.11	81.38±3.70	0.947
Posttest	81.38±2.77	77.50±7.75	74.38±3.50	0.042
Delta	0.88±0.61	-3.63±1.41**	-7.00±1.31**#	0.000

Description: *Significant vs. CG ($p \leq 0.05$); **Significant vs. CG ($p \leq 0.001$); #Significant vs. STG ($p \leq 0.001$).

and after exercise in the control group did not show any significant difference ($p \geq 0.05$). However, in the treatment group there was a significant difference in systolic blood pressure in both strength training and endurance training ($p \leq 0.001$). Systolic blood pressure was lower after exercise than before exercise in both the strength training and endurance training groups (Figure 1 and Table 2). Further analysis of changes in diastolic blood pressure before and after treatment in each group in Figure 2.

The data analysis of diastolic blood pressure in the control group between before and after treatment there was no significant difference ($p \geq 0.05$). There was a significant

difference in diastolic blood pressure between before and after exercise in the strength training and endurance training groups ($p \leq 0.001$). The study also showed that diastolic blood pressure after treatment was lower than before exercise (Figure 2 and Table 2). Analysis of physical exercise as a modulator of decreasing resting heart rate before and after treatment in each group (Figure 3).

Analysis of resting heart rate before treatment and after treatment in the control group, did not show a significant difference ($p \geq 0.05$) (Figure 3 Table 2), but there was a significant difference in resting heart rate pretest and posttest in the strength training and exercise groups. endurance ($p \leq 0.001$). Our data show that resting heart rate is lower, after strength training and endurance training, than before treatment (Figure 3 and Table 2). One-way ANOVA analysis of the decrease in blood pressure (systolic and diastolic) and resting heart rate before treatment showed no significant difference ($p \geq 0.05$) (Table 2).

Discussion

The results of this study prove that physical exercise is done properly and regularly, a very important factor for maintaining heart health and fighting various diseases (Souissi et al., 2020). Physical exercise, as the basis for lifestyle change interventions in preventing as heart disease (Rejeki et al., 2021; Andarianto et al., 2022; Rejeki et al., 2021). The findings of this study prove that moderate-intensity exercise, frequency 3x/week for 4 weeks, improves cardiovascular health in obese adolescent female participants (Table 2). The improvement in heart health can be seen from the decrease in systolic blood pressure, diastolic and resting heart rate after strength training and endurance training (Figure 1-3, Table 2). Several previous studies, which are similar to this study, also found that individuals who limit their passive and active lifestyle to physical exercise have normal blood pressure, stable body weight (Durrani & Fatima, 2015), higher cardiac output, blood pressure, lower resting heart rate, higher insulin sensitivity, better plasma lipoprotein profile than someone who is physically inactive (Nystoriak & Bhatnagar, 2018). Research identical to this study also found a decrease in blood pressure and resting heart rate after doing an endurance training program and strength training 3x/week, (Jamka et al., 2021). Research with walking intervention and crossfit exercise on participants in the age group 14 – 38 years, significantly lowers blood pressure (Almutawa et al., 2020), also found stronger heart muscle, decreased sympathetic nerve activity and decreased resting heart rate ≤ 60 bpm in marathon runners (Oh et al., 2016). Durrani's research involving 701 participants, children aged 12-16 years, found a relationship between physical activity and blood pressure (Durrani & Fatima, 2015). In another study, someone who did regular physical exercise found a decrease of 20 mmHg in systolic blood pressure and 11 mmHg in diastole (Kui et al., 2022). In addition, physical exercise was found to cardiac morphological changes that will cause aortic diameter widening accompanied by left ventricular fibrosis, improve oxidative profile and metabolic health (Dupuy et al., 2022).

The improvement in cardiovascular health is the effect of exercise adaptation in increasing the promoting increased vasodilation through relaxation of vascular smooth muscle cells. Given this effect, it is important to decrease the activity of Endothelial Nitric Oxide Synthase (eNOS), which contributes to blood pressure (Ramos et al., 2019). Resting heart rate and blood pressure were lower than the control group and before exercise, this shows that exercise is able to modulate changes in the heart system, both in form and function, thereby improving cardiovascular health. Exercise is believed to be a modulation of changes in heart size, as a result of increasing left and right ventricular cavities and increasing the thickness of the heart muscle wall and cardiac septum. Endurance training is believed to be beneficial exercise to improve heart function, such as decreasing heart rate. The heart rate is estimated to decrease by 10-15 bpm, that the individual is able to work hard efficiently (Pinckard et al., 2019).

Our study findings also show that heart rate and blood pressure are lower in endurance training than in strength training. Endurance training in general increases the oxidative ability to meet oxidative demands, the heart will contract and relax, cardiomyocytes and increase the strength of heart contraction, which is more optimal than strength training. The rate of contraction and relaxation requires increased adaptation of the cardiomyocyte contractile system, which is associated with an increase and the rate of intracellular Ca2+ release. Coordination between Ca2+ mediated Ca2+ type L channels and activation of the ryanodine receptor (RyR). This causes an increase in Ca2+ ion sensitivity, resulting in greater force and speed of contraction after exercise (Nystoriak & Bhatnagar, 2018). A decrease in blood pressure and heart rate is a complex event, many factors influence it, an increase in peripheral vascular resistance and autonomic nervous activity is the most important mechanism (Oh et al., 2016).

Improved heart health is strongly suspected to be the effect of endurance exercise, as a modulator of changes in fat mass (Shim & Kim, 2017). Therefore, endurance training is described as the optimal form for reducing the risk of heart disease and increasing parasympathetic activity (Grässler et al., 2021). Previous studies have also reported that endurance training induces greater improvements in cardiorespiratory fitness and cardio-metabolic variables (Schroeder et al., 2019), decreased acute stress reactivity and decreased heart rate and heart rate variability compared to the control group (Arvidson et al., 2020). Strength training also has a modulating effect on cardiac performance, although not as high as resistance training. Strength training, affects the increase in the strength of heart muscle contraction, heart muscle endurance, and reduces damage to the inner walls of blood vessels, to improve blood vessel function (Shim & Kim, 2017). Strength of heart muscle contraction, is the impact of strength training that causes cardiac muscle hypertrophy, skeletal muscle hypertrophy. Hypertrophy causes an increase in stronger contractions and a more complete emptying process in systole, with greater stroke volume and cardiac output (Schroeder et al., 2019). Therefore, both forms of exercise in this study are beneficial for the obese group, in addition to improving cardiovascular health, this exercise is also believed to initiate an increase in muscle mass and decrease fat mass in obesity (Sugiharto et al., 2022; Sugiharto et al., 2021; Sugiharto et al., 2022).

The findings of this study provide a starting point for understanding exercise as a modulator of improved

cardiovascular health, and provide a solid foundation for understanding that well-organized exercise causes response and adaptation. Response and adaptation to exercise not only change shape, but also function in all body systems, not only the heart. Although exercise modulation for 4 weeks, in improving heart health may not be optimal. However, training for 4 weeks is the beginning of the adaptation process to the exercise program, as described in the general adaptation of the body. But this research also has limitations, among others the study participants only used one group of obese adolescent girls, on heart health, this study has not measured the parameters of changes in body fat, muscle mass and changes in the endothelium associated with heart health. In addition, they have not been able to fully control the physical activities carried out, outside the exercise program that has been set for 4 weeks. Perhaps the results of this study cannot be generalized to all age groups and genders. However, the findings of this study still have significance in developing the science of exercise physiology, by providing substantial data and information, and opening up opportunities for further research.

Conclusion

Overall, it was concluded that endurance and strength exercise moderate intensity, for four weeks improved cardiovascular health, by decreasing blood pressure and resting heart rate. However, endurance training lowers resting blood pressure and heart rate more than strength training, therefore endurance training can be recommended as a modulator to improve cardiovascular health in obesity.

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ФІЗИЧНІ ВПРАВИ ЯК ФІЗІОЛОГІЧНИЙ МОДУЛЯТОР ПОКРАЩЕННЯ ЗДОРОВ'Я СЕРЦЕВО-СУДИННОЇ СИСТЕМИ В ЖІНОК З ОЖИРІННЯМ

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Реферат. Стаття: 5 с., 2 табл., 2 рис., 28 джерел.

Метою дослідження було проаналізувати ефективну форму фізичних вправ для покращення здоров'я серцево-судинної системи в осіб з ожирінням.

Матеріали та методи. Учасницями були відібрані двадцять чотири (24) молоді жінки з ожирінням віком 20-24 роки, які відповідали критеріям. Учасниць розподілили на 3 групи: контрольну, групу силових тренувань і групу тренувань на витривалість, по 8 учасниць у кожній групі. Силові тренування проводилися з використанням силових тренажерів, а для тренувань на витривалість використовували бігову доріжку. Вправи виконували за середньої інтенсивності, по 35 хвилин, частота – 3 рази на тиждень, протягом 1 місяця. Частоту серцевих скорочень та артеріальний тиск, як параметри

здоров'я серця, вимірювали до та після процедур. Для аналізу даних використовували однофакторний дисперсійний аналіз за рівня значущості 5%.

Результати. Результати показали наявність статистично значущої різниці у здоров'ї серцево-судинної системи між тренуваннями на витривалість і силовими тренуваннями ($p \leq 0,05$).

Висновки. На підставі результатів дослідження було показано, що тренування на витривалість є потенційним фізіологічним модулятором для покращення здоров'я серцево-судинної системи в жінок з ожирінням.

Ключові слова: здоров'я серцево-судинної системи, фізичні вправи, ожиріння, кров'яний тиск.

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ORIGINAL SCIENTIFIC ARTICLE

ANALYSIS OF POSITIONAL DIFFERENCES IN THE THAI NATIONAL FOOTBALL TEAM PLAYERS' PERFORMANCE USING GLOBAL POSITIONING SYSTEM TRACKING

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Abstract

Study purpose. The understanding of a performance profile in field sports using global positioning systems provides crucial data for the development of athletes in each position. In order to better understand the physiological demands placed on individual football player positions as center back, defender, midfielder, and forward during games in terms of speed, total distance covered, and number of sprints, the data were recorded using Global Positioning Systems technology.

Materials and methods. From 22 official games, the professional Thai national football team players were selected. An analysis of the physiological demands placed on Thai national football team players in terms of speed, total distance traveled, number of sprints, and maximum speed measured was carried out. The analysis data were obtained through 22 matches with four player positions (center back, defender, midfielder, and forward).

Results. The distance indicator in the individual position of a forward player was significantly higher when compared to a defender ($p = 0.0006$). At the high-intensity running zone, the distance covered by a forward was found to be significantly higher when compared to any other zone. Furthermore, the sprint and maximum speed indicators in the forward position of a professional Thai national football player were shown higher than in the center back, defender and midfielder positions ($p = 0.0001$, $p = 0.0001$ and $p = 0.0046$, respectively).

Conclusions. The Thai national football team players' performance per complete game in this study was lower than that of foreign professional teams in terms of their total distance and high-intensity running. With the use of a greater quantity of data and more accurate calculation techniques, coaches and training staff will be able to develop appropriate routines to enhance the competition preparation level of the professional Thai national football team players.

Keywords: Global Positioning System, sprint distance, max speed, zone of high-intensity running.

Introduction

An emerging trend in field sports, particularly in football or soccer, rugby, and field hockey, is the use of global positioning systems (GPS) to analyze performance. Match performance and training intensity have been the main topics of GPS research in women and men field sports (Schutz & Chambaz, 1997). Reporting the distance traveled and the amount of time spent is the need for standardized methods to determine the occurrence of high intensity running, sprinting maximal speed, and amount of high intensity running (Carling et al., 2012). Furthermore, GPS analysis can help athletes in field sports build their training schedules and monitoring procedures. The ability of GPS technology to track player movement simultaneously among multiple athletes is especially useful in intermittent running sports like soccer, field hockey, and rugby, where motions like tackles and changes in direction occur frequently (Hodun et al., 2016). The amount of ground traveled during a time-specific match serves as a benchmark for expectations for running performance; however, the stated total distance is not necessarily comparable due to variations in regulation timings between sports and individual playing time as a result of substitutions. Instead, relative distance or work rate (distance/time,

expressed in m/min) is used to assess the overall match effort of various sports and individual players (Folland et al., 2017).

Using GPS analysis to evaluate positional differences within a sport is another important use. Forwards, midfielders, and defenders are the standard categories for positions in field hockey and soccer. According to one paper on international soccer players (Hewitt et al., 2014), midfielders cover much more ground overall than defenders and significantly more ground at high intensities than both defenders and forwards. At sprinting velocities (>19 km/hr), both midfielders and forwards covered noticeably more ground (Vescovi, 2012). In NCAA soccer, midfielders and forwards traveled farther overall than defenders. At sprint speeds, forwards and defenders both covered more ground than midfielders. Midfielders were shown to cover more ground overall than defenders in young soccer, partly because more labor was done at speeds below the high intensity running threshold (Vescovi & Favero, 2014). Compared to midfielders, forwards recorded longer sprint distances and faster peak speeds. Sports positions differ from one another in terms of running performance markers, albeit these may change depending on the level of competition. Soccer and field hockey forwards sprint more frequently and faster than other positions (Ferro et al., 2014). Due to opponent movement, defenders might not run long total distances or long sprint lengths. Forwards typically run less than backs, relying more on their strength during scrums and set pieces. In order to reflect match demands, data from GPS analysis can be used to construct sprint training over sport-specific distances, high intensity running and repetitive sprinting, and aerobic training relevant to positions (Reinhardt et al., 2019).

While GPS has been utilized in field sports on a global scale for some time, there is little information available from Thai national field sports such as soccer, rugby. Therefore, the purpose of this study was to use GPS technology to explain the physiological demands placed on the individual player position of Rajpracha Football club during games in terms of speed, total distance covered, and number of sprints recorded. Additionally, a performance profile's comprehension (taking into account sprinting and high-intensity running attempts) can lessen the influence of averaged data and increase the specificity of training plans.

Materials and Methods

Study participants

Sixteen athletes from Thai national football player were recruited in the present study. The participants were young adults aged 18-34 years from Rajpracha FC athlete. The calculated sample size was 16 in each group using n4studies, at a significance level of 0.05 and power of 0.90, based on results obtained from previous studies (Burgess et al., 2006). All participants completed a questionnaire for demographic data. All participants received a detailed description of the procedure and provided written informed consent. The study was approved by the Human Research Ethics Committee of Walailak University (approval number: WUEC-22-286-01). All statistics was obtained in the full game of 2021, when the Thai national football league was completed. The current study used a descriptive and observational approach to describe and assess the game activity profile of a professional Thai national football team that played in a total of 22 matches.

Study Organization

22 official matches served as the basis for the game movement study. All gamers who participated in games were included in the study. Following matches, GPS data were downloaded, and the following metrics were derived: total distance, time spent in various speed zones, top speed, number of surges, and an exertion index that reflected the level of play. The number of sprints, maximum speed, and total distance were measured using an OH coach 10GPS/GLONASS Hz, and an electronic performance tracking system was created to measure player performance. The K-Shirt, which is a bib intended to keep a device inside, was utilized to hold the GPS tracking. The device for the athlete is now less intrusive thanks to research into the position. The t-shirt is made of Seemless fabric, a highly technological material that enables perfect adherence of the same and consequently of the instruments used, to the body, analyzing in detail the athletes' technical skills and avoiding the margin of error that would result from a positioning of the devices in a manner that is not completely adherent. Additionally, in order to avoid measurement error between units, every player used the same unit throughout every match. Athletes' speed zones were divided into five categories: zone 1 (1.0 to 5.99 km/h), zone 2, 6.0 to 10.99 km/h, zone 3, 11.0 to 15.49 km/h, zone 4, and zone 5 (>20 km/h) (Vescovi, 2012). The distance (m) covered by each team during each minute of play for each of the 22 games in the Thai national football league was presented as a total for the team encompassing the full game. Additionally, a computation of the average sprint frequency covered by each player across the 22 games was made.

Statistical Analysis

Mean and standard deviations (Mean ± SD) are used to represent data. One-way ANOVA was used to assess multiple comparisons, and the Tukey multiple comparisons test was used as a post hoc analysis. The statistical software SPSS (SPSS version 26; IBM, Armonk, NY, USA) was used for all statistical analyses, with statistical significance set at $P < 0.05$.

Results

Demographic data of player

Table 1 summarizes the demographic data of participants enrolled in the present study. The results demonstrated that high was significantly lower in MF and DF than CB ($P = 0.0303$ and 0.0040, respectively). The mean of high of DF was shown significantly lower than FW ($P = 0.0072$). In addition, weight of DF was significantly lower than FW.

Total distance of the player position

The distance and distance/min are shown in Fig 1. The total distance in the individual of player (CB, DF, MF, FW)

Table. 1. The demographic data of participants

Player position	Age (year)	High	Weight	BMI	%Fat
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Center back (n = 5)	23.80 ± 5.89	183.40 ± 5.50	78.8 ± 7.45	23.43 ± 1.84	10.96 ± 3.07
Defender (n = 5)	22.00 ± 2.31	169.00 ± 3.46$^{**, ††}$	65.85 ± 3.52†	23.06 ± 0.29	9.74 ± 1.78
Midfielder (n = 5)	26.43 ± 6.29	173.86 ± 4.56*	70.36 ± 8.92	23.28 ± 2.08	10.57 ± 4.33
Forward (n = 5)	24.80 ± 5.26	182.40 ± 6.88	81.72 ± 10.45	24.56 ± 1.82	11.51 ± 3.72

Note: Data are presented as mean ± SD. *P < 0.05, **P < 0.01 indicates a significant difference when compared with CB. †P < 0.05, ††P < 0.01 indicates significant difference when compared with FW, with one-way ANOVA (Tukey's multiple comparison test). CB, Centre back; DF: Defender. MF, Midfielder; FW: Forward.

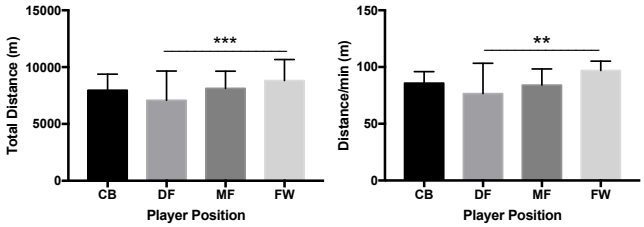

Fig. 1. Total distance of the player position, as determined by GPS monitoring. Note: Data are present as mean ± standard deviation (SD). **P < 0.01 indicates a significant difference between FW and DF group. ***P < 0.001 indicates a significant difference between FW and DF group, with ANOVA (Tukey multiple comparison test). CB, Centre back; DF: Defender. MF, Midfielder; FW: Forward

was 7973 ± 1410, 7082 ± 2571, 8128.59 ± 1509, 8819 ± 1849 meter, respectively. Figure 1 displays the distance of FW was significantly increased when compared to DF (P = 0.0006). The mean values of distance/min were 84.08 ± 14.25, 73.67 ± 26.02, 84.08 ± 14.25, 91.22 ± 18.85 meter of CB, DF, MF, FW, respectively. The distance per min in the FW was significantly increased when compared to DF (P = 0.0018).

Player's distance with zone of intensity

The value shown in Table 2 and Figure 2 are divided into Zone of intensity including low intensity Zones (1 tot 3) and high intensity Zones (4 and 5) and represent the cumulative distances covered by all players. Distance with Zones 1, DF was significantly decreased when compared to CB (P = 0.0001). Significant differences of distance were found in MF and FW when compared to DF, (P = 0.0185 and P = 0.0045, respectively). At Zone 3, the mean of distance in FW was significantly higher than that CB, (P = 0.0001). And the distance in FW and was significantly higher than that DF (P = 0.0013). Furthermore, the distance at Zone 4, which FW was significantly higher when compared to CB, DF, MF (P = 0.0001, 0.0001, 0.001 respectively). FW in Zone 5 was significantly higher when compared to CB, DF, MF (P = 0.0001, 0.0001, 0.002 respectively).

Sprint distance with player position

The sprint distances with player position shown in Figure 3 are represent the sprint distance in each player

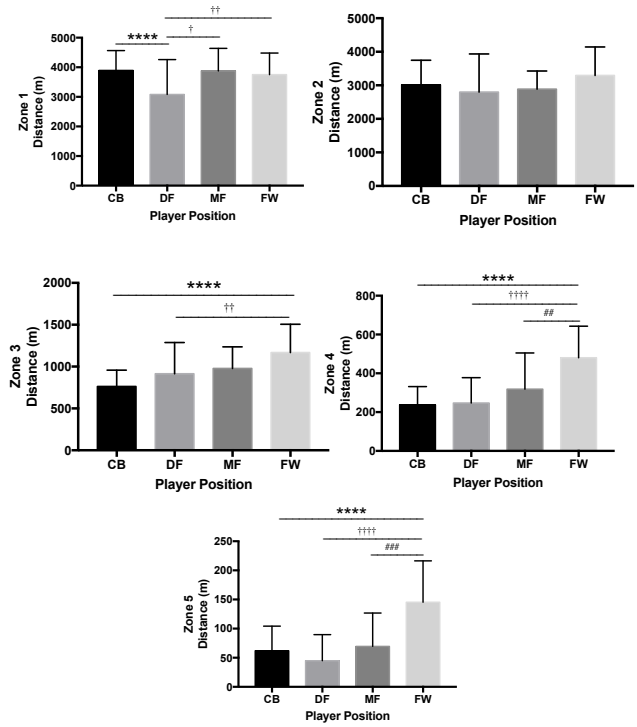

Fig. 2 .Player's distance with zone of intensity, as determined by GPS monitoring. Note: Data are presented as mean ± SD. ****P < 0.0001 indicates a significant difference when compared with the center back group. †P < 0.05, ††P < 0.01 indicates significant difference when compared with the defender group. ##P < 0.01, ### P < 0.001 indicates significant difference when compared with the midfielder group, with one-way ANOVA (Tukey's multiple comparison test). CB, Centre back; DF: Defender. MF, Midfielder; FW: Forward

position. Sprint distance in FW was significantly higher when compared to CB, DF, MF (P = 0.0001, P = 0.0001 and P = 0.0046 respectively).

Max speed with player position

Figure 4 summarizes the mean max speed (km/h), we observed that the mean max speed in DF was significantly lower when compare to CB, FW (P = 0.0049 and P = 0.00001 respectively)

Table. 2. Player's distance with zone of intensity

Zone of intensity	Group	Intensity	P-value	95% CI	
				Lower	Upper
Zone 1	Center back (CB)	Defender (DF)****	0.0001	345.7	1279
		Midfielder (MF)	0.9999	-661.3	696.7
		Forward (FW)	0.8701	-341.7	626.5
	Defender (DF)	Midfielder (MF)†	0.0185	-1492	-97.53
		Forward (FW)††	0.0045	-1180	-160.6
	Midfielder (MF)	Forward (FW)	0.9681	-584.3	833.8
Zone 2	Center back (CB)	Defender (DF)	0.6238	-254.2	694.4
		Midfielder (MF)	0.9621	-560.9	818.8
		Forward (FW)	0.4576	-770.2	213.5
	Defender (DF)	Midfielder (MF)	0.9871	-799.6	617.4
		Forward (FW)	0.0637	-1016	19.22
	Midfielder (MF)	Forward (FW)	0.4584	-1128	313.1
Zone 3	Center back (CB)	Defender (DF)	0.0755	-310.6	10.3
		Midfielder (MF)	0.0843	-447.7	19.12
		Forward (FW)****	0.0001	-570.7	-237.9
	Defender (DF)	Midfielder (MF)	0.8987	-303.8	175.6
		Forward (FW)††	0.0013	-429.3	-79.03
	Midfielder (MF)	Forward (FW)	0.1829	-433.7	53.67
Zone 4	Center back (CB)	Defender (DF)	0.9866	-81.54	62.77
		Midfielder (MF)	0.1949	-185.5	24.43
		Forward (FW)****	0.0001	-317.5	-167.8
	Defender (DF)	Midfielder (MF)	0.3194	-178.9	36.66
		Forward (FW)††††	0.0001	-312	-154.5
	Midfielder (MF)	Forward (FW)##	0.0010	-271.7	-52.51
Zone 5	Center back (CB)	Defender (DF)	0.3359	-9.396	43.83
		Midfielder (MF)	0.9581	-46.2	31.23
		Forward (FW)****	0.0001	-119.3	-47.46
	Defender (DF)	Midfielder (MF)	0.3721	-64.46	15.05
		Forward (FW)††††	0.0001	-137.6	-63.55
	Midfielder (MF)	Forward (FW)###	0.0002	-122.4	-29.38

Note: Data are presented as mean ± SD. ****P < 0.0001 indicates a significant difference when compared with the center back group. †P < 0.05, ††P < 0.01 indicates significant difference when compared with the defender group. ##P < 0.01, ### P < 0.001 indicates significant difference when compared with the midfielder group, with one-way ANOVA (Tukey's multiple comparison test). CB, Centre back; DF: Defender. MF, Midfielder; FW: Forward

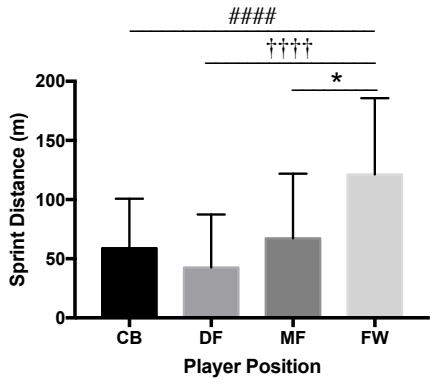

Fig. 3. Sprint distance of the player position, as determined by GPS monitoring. Note: Data are present as mean ± SD. *P < 0.05 indicates a significant difference between FW and MF group. ††††P < 0.0001 indicates significant difference between FW and DF group. ####P < 0.0001 indicates significant difference between FW and CB group, with ANOVA (Tukey multiple comparison test). CB: Centre back; DF: Defender. MF, Midfielder; FW: Forward.

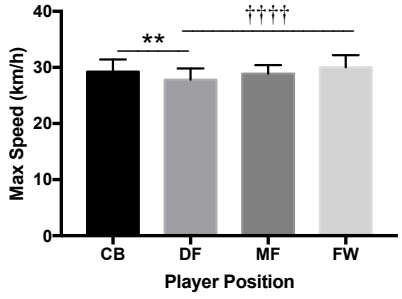

Fig. 4. Max speed with player position, as determined by GPS monitoring. Note: Data are present as mean ± SD. **P < 0.01 indicates a significant difference between CB and DF group. ††††P < 0.0001 indicates significant difference between FW and DF group, with ANOVA (Tukey multiple comparison test). CB: Centre back; DF: Defender. MF, Midfielder; FW: Forward.

Discussion

We used GPS monitoring to analyze the physiological demands placed on each Rajpracha FC player position during

games in terms of speed, total distance traveled, and the number of sprints recorded for better physical preparation of players and knowledge for competitive performance. The major study showed that player involvement in game events increased with player distance traveled. The average of total distance, which forward was shown higher than defender. Together with distance/min also shown higher in forward. Total sprint distance was shorter and slower for defender and canter backs, respectively. This study's shorter distances are not likely the result of players being more physically fit than they were in prior games. They are more likely the result of methodological discrepancies or even differences in playing style between the studies. The match's total distance serves as a broad indicator of its physical difficulty. The distance travelled during a time-specific match can be used as a benchmark for running performance expectations, but reported total distance isn't always comparable because to differences in regulation timings between sports and individual playing time as a result of substitutions. Total distance and work rate are useful performance parameters for determining weariness in between match periods. Although a reduction in distance or work rate can also result from outside influences like the result of a game, where an opponent is located, or how a player is arranged (Hewitt et al., 2014; White & MacFarlane, 2015). In the past, studies have shown that elevated midfielders cover significantly more ground overall than defenders and that midfielders cover significantly more ground when moving quickly than either defenders or forwards. At sprinting velocities (>19 km/hr), midfielders and forwards covered much more ground (Hewitt et al., 2014). In addition, it was discovered that midfielders covered more ground overall than defenders, largely because they put in more effort while working at slower rates. Compared to midfielders, forwards recorded longer sprint distances and faster peak speeds (Vescovi & Favero, 2014). Our research revealed that Rajpracha football club athletes had comparable outcomes to those of other international soccer teams, with midfielders covering more ground overall than defenders but not by a margin that was statistically distinct. Additionally, it was discovered that forwards covered more ground in a sprint than center backs, defenders, and midfielders. We found that the maximum speed of the forward was much higher than that of the center back, defender, and midfielder (mean maximum speed, km/h).

Forward displayed considerably higher total distance in high-intensity velocities (zone 4,5) than center back, midfielder, and defense combined. Additionally, compared to midfielders, center backs, and defenders, forwards recorded longer sprint distances and faster peak speeds. Running performance indicators differ between positions in sport, which has implications for position-specific training, albeit they may differ depending on the level of competition (Burgess et al., 2006). Midfielders in soccer typically run the length of the field when transitioning between defense and offensive, therefore it makes sense that they would cover a bigger overall distance (Aughey, 2011). Soccer forwards sprint more frequently and faster than players in other positions. Due to opponent movement, defenders might not run long total distances or long sprint lengths. In order to represent match demands, data from GPS analysis can help build sprint training over sport-specific distances, high intensity running and repetitive sprinting, and aerobic training relevant to positions. By the way, the Thai Rajpracha football player's performance per complete game in this study (73 km) was lower than that of foreign professional teams like the Brazilian U20 team (88 km) (Ramos et al., 2019), the Australian professional league (97 km), and the Danish first division (103 km) (97 km) (Krustrup et al., 2005; Gabbett & Mulvey, 2008).

Overall, the study's findings are a useful tool for learning more about training since GPS makes it possible to track and analyze movement patterns during the course of training. An earlier study found that match scheduling reduced training load as expected, but acceleration and sprint performance also declined over the course of the season as measured by regular performance testing (Mara et al., 2015). More knowledge of physical performance markers, training demands, and their interactions over the course of a competitive season would assist coaches develop periodization plans that are effective for the player position. Despite our findings, these studies demonstrate that because training does not replicate the physiological demands of matches, it may not have effectively prepared players for match play. GPS analysis could be used to track training and inform coaching and training specialists on whether training goals have been met. If specialized training adaptations are to have an ideal transfer to performance and decrease fatigue and consequent injury by increasing training program specificity, understanding the needs of field sport competition is a critical component of an efficient training program (high intensity running and sprinting). Coaches can determine an athlete's present state of fitness in connection to the necessary competitive demands of the player position in the squad by taking average work rates throughout performance into consideration. Despite these drawbacks, high-intensity running, sprinting statistics, and work rate should still be used to guide training, especially when taking age and positional disparities into account, as shown by the Thai Rajoracha football squad.

Conclusions

Global Positioning Systems have recently become popular for monitoring field sport performance, especially in rugby and soccer. Football field sports research using GPS has focused on match performance, tiredness, and training intensity. The requirement for consistent techniques to ascertain the incidence of high intensity running and sprinting is of particular concern for GPS analysis. The Thai rajpracha football team's use of GPS analysis can help with the creation of training schedules and inspection procedures. The Thai Rajpracha football team's coaches and training staff will be able to construct appropriate workouts to improve competition preparation thanks to a greater availability of data and more precise determination methods.

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Conflict of interest

The authors declare that there is no conflict of interest.

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АНАЛІЗ ПОЗИЦІЙНО-ЗУМОВЛЕНИХ ВІДМІННОСТЕЙ У РЕЗУЛЬТАТИВНОСТІ ГРАВЦІВ НАЦІОНАЛЬНОЇ ЗБІРНОЇ ТАЇЛАНДУ З ФУТБОЛУ ЗА ДОПОМОГОЮ ВІДСТЕЖЕННЯ З ВИКОРИСТАННЯМ ГЛОБАЛЬНИХ СИСТЕМ ПОЗИЦІОНУВАННЯ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 2 табл., 4 рис., 16 джерел.

Мета дослідження. Розуміння профілю результативності у спорті на відкритому повітрі з використанням глобальних систем позиціонування забезпечує критично важливі дані для розвитку потенціалу спортсменів у кожній ігровій позиції. Для того, щоб краще зрозуміти фізіологічні вимоги під час гри до окремих позицій футболістів, таких як центральний захисник, захисник, півзахисник і нападник, за показниками швидкості, загальної пройденої дистанції та кіль-

кості пробігів на коротку дистанцію з максимальною швидкістю (спринт), ці дані реєстрували за допомогою технології глобальних систем позиціонування.

Матеріали та методи. Із 22 офіційних ігор були відібрані професійні гравці національної збірної Таїланду з футболу. Був проведений аналіз фізіологічних вимог до гравців національної збірної Таїланду з футболу за вимірюваними показниками швидкості, загальної пройденої дистанції, кількості пробігів на коротку дистанцію з максимальною швидкістю та максимальної швидкості. Дані аналізу були одержані в рамках 22 матчів на основі чотирьох позицій гравців (центральний захисник, захисник, півзахисник і нападник).

Результати. Показник загальної пройденої дистанції на індивідуальній позиції нападника був статистично значуще вищим порівняно із захисником (p = 0,0006). У зоні високоінтенсивного бігу дистанція, пройдена нападником, була значно вищою порівняно з будь-якою іншою зоною. Крім того, показники кількості пробігів на коротку дистанцію з максимальною швидкістю та максимальної швидкості на позиції нападника у професійного гравця збірної Таїланду з футболу виявилися вищими, ніж на позиціях центрального захисника, захисника та півзахисника (p = 0,0001, p = 0,0001 та p = 0,0046 відповідно).

Висновки. Результативність гравців національної збірної Таїланду з футболу за кожну повну гру в цьому дослідженні була нижчою, ніж в іноземних професійних команд, за показниками загальної дистанції та високоінтенсивного бігу. Використовуючи більшу кількість даних і точніші методи розрахунку, тренери та навчальний персонал зможуть розробляти відповідні комплекси вправ для підвищення рівня підготовки до змагань професійних гравців збірної Таїланду з футболу.

Ключові слова: система глобального позиціонування, дистанція спринту, максимальна швидкість, зона високоінтенсивного бігу.

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ORIGINAL SCIENTIFIC ARTICLE

KNOWLEDGE, ATTITUDE AND PRACTICES ADOPTED BY RECREATIONAL RUNNERS TOWARDS CORE STABILITY EXERCISES IN PREVENTING LOW BACK PAIN: A CROSS-SECTIONAL STUDY

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Abstract

Background. Core stability and good running mechanics are fundamental components required for running, including those running for leisure with or without a competitive aspect. Thus, adequate knowledge, attitude, and practice (KAP) of core stability exercises (CSE) are necessary to minimize the incidence of low back pain (LBP). Therefore, this study intended to determine recreational runners' KAP toward CSE to prevent LBP and reveal the association between their demographic characteristics and levels of practice toward CSE.

Materials and methods. A cross-sectional study design was adopted, and three hundred recreational runners were selected using a simple random sampling approach. A semi-structured questionnaire was distributed among them using Google Forms. It consisted of 28 items capturing the participants' demographic characteristics and KAP toward CSE. Out of 300, 257 completed questionnaires were received, indicating an 86% of response rate. Data analysis was carried out using Statistical Package for the Social Science (SPSS) 28.0.

Results. The correct response to the knowledge-related items in the questionnaire was from 65% to 91%. Precisely, 91.4% of study participants understood CSE. Furthermore, most participants showed a positive attitude toward CSE, considering that it is essential for running (79%), improving fitness (76%), reducing the risk of injuries (71%), and boosting their appearance (54%). Most participants (>85%) performed CSE for recommended frequency and duration to strengthen their core muscles and prevent LBP. The recreational runners had good practice toward CSE.

Conclusions. Recreational runners possess adequate knowledge, a positive attitude, and good practice toward CSE. This study suggested that motivational strategies and awareness programs can be conducted to improve recreational runners' KAP toward CSE preventing LBP.

Keywords: knowledge, attitude, practice, core muscles, runners, exercise, low back pain.

Introduction

Running is among the most popular types of exercise and physical activity in individuals who engage in vigorous-intensity physical activity (Dai et al., 2015). Furthermore, in terms of participation, running is one of the most popular workout activities on the planet (Lee et al., 2014; Scheerder et al., 2015). Running's popularity is most likely owing to its health benefits (Hespanhol Junior et al., 2015). A recreational runner was defined as someone who had been running for at least six months and had completed 1 to 3 weekly sessions (Mulvad et al., 2018). Runners report changes in

their lifestyles after starting to run regularly, including better eating habits, good sleeping patterns, and less alcohol and tobacco consumption. They also say jogging makes them happier, more relaxed, and more energized (Harris, 1981; Novacheck, 1998). The health benefits of running are well recognized, as seen by the growing popularity of recreational running events in several locales across Western civilization (Franke et al., 2019). Despite the advantages of running, the amount of documented running injuries in the literature is concerning (Van der Worp et al., 2015). According to existing research, running-related injuries mostly impact the joints of the lower leg, pelvis, and lumbar spine, causing uncomfortable muscles, tendons, joints, and low back pain (LBP) (Dias Lopes et al., 2012). Similarly, many runners suffer from LBP due to poor knowledge and awareness of body mechanics. As such, LBP accounts for roughly 20 to 30 percent of typical complaints among runners (Abdelraouf & Abdel-Aziem, 2016; Maselli et al., 2020).

The stability of core muscles is essential to running-related back injuries. The deep core muscles have been shown to activate before voluntary lower extremity movement, implying that they may act to stabilize the spine in preparation for the loads encountered during dynamic tasks such as running (Fredericson & Moore, 2005). The superficial muscles' primary role is to move the thoracic cage and pelvis and deliver forces to the extremities (Bergmark, 1989). During running, the total axial pressure on the lumbar spine exceeds three times the upper body's weight above the fifth lumbar segment (Cappozzo, 1983). Likewise, during a repetitive, dynamic activity like running, dysfunction of the deep core musculature can result in improper loading of the spine, poor muscular coordination, compensatory movement patterns, muscle tension, or injury to spinal structures (Hibbs et al., 2008). A suitable amount of deep core muscular activation is required to support the spine; nevertheless, excessive or inappropriate activation of these muscles may result in aberrant spinal loading and LBP (McGregor & Hukins, 2009). When the deep core muscles are weak, the lumbar spine is subjected to higher compressive and shear loads. The superficial trunk muscles are shown to be the major compensators, indicating that these muscles are at the most significant risk of injury or fatigue. Hence, runners with deep core muscle weakness may be at a higher risk of developing LBP (Raabe & Chaudhari, 2018).

In runners, core stability exercise (CSE) enhances core stability while positively impacting running performance (Hsu et al., 2018; Mehda et al., 2019). Previous studies have demonstrated that six weeks of core-stability training in school track and field athletes improved dynamic balance, core endurance, dynamic postural control, and running economy (Bagherian et al., 2019; Sandrey & Mitzel, 2013). To gain the full benefits of CSE, the amount of knowledge the runners have and their attitude towards it is paramount. Knowledge plays a vital role in influencing individuals' positive attitudes toward exercise. Individuals with a higher understanding of sports injury prevention and management had a more favorable attitude toward injury prevention and management tactics (K.-M. Wang et al., 2012). However, exploring the literature, no prior studies have been conducted to bring out runners' knowledge and attitudes regarding the significance of CSE and their practices to prevent LBP. Thus, this study intended to assess the knowledge (understanding), attitude, and practice (KAP) adopted by recreational runners towards CSE in reducing the risk of LBP. It also focused on exploring the association between the recreational runners' demographic characteristics and their levels of practice concerning CSE.

Materials and Methods

Study design

A cross-sectional study design was adopted to reveal recreational runners' KAP towards CSE belonging to Selangor state, Malaysia. This study was conducted between January 2021 and March 2021. The ethical clearance for this study was obtained from the Research and Ethics committee of INTI International University, Malaysia (INTI-IU/FHLS-RC/BPHTI/7NY12020/009). Participants are mandated to complete the informed consent form before starting the survey.

Participants

Considering the population size of recreational runners belonging to various running clubs of Selangor state, confidence level (95%), and acceptable margin of error (5%), a sample size of 300 recreational runners was selected using simple random sampling methods. Of the 300 questionnaires administered, 257 completed questionnaires were returned, demonstrating an 86% response rate. The participants include both gender with ages ranging from 18 to 65 years and have been running for the last six months. Competitive runners and individuals who were unable to read and understand English were excluded from the study.

Instrumentation

A semi-structured questionnaire was developed and consisted of four sections (28 items). The questionnaire's first section deals with the recreational runners' demographic information (07 items). The second section addresses the recreational runners' knowledge of CSE by counting the correctness of their responses to each item using either 'True' or 'False or 'Not Sure' (07 items). The third section covers the recreational runners' attitude toward CSE through the options of a five-point Likert scale [Strongly Disagree', 'Disagree', 'Neutral', 'Agree', and 'Strongly Agree']. All attitude-related items were structured as direct-worded questions except those capturing the runners' attitude toward exhaustion and motivation, availability of time to do CSE, significance/helpfulness, and knowledge about CSE, which were considered reverse-worded items. The last section reveals the recreational runners' practice toward CSE through the options, i.e., 'Yes', 'Sometimes', or 'No' (05 items).

Procedure

Before administering to the subjects, the content validity of the questionnaire was carried out through experts' judgments. The questionnaire was distributed to participants using 'Google forms. A survey link, along with the objective of conducting the survey, was sent to all those recreational runners belonging to various running clubs;

poll links were shared on club-specific social media pages, and responses were collected. All participants were asked to respond after filling out the informed consent form. The collected questionnaires were checked for accuracy and completeness.

The recreational runners' knowledge of CSE was measured based on the overall number of points they received. One point would be awarded for choosing "true" for the statements. The options of 'false' and 'not sure' would be considered zero points. Precisely, responses for each attitude-related item were measured as the frequency and percentage of those who opted for 'Strongly Agree' and 'Agree' concerning direct-worded items and 'Neutral', 'Strongly disagree', and 'Disagree' concerning reverse-worded items. In focus on revealing the recreational runners' practice of CSE, the responses on each practice-related item were described in frequency and percentage of those who opted for 'Yes' (1 point), 'No' (0 points), or 'Sometimes' (0 points). The total score ranged from 0 to 5, in which a score of 4-5 denotes good practice concerning CSE. However, a score of 1-3 means poor practice concerning CSE.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 28.0. The recreational runners' KAP toward CSE were analyzed using descriptive statistics (i.e., frequency and percentage). Since the demographic characteristics consist of body mass index (BMI), age, education level, running experience, the incidence of LBP, and its duration and the response of the subjects to the practice-related items in the questionnaire are captured and reported in the form of categories, a Chi-square test was applied to examine the association between the participants' characteristics and their practice concerning CSE at 5% significance level. The chi-square test is a nonparametric test used to test the hypothesis of no association between two or more groups, populations, or criteria (i.e., to check independence between two variables), and it is meant explicitly to categorical data, not for analyzing parametric or continuous data (Singhal & Rana, 2015)

Results

Demographics of participating runners

Among the participants (n=257), half of them were female (52.9%), aged between 18 and 30 years (52.1%), and observed under normal BMI (51.8%). 75.5% possess an undergraduate degree as their highest education level. 35.8% had a recreational running experience between 6 months and 2 years. Besides, only 28.8% were currently suffering from LBP, and 13.2% had a history of LBP for 1 to 2 years (Table 1).

Table 1. Demographic characteristics of participants

Characteristics		Frequency (n)	Percentage (%)
Gender	Male	121	47.1
	Female	136	52.9
Age (Years)	18 to 30	134	52.1
	31 to 50	92	35.8
	51 to 65	31	12.1
BMI (kg/m^2)	Underweight (<18.5)	15	5.8
	Normal (18.5-22.9)	133	51.8
	Overweight (23-24.9)	48	18.7
	Obese 1 (25-29.9)	50	19.5
	Obese 2 (>30)	11	4.3
Education Level	Secondary Education	14	5.4
	Diploma	22	8.6
	Bachelor Degree	194	75.5
	Master Degree	27	10.5
Recreational Running Experience (Years)	6 months to 2	92	35.8
	3 to 5	70	27.2
	6 to 10	47	18.3
	More than 10	48	18.7
Suffer from LBP	Yes	74	28.8
	No	183	71.2
History of LBP (Years)	1 to 2	31	13.2
	3 to 5	28	10.9
	> 5	15	5.8

LBP= low back pain, CSE= core stability exercise, BMI= body mass index

Table 2. Recreational runners' knowledge of CSE

Knowledge items	Correctness of Response	
	True n (%)	False/Not sure n (%)
CSE improves running economy	175 (68.1)	82(31.9)
CSE is necessary for good running mechanics	206 (80.2)	51 (19.8)
Core muscles play a vital role in controlling and influencing the body's movements	235 (91.4)	22 (8.6)
Trunk rotation and load transfer are the primary functions of the core	167 (65.0)	90 (35.0)
Exercises like crunches and sit-ups are insufficient to develop the core	199 (77.4)	58 (22.6)
CSE involves training the body's posture through complex and dynamic movements	229 (89.1)	28 (10.9)
CSE reduces the risk of LBP	223 (86.8)	34 (13.2)

LBP= low back pain, CSE= core stability exercise

Recreational runners' knowledge about the CSE

91.4% of participants agreed that the core muscles play a vital role in controlling and influencing the body's movements. 65% knew the primary function of the core muscles. 89.1% of the respondents identified that core stability trained the body's posture through complex and dynamic activities and agreed that CSE is necessary for good running mechanics. Furthermore, 68.1% reported that it improves the running economy. 77.4% stated that crunches and sit-ups are insufficient to develop the core. Moreover,

86.8% possess sufficient knowledge that regular practice of CSE reduces the risk of LBP (Table 2).

Recreational runners' attitude towards CSE

More than 70% of the participants agreed that CSE is vital for running, improves their fitness level, and reduces the risk of back injury. Half of the participants (53.7%) perceived that CSE boosts their appearance. Notably, 32.7% reported on lack of time to do CSE. 37% felt a lack of motivation and fatigue from not exercising regularly. Besides, 89% disagreed that practicing CSE does not provide a significant result and could be more helpful. 72% perceived that the lack of knowledge did not justify skipping the exercise (Table 3).

Table 3. Recreational runners' attitude towards CSE

Attitude items	Correctness of Response	
	Runners opted for Strongly agree and Agree n (%)	Runners opted for Neutral, Disagree, and Strongly Disagree n (%)
CSE is essential for running	202 (78.6%)	55 (22.4%)
Other athletes are doing CSE	102 (39.7%)	155 (60.3%)
CSE improves fitness level	194 (75.5%)	63 (24.5%)
CSE reduces the risk of back injury	182 (70.8%)	75 (29.2%)
CSE boosts my appearance	138 (53.7%)	119 (40.3%)
Lack of time to do CSE	84 (32.7%)	173 (67.3%)
Lack of motivation or too exhausted to do CSE	95 (37%)	162 (63%)
It is not significant or helpful	27 (20.5%)	230 (89.5%)
Lack of knowledge about CSE	72 (28%)	185 (72%)

CSE= core stability exercise

Recreational runners' practice toward CSE

Most participants (>90%) performed CSE in a slow and controlled manner and those stopped doing CSE if it aggravated their LBP. Above 85% performed CSE for recommended frequency and duration to strengthen their core muscles and prevent LBP. Those also reported no practice of holding their breath while performing CSE (Table 4). Furthermore, all demographic variables except the education level are significantly associated with the practice of CSE among recreational runners (Table 5).

Discussion

Core muscles can be classified into local and global stabilization systems. These systems provide core stabilization in terms of strength and balance to body parts during sports activities (Bergmark, 1989). In this study, most participants (91.4%) understood that core muscles play a vital role in controlling and influencing body movements. 65% knew the core muscles' primary function. Likewise, 80% recognized that CSE is necessary for good running mechanics. 68.1% reported that it improves the running economy. Such findings conformed with an earlier study that stated that CSE might improve male college athletes' static balance, core endurance, and running economy (Hung et al., 2019). Further, 89.1% agreed that CSE involves training the body's posture through complex and dynamic movements. Several studies have also proved that the core muscles aid in stabilizing the lumbar spine and postural maintenance (Hides et al., 1996; Hodges et al., 2007; Kibler et al., 2006). Szczygieł et al. demonstrated that four weeks of core deep muscle training helps to improve posture, particularly trunk postural control in the sagittal plane (Szczygieł et al., 2018). In summary, the current study implies that recreational runners possess sufficient knowledge about CSE.

Earlier studies demonstrated that CSE minimizes pain in the short term for patients with chronic LBP and is most commonly used during clinical practice (Shamsi et al., 2016; X.-Q. Wang et al., 2012). Other studies also proved that core muscle training helps reduce the risk of LBP and alleviates chronic LBP (Akbari et al., 2008; Andrusaitis et al., 2011; França et al., 2010). As such, most participants (86%) believed that CSE reduces the risk of LBP. This condition might be because CSE helps to improve core muscle strength and thus reduces the risk of LBP. The core muscles decrease such injury risk in the low back area by sustaining force control during mobilizing (Liemohn et al., 2005). Additionally, incorporating core muscle training into a daily routine can enhance core muscular strength, decrease the incidence of back pain injuries, and enhance sports performance (Hibbs et al., 2008).

In this study, the recreational runners demonstrated a positive attitude toward CSE, where 78% felt that it is essential for running. A systematic review and meta-analysis of the relationship between core strength training, core muscle strength, and athlete performance found that CSE improved core muscle strength but had a limited impact on athletic performance (Prieske et al., 2016; Reed et al., 2012). However, in this study, above 75% of the participants agreed that CSE improved their fitness level, and it is in conformance with an earlier study by Hung et al. in which core muscle training has commonly been employed in rehabilitation as well as improving fitness.

Table 4. Recreational runners' practice toward CSE

Practice items	Yes n (%)	Sometimes n (%)	No n (%)
I perform/practice CSE for recommended frequency and duration	226 (87.9%)	30 (11.7%)	1 (0.4%)
I perform CSE to strengthen the core muscles and prevent LBP	227 (88.3%)	29 (11.3%)	1 (0.4%)
I stop performing CSE if it aggravates my LBP	241 (93.8%)	16 (6.2%)	0 (0%)
I do not hold my breath while performing CSE	229 (89.1%)	24 (9.3%)	4 (1.6%)
I perform CSE in a slow and controlled manner	235 (91.4%)	21 (8.2%)	1 (0.4%)

LBP= low back pain, CSE= core stability exercise

Table 5. Association between recreational runners' characteristics and their practice toward CSE

Demographic characteristics		Total	Poor	Good	Chi-square (p-value)
		N (%)	N (%)	N (%)	
Gender	Male	121 (47.1)	11 (34.3)	110 (48.9)	5.369 (0.002)*
	Female	136 (52.9)	21 (65.6)	115 (51.5)	
Age (years)	18 to 30	134 (52.1)	17 (53.1)	117 (52.0)	4.268 (0.009)*
	31 to 50	92 (35.8)	13 (40.6)	79 (35.1)	
	51 to 65	31 (12.1)	2 (6.2)	29 (12.9)	
BMI (kg/m^2)	Underweight (<18.5)	15 (5.8)	4 (12.5)	11 (4.9)	9.002 (0.000)*
	Normal (18.5-22.9)	133 (51.8)	21 (65.6)	112 (49.8)	
	Overweight (23-24.9)	48 (18.7)	2 (6.2)	46 (20.4)	
	Obese 1 (25-29.9)	50 (19.5)	5 (15.6)	45 (20)	
	Obese 2 (>30)	11 (4.3)	0 (0.0)	11 (4.9)	
Education Level	Secondary Education	14 (5.4)	1 (3.1)	13 (5.8)	1.503 (0.682)
	Diploma	22 (8.6)	2 (6.2)	20 (8.9)	
	Bachelor Degree	194 (75.5)	24 (75.0)	170 (75.6)	
	Master Degree	27 (10.5)	5 (15.6)	22 (9.8)	
Recreational Running Experience (Years)	6 months to 2	92 (35.8)	12 (37.5)	80 (35.6)	5.940 (0.031)*
	3 to 5	70 (24.2)	5 (15.6)	65 (28.9)	
	6 to 10	47 (18.3)	8 (25)	39 (17.3)	
	More than 10	48 (18.7)	7 (21.9)	41 (12.8)	
Suffer from LBP	Yes	74 (28.8)	14 (43.8)	60 (26.7)	3.988 (0.046)*
	No	183 (71.2)	18 (56.2)	165 (73.3)	
History of LBP (Years)	Empty	180 (70)	18 (56.2)	162 (72)	5.005 (0.020)*
	1 to 2	34 (13.2)	18 (56.2)	162 (72)	
	3 to 5	28 (10.9)	5 (15.6)	29 (12.9)	
	> 5	15 (5.8)	3 (9.4)	12 (5.3)	

*Significant at 0.05 level; LBP= low back pain, CSE= core stability exercise

The present study also uncovers the reasons for not engaging in or regularly continuing CSE. 32.7% of the recreational runners stated a lack of time to do CSE. 37% reported a lack of motivation and fatigue as reasons for not practicing CSE. Group exercises with peer encouragement could help improve a runner's motivation to perform CSE regularly (Jõesaar et al., 2012). Shaw et al. reviewed the impact of virtual reality (VR) on players' motivation and exercise performance. They revealed that greater cooperation and motivation were achieved due to the competitive experience in VR games (Shaw et al., 2016). Thus, VR is a viable solution for motivating runners to complete their CSE because it employs virtual players instead of actual ones.

Moreover, this study observed that the recreational runners had good practice toward CSE preventing LBP. More than 90% of them performed CSE in a slow and controlled manner and those stopped doing CSE if it aggravated their LBP. These findings align with the previous literature (Harvard health publishing, 2016; Princing, 2021). Besides, above 85% performed CSE for recommended frequency and duration to strengthen their core muscles and prevent LBP. Those also practiced CSE without holding their breath. In line with these findings, a previous study stated that CSE is performed for recommended frequency and duration, for instance, 20-minute sessions twice a week for ten weeks (Puntumetakul et al., 2021). It is also essential to do CSE without holding your breath (Hopkins, 2009).

Besides, recreational runners' age and gender showed a significant association with their practice toward CSE. These findings align with past studies (Gomes et al., 2017; Mao et al., 2020). Further, their BMI and running experience were significantly associated with their practice toward CSE. These findings might be due to those participants understanding the importance of CSE and regularly practicing them to prevent LBP. Previous literature also stated that BMI highly impacts an individual's exercise adherence (Khaled et al., 2016). Past exercise experience among individuals had stable behavior in the long run and acted as a critical forecaster of future behavior (Rodrigues et al., 2020). Suffering from LBP and a history of LBP among recreational runners showed a significant association with their practice toward CSE. This result is consistent with a recent study stating that individuals with LBP were more adherent to the exercise-based rehabilitation program (Shahidi et al., 2022). There is a need to assess the extent of the practice of CSE between recreational runners with and without LBP in future studies. Besides, as the participants' age, gender, BMI, running experience, suffering from LBP, and history of LBP were significantly associated with their levels of practice toward CSE, the researchers would frame and implement appropriate strategies focusing on those demographic categories to improve the participants' levels of practice of CSE preventing LBP.

On the other hand, this study observed no significant association between recreational runners' education level and their practice toward CSE. In line with this finding, (Shettigar et al., 2019) found that an individual's level of education was not significantly associated with exercise

adherence. However, previous studies stated that education level is associated with the level of practice of physical exercise (Tarducci et al., 2016). Therefore, further research is warranted to explore the impact of educational status among recreational runners on practice toward CSE.

This study is limited to the recreational runners of Selangor state, Malaysia. It can be extended in the future among recreational runners across Malaysia to generalize the findings. The difference in KAP among recreational runners concerning their demographic variables can be revealed in further research.

Conclusion

This study is the first one that addresses the KAP about CSE in preventing LBP among recreational runners belonging to Selangor, Malaysia. The finding reveals that recreational runners have adequate knowledge and understanding of CSE and regularly practice them to reduce the risk of LBP. Furthermore, most of the participating runners exhibited a positive attitude toward CSE, in which more than 75% of them felt that it is vital for running and improves their fitness level. Recreational runners showed good practice toward CSE. More than 85% performed CSE for recommended frequency and duration to strengthen their core muscles and prevent LBP. All demographic variables except the education level of recreational runners were significantly associated with their practice toward CSE. The findings of this study add to the existing literature on KAP recreational runners towards CSE in preventing LBP. Still, motivational strategies and awareness and training programs can be conducted for Malaysian recreational runners to enrich their KAP toward CSE and prevent LBP.

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Conflict of interest

No potential conflict of interest was reported by the author (s).

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ЗНАННЯ, СТАВЛЕННЯ ТА ПРАКТИКИ, ЗАСВОЄНІ БІГУНАМИ-ЛЮБИТЕЛЯМИ ЩОДО ВПРАВ НА СТІЙКІСТЬ КОРПУСУ ДЛЯ ЗАПОБІГАННЯ БОЛЮ В ПОПЕРЕКУ: ПЕРЕХРЕСНЕ ДОСЛІДЖЕННЯ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 2 табл., 4 рис., 16 джерел.

Історія питання. Стійкість корпусу та гарна бігова механіка є основними компонентами, необхідними для бігу, включаючи тих, хто бігає для відпочинку зі змагальним аспектом або без нього. Отже, для мінімізації випадків болю в попереку (БП) необхідні адекватні знання, ставлення та практика (ЗСП) вправ на стійкість корпусу (ВСК). Таким чином, метою цього дослідження було визначити ЗСП бігунів-любителів щодо ВСК для запобігання БП та виявити зв'язок між їхніми демографічними характеристиками та рівнями практики стосовно ВСК.

Матеріали та методи. Було прийнято план перехресного дослідження, і методом простої випадкової вибірки було відібрано триста бігунів-любителів. За допомогою Google Forms серед них було розповсюджено напівструктуровану анкету. Вона складалася з 28 пунктів, що відображали демографічні характеристики учасників і їхні ЗСП щодо ВСК. Із 300 було отримано 257 заповнених анкет, що вказує на частку 86% тих, хто відповів. Аналіз даних проводили за допомогою ПЗ Statistical Package for the Social Science (SPSS) 28.0.

Результати. Правильні відповіді на запитання в анкеті, пов'язані зі знаннями, становили від 65% до 91%. Точніше, 91,4% учасників дослідження розуміли ВСК. Крім того, більшість учасників показали позитивне ставлення до ВСК, вважаючи, що це істотно важливе для бігу (79%), покращення фізичної форми (76%), зниження ризику травм (71%) та покращення їхнього зовнішнього вигляду (54%). Більшість учасників (>85%) виконували ВСК з рекомендованою частотою та тривалістю, щоб зміцнити свої м'язи корпусу та запобігти БП. Бігуни-любителі мали гарну практику ВСК.

Висновки. Бігуни-любителі мають достатні знання, позитивне ставлення та гарну практику щодо ВСК. Це дослідження дало підстави припустити можливість проведення мотиваційних стратегій і програм підвищення обізнаності для покращення ЗСП бігунів-любителів щодо ВСК з метою запобігання БП.

Ключові слова: знання, ставлення, практика, м'язи корпусу, бігуни, вправа, біль у попереку.

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EFFECTS OF CONCURRENT RESISTANCE AND AEROBIC TRAINING ON BODY COMPOSITION, MUSCULAR STRENGTH AND MAXIMUM OXYGEN UPTAKE IN MEN WITH EXCESS WEIGHT

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Abstract

The study purpose was to compare the effects of concurrent resistance and aerobic training to resistance and/or aerobic training alone on body composition, muscular strength and maximum oxygen uptake in overweight and obese men.

Materials and methods. Twenty-four overweight and obese (BMI = 23.0 – 29.9 kg/m^2) volunteers who were male students from Ubon Ratchathani Rajabhat University, aged 19-22 years were assigned into 3 groups: 1) resistance training group (RT), 2) aerobic training group (AT) and 3) concurrent resistance and aerobic training group (RT+AT). The training was 45 minutes per session and 2 days per week. Body composition along with muscular strength (1-RM) and maximum oxygen uptake (VO_2max) were measured before (2-3 days prior) and after (2-3 days post) a 5-week training period.

Results. Waist circumference was significantly decreased in all three groups, but the RT+AT group also found improvement in percentages of fat-free mass (0.49 ± 0.49%, p = 0.021, mean ± SD) and skeletal muscle mass (1.01 ± 0.95%, p = 0.025) when compared to their baseline. Similarly, 1-RM in leg extension was significantly increased in all three groups, while the RT group (47.67 ± 14.85%, p = 0.01) and the RT+AT group (42.08 ± 21.70%, p = 0.039) showed a substantially larger improvement in the 1-RM in leg extension when compared to the AT group (20.37 ± 13.97%). Finally, VO_2max was significantly increased in all three groups (baseline to post-intervention), though they were not significantly different between groups.

Conclusions. Concurrent resistance and aerobic training can reduce waist circumference and increase fat-free mass, skeletal muscle mass, 1-RM and VO_2max. Therefore, this training strategy may serve as a useful alternative way to improve overall physical fitness and health promotion in overweight to obese male population.

Keywords: concurrent training, resistance training, aerobic training, 1-repetition maximum, maximum oxygen uptake, excess weight.

Introduction

The prevalence of overweight and obesity has increased in children and adolescents due to a decrease in physical activity and an increase in access to dietary diversity (Mistry & Puthussery, 2015). Convenience and access to food are key contributors to overweight and obesity, indicated by a body mass index that exceeds 23.0 kg/m^2 and a higher tendency of being overweight and obese (WHO, 2020). Exercise can help prevent and reduce overweight and obesity. It is more effective when combined with diet control (Shaw et al., 2006). Resistance and aerobic training contributed to body composition development and physical fitness promotion differently in terms of training styles and outcomes (ACSM, 1995).

Resistance training is the use of weight as a factor in muscle training. The weights can be body weights, weight plates, or exercise equipment. Increasing muscle size and strength depends on the following factors: mechanical tension, metabolic stress and muscle damage (Schoenfeld et al., 2019). Forms of resistance training have increased in recent years. Traditional resistance training is to select exercise postures to perform for a specific number of sets and reps (ACSM, 2002).

Aerobic training is known to have a positive effect on the heart and circulatory system. It increases energy expenditure. It can be continuous or intermittent exercise. The intensity depends on VO_2max, or heart rates that are divided into different levels (Hunter et al., 2015). The appropriate exercise duration that will cause the body to use fat for energy also depends on the intensity (Carnier et al., 2013).

Concurrent resistance and aerobic training may be an alternative form of training used to improve body composition and physical fitness because the basis of concurrent training is to combine resistance and aerobic training in 1 session of training (Geoffrey, 2017). Those performing this type of training may be benefited from the increase in muscle mass from resistance training and the improvement of the cardiovascular system from aerobic training (Pito et al., 2022). A study reported that beginners were more likely to improve their muscle gains faster than regular exercisers. Cardiorespiratory fitness was also increased, which is good for recovery (Antonio et al., 2015). In addition, a study in obese adolescents revealed that concurrent resistance and aerobic training can reduce body fat mass (Monteiro et al., 2015). Resistance training at moderate intensity (55-70% 1RM) to high intensity (70-85% 1RM) combined with aerobic training at moderate intensity (75% of the maximal aerobic speed) can develop 1-RM and VO_2max. Especially, concurrent resistance and aerobic training are more effective in developing muscle strength than aerobic training alone. It is also able to improve VO_2max better than resistance training alone (Khalafi et al., 2022). However, some studies showed that concurrent training can provide increases in the 1-RM upper and lower limb strength similar to resistance training alone. There was no difference in VO_2max between the concurrent training and the aerobic training groups (Pito et al., 2022). However, performing both training sessions at the same time may not affect the development of basic physical fitness. Proper arrangement of training postures for the concurrent training program and quality training duration per training session are important variables in the concurrent training program design.

Therefore, the researchers were interested in studying the concurrent resistance and aerobic training to improve overall health, in particular, the improvement of body composition, muscular strength and maximum oxygen uptake among overweight and obese male adolescents with the aim to see whether the concurrent resistance and aerobic training can be an alternative form of training or not.

Materials and methods

Study participants

Twenty-four male students from Ubon Ratchathani Rajabhat University (age 20.17 ± 0.96 years) volunteered for this study. The inclusion criteria were as follows: 1) measured and reported as overweight and obese (BMI = 23.0-29.9 kg/m^2) and 2) likely to be untrained and able to do exercise training or physical activities. Written informed consent was obtained from all the participants after they had been informed about the details, purpose and procedures of the study. The study was approved by Ubon Ratchathani Rajabhat University Human Ethics Committee (HE652060) (Fig. 1).

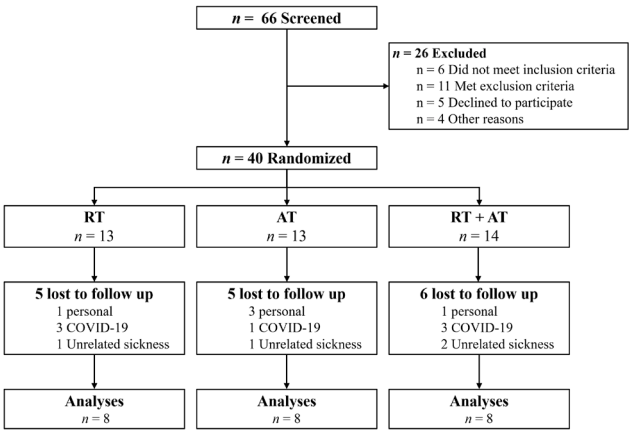

Fig. 1. Training trial profile. COVID-19: Participants lost to follow-up due to COVID-19 infection or close contact with person infected by COVID-19 during the fifth wave of the COVID-19 pandemic. Abbreviations: RT, resistance training; AT, aerobic training; RT + AT, concurrent resistance and aerobic training

Study organization

The participants were randomly divided into three experimental groups: resistance training group (RT, n = 8), aerobic training group (AT, n = 8) and concurrent resistance and aerobic training group (RT+AT, n = 8). The study duration was 5 weeks of training. All the participants were evaluated at the baseline and the end of the study (Between 2 to 3 days of the last training session) (Fig. 2).

Training program

The resistance training group followed the resistance training principle (ACSM, 2002) and performed 4 exercises at 60-70% 1RM, 8-15 reps range and 3 sets of each exercise with 1-minute recovery between sets; 1) lat-pulldown (Nautilus OneTM S6LATP, USA), 2) leg extension (Nautilus OneTM S6LE, USA), 3) chest press (Nautilus OneTM S6CP, USA) and 4) leg curl (Nautilus IMPACTS1301, USA). The resistance training consisted of two training sessions per week on non-consecutive days for 5 weeks. The training duration was about 45 min, including warm-up, training and cool down (a total of 90 min·week-1 or 450 min over 5 weeks).

The aerobic training group followed the aerobic training guideline and used the heart rate to monitor (Polar H10, Finland) the intensity (ACSM, 1995). This group performed treadmill (Star Trac 10TRX, USA) incline-walking (2.5 incline level) with a speed of 65-75% of maximum heart rate (MHR) for 35 min continuously. The training duration lasted 45 min, including warm-up, training and cool down (a total of 90 min/week or 450 min over 5 weeks).

$\dot{V}O_2$max

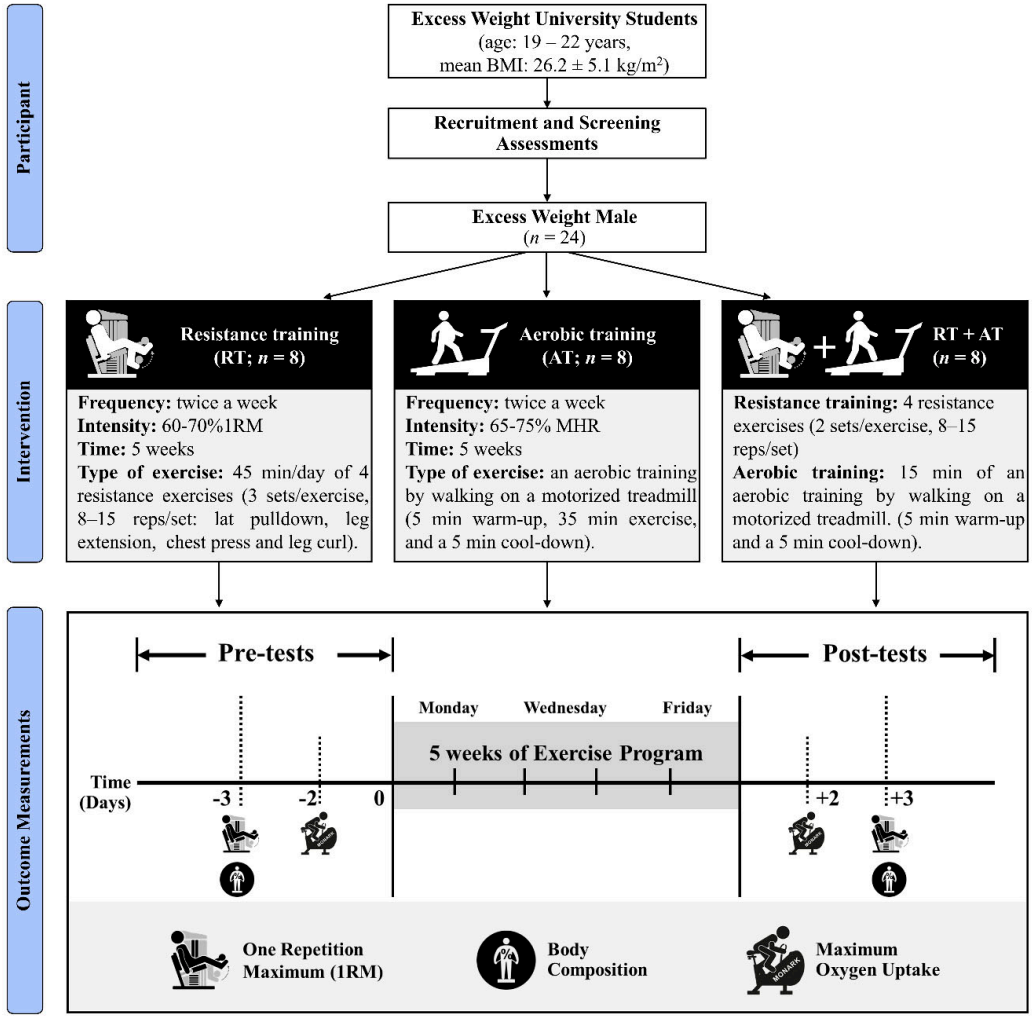

Fig. 2. Outline of training and testing schedule. Abbreviations: reps, repetition; MHR, maximum heart rate

The concurrent resistance and aerobic training group followed both resistance and aerobic training. The exercise and program design were similar to those of the two-intervention by performing resistance training exercises as same as the resistance training group. The only difference was that the training set of each exercise was reduced to 2 sets to reserve the time and move on to the aerobic session after the subjects had done all resistance training exercises immediately. This group performed the treadmill incline-walking with the same incline level and intensity, but the duration was 15 min. The training duration was about 45 min, including warm-up, training and cooldown (a total of 90 min/week or 450 min over 5 weeks).

Measures

Body composition measurement

The body composition was measured using a bioelectrical impedance analysis machine (BIA) by body composition analyzer (Seca mBCA, Hamburg, Germany). The outcome variables were body mass index (BMI, kg/m^2), waist circumference (WC, cm), fat-free mass (FFM, kg), fat mass (FM, %) and skeletal muscle mass (SMM, kg).

1-Repetition maximum measurement

The 1-repetition maximum was assessed in 4 exercises using a stationary weight machine: 1) lat pulldown, 2) leg extension, 3) chest press and 4) leg curl. The participants were asked to perform these exercises. The demonstration was done before correcting the way of measure by experience resistance training. Every exercise included warm-up for a few sets and rest for at least 2 min. Then the advisor predicted the reasonable weight and asked the participants to go for maximum repetitions. The repetitions were counted by the advisor and calculated as the 1-RM by 1-RM calculator. They had to rest for 2 min before doing the next exercise test, considered alternated upper and lower exercise tests.

Maximum oxygen uptake measurement

The maximum oxygen uptake was measured by the Astrand-Rhyming cycle ergometer test by performing

6 min on a cycle ergometer bike (Monark Ergomedic 828E, Vansbro, Sweden). The participants were allowed to warm up for 1 min with 0 loads at 50-55 cadence speed (round per min; RPM). They had to maintain the cadence speed throughout 6 min of the test. The test was started by the increasing load to 75 watts (1.5 kiloponds). The heart rate is attached to the chest to monitor the heart rate being measured every minute. The final heart rate was calculated for maximum oxygen uptake by O2max calculator.

Statistical analysis

Statistical calculations were performed using SPSS 26 (IBM Corp. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp). Descriptive data were shown as means and standard deviation (SD). Data normality was evaluated by using the Shapiro-Wilk test. The one-way analysis of variance (ANOVA) with a post-hoc Bonferroni adjustment was used to evaluate differences in body composition, 1-repetition maximum and maximum oxygen uptake between groups. A paired t-test (comparison between values obtained before and after intervention) was completed. P values < 0.05 was considered to be statistically significant.

Results

The general characteristics and baseline measured of the resistance training (RT), aerobic training (AT) and concurrent resistance and aerobic training (RT+AT) groups are presented in Table 1. No significant differences existed among the three groups for any variables. After 5-week, the waist circumference was reduced in all three groups by -2.59 ± 2.52%, -2.61 ± 2.02% and -2.03 ± 2.12%, respectively. However, the RT+AT group was the only group found significantly increased fat-free mass and skeletal muscle mass by 0.49 ± 0.49% and 1.01 ± 0.95%, respectively compared to the baseline (Table 2).

The 5-week training program significantly increase the 1-repetition maximum indices in all groups when compared to their baseline (Table 3). In particular, the RT group

Table 1. Participants characteristics in the 3 training groups.

Characteristics	RT (n = 8)	AT (n = 8)	RT+AT (n = 8)
Age (y)	20.63±0.92	20.13±1.25	19.75±0.46
Weight (kg)	73.85±10.12	79.08±20.78	78.29±8.69
Height (cm)	174.50±5.04	168.75±7.21	172.13±4.16
BMI (kg/m^2)	24.29±3.18	27.83±7.57	26.57±3.44
Resting heart rate (b/m)	72.88±5.00	72.00±5.37	68.00±4.90
SBP (mmHg)	124.00±5.68	123.00±6.41	123.25±4.23
DBP (mmHg)	74.00±5.45	71.25±4.65	71.50±5.21

RT – resistance training group, AT – aerobic training group, RT+AT – concurrent resistance and aerobic training group; BMI – body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure. Values are mean ± SD. No significant difference was found between the 3 groups for any variable

Table 2. Mean changes in body composition in all 3 training groups after 5-week training

Variables	RT (n = 8)			AT (n = 8)			RT+AT (n = 8)		
	Pre-test	Post-test	% change	Pre-test	Post-test	% change	Pre-test	Post-test	% change
Body composition									
Weight (kg)	73.85±10.12	73.79±10.38	-0.08±2.22	79.08±20.78	77.13±17.96	-2.46±3.93	78.29±8.69	77.88±8.74	-0.52±2.21
BMI (kg/m^2)	24.29±3.18	24.23±3.32	-0.23±2.23	27.83±7.57	27.13±6.62	-2.52±3.92	26.57±3.44	26.35±3.52	-0.81±2.19
Waist circumference (cm)	82.00±8.80	79.88±6.49	-2.59±2.52*	91.00±18.72	88.63±17.05	-2.61±2.02*	86.38±8.05	84.63±8.77	-2.03±2.12*
Fat-Free mass (kg)	60.57±5.94	60.78±6.05	0.34±3.66	57.94±70.04	57.57±6.64	-0.63±2.09	58.95±2.01	59.24±1.94	0.49±0.49*
Fat mass (%)	17.85±9.58	17.71±10.12	-0.77±14.92	24.71±10.83	23.75±9.98	-3.89±9.96	24.96±5.23	24.60±5.14	-1.43±3.93
Skeletal muscle mass (kg)	29.37±2.91	29.64±3.01	0.92±3.02	28.11±3.81	28.01±3.72	-0.36±1.94	28.39±1.36	28.68±1.55	1.01±0.95*

*Significant p<0.05 (pre vs post)

Table 3. Mean changes in 1-repetition maximum and maximum oxygen uptake in all 3 training groups after 5-week training

Variables	RT (n = 8)			AT (n = 8)			RT+AT (n = 8)		
	Pre-test	Post-test	% change	Pre-test	Post-test	% change	Pre-test	Post-test	% change
1-Repetition maximum									
Lat pulldown (kg)	33.90±4.60	48.96±6.64	44.43±23.77*	27.50±5.92	34.41±6.82	25.14±26.38*	32.50±5.82	43.88±6.99	35.00±23.64*
Chest press (kg)	32.11±7.00	50.54±7.20	57.38±44.36*	24.89±5.27	34.03±7.02	36.77±13.64*	29.53±5.30	44.05±5.76	49.20±28.97*
Leg extension (kg)	60.73±7.17	89.68±8.40	47.67±14.85*#	47.81±10.81	57.55±14.96	20.37±13.97*	46.38±10.39	65.89±15.50	42.08±21.70*‡
Leg curl (kg)	60.85±8.01	85.40±7.30	40.35±23.31*	47.20±11.35	55.68±12.82	17.96±12.95*	48.04±14.65	66.60±15.08	38.64±31.21*
Maximum oxygen uptake									
VO_2max (mL/kg/min)	35.35±1.69	37.93±1.35	7.31±4.19*	34.45±6.23	39.00±6.00	13.21±7.72*	41.07±5.96	46.03±6.41	12.09±13.59*

*Significant p<0.05 (pre vs post), #Significant p<0.05 (RT vs AT), ‡Significant p<0.05 (RT+AT vs AT)

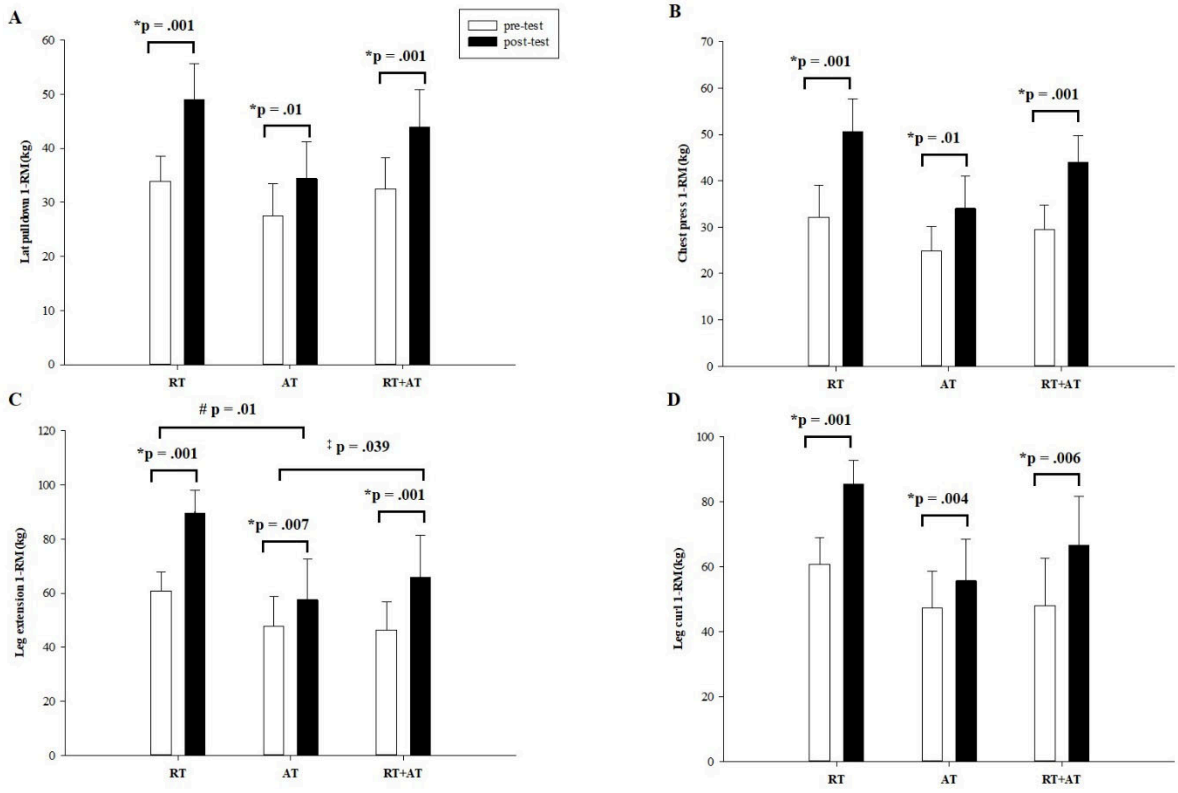

Fig. 3. Change in 1-repetition maximum (A; Lat pulldown, B; Chest press, C; Leg extension and D; Leg curl) before and after 5-week training. Values are present as mean ± SD. *Significant p<0.05 (pre vs post), #Significant p<0.05 (RT vs AT), ‡Significant p<0.05 (RT+AT vs AT)

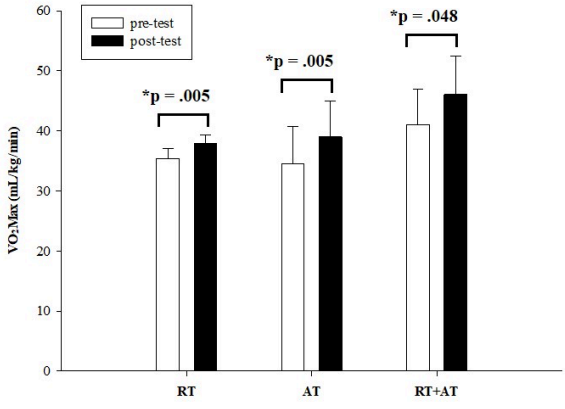

Fig. 4. Change in maximum oxygen uptake before and after 5-week training. Values are present as mean ± SD. *Significant p<0.05 (pre vs post)

significantly increased in leg extension 1-RM which was 47.67 ± 14.85% compared to the AT group (20.37 ± 13.97%, p = 0.01) and the RT+AT group accordingly significantly increased leg extension 1-RM more than AT group (42.08 ± 21.70% and 20.37 ± 13.97%, respectively, p = 0.039) (Fig. 3). In general, the O2max was significantly increased in all three groups (RT, AT and RT+AT) compared to baseline by 7.31 ± 4.19%, 13.21 ± 7.72% and 12.09 ± 13.59%, respectively. However, there were no significant differences between the groups (Fig. 4).

Discussion

The present study examined the effects of concurrent resistance and aerobic training for 5 weeks on body composition, muscular strength and maximum oxygen uptake (VO_2max) in men with excess weight. Our results findings showed that the changes in waist circumference were observed in all groups after 5 weeks of training in this study, presumably, due to the effects of resistance training, aerobic training and concurrent training. Overweight and obese people can increase their physical activities that consume more energy so that the body burns excess energy from visceral fat in all three forms of exercise. Particularly, concurrent resistance training and aerobic training can increase lean body mass and muscle mass because resistance training causes muscles to contract against resistance. It also increases muscle strength. Over several weeks of training, there is an increase in muscle fibers in number and thickness, an important part of increasing muscle mass and strength (Pito et al., 2022). Concurrent training among overweight or obese people has been demonstrated by Monteiro et al., 2015 this study reported that the concurrent training was performed 3 times per week for 20 weeks. The findings revealed that the body fat can be reduced (Monteiro et al., 2015). Similarly, a study by Dâmaso et al., 2014 reported that the AT + RT group showed better results in terms of decreased body fat mass and visceral fat and increased body lean mass unlike the AT group, which are consistent with the results of the present study. It may be because the development of body composition is related to balance and energy metabolism. As for concurrent training, the body uses

both anaerobic and aerobic energy systems. In terms of the principle of variety, the concurrent training group was given the same exercise posture as the resistance training group, but adding aerobic training made the training less boring than the single-mode training group. To see a clear change effect, the training duration and the frequency per week should be increased. It was also found that exercise training with nutrition control has contributed to an increase in fat-free mass and skeletal muscle mass (Dâmaso et al., 2014).

An increase in the 1-repetition maximum was found the largest in the RT group and the smallest in the AT group while the RT+AT group was similar to the RT group. It may arise because of the resistance training uses weights to put stress on the muscles, resulting in increased thickness and strength in the muscle fibers. This is consistent with a study by Khalafi et al. (2022) found that the concurrent training versus aerobic or resistance training group in which increased upper-muscle maximal strength compared to aerobic training alone. In addition, the maximal strength in the leg extension of the concurrent training group improved better than the aerobic training group which likely involved enhancements in neuromuscular function in the concurrent training group. Moreover, the aerobic training group did not practice leg extension during the program and the neuromuscular strength of this part was not developed (Khalafi et al., 2022). Schoenfeld et al., 2019 reported that training for muscular strength does not require high-volume training. A minimum of 13 min in a strength training session is sufficient for maintaining and developing muscle strength (Schoenfeld et al.,2019). In this study, the concurrent resistance plus aerobic training group had to do resistance training at moderate-volume training, but there was change in 1-RM. This is consistent with the study of Wewege et al. (2017). They found that short-term high-intensity training and moderate-intensity continuous training had no different effect on aerobic training for improvements of body composition (Wewege et al., 2017). That is, the high-intensity training group spent 40% less training time than the moderate-intensity continuous training group. Both high-intensity training and moderate-intensity continuous training showed similar effectiveness across body composition and fat mass reduction. However, in strength training, the training volume did not have much effect on the increase in 1-RM. A study by Krieger (2009) that compared the number of sets in training with increases in muscle strength found that 2-3 sets per exercise increased by 46% greater strength gains than 1 set per exercise. Also, there was no significant difference between 2-3 sets per exercise and 4-6 sets per exercise. Therefore, in this study, the resistance training group with 3 sets per exercise and the concurrent group with 2 sets per exercise gained similar 1-RM. Even the AT group who did not receive resistance training still showed changes which may be due to lifestyle limitations. That is, 62.5% of the AT group was studying in Sports and Exercise Science, so they had to do more forms of physical activity in various courses than general students. In addition, the principle of progression, which gradually increased training intensity, may also affect VO_2max (Krieger, 2009).

Concurrent resistance plus aerobic training can develop VO_2max because during the resistance training, the fast-twitch fibers of the glycolysis-lactic acid energy system are used, causing the ATP energy system as well as liver and muscle glycogen, to be used for energy. In moderate-intensity training with 60-90 seconds of rest between sets, muscle fatigue from training increases breathing because the muscles need nutrient- and oxygen-rich blood. In resistance training, the heart rate was found to increase similar to that of aerobic training. When performing continuous aerobic training after a resistance training session, the body is more ready to warm up the muscles. Consistent with the study of Khalid et al. (2019) comparing aerobic interval training and resistance interval training in patients with myocardial infarction. It was found that the group receiving both aerobic interval training and resistance interval training showed an increase in VO_2(peak oxygen uptake) after 6 weeks of training. In addition, the resistance training did not impair VO_2max in any way (Khalid et al., 2019). A study by Khalafi et al. (2022) also showed that there was a difference in VO_2max in the concurrent resistance and aerobic training group compared to the resistance training group. This indicates that VO_2max can be enhanced by concurrent resistance and aerobic training. That is, if continuous resistance training is combined with aerobic training, it will not adversely affect the improvement of VO_2max. However, the aerobic training group showed slower improvement in the VO_2max (Khalafi et al., 2022). Increasing VO_2max alone cannot make a person develop all aspects of physical fitness. The duration of training, intensity and frequency of training must be considered to suit each individual. Especially among overweight and obese people, concurrent resistance and aerobic training is an effective and safe alternative, which can be performed easily, to improve physical fitness and promote overall health.

Conclusions

Concurrent resistance and aerobic training improved body composition by reduction in the waist circumstance, increasing fat-free mass and skeletal muscle mass and improving the 1-repetition maximum similar to that of resistance training. It also improved VO_2max in overweight and obese students. Therefore, the concurrent resistance and aerobic training was not interfering with either muscular strength or cardiovascular endurance development. This training method could be an alternative training program for improving and enhancing protective factors to promote the health and well-being for excess weight students.

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Conflict of interest

The authors declare that they have no conflict of interest.

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ВПЛИВ ОДНОЧАСНИХ СИЛОВИХ ТА АЕРОБНИХ ТРЕНУВАНЬ НА КОМПОЗИЦІЮ ТІЛА, М'ЯЗОВУ СИЛУ ТА МАКСИМАЛЬНЕ СПОЖИВАННЯ КИСНЮ В ЧОЛОВІКІВ ІЗ НАДМІРНОЮ ВАГОЮ

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Реферат. Стаття: 7 с., 2 табл., 4 рис., 16 джерел.

Метою дослідження було порівняти вплив одночасних силових та аеробних тренувань із лише силовим та/або аеробним тренуванням на композицію тіла, м'язову силу та максимальне споживання кисню в чоловіків із надмірною вагою та ожирінням.

Матеріали та методи. Двадцять чотири добровольці з надлишковою вагою та ожирінням (ІМТ = 23,0-29,9 кг/м^2), віком 19-22 роки, чоловічої статі, які були студентами університету Убон Рачатані Раджабхат (Таїланд), були розподілені на 3 групи: 1) група силових тренувань (СТ), 2) група аеробних тренувань (АТ) і 3) група одночасних силових та аеробних тренувань (СТ+АТ). Тренування тривало 45 хвилин на заняття та 2 дні на тиждень. Композицію тіла разом із м'язовою силою (1-RM – 1-повтор максимум) та максимальним споживанням кисню (VO_2max) вимірювали до (за 2-3 дні) і після (через 2-3 дні) 5-тижневого періоду тренувань.

Результати. Окружність талії значно зменшилася в усіх трьох групах, але група СТ+АТ також виявила покращення у відсотках маси тіла без жиру (0,49 ± 0,49%, p = 0,021, середнє значення ± стандартне відхилення) та маси скелетних м'язів (1,01 ± 0,95%, p = 0,025) порівняно з їхнім базовим рівнем. Аналогічно, показник 1-RM під час розгинання ніг значно зріс в усіх трьох групах, тоді як група СТ (47,67 ± 14,85%, p = 0,01) і група СТ+АТ (42,08 ± 21,70%, p = 0,039) продемонстрували значно більше покращення показника 1-RM під час розгинання ніг порівняно з групою АТ (20,37 ± 13,97%). Нарешті, показник VO_2max значно збільшився в усіх трьох групах (від початкового рівня до рівня після завершення експерименту), хоча ці показники статистично значущо не відрізнялися між групами.

Висновки. Одночасні силові та аеробні тренування можуть зменшити окружність талії та збільшити масу тіла без жиру, масу скелетних м'язів, показники 1-RM та VO_2max. Таким чином, ця стратегія тренувань може слугувати корисним альтернативним способом покращення загальної фізичної форми та зміцнення здоров'я чоловіків із надмірною вагою та ожирінням.

Ключові слова: одночасні тренування, силові тренування, аеробні тренування, 1-повтор максимум, максимальне споживання кисню, надмірна вага.

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ORIGINAL SCIENTIFIC ARTICLE

APPLICATION OF ELECTRONIC MEANS IN ENDURANCE COORDINATION TESTING OF STUDENTS WITH DISABILITIES WHO ARE WAR VETERANS

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Abstract

The purpose of the study was to determine the effectiveness of the use of electronic means created based on information and communication technologies in coordination testing of the endurance of students with disabilities who are war veterans in practical physical education classes.

Materials and methods. To solve research problems, scientific intelligence applied the implementation of research at the theoretical and empirical levels. Analysis, synthesis, generalization, induction, systematization, pedagogical experiment, methods of mathematical statistics and technical modeling were used. The study involved 46 students who are war veterans (males aged 29-35).

Results. An electronic mean for determining coordination endurance based on information and communication technologies and software has been developed. The design of the mean involves the use of mobile and stationary measuring units and a personal computer. The measuring unit contains analog and digital sensors. Information about the student's performance on the test is displayed on the personal computer screen. Approbation of the developed mean involved establishing the degree of its authenticity by comparing the results of testing the coordination endurance of students with disabilities who are war veterans implemented using traditional methods of measurement and the results of testing using the developed mean. The calculation of the reliability and validity of the tests showed that the recording of control results by electronic means allows ensuring a high level of authenticity of the tests.

Conclusions. The use of the electronic control means of coordination endurance presented in the work allows the achievement of a high level of reliability of control results in real time. Based on the summaries of the conducted empirical research, it was established that the introduction of electronic means of control in the process of physical education of students with disabilities who are war veterans helps to ensure the effectiveness of this process.

Keywords: student with disabilities, war veterans, physical education, testing, control, means, information and communication technologies, inclusive.

Introduction

Ukrainian society has been in a state of war for several years in a row. As a result, the number of war veterans in the country is constantly increasing. Ensuring the opportunity for war veterans to obtain quality education in accordance with the characteristics, needs and opportunities is one of the key priorities of modern Ukrainian social and educational policy.

The main component of social interaction and integration of war veterans, among whom there are many people with disabilities, in higher education is inclusion (Ghosh, Santana, & Opelt, 2020). Among the main educational areas of inclusion implementation are the formation and improvement of motor functions that are impaired as a result of a pathological process, compensation of the main defect, and correction of secondary violations that arose in connection with participation in combat operations (Barmak, Barmaksezian, & Der-Martirosian, 2021).

There is no doubt that in order to work with students with disabilities, it is necessary to introduce special methods,

pedagogical technologies, and adaptive technical means into the educational process (Page, Anderson, & Charteris, 2021).

Obtaining new scientific data on physical education as a component of the inclusion of students with disabilities (Grenier, 2007), whose number in higher education institutions of Ukraine is currently constantly increasing at the expense of war veterans, is a social need of Ukrainian society, which has especially gained importance recently, in connection with a full-scale invasion of russia on the territory of Ukraine and prolonged hostilities.

In scientific sources, the potential of physical education in the inclusion of students with disabilities is analyzed (Barboza, Ramos, Abreu, & Castro, 2019; Bertills, Granlund, Dahlström, & Augustine, 2018b; Lieberman, & Houston-Wilson, 2017). It was determined that for such students, physical activity is fundamental to health and individual well-being (Klavina, Jerlinder, Hammar, & Soulie, 2014). The role and place of physical education in the process of formation of vital skills, full physical and psychological rehabilitation of war veterans are proven (Jenner, 2017). In contrast to knowledge, abilities, and skills, in the process of physical education, the acquisition of experience of independent activity in the direction of physical improvement based on universal knowledge by war veteran students is expected (Hunter-Johnson, 2018).

The work of researchers who analyzed the experience of the development of inclusive physical education in universities is of great importance for our research (Sokurianska, Bataeva, & Bakirov, 2019; Molina, 2015). Based on the study of several international documents, it was established that students with disabilities should not be limited in the process of physical education, but a differentiated approach should be applied to them (Blavt, 2022; Malekpour, Isfahani, Amiri, Faramarzi, Heidari, & Shahidi, 2012).

Certain works are focused on new facts, ideas, and approaches to the development and implementation of the process of eliminating health defects in the context of the progress of information and communication technologies (ICT) (Gogoi, 2019; Koryahin, Iedynak, Blavt, Galamandjuk, Prozar, Zaikin, Veselovska, Golub, Kucher, & Gurtova, 2019). The expediency of introducing modern ICT into the process of physical education of students is substantiated (Blavt, Iedynak, Pityn, Hluhov, Guska, Stadnyk, Zaikin, & Karatnyk, 2022; Bhat, Nazir, & Khan, 2018). A number of works are focused on the application of the potential of ICT as a control tool in physical education (Koryahin, Mykytyuk, Turchyn, Blavt, Prystynskyi, & Stadnyk, 2021; Mykytyuk, Blavt, Hnatchuk, Stechkevych, & Helzhynska, 2022; O'Brien, Bourne, Heerey, Timmins, & Pizzari, 2019).

Therefore, the current state of development of the content of physical education of students with disabilities – war veterans at the current stage is different from what is needed, and the research is characterized by individual character and fragmentation. This makes it necessary to carry out further research in the indicated direction, in particular through the development (modernization) of innovative practices of pedagogical content, physical education, and ICT.

The purpose of this study is to determine the effectiveness of the use of electronic means created based on information and communication technologies in coordination testing of the endurance of disabled students of war veterans in practical physical education classes.

Materials and methods

Research methods

Scientific intelligence involved the implementation of research at the theoretical and empirical levels. At the same time, when solving tasks at the theoretical level, general scientific research methods were used: analysis, synthesis, generalization, induction, and systematization.

At the empirical level of the research, a pedagogical experiment, methods of mathematical statistics and technical modeling were applied in the process of creating electronic means.

For the assessment of coordination endurance, the ability to perform complex coordination exercises is monitored for a certain time without disturbing the rhythm of their execution, balance, and coordination of movements during the performance of the test task, specialized test exercises were used: "Walk to the goal", "Kopylov's test" (Bös, 2001; Columbet, 2014). In the selection of test exercises, it is taken into account that walking is an important component of the functional state of the body, taking into account the presence of disorders in students with disabilities. Taking into account the above, the test exercise "Walking to the goal" was used in the study to determine the level of development of the ability to navigate in space. Carrying out the test. The test participant is given the opportunity to estimate the distance to the center of the circle from the starting line during an arbitrary time. Then they blindfold the student with a tight bandage and make him walk to the center of the circle at any pace. At the end of the distance, the test participant stops on his own and signals the end of the test by raising his hand. The center of gravity of the body is marked with chalk between the feet. Result. The distance (measured in centimeters) from the projection of the body's center of gravity, marked on the floor, to the center of the circle.

Kopylov's test. With the help of the test, the development of the ability to coordinate hand movements is being tested. Carrying out the test. The test participant takes the starting position with the body bent forward, holding the ball in one hand. At the command "Start!" performs an imaginary figure eight between the legs at knee level with the ball as quickly as possible. The ball must be passed from hand to hand. With an arbitrary amplitude of the hands, the test participant should not tear off the feet from the floor. To get familiar with the test, students do 4-5 full "eights" beforehand. One scoring attempt is allowed. If the ball is released from the hands, the attempt is repeated. Result. Time to perform ten "eights", recorded with an accuracy of 0.1 seconds.

The tests selected by us provide sufficiently reliable information about the level of development of coordination endurance. In addition, these are quite simple exercises that do not require additional complex equipment. In the selection of test exercises, it is taken into account that walking is an important component of the functional state of the body, taking into account the presence of disorders in students with disabilities.

Study participants

The first-year students from Lviv Polytechnic National University, Kamianets-Podilskyi Ivan Ohiienko National

University, Educational and Rehabilitation Institution of Higher Education "Kamianets-Podilskyi State Institute" took part in a pedagogical experiment. The study involved 46 students – war veterans (males 29-35 years).

Those who were unable to participate in full training because of an injury, sickness, or any physical complaint were excluded. All students provided written, informed consent for their involvement in this study.

The organization of the study took into account the provisions of the Declaration of Helsinki of the World Medical Association (WMA-2013) on the ethical principles of medical research with human participation; the research protocol was approved by the ethics committee of the Lviv Polytechnic National University.

Study organization

It provided for the organization of pedagogical testing using selected test exercises at the beginning of the school year and at the end of the physical education course. For this, traditional methods of recording test results were used and a device for controlling coordination endurance was developed during the research.

Statistical analysis

The following methods of mathematical statistics were used for the statistical analysis of the research results: dispersion and correlation analysis to determine reliability and validity coefficients. The level of reliability of the tests was established by calculating the correlation coefficient. Descriptive statistics methods were used to analyze the test results of the studied sample of students. The work uses SPSS Version 21.

Results

To carry out scientific research in a certain direction, we note that people with disabilities have the greatest requirements in physical development precisely for coordination endurance, since they are prone to failure when fatigued due to various "breaks" in the body (Qi, & Ha, 2012). Coordination is characterized by the ability of people to control their movements (Hirtz, 1985). It should be noted that the level of coordination endurance, as a type of special endurance, is determined not only by the degree of development of vegetative functions that provide movement but also by its stability, which acts as a factor of resistance against fatigue of the neuromotor functions of movement control (Schielke, 1989).

It has been proven that this quality is already embedded in every person from birth, but it must be developed by performing a set of various exercises. In addition, the effectiveness of all motor abilities limits the development of coordination abilities, which at the same time are an important component of physical fitness. Compared to other motor abilities, coordination endurance is the most multi-component in terms of structure and measurement, and it is difficult to control its development (Golle, & Rymarcewicz, 2021).

On the other hand, the control of the development of coordination endurance using the test exercises defined in the study depends on the human factor.

The perception of the person performing the control, in the standardization of compliance with all methodological requirements that are visually established during the control, the performance of exercises complex in terms of the coordination structure during a certain time, when the main parameters of different dimensions are measured: maintaining the rhythm of the performance, stability of posture, coordination of movements, as required by the test task, can be subjective. The possibility of errors also occurs when recording results with a stopwatch, ruler, etc.

The developed electronic means for testing coordination endurance (Fig. 1) uses a mobile measuring unit, which is placed on the body of a student performing a test task, a stationary unit, and a personal computer. The measuring unit contains analog and digital sensors (Hotra, Mykytyuk, Diskovskyi, Barylo, & Vezyr, 2018), whose function is to register signals that occur during exercise, a microcontroller, and a transceiver module (Wojcik, Vistak, Mykytyuk, Politanskyi, Diskovskyi, Sushynskyi, Kremer, Prystay, Jaxylykova, & Shedreyeva, 2020).

Results are displayed using the LCD of a personal computer or mobile telecommunication system, which has a high-speed interface subsystem in which the received signal

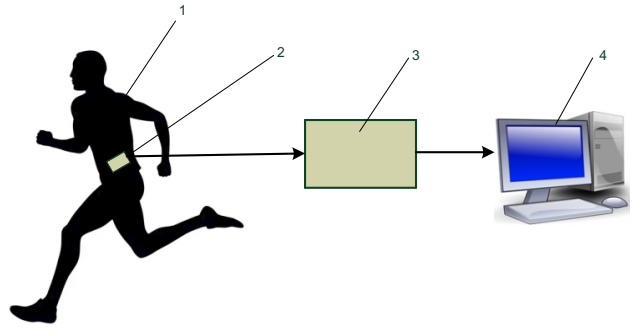

Fig. 1. Scheme electronic means in endurance coordination testing and where: 1 – student, 2 – mobile measuring unit, 3 – stationary measuring unit, 4 – personal computer

is processed on a real-time scale. In the internal memory of a personal computer with the use of developed software, it is provided for the analysis of the received test signals and their storage.

The microcontroller used to implement the electronic means contains a classic set of computing elements, uses a real-time timer, and has a program memory with the possibility of self-programming. In addition, the microcontroller provides registration and programmatic analysis of input information for recording test results and regulates the components of the developed structure.

To implement the electronic means, the ESP8266 Wi-Fi wireless communication USB 17 interface was used. The interface additionally provides the ability to control the preservation of the execution rhythm, balance, and coordination of movements.

The study involved determining the degree of reliability (Vanhelst, Beghin, Fardy, Ulmer, & Czaplicki, 2016) in three values: within-subject variation, change in mean value, and test-retest correlation (Tab. 1). Thus, we meant the repeatability or reproducibility of a measure or variable (Zanevskyy, & Labartkava, 2020). It is recognized that an

Table 1. The results and authenticity of control test trials of coordination endurance (n = 46)

Statistical parameters	Test tasks and measurement results							
	Walking to the goal (cm)		Walking to the goal (cm)		Kopylov's test (s)		Kopylov's test(s)	
Period of the experiment	at the beginning		at the end		at the beginning		at the end	
Method of measurement	T	A	T	A	T	A	T	A
M	53.3	51.6	47.4	42.3	1.10	1.04	1.00	0.56
S	3.6	2.1	3.6	2.1	0.09	0.06	0.07	0.05
V (%)	42.6	29.1	43.1	24.8	47.4	22.1	45.8	21.5
Reliability(rtt)	0.719	0.911	0.697	0.944	0.715	0.911	0.726	0.926
Validity (rtt)	0.119	0.239	0.169	0.258	0.155	0.223	0.171	0.226

*Note: T – using the test exercises, A – using the electronic means

important use of reliability is the estimation of sample size for experimental studies. Since we were interested in the issue of reproducibility of individual values obtained using different equipment, but by the same observer. In order to estimate the standard error under such conditions, it was considered appropriate to use many students and several trials rather than one and many trials.

The obtained results of the V(%) indicator when measured by the traditional method within the limits (significant variation) indicate that the stability of the test results is lower than the required metrological standards of reliability. Intraclass correlation coefficients reliability from moderate to excellent was observed for all students in the process of testing by using the test exercises (0.72-0.80) and using the electronic means (0.85-0.95); coefficients validity in the process of testing by using the test exercises (0.10-0.20) and using the electronic means (0.20-0.25). Thus, the device was sensitive to detect small changes during the test exercise.

Discussion

Considering that Ukraine has been in a state of martial law for a year and has been in a state of war for eight years, the educational community faces new challenges: ensuring a full-fledged opportunity to receive higher education for participants in hostilities, and above all for war veterans, among whom there are many persons with disabilities. Therefore, there are many problems with the participation of persons with disabilities in the educational process in universities, in particular, when an inclusive perspective is added to the high-quality teaching of physical education. We agree with our research (Ghosh, Santana, & Opelt, 2020; Lieberman, & Houston-Wilson, 2017), that physical education at the university is one of the main ways of correcting violations of physical development, motor readiness, and psychomotor skills of students with disabilities – war veterans.

It has been proven that for students with disabilities to fully receive quality physical education, opportunities for evaluating the effects of this process must be created. The quality of physical education is determined by the quality of receiving operational reliable information about its progress (Ivashchenko, Yermakova, Cieślicka, & Śukowska, 2015; Koryahin, Mykytyuk, Blavt, Dolnikova, & Stadnyk, 2020; O'Brien, Philpott, Lester, Belton, Duncan, Donovan, Chambers, & Utesch, 2021). We support ideas (Koryahin, Blavt, Vanivska, & Stadnyk, 2020) about the need to use ICT means in the physical education of students with disabilities, in particular war veterans, which ensure the urgency and objectivity of the received control information.

In our study, we considered the possibility of the application of electronic means, developed using ICT, in the process control of physical education of students with disabilities and war veterans as an opportunity to increase the effectiveness of control and physical education in general. This expands the available information (Gogoi, 2019; Mykytyuk, Blavt, Hnatchuk, Stechkevych, & Helzhynska, 2022) regarding the necessity and feasibility of using ICT in physical education.

We align the research findings with the existing idea that in addition to providing students with disabilities with choices about what is assessed, it is possible to provide options related to how students are assessed (Ivashchenko, 2020). In this sense, it is the parameters of coordination endurance, which were investigated in the implemented research, that are the most optimal option for evaluating the results of physical education of students with disabilities of war veterans.

Compared to other forms of physical education, there is a limited amount of research that supports the practice of inclusion for war veterans in higher education, and although interest has grown significantly over the past decade, no experimental research has been conducted in this area to date.

The works established (Blavt, 2022; Malekpour, Isfahani, Amiri, Faramarzi, Heidari, & Shahidi, 2012; Stodden, Langendorfer, & Roberton, 2009), that the construction of the physical education process based on the results of permanent control allows to intensify the process of physical training and increase the efficiency of managing this process. In connection with the above, the question of the necessity for each student with a disability an individual trajectory for his physical education, which is implemented in different but defined forms, and contributes to the achievement of a positive result based on the results of objective control, is actualized.

Conclusions

It was found that since the first use of ICT until today, this industry is characterized by significant progress and innovation. As for the educational sector, the use of ICT

made it possible to reformat the organizational forms of this process, in particular, physical education. Considering the intensive development of ICT, the use of their potential in the educational process of physical education is a determining factor in ensuring the effectiveness of this process.

Control in physical education is positioned as a mandatory and necessary method of monitoring this process. The expediency of careful control of coordination endurance, which in terms of structure and measurement is the most multicomponent and difficult to control its development, in the physical education of students with disabilities – war veterans is determined by the objective necessity of carrying out the inclusive process in the conditions of an educational institution.

The research paper presents a electronic means of control of coordination endurance developed based on ICT in students with disabilities – war veterans. Experimental practical testing of the electronic means of control, reliability and validity were determined, the coefficients of which exceed the obtained control values using test exercises. Based on the summaries of the conducted empirical research, it was established that the introduction of electronic means of control in the process of physical education of students with disabilities – war veterans helps to ensure the effectiveness of this process. Improving test results as evidence of the performance of physical education.

The issue of optimization of physical education involves such a construction of this process, in which the choice of means, methods, methods, forms, and pace of learning takes into account the peculiarities of the motor and functional readiness of students, the level of their physical development and state of health, reliable information on this can be obtained from the results of objective urgent control.

Conflicts of interest

No conflicts of interest exist.

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ЗАСТОСУВАННЯ ЕЛЕКТРОННИХ ЗАСОБІВ У ТЕСТУВАННІ КООРДИНАЦІЙНОЇ ВИТРИВАЛОСТІ СТУДЕНТІВ З ІНВАЛІДНІСТЮ – ВЕТЕРАНІВ ВІЙНИ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 2 табл., 4 рис., 16 джерел.

Мета дослідження – полягає у визначенні ефективності використання електронних засобів, створених на основі інформаційно-комунікаційних технологій, у тестуванні координаційної витривалості студентів з інвалідністю ветеранів війни у їхньому фізичному вихованні.

Матеріали та методи. Для вирішення дослідницьких завдань наукової розвідки, дослідження реалізовано на теоретичному та емпіричному рівнях. Використано аналіз, синтез, узагальнення, індукція, систематизація, педагогічний експеримент, методи математичної статистики та технічного моделювання. У дослідженні взяли участь 46 студентів – ветеранів війни (чоловіки 29-35 років).

Результати. Розроблено електронний засіб для визначення координаційної витривалості на основі інформаційно-комунікаційних технологій та програмного забезпечення. Конструкція засобу передбачає використання мобільного та стаціонарного вимірювальних блоків та персонального комп'ютера. Вимірювальний блок містить аналогові та цифрові сенсори. Інформація про виконання тесту студентом подається на екран персонального комп'ютера. Апробація розробленого пристрою передбачала установлення ступеня його автентичності, шляхом порівняння результатів тестування координаційної витривалості виховання студентів з інвалідністю – ветеранів війни реалізованого з використанням педагогічних тестів та тестування з використанням розробленого засобу контролю. Обчислення надійності та валідності тестів показало, що фіксація результатів контролю електронним засобом дозволяє забезпечити високий рівень автентичності тестів.

Висновки. Використання представленого у роботі електронного засобу контролю координаційної витривалості дозволяє досягти високого рівня достовірності результатів контролю в режимі реального часу. На підставі підсумків проведеного емпіричного дослідження встановлено, що впровадження електронних засобів контролю в процес фізичного виховання студентів з інвалідністю – ветеранів війни сприяє забезпеченню ефективності цього процесу.

Ключові слова: студент з інвалідністю, ветеран війни, фізичне виховання, тестування, контроль, засіб, інформаційно-комунікаційні технології, інклюзія.

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ORIGINAL SCIENTIFIC ARTICLE

MATURITY STATUS AND FAT-FREE MASSES AS DETERMINANTS OF PHYSICAL FITNESS AMONG MACEDONIAN SCHOOLCHILDREN AGED 6 TO 14

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Abstract

Study purpose. The research goal was to establish if the fat-free mass, chronological age and maturity status are determinants of physical fitness, and to analyze the development changes of fat-free mass and physical fitness in concordance with chronological age and maturity status in schoolchildren aged 6 to 14.

Materials and methods. The research was conducted on a sample of 9106 students aged 6 to 14 years. In order to reach the research goals, the following variables were measured: height, weight, sitting height, fat mass, fat-free mass and various components of the physical fitness (lower limbs explosive strength, handgrip strength, abdominal muscle repetitive strength, speed and agility). The values of body mass and biological maturation indexes (APHV) were obtained by using formulas.

Results. The boys' age at peak height velocity was estimated at 13.00±0.82, and the girls' one at 11.57± 0.68. The relationships between chronological age and age at peak height velocity with fat-free mass was r=0.82 to 0.94 in the boys and r=0.83 to 0.92 in the girls. The relationships between fat-free mass and physical fitness tests in the boys were: standing long jump (r=0.55), 30 sec sit-ups (r=0.37), handgrip strength (r=0.75) and shuttle run 4 × 10 meters (r=-0.40); and in the girls – standing long jump (r= 0.45), 30 sec sit-ups (r= 0.36), handgrip strength (r= 0.74) and shuttle run 4 x 10 meters (r= -0.43). The differences in fat-free mass and physical fitness tests were more prominent when the comparison was done with relation to the biological maturation (APHV) and chronologic age.

Conclusions. On the basis of the obtained results, it can be concluded that maturity status and fat-free mass determinate the physical fitness performances in the schoolchildren of both genders. Also, the age at peak height velocity should be used in Physical Education as a tool of monitoring, ranging and classification of physical performances in children and adolescents.

Keywords: physical fitness, fat-free mass, maturity status, children, adolescents.

Introduction

The analysis of the body mass components are necessary for understanding what impact the physical growth, diet effects, diseases and physical activity, among other environmental factors, have on human's organism (Valtueña Martínez et al., 1996). The studies which deal with the body composition most often investigate absolute and relative body mass components, since they change during the period of growing and biological maturation, so it is necessary to pay attention when selecting the assessment methods of the same children and adolescents (Malina & Geithner, 2011).

The body composition components can be determined by methods on the field or in laboratory. The monitoring of body composition components in children and adolescents is of a particular significance in assessing different phases of growth and maturation (Sherar et al., 2005).

From the perspective of anthropometry, body composition is normally considered as a two-component model consisting of fat mass and fat-free mass. Namely, fat

mass provides information about the increase of body fat in the person, which associates with a serious risk of several diseases such as cardiovascular disease, hypertension, insulin resistance, hyperinsulinemia, total obesity, abdominal adiposity, deteriorated health skeleton condition and a great number of metabolic risk factors (Pulgaron & Delamater, 2014; Seidell et al., 1989). Whereas the fat-free component plays an important role in physical performances (Poortmans et al., 2005), body position maintenance and movements in adults, children and adolescents.

It is known that the body composition proportions (fat mass and fat-free mass) change during the period of growth and biological maturation. Therefore, the body composition components can be determiners when analyzing physical fitness performances in schoolchildren. In this direction, physical fitness is a powerful indicator of the health condition in childhood, adolescence and adulthood alike (Ortega et al., 2007). For example, the muscle strength and global muscular fitness have a specific importance in doing different daily routines and activities throughout lifetime (Thivel et al., 2016). Agility and speed are the fitness components that are related to different sports (Farrow, Young & Bruce, 2005; Uzun et al., 2020) and are necessary for the individual to perform successfully different fundamental motoric skills and movement models (Couturier, Chepko & Holt, 2014).

Within the teaching of physical education, the physical performances such as strength, speed and agility are mainly developed during the learning process depending on the gender and age. These physical qualities' development involves collaborative/ cooperative activities, such as jumping, running and throwing, which are performed every day through playing (Milanese et al., 2020). Further, physical performance is determined not only by the levels of physical activities (Sola, Brekke & Brekke, 2010), but by the levels of biological maturation of children and adolescents as well, since the intensity and duration of puberty period is individually specific and may significantly vary from one person to another (Malina, Bouchard & Bar-Or, 2004).

Taking into consideration the fact that the changes during the growth, development and biological maturation take place in childhood and adolescence, it is possible for the maturity status (MS) and the fat-free component level (FFM) to be determinants of the physical fitness performances in schoolchildren.

Therefore, the research goal was to establish if fat-free mass, chronological age and maturity status (APHV) are determinants of physical fitness performance (strength, strength endurance, speed and agility), and to analyze fat-free mass and physical fitness concor with chronological age and maturity status in Macedonian schoolchildren aged 6 to 14.

Material and Methods

Participants

The research was conducted on a sample of 9106 students aged 6 to 14 years from 19 primary schools (eight rural and eleven urban) from the East and Central Macedonia. The total sample of respondents was divided, according to the gender, into two subsamples (subsample n1 = 4573 boys and subsample n2 = 4443 girls). These two subsamples were divided into nine groups regarding their chronologic age (6, 7, 8, 9, 10, 11, 12, 13 and 14 years). The average age of the respondents of both genders was 10.05±2.41 years. Parents or legal guardians signed a document that they agreed for their child to participate in the research. The study protocol was performed following the ethical guidelines of the Declaration of Helsinki of 1961 (revision of Edinburgh 2013).

Anthropometric Measurements and Body Composition

The anthropometric measurements were carried in accordance with the methodology of International Biology Program (IBP). The weight was taken with medical decimal weighing scale. The height and sitting height were taken with a Martin's anthropometry. During measurements, the children were in underwear and barefooted. Body mass index was calculated as body weight in kilograms divided by the square of height in meters.

Components of body composition were assessed using bioelectrical impedance. The measuring was conducted with an OMRON BF511 body composition monitor, by means of which body weight, muscle mass percentage, body fat percentage, and fat-free mass were determined. In order to provide highly precise results from the body composition assessment, we ensured that the preconditions recommended by ACSM and Heyward (1992) were fulfilled prior to each measuring.

Evaluation of Physical Fitness

Four tests, which are part of the national MAKFIT battery, validated and standardized, were applied in the following order: Hand grip test, Standing broad jump test, 30 sec sit-ups and Shuttle run: 4 × 10 meters (Gontarev et al., 2018).

Maturity State

Maturity status was determined using the predictive non-invasive methods of Sherar et al. (Sherar et al., 2005). The prediction equation requires measurements of height, sitting height, and weight together with the birth-date and gender. This method uses a maturity-offset protocol, allowing for the prediction of time before or after peak height velocity from age, age at peak height velocity, and an estimation of percentage of adult stature attained.

Statistical analysis

The normal distribution of the variables was established through the Kolmogorov-Smirnov test. The basic descriptive statistical parameters were calculated for all the variables (mean and standard deviation). The gender differences were established through the t-test for independent samples. The association between the variables was established by the use of Pierson's coefficients of correlation. The differences regarding the age and APHV were established with the analysis of the variance and Turkey's test of specificity. Also, the calculation was made about the coefficients of determination r^2 and standard error of estimation. In all calculations, $p < 0.05$ was considered. All the analyses were performed using the Statistical Package SPSS, v. 22.0 for Windows.

Results

The anthropometric measures, physical fitness performances and body composition of the examined respondents' sample are presented in Table 1. The inspection of the Table shows that between the girls and boys there are not statistically significant differences to be established in the variables of years (p = 0.107) and sitting height (p = 0.642). The boys demonstrate higher values in: peak years of growth velocity, weight, height, body mass index, body fat expressed in kilograms and the fat-free component (p<0.001). Along with that, boys achieve better results in the fitness tests: standing long jump, 30 sec sit-ups, handgrip strength and 4 x 10m shuttle run (p <0.001).

The relations between the tests for physical fitness assessment with chronological age, fat-free mass and age at peak years of growth velocity are presented in Table 2. All the tests for assessing physical fitness were statistically significantly related to chronological age, fat-free mass and peak years of growth velocity. With the boys, the determination coefficients (r2) ranged as follows: in the test of "standing long jump" from 30 to 48%; for the test of "30 sec sit-ups" – from 14 to 27%; for the test of "handgrip strength" – from 52 to 58%; and for the test of "4 x10 meters shuttle run" – from 16 to 31%. With the girls, the determination coefficients were relatively lower. As for the test of "standing long jump", the coefficients ranged from 20 to 32%; for the

Table 1. Anthropometric profile, body composition and physical performance of the sample studied

	Boys (n=4573)		Girls (n=4443)		t	p
	Mean	SD	Mean	SD		
Age (years)	10.09	2.39	10.01	2.44	1.61	0.107
MS (APHV)	13.00	0.82	11.57	0.68	90.38	0.000
Anthropometry						
Height (cm)	144.58	15.67	143.27	14.68	4.08	0.000
Sitting height (cm)	76.00	7.31	75.93	7.37	0.47	0.642
Weight (kg)	42.41	15.48	40.88	14.04	4.93	0.000
BMI (kg/m^2)	19.65	4.00	19.38	3.95	3.16	0.002
Body composition						
Fat mass (kg)	9.77	6.24	10.38	6.61	-4.48	0.000
FFM (kg)	32.64	11.12	30.50	8.41	10.33	0.000
Physical fitness						
Standing long jump (cm)	140.87	32.03	120.09	24.33	34.60	0.000
30 sec sit-ups (n)	15.33	5.74	12.78	5.36	21.74	0.000
Handgrip strength (kg)	24.71	16.43	20.14	12.05	14.54	0.000
4×10 m shuttle run test (sec)	13.95	2.00	15.12	2.04	-27.46	0.000

t, Student's t-value, MS, maturity stage, APHV, peak growth velocity years, BMI, body mass index, FFM, fat-free mass.

Table 2. Relationship between physical fitness tests with fat-free mass and maturity status in schoolchildren of both sexes

Physical fitness	Independent variable	Boys				Girls			
		r	r^2	SEE	p	r	r^2	SEE	p
Standing long jump (cm)	Age (years)	0.70	0.48	23.02	0.000	0.57	0.32	0.32	0.000
	MS (APHV)	0.66	0.43	24.11	0.000	0.54	0.30	20.42	0.000
	FFM (kg)	0.55	0.30	26.80	0.000	0.45	0.20	21.76	0.000
30 sec sit-ups (n)	Age (years)	0.52	0.27	4.90	0.000	0.45	0.20	4.79	0.000
	MS (APHV)	0.47	0.22	5.07	0.000	0.43	0.18	4.85	0.000
	FFM (kg)	0.37	0.14	5.34	0.000	0.36	0.13	5.01	0.000
Handgrip strength (kg)	Age (years)	0.72	0.52	11.39	0.000	0.72	0.51	8.42	0.000
	MS (APHV)	0.76	0.58	10.65	0.000	0.76	0.57	7.89	0.000
	FFM (kg)	0.75	0.57	10.83	0.000	0.74	0.55	8.10	0.000
4 ×10 m shuttle run test (sec)	Age (years)	-0.56	0.31	1.66	0.000	-0.52	0.27	1.74	0.000
	MS (APHV)	-0.50	0.25	1.73	0.000	-0.50	0.25	1.76	0.000
	FFM (kg)	-0.40	0.16	1.83	0.000	-0.43	0.18	1.84	0.000

MS, maturity stage, APHV, peak years of growth velocity, SEE, standard error of estimation, r, correlation, r2, coefficient of determination

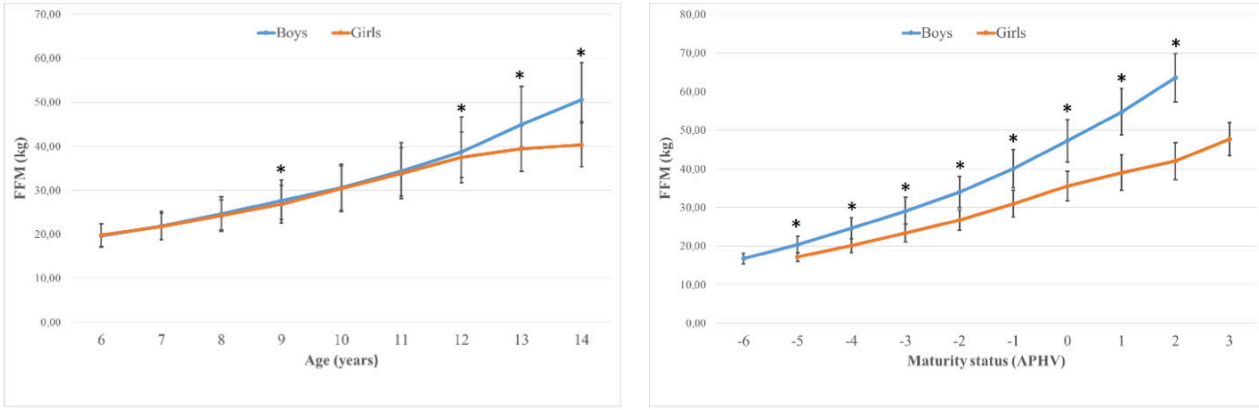

Fig. 1. Mean FFM values of children and adolescents by chronological age and maturity status.*, significant difference in relation to girls

test "30 sec sit-ups" – from 13 to 20%; the test "handgrip strength" – from 51 to 57%; and the test "4 x 10 meters shuttle run" – from 18 to 27%. The relationships between chronological age, age at peak height velocity and fat-free mass were r=0.82 to 0.94 in boys and r=0.83 to 0.92 in girls.

Chart 1 represents the comparisons of fat-free mass with reference to the chronologic age and peak years of growth velocity in both genders. In the comparisons by chronological age, differences are observed from 12 to 14 years ($p < 0.05$), however, when compared by maturity status, the differences are significant in all peak years of growth velocity (from -5APHV to +2APHV) ($p < 0.001$).

The comparisons of physical fitness performances to chronologic age and peak years of growth velocity are represented in Chart 2. Inspecting the chart, it is obvious that statistically significant differences ($p > 0.05$) were established in all of the physical fitness tests between the boys and girls of all age categories. Also, statistically significant differences were established on all APHV levels between the boys and girls in all physical fitness tests. In general, the use of the peak years of growth velocity allows a better categorization of the performance of the children and adolescents studied.

Discussion

The first research goal was to establish if fat-free mass, maturity status and chronological age are determinants of physical fitness performance (explosive power of lower limbs, handgrip strength, abdominal muscle repetitive strength, speed and agility) in Macedonian schoolchildren aged 6 to 14. The results showed a moderate relationship between fat-free mass, maturity status and chronological age with the physical fitness tests for assessing the explosive power of the lower limbs, absolute handgrip strength, abdominal muscle repetitive strength, speed and agility in both genders.

The obtained study results are in accordance with previous study works, where it is established that the physical fitness of children and adolescents is under the influence of of different factors, such as gender, age, body composition, biological maturation phase, physical activity level, apart from other factors (Malina, 2005; Malina, Bouchard, & Bar-Or, 2004).

Generally speaking, these relationships are explained due to the fact that the maximal power, explosive power, muscle strength, speed and agility are presented in a series of motor actions that must be developed efficiently. Therefore, the result of these tests is reflected in the performance and depends on the acquired muscle strength levels. Consequently, the muscle strength is defined as an ability of manifesting maximum strength in the shortes period of time, which is of crucial importance for a wide range of activities, such as running, jumping, exeleration and throwing, whereby all the tests in the present research depend on the fat-free mass (Beaudart et al., 2019; Avcin et al., 2023).

The research results indicate that chronological age, age at peak height velocity and fat-free mass during childhood and adolescence have a positive effect on physical fitness performances. A large number of research studies indicate that the proper muscle mass maintenance has important implications in everyday life and is of essential importance in performing activities of daily living (Thivel et al., 2016) and provides great benefits related to health (Smith et al., 2014).

A considerable number of previous research works point that the high level of fat-free mass can increase the insulin sensitivity (Nam et al., 2001; Berman et al., 2012), and the low level of the muscle mass is associated with a great number of metabolic risk factors and insulin resistance (McCarthy et al., 2014; Cohen et al., 2014). In this connection, the preservation and increase of skeleton muscle mass in childhood and adolescence shod be a constant care on the part of Physical Education teachers and parents. It is because maintaining the optimal skeleton muscle mass in childhood and adolescence can improve peak muscle mass and bone strength (Liu et al., 2019), and it has a positive effect on the physical performances.

The second research goal was to analyze fat-free mass and physical fitness performances in relation to chronological age and maturity status. The results showed coherence between the two indicators because the analysis based on both chronologic age and maturity status (through APHV) showed significant differences between the two genders, but the gender differences were more prominent when the analysis was done based on the maturity status (through APHV). Also, as the chronologic age and maturity status were increasing, the level of all fitness components increased too. Data from cross-sectional studies confirm our findings

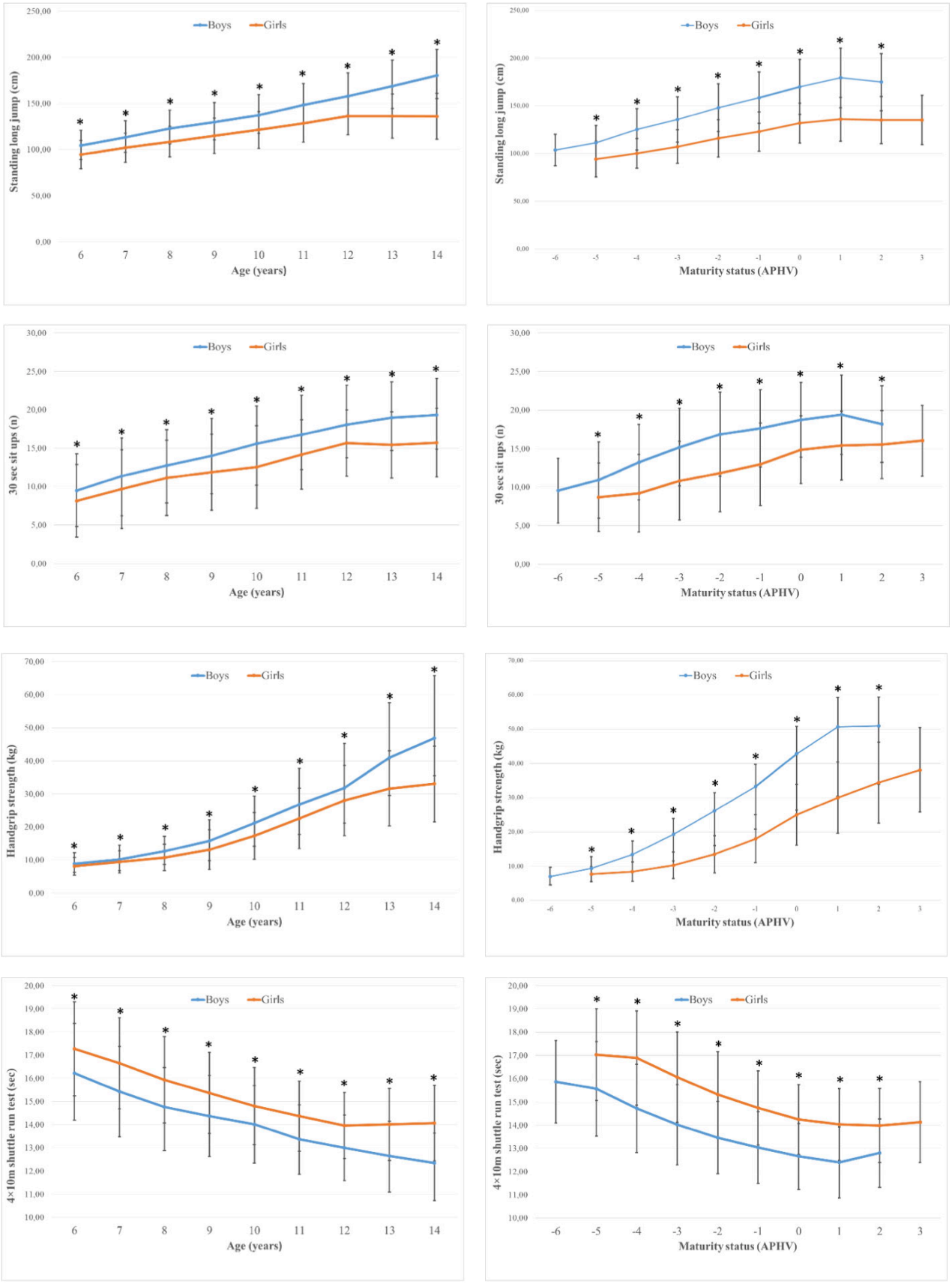

Fig. 2. Mean physical performance values of children and adolescents by chronological age and maturity status.*, significant difference in relation to girls

in as much as physical fitness enhancements were reported in groups of increasing age (Santos et al., 2014; Catley & Tomkinson 2013; Woll et al., 2011).

The research results suggest that the assessment and monitoring of fat-free mass and physical fitness performances of children and adolescents should be carried out with control of maturity status since this type of somatic maturation's indicator is often determined with regression equations that are specific for the age and gender (Moore et al., 2015), which aim to classify the state of maturation by APHV.

In general, it is considered that school children can have advantages or disadvantages in physical fitness testing by being more or less mature than their chronologically age matched counterparts. Thus, the control of time and rate of growth is of a significant importance, having in mind that the maturation is highly individual and asynchronous with the decimal age during the adolescence (Malina, Bouchard & Bar-Or, 2004). Therefore, it is of a crucial significance to classify schoolchildren according to their maturity status, especially if we wish to analyze the relation between fat-free mass and physical fitness.

In this respect, the schoolchildren of same chronological age differ considerably in their maturity status, so that there are differences in the height, weight, fat mass and fat-free mass between the adolescents of earlier maturation compared to those of average and late maturation. Actually, the adolescents who reach later maturation have in general lower functional and physical characteristics (i.e. more linear physique, lower values of the absolute and relative fat component) than their average and accelerated maturing counterparts.

In fact, as it is noted in Graphs 1 and 2, the greatest changes are observed after the APHV level forward, especially in fat-free mass, lower limbs explosive power, handgrip absolute strength, and speed and agility. Consecutively, the girls show poorer performances, whereas the boys keep improving their performances as they mature further.

It is known that often during the classes of Physical education and sport the motor actions of deceleration, acceleration, change of direction, jumping and bouncing require the ability of speedy absorbing and manifesting both unilateral and bilateral strength, and it is during these activities that many boys and girls may show different physical performance results due to children's different rhythm of maturation.

That is why it is necessary to introduce control of maturity status in classes of Physical Education and sports practice, since this indicator can contribute for adequate classification of schoolchildren. The mentioned is also considered to be a powerful indicator in classification of working groups, especially it comes about variables that refer to strength physical capacity, speed, agility and strength endurance, respectively (Malina, Bouchard & Bar-Or, 2004).

The present study has certain advantages, having in mind that it is one of the first studies conducted in the R. N. Macedonia which was held on a great sample of respondents (from 6 to 14 years of age), where, apart from the chronological age, the maturity status was also taken into consideration. Along with that, the sample selection and reliability of fitness tests and anthropometric measurements allow generalizing the results to contexts with similar characteristics. On the other hand, the transversal character of the research is noticed as a main limitation, since longitudinal research works enable the investigators to establish the cause-and-effect relationships, and even to check the changes in course of time. The maturity status control by the use of non-invasive method (the anthropometric one) can cause small prejudices in the results, yet, in the absence of other methods, the authors think that the application of this method is compatible. Along with that, this method has been applied in a greater number of previous research studies and it has appeared to be valid and reliable (Mirwald et al., 2002; Marinho et al., 2020; Cossio-Bolaños et al., 2021; Avcin et al., 2023).

Conclusions

On grounds of the obtained results, it can be concluded that fat-free mass, chronological age and maturity status are determinants of physical fitness performance (lower limbs explosive power, absolute handgrip strength, abdominal muscles' repetitive strength, speed and agility). Perhaps maturity status should be introduced in Physical education and sport as a tool for classification of physical fitness performances, especially with schoolchildren before and during the adolescence phase, since it ostensibly reduces physical and anthropometric differences in relation to chronological age.

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СТАН ЗРІЛОСТІ ТА МАСА ТІЛА БЕЗ ЖИРУ ЯК ВИЗНАЧАЛЬНІ ЧИННИКИ ФІЗИЧНОЇ ПІДГОТОВЛЕНОСТІ СЕРЕД МАКЕДОНСЬКИХ ШКОЛЯРІВ ВІКОМ ВІД 6 ДО 14 РОКІВ

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Реферат. Стаття: 8 с., 2 табл., 2 рис., 32 джерела.

Мета дослідження. Мета дослідження полягала в тому, щоб установити, чи є маса тіла без жиру, хронологічний вік і стан зрілості визначальними чинниками фізичної підготовленості, а також проаналізувати зміни розвитку маси тіла без жиру та фізичної підготовленості у відповідності з хронологічним віком і станом зрілості у школярів віком від 6 до 14 років.

Матеріали та методи. Дослідження проведене на вибірці з 9106 учнів віком від 6 до 14 років. Для досягнення цілей дослідження вимірювали такі змінні: зріст, вага, висота в положенні сидячи, маса жиру, маса тіла без жиру та різні компоненти фізичної підготовленості (вибухова сила нижніх кінцівок, сила хвату, сила багатократного напруження м'язів живота, швидкість і спритність). Значення індексів маси тіла та біологічного дозрівання (APHV – вік на момент пікової швидкості зростання) отримували за допомогою формул.

Результати. Вік на момент пікової швидкості зростання у хлопчиків оцінювали в 13,00±0,82 року, у дівчат – в 11,57±0,68 року. Співвідношення між хронологічним віком і віком на момент пікової швидкості зростання та масою тіла без жиру становило r=0,82-0,94 у хлопчиків та r=0,83-0,92 у дівчат. Співвідношення між масою тіла без жиру та показниками фізичної підготовленості у хлопців становили: стрибок у довжину з місця (r=0,55), присідання протягом 30 с (r=0,37), сила хвату (r= 0,75) та човниковий біг 4 × 10 метрів (r= -0,40); у дівчат – стрибок у довжину з місця (r=0,45), присідання протягом 30 с (r=0,36), сила хвату (r=0,74) та човниковий біг 4 × 10 метрів (r=-0,43). Відмінності в тестах маси тіла без жиру та фізичної підготовленості були помітнішими, коли порівнювали біологічне дозрівання (APHV) і хронологічний вік.

Висновки. На підставі одержаних результатів можна зробити висновок, що стан зрілості та маса тіла без жиру визначають показники фізичної підготовленості школярів обох статей. Крім того, вік на момент пікової швидкості зростання слід використовувати у фізичному вихованні як засіб моніторингу, ранжування та класифікації фізичних показників дітей і підлітків.

Ключові слова: фізична підготовленість, маса тіла без жиру, стан зрілості, діти, підлітки.

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ACUTE EFFECTS OF DRY NEEDLING ON LOWER LIMB MUSCLE STRENGTH IN CROSSFIT ATHLETES WITH LATENT TRIGGER POINTS: A RANDOMIZED TRIPLE-BLINDED PILOT CLINICAL TRIAL

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Abstract

Study purpose. The purpose of this study was to evaluate the acute effect of deep dry needling (DP) on lower-limb muscle strength-related variables in CrossTraining recreational athletes with latent trigger point (TrP).

Materials and methods. A total of 19 healthy CrossFit®-trained males (27.8 [4.7] years; 79.8 [10.4] kg; 1.76 [0.07] cm) with myofascial TrP in quadriceps, gluteus or gastrocnemius muscles completed this repeated-measures triple-blind pilot clinical trial. Participants were randomly allocated into either experimental (EG, n = 10) or Sham (SG, n = 9) groups. After allocation, the assessment of lower-limb muscle power (squat jump [SJ] and countermovement jump [CMJ]) and maximal isometric hip abduction and quadriceps strength were measured at baseline and after 48 hours of the intervention.

Results. The results are expressed as Δ (SD) [95% CI]; unbiased Cohen's d [d_{unb}, 95% CI]). DN has been shown to reduce the presence of muscle TrP. The maximal isometric hip abduction strength had a moderate-to-high significant increase in the EG (left: 21.5 (16.9) [9.42, 33.57]; 0.55 [0.19, 0.99], right: 20.3 (16.2) [8.70, 31.89]; 0.74 [0.25, 1.35]); however, the Sham group only showed significant improvement in the left hip abductor muscles 15.77 (15.37) [3.96, 27.59]; 0.57 [0.11, 1.12]) with no significant changes in the right side.

Conclusions. The acute reduction of myofascial TrP was observed with the application of DN but had no significant effect on maximal isometric strength or jump height compared to the Sham group. Results of this pilot clinical trial can be used to commission future research.

Keywords: dry needling, muscle strength, trigger point, trigger area.

Introduction

CrossTraining is a high-intensity functional training modality, which has had a fast growth worldwide with CrossFit® as the most popular registered trademark (with presence in 142 countries and more than 10,000 affiliates) (Claudino et al., 2018). This discipline is characterized by the execution of high-intensity interval training (HIIT) with external loads or the body mass itself, so that physical performance depends largely on the ability to generate muscle strength (Claudino et al., 2018). Although no direct data have been reported on the prevalence of myofascial pain syndrome in CrossTraining, de Almeida et al. (2019) suggested that this modality might evoke in myofascial pain syndrome which is associated to CrossFit®-related spinal injuries (de Almeida, Carvalho, & Ribeiro Neto, 2019). This makes sense considering the moderate prevalence of this condition in Spinal Disorders (Chiarotto, Clijsen, Fernandez-de-Las-Penas, & Barbero, 2016) and in neck and shoulder-related disorders (Ribeiro et al., 2018).

Myofascial pain syndrome is characterized by symptoms and signs generated by trigger points (TrP) in the body including muscle pain (referred pain), decreased range of mo-

tion, uncoordinated movements (changes in motor patterns), muscle fatigue, delayed muscle relaxation and recovery, and spasms (de las Peñas, 2013). TrP are discrete, focal, hyperirritable spots located in a taut band of skeletal muscle that may be spontaneously painful (i.e., active) or only painful with compression (Shah et al., 2015). The prevalence of myofascial pain syndrome, and TrP, is high among physically active individuals and athletes (Fett, Trompeter, & Platen, 2019; Hidalgo-Lozano et al., 2013; Noormohammadpour, Farahbakhsh, Farahbakhsh, Rostami, & Kordi, 2018; Skootsky, Jaeger, & Oye, 1989) with significant differences of the anatomical distribution according the sport discipline (Park et al., 2010). This has been associated to changes in muscle status including alterations on intracellular Ca2+ levels, reactive oxygen species production, and decline in force production (Jafri, 2014).

Evidence of low to moderate quality suggests that dry needling (DN) can be an effective strategy for eliminating myofascial TrP (Mayoral del Moral, 2005). In fact, having latent TrP has been shown to generate strength losses while their treatment and elimination have shown an increase in strength levels (Calvo-Lobo, Pacheco-da-Costa, & Hita-Herranz, 2017; Cubukcu, Alimoglu, Samanci, & Gurbuz, 2007; Lisinski & Huber, 2017). Notwithstanding, evidence is not clear in this regard (Espejo-Antúnez et al., 2017) and more high-quality clinical studies are needed (Gattie, Cleland, & Snodgrass, 2017). Some authors have even suggested that this practice may be detrimental to strength because of the pain it causes (Prado, 2017). So far, most of the studies have been carried out on upper limbs and there is a need for further work with athletic population. Therefore, the aim of this study was to evaluate the acute effects of DN versus placebo (sham) on lower-limb muscle strength in CrossFitters with latent TrP.

Materials and methods

Trial design

This was a double-arm triple-blind (participants, the evaluator, and the data analyzer) and repeated-measures randomized pilot study in trained men. All outcome variables were assessed before and 48 hours after the DN intervention. This study is reported according to the Consolidated Standards of Reporting Trials (CONSORT) extension to pilot and feasibility trials (Eldridge et al., 2016).

Participants

Healthy Colombian male CrossFitters attending to the physical fitness center 'Soy Hakuna' (Envigado, Antioquia), with latent TrP in gluteal, quadriceps and gastrocnemius muscles (diagnosed by palpation) were potentially eligible to participate in this clinical trial. Participants were recruited on a voluntary basis, and all signed an informed consent form to be randomly assigned to either the experimental (EG: dry needling) or placebo (Sham) groups. In the consent, detailed information was given about the aim of the study, the measurements to be made, the conditions (comfortable clothing and features of the anthropometric assessment), and the approximate duration of the evaluation. All procedures were conducted in accordance with the ethical guidelines of the Declaration of Helsinki. Compliance with the stipulations of the Ministry of Social Protection in Resolution 8430 of 1993 was guaranteed and the study protocol was approved by the Institutional Review Board at Universidad de Antioquia (Act N°059, September 12th, 2019).

The inclusion criteria were as follows: a) to have at least ≥1 year experience in CrossTraining; b) to reside in Medellín or its metropolitan area (including Envigado); c) to have agreed to participate in the study by signing the informed consent form; d) to have a Colombian health system affiliation; e) to have latent TrP in quadriceps, gluteal and gastrocnemius muscles. Additionally, the following were considered as exclusion criteria: a) consumption of psychoactive substances; b) suffering from acute or chronic injuries; c) use of performance and image-enhancing drugs; d) consumption of drugs; e) diagnosed with chronic diseases (e.g., diabetes, hypertension); f) excessive alcohol consumption; g) surgery or operation during the same month of the interventions; h) non-attendance to the baseline assessment.

Dry Needling Intervention

A DN intervention was performed by a physiotherapist expert in this technique. After finding the latent TrP in each quadriceps, gluteus and gastrocnemius, the subjects in both groups underwent a DN or Sham session. Following previously published procedures (Tasoglu, Sahin Onat, Boluk, Tasoglu, & Ozgirgin, 2017), the patient's anatomical location was cleaned with alcohol for asepsis and with 0.40 x 0.25 mm needles a direct deep DN puncture was performed on the latent TrP (EG). This technique has been shown to be effective for the improvement in acute pain in myofascial pain syndrome patients (Yehoshua, Rimon, Mizrahi Reuveni, Peleg, & Adler, 2022), however, this is the case with placebo or sham, but the evidence is of low to moderate quality A similar procedure was performed on the Sham group subjects but without inserting the needle into the skin after the guide was placed. The intervention took 15 minutes with each athlete and was performed in May 2020.

Outcomes

Dependent variables were strength-related variables: i) lower-limb muscle power through countermovement and squat jump tests; and ii) maximal isometric hip abduction and quadriceps strength. All variables were measured after a 5-min warm up that consisted of four rounds of 30 seconds plank, 10 elbow flexion-extensions, prone cubitus, 10 deep squats with the hands behind the head.

Myofascial trigger points

The physiotherapist performed the evaluation of latent TrP in the quadriceps, gluteal and gastrocnemius muscles using flat palpation or pincer grip techniques according to the diagnostic criteria (the presence of a taut band, the presence of a tender spot during palpation, and the reproduction of referred pain during compression) previously published (Rozenfeld, Strinkovsky, Finestone, & Kalichman, 2021). As a clinical criterion, a participant's improvement was determined when at least three latent TrP decreased after the intervention. Rozenfeld et al. reported that the palpation of myofascial TrP is a moderately reliable diagnostic tool in the hip and thigh muscles and can be used

in clinical research (Rozenfeld, Finestone, Moran, Damri, & Kalichman, 2017).

Lower-limb muscle power

Squat jump (SJ) and countermovement jump (CMJ) tests were performed. The assessment protocol was carried out after the 3-min warm-up described previously. Participants performed two attempts for each jump test with a 1-min rest interval between attempts following laboratory procedures reported in previous articles published by our research group (Bonilla et al., 2021; Vargas-Molina et al., 2022). The tests were performed on a jump mat DIN-A2 Chronojump (Boscosystem®, Spain). This device has been previously reported to be reliable and valid for measuring vertical jump height (Pueo, Penichet-Tomas, & Jimenez-Olmedo, 2020). The highest jump of the two attempts (in centimeters) was used for statistical analysis using the manufacturer open-source software https://chronojump.org/es/programa/.

Maximal isometric muscle strength

A strain-gauge force sensor kit (Chronojump, Boscosystem®, Spain) was used to measure muscle strength. The characteristics of the force sensor include a maximal capacity of 500 kg, output impedance 350 ± 3 Ω, insulation resistance of >2000 MΩ and input impedance of 365 ± 5 Ω. Three minutes after the athlete performed the jump tests, the maximal isometric hip abduction strength was measured with the subject side lying (Figure 1). For the evaluation of maximal isometric quadriceps strength, the subject was seated in position for a 90° knee extension (Figure 2).

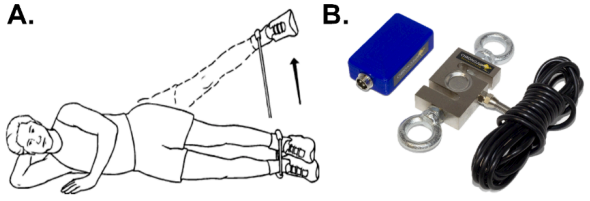

Fig. 1. Assessment of the maximal isometric hip abduction strength. A. Participants were instructed to raise top leg keeping knee straight while were side lying with a band around ankles. Source: Taken from Iris Hattiesburg Clinic at shorturl.at/aoPW8 (Accessed on 5 February 2023) under copyright and owned by VHI Healthcare. B. The band was attached to a force sensor able to record the maximal isometric strength in real time. Source: Taken from Chronojump Bosco System® at https://chronojump.org/product/force-sensor-kit-able-to-add-accessories/ (Accessed on 5 February 2023)

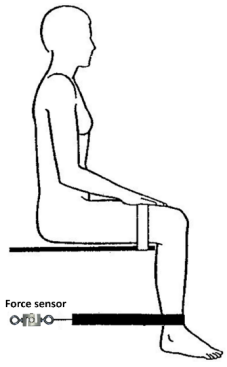

Fig. 2. Assessment of the maximal isometric quadriceps strength. Taken and modified from Stoll, Huber, Seifert, Michel, and Stucki (2000)

The following were taken into account to consider a valid measurement: a) the gauge straps had a standard distance, so that the length did not vary in either the pretest or posttest; b) in knee extension, the free leg did not touch the floor; c) in knee extension, the entire back was supported on the backrest; d) the test was performed with each limb; e) in both tests, dorsiflexion was allowed while performing the movement; and f) the participant started by applying a small force and then increased to the greatest amount of force possible. Data were collected in Newton using the free software provided by the manufacturer.

Sample size

Due to the lack of similar studies, a sample size of 10 patients in each group was considered suitable for this pilot study. Therefore, non-probability sampling (convenience sampling) was implemented. After the call to participate in this study, 20 subjects were suitable for eligibility from the available population (i.e., Cross-trained men attending the fitness and strength conditioning center 'Soy Hakuna' located in Envigado, Colombia).

Randomization

The subjects were randomly assigned to the EG and Sham groups using the permuted block technique within the Epidat statistical software (the evaluator did not have access to this information). This randomization was intended to ensure the balance of the groups from the beginning of the investigation. After group assignment, all participants were contacted and notified of the group to which each one had been assigned.

Blinding

This was a triple blind study. In the evaluation protocols, the examiners that performed pre- and post-test measurements did not know which group the participants belonged to while the researcher in charge of the interventions did not have access to the evaluations; therefore, the investigator in charge of analyzing the data was blinded The participants were also blinded, as none of them knew to which group they belonged (groups were named as A and B) so that all participants thought they were performing the same intervention. In the end, there were three blind processes: i) participants, ii) evaluators, iii) researcher who analyzed the data.

Bias

Valid and reliable instruments were used to control for reporting bias. Moreover, all participants were subjected to the same measurement protocol and the evaluators were trained for these measurements. To control confounding variables, such as diet, sleep and motivation, the following recommendations were made: a) subjects should follow their normal diet; b) subjects should sleep at least seven hours a day during the days of the study; c) they should not perform strength training.

Statistical Analysis

The descriptive statistics are expressed as mean and standard deviation (SD). A fourfold contingency table was used

to represent the set of improvement counts of the latent TrP in relation to DN versus Sham using the online free software OpenEpi (www.openepi.com). Based on current recommendations to improve data analysis practices (Martin & Teste, 2022), we implemented an estimation approach following analytical procedures reported in previous articles published by the DBSS Research Division (Bonilla, Kreider et al., 2021; Bonilla, Méndez et al., 2021). Thus, to determine statistical significance, we examined the 95% CIs for the difference between the mean change scores (Δ = post – pre). If the 95% CI excludes zero, the difference will attain significance at the $p<0.05$ level. Effect size was calculated as unbiased Cohen's d (dunb), considering a result of ≤0.2 as a small, 0.5 as a moderate, ≥0.8 as a large effect, and ≥1.30 as a very large effect (Rosenthal, 1996). Estimation plots were generated to display the repeated measures data across two time points (at baseline and after eight weeks). A difference-in-differences (Diff-in-Diff) analysis was performed to compare changes in the outcome variables between the groups (Cumming, 2013).

Results

A total of 20 participants were potentially eligible; however, one man of the Sham group did not show up for the baseline assessment session and was, therefore, excluded from the study. The rest of the participants attended and complied with the intervention without attrition (Figure 3).

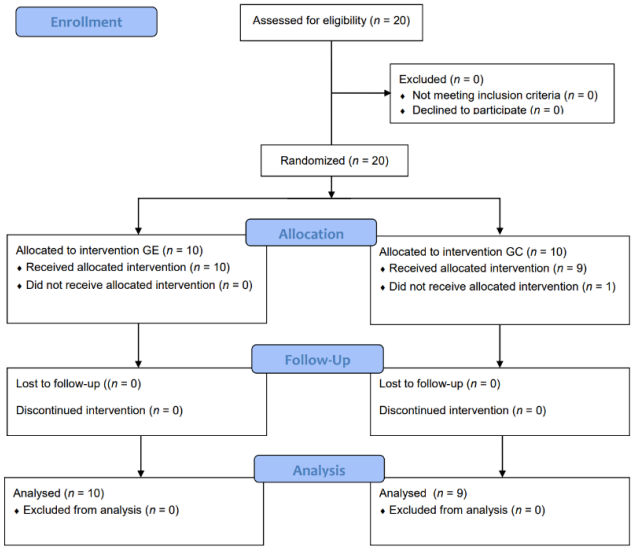

Fig. 3. CONSORT flow diagram

Table 1. Descriptive information of participants at baseline

	EG (n = 10)	Sham (n = 9)	p
BM, kg	78.4 (6.54) [70, 92]	81.2 (6.74) [69, 91]	0.420
Stature, cm	176 (7.06) [165, 190]	177 (5.78) [165, 186]	0.647
BMI, kg/m^2	25.4 (1.35) [23.3, 28.4]	25.9 (1.17) [24.1, 28.1]	0.421
SJ, cm	37.3 (4.41) [31.9, 44.4]	36.1 (4.81) [28.1,44.4]	0.606
CMJ, cm	41.1 (3.91) [33.9, 47.2]	41.4 (4.92) [36.5, 51.1]	0.864
MVC Hip-L, N	148 (31) [102, 196]	135 (24.7) [98, 171]	0.318
MVC Hip-R, N	154 (26.1) [120, 192]	139 (24.9) [101, 174]	0.235
MVC Knee-L, N	406 (83.6) [312, 539]	412 (83) [279, 579]	0.892
MVC Knee-R, N	387 (90.3) [253, 520]	435 (77.5) [309, 560]	0.234

Data is presented as mean (standard deviation) [95% confidence interval]. BM: body mass in kg; BMI: body mass index; CMJ: countermovement jump; LL: lower limit; MVC Hip-L: maximum voluntary contract in left hip abduction; MVC Hip-R: maximum voluntary contract in right hip abduction; MVC Knee-L: maximum voluntary contract in left knee extension; MVC Knee-R: maximum voluntary contract in right knee extension; N: newtons; SJ: Squat jump. A two-tailed p value for testing the null hypothesis of no difference between the two group means is reported

Table 1 presents a descriptive analysis of the sample of participants at baseline without significant differences between EG and Sham groups while Table 2 shows the reliability of the tests that were performed.

The results of all variables are expressed as Δ (SD) [95% CI]; dunb [95% CI] and presented in Table 3. After post-test assessments, there were no significant differences in SJ, CMJ and the maximal isometric quadriceps (right and left) strength compared to baseline measures in any group. The maximal isometric hip abduction strength had a moderate-to-high significant increase in the EG (left: 21.5 (16.88) [9.42, 33.57]; 0.55 [0.19, 0.99], right: 20.3 (16.2) [8.70, 31.89]; 0.74 [0.25, 1.35]); however, the Sham group only showed statistically significant improvement in the left hip abductor muscles (15.77 (15.37) [3.96, 27.59]; 0.57 [0.11, 1.12]) with no changes on the right side (5.45 (14.51) [-5.70, 16.61]; 0.18 [-0.17, 0.57]).

Table 2. Test-retest reliability

	ICC	LL	UL	Mean	CV (%)	SWC	SWC (%)
CMJ	0.99	0.97	0.99	41.10	2.61	2.97	7.22
SJ	0.95	0.89	0.98	37.20	1.03	1.06	2.85
MVC Hip-L	0.87	0.76	0.94	140.30	0.15	0.59	0.42
MVC Hip-R	0.88	0.96	0.99	145.20	0.89	3.59	2.47
MVC Knee-L	0.94	0.87	0.97	407.30	0.06	0.64	0.16
MVC Knee-R	0.98	0.79	0.95	401.40	0.05	0.56	0.14

CMJ: countermovement jump; ICC: intraclass correlation coefficient; LL: lower limit; MVC Hip-L: maximum voluntary contract in left hip abduction; MVC Hip-R: maximum voluntary contract in right hip abduction; MVC Knee-L: maximum voluntary contract in left knee extension; MVC Knee-R: maximum voluntary contract in right knee extension; SJ: Squat jump; SWE: smallest worthwhile change; UL: upper limit

Table 3. Pre- and post-intervention data on the study variables

Variable	Group	Pretest	Postest	Δ	d_{unb}
		Mean (SD)	Mean (SD)	Mean(SD) [95% CI]	δ [95% CI]
SJ (cm)	EG	37.25 (4.40)	37.48 (3.12)	0.23 (3.27) [-2.10, 2.57]	0.05 [-0.47, 0.59]
	Sham	36.13 (4.81)	36.48 (4.32)	0.35 (5.40) [-3.80, 4.50]	0.06 [-0.69, 0.84]
CMJ (cm)	EG	41.08 (3.90)	41.20 (4.17)	0.12 (2.13) [-1.39, 1.64]	0.02 [-0.29, 0.35]
	Sham	41.43 (4.91)	39.60 (4.85)	-1.82(4.67) [-5.42,1.76]	-0.33 [-1.01, 0.28]
MVC Hip-L	EG	148.2 (30.965)	169.7 (39.79)	21.5 (16.88) [9.42, 33.57] *	0.55 [0.19, 0.99]
	Sham	134.89 (24.68)	150.67 (25.30)	15.77 (15.37) [3.96, 27.59] *	0.57 [0.11, 1.12]
MVC Hip-R	EG	153.8 (26.12)	174.1 (23.58)	20.3 (16.20) [8.70, 31.89] *	0.74 [0.25, 1.35]
	Sham	139.33 (24.89)	144.79 (27.58)	5.45 (14.51) [-5.70, 16.61]	0.18 [-0.17, 0.57]
MVC Knee-L	EG	406.3 (83.58)	454.7 (116.39)	48.4 (85.80) [-12.98, 109.78]	0.43 [-0.10, 1.03]
	Sham	411.56 (83.03)	462.89 (101.6)	51.33 (91.89) [-19.30, 121.97]	0.49 [-0.16, 1.23]
MVC Knee-R	EG	386.7 (90.25)	398.4 (110.2)	11.7 (84.02) [-48.40, 71.70]	0.10 [-0.40, 0.63]
	Sham	434.67 (77.54)	443.33 (69.03)	8.66 (73.19) [-47.59, 64.92]	0.10 [-0.53, 0.76]

Data is presented as mean and standard deviation (SD). Δ: post-test – pre-test; d_{unb}, unbiased Cohen's d; CI, confidence interval; CMJ: countermovement jump; EG: experimental group; MVC Hip-L: maximum voluntary contract in left hip abduction; MVC Hip-R: maximum voluntary contract in right hip abduction; MVC Knee-L: maximum voluntary contract in left knee extension; MVC Knee-R: maximum voluntary contract in right knee extension; SJ: Squat jump. * Statistically significant change ($p<0.05$)

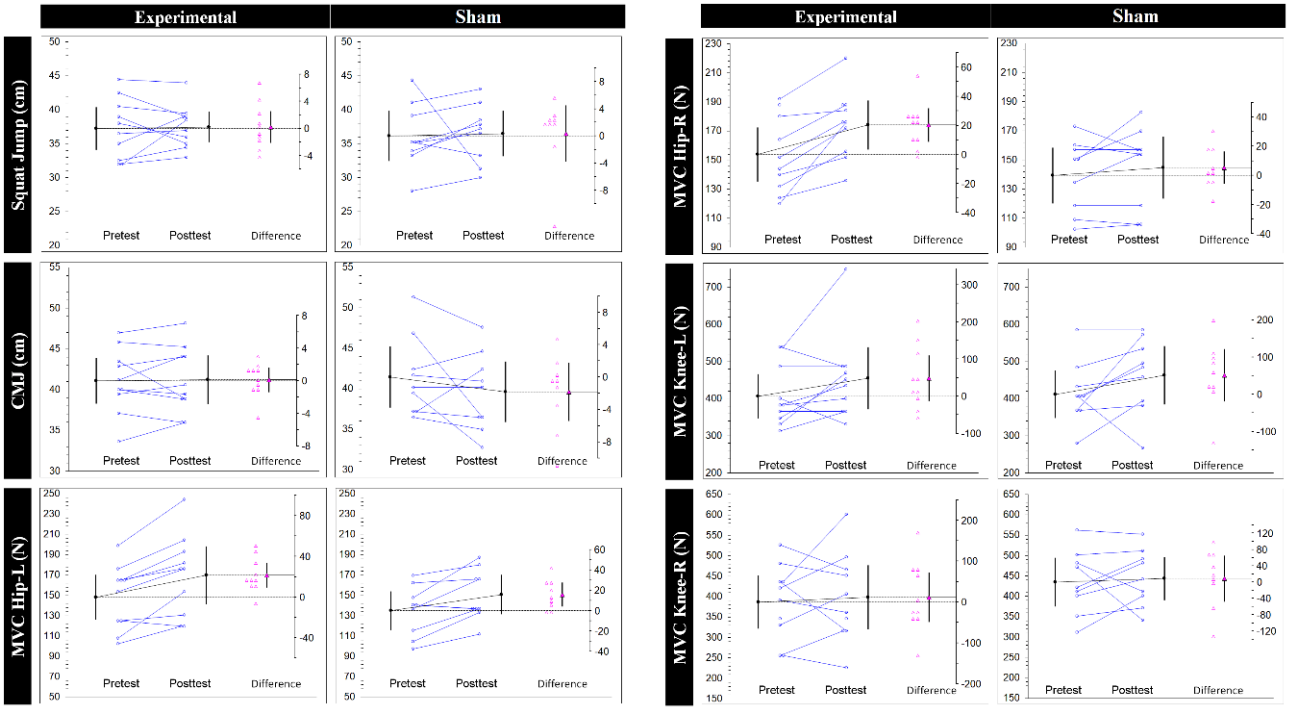

Fig. 4. Estimation plots showing pre- and post-intervention values on analyzed variables. Paired data from Experimental (left) and Sham (right) groups are shown as small circles joined by blue lines. The differences between the initial (pre) and final (post) means are plotted on a floating difference axis whose zero is aligned with the pre-test mean. The filled pink triangle marks the difference on that axis and the 95% CI on that difference is displayed. The differences are shown as open triangles on the difference axis. CMJ: countermovement jump; MVC Hip-L: maximum voluntary contract in left hip abduction; MVC Hip-R: maximum voluntary contract in right hip abduction; MVC Knee-L: maximum voluntary contract in left knee extension; MVC Knee-R: maximum voluntary contract in right knee extension; SJ: Squat jump

Figure 4 shows the Gardner Altman estimation plots of the variables that showed a significant pre-post difference in each group.

Although the analysis of the fourfold (2×2) contingency table with cases of success (pain improvement counts) showed a statistically significant association ($p<0.05$)

Table 4. Statistical results of the fourfold (2×2) contingency table

	Dry needling	Sham	Total
Success	9	1	10
No success	1	8	9
Total	10	9	19

Risk-based* Estimates with confidence intervals at 95%				
Point Estimates		**Confidence Intervals**		
Type	**Result**	**Lower**	**Upper**	**Type**
Estimated risk in the exposed	90.0 %	57.41	100.0	Taylor series
Estimated risk in the nonexposed	11.11 %	0.0	45.67	Taylor series
Overal risk	52.63 %	31.7	72.67	Taylor series
Risk ratio	8.1	1.262	51.99	Taylor series
Risk difference	78.89 %	51.19	106.6	Taylor series
Etiologic Fraction in the Population	78.89 %	42.86	100	
Etiologic Fraction in the Exposed	87.65 %	20.75	98.08	

Odds-Based Estimates and Confidence Limits			
Point Estimates		**Confidence Limits**	
Type	**Value**	**Lower, Upper**	**Type**
CMLE Odds Ratio*	45.82	3.733, 1746[1]	Mid-P Exact
		2.824, 3528[1]	Fisher Exact
Odds Ratio	72	3.842, 1349[1]	Taylor series
Etiologic fraction in pop.(EFp|OR)	88.75%	67.67, 100	
Etiologic fraction in exposed(EFe|OR)	98.61%	73.97, 99.93	

*Conditional maximum likelihood estimate of Odds Ratio. (P)indicates a one-tail P-value for Protective or negative association; otherwise, one-tailed exact P-values are for a positive association. ° [1] 95% confidence limits testing exclusion of 0 or 1, as indicated

between DR and the elimination of TrP (Table 4), there were no significant differences between the EG and Sham groups with regards to the change in selected strength variables. The results of this Diff-in-Diff analysis (DID [95% CI], p value) is reported in Table 5, Figure 5.

Table 5. Difference-in-differences analysis

Variable	Mean (Δ_2–Δ_1)	DID	95% CI	p
SJ	0.35-0.23	0.11	-5.42, 5.65	0.96
CMJ	-1.82-0.12	-1.95	-7.84, 3.93	0.50
MVC Hip-L	15.77-21.5	-5.72	-46.79, 35.34	0.77
MVC Hip-R	5.45-20.3	14.84	-48.58, 18.89	0.37
MVC Knee-L	51.33-48.4	2.93	-125.7, 131.55	0.96
MVC Knee-R	8.66-11.7	-3.03	-120.5, 114.39	0.96

Difference of differences (DID) for EG (Δ_1) and Sham (Δ_2) groups. The p value is two-tailed for testing the null hypothesis of no difference between the two group means with statistical significance when $p<0.05$.

Discussion

Considering that strength is a determining capacity for different sports modalities, including CrossTraining® (Dexheimer et al., 2019), this study aimed to evaluate for the first time the acute effects of a DN intervention on lower-limb muscle power and maximal isometric hip abduction and quadriceps strength in trained CrossFitters with Latent TrP. Our main findings showed reduction of latent TrP in the quadriceps, gluteus, and gastrocnemius muscles when DN was performed, and DN was not observed to have any effect on lower-limb muscle power or maximal isometric quadriceps strength.

Similar to previous reports (Gattie et al., 2017), the DN intervention was able to clinically reduce the number of TrP; in fact, our results showed that a participant was 8.1 times more likely to decrease latent TrP when DN was performed than when it was not (table 4). These findings are in agreement with literature since DN has shown to be effective to reduce pain (Kamali, Sinaei, & Morovati, 2019; Khan, Ahmad, Ahmed, Sadiq, & Asim, 2021) and to possibly generate positive changes at the neuromuscular level (Ceballos-Laita et al., 2021; Perez-Bellmunt et al., 2021). It should be noted that potential improvements have also been described in hip or knee osteoarthritis (Jimenez-Del-Barrio et al., 2022), plantar heel pain or plantar fasciitis (Llurda-Almuzara et al., 2021) and post-stroke patients (Fernandez-de-Las-Penas et al., 2021).

The precise mechanisms that cause TrP in skeletal muscle, as well as the effects that NP has on them, are not fully understood. However, it is suggested that that TrP may arise due to a combination of several factors, including alterations in the excitation-contraction coupling mechanism of

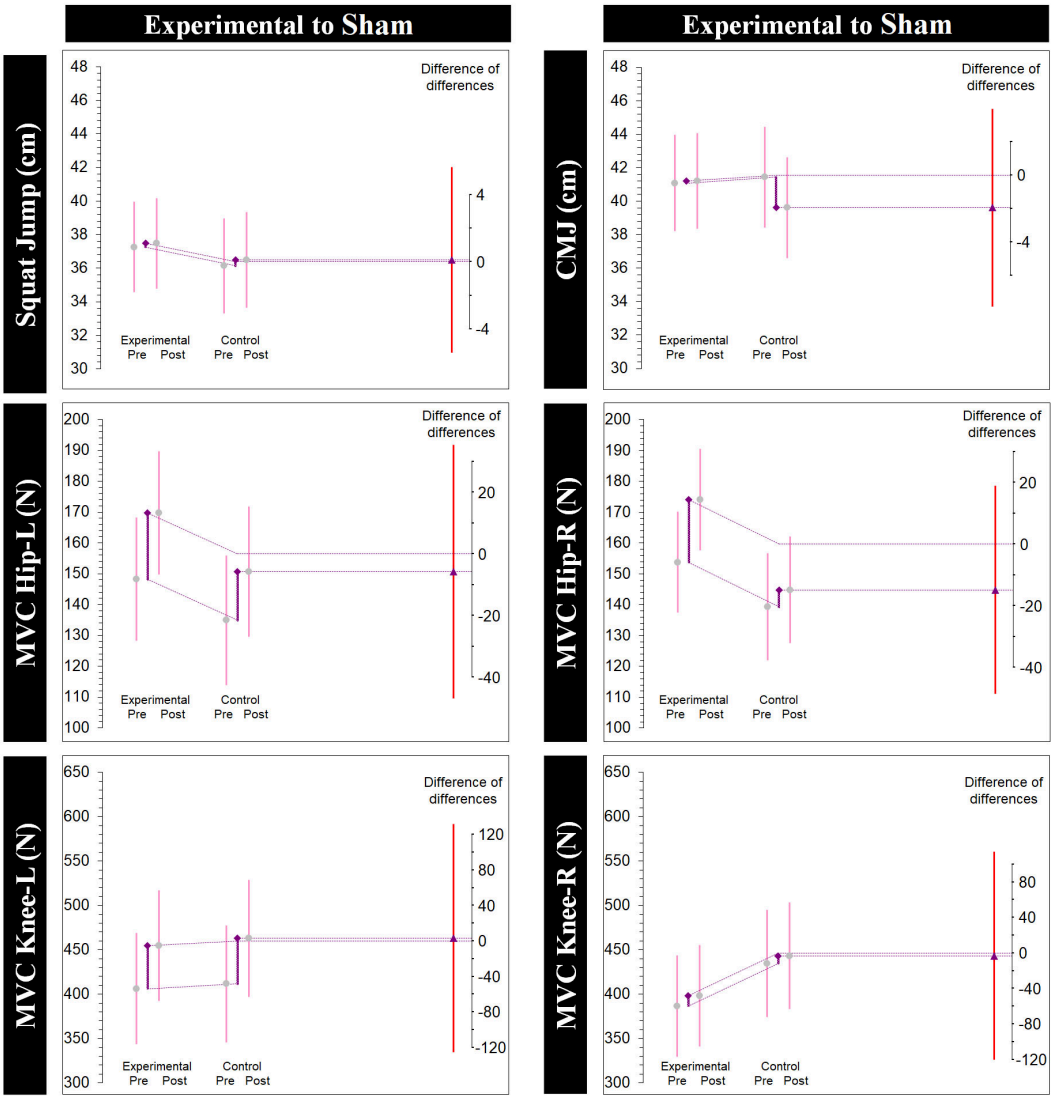

Fig. 5. Difference-in-difference estimation plots for all variables. This graphic shows the difference (Δ = post-test – pre-test) of the differences, which is the calculation of the group means: Experimental (Δ1) and Sham (Δ2) groups on selected variables. The effect chosen for examination is displayed as the triangle, with its 95% CI, against a floating different axis. CMJ: countermovement jump; MVC Hip-L: maximum voluntary contract in left hip abduction; MVC Hip-R: maximum voluntary contract in right hip abduction; MVC Knee-L: maximum voluntary contract in left knee extension; MVC Knee-R: maximum voluntary contract in right knee extension; SJ: Squat jump

muscle fibers, elevated intracellular calcium concentrations, changes in intramyocellular pH, and inflammation (Perreault et al., 2022; Zhang et al., 2020). In this regard, Shah et al. (Shah, Phillips, Danoff, & Gerber, 2005) found through an in vivo microanalytical technique that levels of inflammatory mediators, such as tumor necrosis factor, bradykinin, substance P, interleukin-1, and norepinephrine, were significantly higher in active myofascial TrP compared with latent or absent myofascial TrP. In this context, DN may decrease the levels of some of these inflammatory molecules. For instance, Hsieh et al. (Hsieh, Yang, Liu, Chou, & Hong, 2014) showed that DN induced a reduction in substance P levels in rabbit muscles. These present results unveil plausible mechanisms of action of DN on TrP yet warrant further investigation in human trials. CrossTrainer-type HIT can potentially serve as a suitable study model, given its considerable levels of workload demand.

On the other hand, our results showed that the elimination of TrP through a single session of DN did not significantly affect lower-limb muscle power (i.e., SJ or CMJ) or the maximal isometric quadriceps strength in CrossFitters. Interestingly, significant increases on maximal isometric hip strength for each limb (+13.1% right; +14.5% left) were only found in the EG with no differences when compared to the Sham group which improved solely the left-limb hip strength. Of note, Haser et al. (Haser et al., 2017) showed that elite soccer players who received a DN and water pressure massage intervention for 4 weeks had a significant effect on knee muscle strength (flexion and extension) and hip flexion range of motion compared to placebo (an

inactive laser device with water pressure massage) and the control group (no intervention).

Consistent with our results, Prado et al. (Prado, 2017) reported no benefits and even found a reduction in jump height after acute DN in apparently healthy men, likely due to changes in electromyographic activity that resulted in a negative impact on muscle strength. Likewise, a recent systematic review and meta-analysis (Mansfield et al., 2019), which included studies involving a diverse range of populations (e.g., different age ranges, healthy, injured, with and without surgery), who manifested TrP and received some form of dry-needling therapy, based on evidence of moderate to very low quality, that there is no discernible effect of DN on force production. However, since there have been few studies evaluating the effects of DN in athletic populations, more controlled clinical trials in this population are needed to establish the effects of DN on muscle strength and its possible mediating mechanisms.

It is important to note that although the results did not show a significant increase in muscle strength after DN, latent myofascial TrP were eliminated. This is relevant because several studies have shown that the presence of myofascial TrP may be related to a decrease in muscle strength. For example, Cubukcu et al. (Cubukcu et al., 2007) reported that the isokinetic and isometric strength levels of the knee flexors and extensors were lower in groups of women with fibromyalgia syndrome and chronic myofascial pain syndrome (who had the presence of TrP), compared to the control group. Similarly, it has been evidenced that older adults with myofascial TrP in the shoulder had lower levels of grip strength (Calvo-Lobo et al., 2017). In studies of patients with different cervical conditions, it was observed that the presence of myofascial pain decreased trapezius strength (Lisinski & Huber, 2017). Moreover, in healthy adults of both sexes, muscle strength for flexion and scaption was lower in subjects with TrP compared to healthy subjects (Celik & Yeldan, 2011). Nevertheless, other authors have concluded that the presence of latent myofascial TrP may not affect the upper-limb strength, at least in apparently healthy non-athletic women (Doraisamy & Anshul, 2011). Although these studies have a different focus than ours, such as the type of population, co-morbidities, and musculoskeletal disorders, they emphasize the negative relationship between myofascial TrP and decreased strength. However, the causal relationship between TrP and loss of strength, or whether strength is immediately restored by the reduction of TrP, is still unclear. In this sense, based on the mechanisms of TrP, it can be hypothesized that the elimination of TrP should increase force production because the muscle would be in a better physiological state for force generation (e.g., for excitation-contraction response, intracellular calcium management, and reduced inflammation).

Limitations

The limitations of this study were: a) the small sample size as a pilot clinical trial; b) the non-measurement of strength before having TrP; c) the diagnosis was performed by palpation and not a more objective one such as electromyography; d) only one DN intervention session was performed; and e) the study was conducted with a single post-test measurement.

Future directions

Considering the need to obtain a higher level of quality of evidence for the effects of DN on TrP and force production-related outcomes, more randomized clinical trials in athletic populations are required, incorporating a more robust assessment of TrP and muscle strength over the medium to long term. To achieve this, we propose a more sensitive assessment of myofascial TrP, using techniques such as electromyography, histochemical analysis, and/or micro-analytical methods. Additionally, since muscle strength is influenced by various variables, it should be evaluated considering aspects such as interaction with other factors (e.g., type of training, fatigue, fitness level), changes over time, and their impact on performance and health. This would not only enable us to analyze the efficacy of DN on TrP, but also determine whether these changes are directly or indirectly associated with force production.

Conclusions

Our results show that the application of DN has acute effects on the reduction of myofascial TrP in the quadriceps, gluteus, or gastrocnemius of recreational CrossFit athletes. However, we did not find any significant effects on maximal isometric strength during knee extension and hip abduction, nor on strength during CMJ and SJ jumps compared to the Sham group. Further controlled clinical trials are needed to evaluate the efficacy of DN on TrP and its relationship with muscle strength outcomes.

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Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the University of Antioquia on 12 September 2019, act number 059.

Data Availability Statement

All data is available upon request.

Conflicts of Interest

The authors declare no conflicts of interest. All authors are responsible for the content of this article.

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НЕГАЙНИЙ ВПЛИВ СУХОГО ГОЛКОВКОЛЮВАННЯ НА М'ЯЗОВУ СИЛУ НИЖНІХ КІНЦІВОК У СПОРТСМЕНІВ, ЯКІ ЗАЙМАЮТЬСЯ КРОСФІТОМ, ІЗ ЛАТЕНТНИМИ ТРИГЕРНИМИ ТОЧКАМИ: РАНДОМІЗОВАНЕ ПОТРІЙНО СЛІПЕ ПІЛОТНЕ КЛІНІЧНЕ ДОСЛІДЖЕННЯ

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Реферат. Стаття: 11 с., 5 табл., 5 рис., 48 джерел.

Мета дослідження. Мета цього дослідження полягала в оцінці негайного впливу глибокого сухого голковколювання на змінні, пов'язані із силою м'язів нижніх кінцівок, у спортсменів-любителів, які займаються крос-тренінгом, із латентною тригерною точкою.

Матеріали та методи. Це потрійно сліпе пілотне клінічне дослідження з повторними вимірюваннями пройшли загалом 19 здорових чоловіків, які займалися кросфітом (27,8 [4,7] року; 79,8 [10,4] кг; 1,76 [0,07] см), з міофасціальною тригерною точкою в чотириголовому, сідничному або литковому м'язах. Учасники були випадково розподілені в експериментальну групу (ЕГ, n = 10) або в контрольну групу (КП, n = 9). Після розподілу на вихідному рівні та через 48 годин після втручання оцінювали силу м'язів нижніх кінцівок (вертикальний стрибок із присіду зігнувши ноги та вертикальний стрибок із зустрічним рухом) і вимірювали силу максимального ізометричного відведення стегна та чотириголового м'яза.

Результати. Результати виражені як Δ (СВ) [95% ДІ]; незміщена оцінка d Коена [dunb, 95% ДІ]). Було показано, що глибоке сухе голковколювання зменшує присутність м'язової тригерної точки. Максимальна ізометрична сила відведення стегна мала помірне або високе статистично значуще збільшення в ЕГ (лівий бік: 21,5 (16,9) [9,42, 33,57]; 0,55 [0,19, 0,99], правий бік: 20,3 (16,2) [8,70, 31,89]; 0,74 [0,25, 1,35]); однак контрольна група продемонструвала статистично значуще збільшення сили лише тих м'язів, що відводять ліве стегно (15,77 (15,37) [3,96, 27,59]; 0,57 [0,11, 1,12]), без статистично значущих змін у правому боці.

Висновки. Негайне скорочення міофасціальної тригерної точки спостерігалося при застосуванні глибокого сухого голковколювання, але не мало статистично значущого впливу на максимальну ізометричну силу або висоту стрибка порівняно з контрольною групою. Результати цього пілотного клінічного дослідження можуть бути використані для підготування майбутніх досліджень.

Ключові слова: сухе голковколювання, м'язова сила, тригерна точка, тригерна зона.

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ORIGINAL SCIENTIFIC ARTICLE

DYNAMICS OF INITIAL SWIMMING READINESS OF JUNIOR SCHOOL CHILDREN IN THE SCHOOL SPORTS CLUB

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Abstract

The purpose of the study was to estimate the effect of swimming lessons in a school sports club on the initial swimming fitness of primary school-aged children.

Materials and methods. The study participants were 73 primary school-aged children ('Sportrend' school sports swimming club). The study used theoretical analysis of scientific and methodological literature, the system of control exercises by O. Obrazhei revised taking into account the contingent of the research to assess the swimming fitness of primary school students under the conditions of a school sports club, and methods of mathematical statistics.

Results. We propose a methodology for assessing the swimming readiness of younger schoolchildren under the conditions of a school sports club. The growth rate of such indicators as reaction to the unsupported position in the water and underwater breath-holding turned out to be lower compared to other indicators. At the same time, the rates of face submersion in the water and squatting in the water increased. The increase in initial swimming skills in children was 49.3% at the control stage compared to the baseline, and the average growth rate was 22.2%. In the assessment of children's initial skills at the end of the training compared to the beginning, the maximum average rate of increase was recorded for the ability to push off and slide (30.1%), the ability to perform a star float (27.4%), and squatting in the water (26.4%), thus swimming lessons have a positive effect on the initial swimming readiness of junior school students.

Conclusions. Statistically significant ($p<0.05$) improvement of primary school students' results on control exercises at all stages of diagnostics of their initial swimming skills formation confirms the positive effect of swimming lessons in a school sports club.

Keywords: swimming, primary school-aged children, sports club, assessment, swimming readiness.

Introduction

Research on physical education and sports raises concerns about the health of school children (Andrieieva et al., 2020; Korolchuk, 2019; Savliuk et al., 2020), even at the initial stages of studying (Limarenko et al., 2014). After all, the foundations of health formation during the period of primary school age are the basis of the health of a working person (Hrytsiv, 2015; Kashuba et al., 2018; Lazko et al., 2021). In connection with the mentioned unfavorable trend, scientists became more active in the search for the most effective means of overcoming it. Thus, the effectiveness of fitness programs in the system of improving the health of schoolchildren is investigated (Andrieieva et al., 2021; Ivanyshyn et al., 2021; Savliuk et al., 2020), gender differences that must be taken into account in the process of their physical education are studied (Berezhna, 2013; Dudko et al., 2017; Futorny et al., 2016), the health-improving effect of various kinds of sports on their morphofunctional state is evaluated (Barbry et al., 2022; Goncharova et al., 2022; Madsen et al., 2022), etc.

Swimming takes one of the leading places among the leaders of the favorable influence on a child's body during

sports training (Sakhnovsky, 1995; Lyashenko et al., 2012). It is concerned as an effective means of developing water skills, overcoming fear of water, strengthening health, and increasing the adaptation capabilities of their body (Button, 2016; Peden et al., 2020; Tian, 2023). In addition, the positive motivation of junior pupils to health-improving swimming classes has been proven (Grashchenkova, 2015; Madsen et al., 2022). Therefore, there is a constant search for reserves to optimize educational and training processes when organizing swimming classes with children of primary school age (Obrazhei, 2021, 2023).

Nowadays, club forms of organizing classes in the studying process of the educational environment of the school are gaining more and more popularity. It has been proven that the effectiveness of a sports club in a secondary education institution depends on the purposefulness of its activity, and its functioning is based on the interaction of the teachers-coaches who ensure its activity, and the parents of the club's students, systematic medical control, which is carried out by the head coach in cooperation with the medical staff of the institution (Lyashenko et al., 2012; Tkachova et al., 2020). The fundamental difference of the school sports club is the possibility of differentiating the content of the educational and training process of junior schoolchildren in the context of the formation of different age groups (Bondar, 2009; Limarenko, 2014; Goncharova, 2020). The same applies to a swimming club. Instead, the issue of determining children's swimming fitness arises when forming groups. The systems of swimming fitness assessment that are widely used in practice today are focused mainly on the use in sports activities (Vogt, 2020; Moreno-Murcia, 2008, 2020; Mouro, 2021) under specific conditions of the organization of the educational and training process (Obrazhei, 2023).

However, despite the growing interest of scientists in the development of sports clubs' activity in swimming in the school educational environment (Bondar et al., 2009; Korolchuk, 2022), a number of questions remain not fully solved, including determination of influence of swimming in a school sports club on the initial swimming fitness of children of primary school age, which determined the subject of the conducted research.

Material and methods

Participants

73 Primary school age children took part in the study, which was carried out based on the "Sportrend" school sports swimming club of Gymnasium No. 315 in Kyiv.

Procedure / Test protocol / Skill test trial / Measure / Instruments

In the research process, we used theoretical analysis of scientific and methodological literature, study, analysis, systematization, and generalization of data from literary sources, the revised system of control exercises by O. Obrazhey was used to assess the swimming fitness of junior pupils in the conditions of a school sports club, and methods of mathematical statistics.

To diagnose the formation of primary schoolchildren's swimming fitness in the conditions of a school sports club we took as a basis an innovative methodology proposed by Obrazhei (2023) aimed at the assessment of swimming skills of primary schoolchildren in the conditions of summer health camps. Along with the use of the recommendations offered by the author concerning the 5-point assessment of results of performance of control exercises (Obrazhei, 2023), we revised the system of the specified exercises according to the contingent of participants and conditions of realization of the educational and training process. We have simplified separate test exercises taking into account the reduced level of swimming fitness of a contingent of junior pupils. In particular, the following exercises were removed from the control exercises: "Jumping into the water", "Sliding and footwork" and "Sliding and handwork". Instead, the following exercises have been added: "Skill of entering water", "Reaction to unsupported position in water" and "Reaction to water getting into eyes or nose". In addition, we have added the "Ability to perform a float" as a basic exercise for teaching swimming to the control exercises.

A total of 10 indicators were evaluated using a 5-point system, namely:

- signs of hydrophobia: 1 – the child refuses to enter the water; 2 – enters the water after long persuasions; 3 – enters the water with the coach; 4 – enters independently, but keeps near the side; 5 – absent;
- face submersion in water: 1 – the child is afraid; 2 – partially submerges after the persuasion of the coach; 3 – dips the face (eyes closed); 4 – dips the head (eyes closed); 5 – dips the head, eyes open;
- squatting in water: 1 – refuses; 2 – squats together with the coach (water level up to the chest); 3 – squats independently, the water level is up to the neck; 4 – squats with the head fully immersed, eyes closed; 5 – independently squats, dives;
- the skill of entering the water: 1 - refuses to jump from the side; 2 – jumps, holding the side with his hands; 3 – jumps with the coach; 4 – independently jumps from the side; 5 – jumps independently with repulsion from the side;
- a reaction to the condition of an unsupported position in the water (or a reaction to the loss of balance, falling, or lack of support): 1 – the child panics, and refuses to continue the exercise; 2 – the child is nervous, needs the coach's support; 3 – the child is alert, restrained or irritated; 4 – the child is calm, relaxed; 5 – the child is self-confident;
- reaction to water getting into the eyes or nose: 1 – the child panics, and refuses to continue the exercise; 2 – the child is nervous and continues the exercise after the help or persuasion of the coach; 3 – the child is alert, restrained or irritated; 4 – the child reacts calmly; 5 – the child is self-confident, plays;
- underwater breath holding: 1 – breath hold only on land (up to 10 s); 2 – breath hold only on land (up to 15-20 s); 3 – holding breath in water (up to 5 s); 4 – breathing delay up to – 10 s; 5 – breath hold for more than 15 seconds;
- the ability to perform a floater: 1 – refusal to perform; 2 – execution of the float is "uncoordinated"; 3 – a floater without gripping the legs for up to 5 seconds; 4 – the floater is performed correctly – up to 10 s; 5 – the floater was performed correctly for more than 15 seconds;

- the ability to perform an asterisk: 1 – refusal to perform; 2 – execution of the asterisk "uncoordinated"; 3 – an asterisk with lowered legs for up to 5 seconds; 4 – the asterisk is executed correctly – up to 10 s; 5-star made correctly for more than 15 seconds;
- the ability to push off and slide: 1 – inability to group near the turning wall, no sliding; 2 – poor grouping, there is a weak undirected repulsion; 3 – sliding after repulsion up to 2 m; 4 – sliding with the correct position of the body after the correct push-off, push-off up to 4 m; 5 – sliding with the correct body position after a correct push-off of more than 5 m.

Individual assessments of the initial swimming readiness of junior school children in the conditions of a school sports club were calculated as the sum of points for all indicators, and group assessments were calculated as the sum of points for each of the indicators (Obrazhei, 2023).

Reliability of the system of evaluation of primary school pupils' swimming fitness in conditions of school sports club was confirmed by means of Cronbach's Alpha coefficient, which was 0.879 and Split-half reliability, which was 0.911.

Data collection and analysis / Statistical analysis

The following methods of statistical analysis were used: descriptive statistics, rank variance analysis for repeated measurements, and dynamic series analysis (Byshevets, 2019, 2021).

Descriptive statistics. Since the experimental data were obtained in an ordinal scale, the average values are presented using the median (Me) and 25 and 75 percentiles.

Rank variance analysis. To compare indicators and general evaluations of initial swimming skills in junior school children, depending on the stage of the training, the χ^2-Friedman multiple rank test was used. At the same time, the Wilcoxon T-test was used to compare the initial swimming skills between the test periods - a non-parametric test for comparing dependent samples with the calculation of the z-statistic.

Analysis of dynamic series. In the assessment process the dynamics of initial swimming skills of junior school children in the conditions of a sports club in an educational environment, traditional methods analysis of time series with the calculation of indicators of a dynamic series were used.

The reliability analysis of the test was aimed at assessing the reliability of testing the initial swimming readiness of junior school children in the conditions of a school sports club. The internal consistency of the test elements was determined according to the criteria of Cronbach's alpha and Gutman's plan reliability. Using the obtained data we proved that testing each of the indicators provides an assessment of the initial swimming skills of children of primary school age.

Differences between indicators were considered statistically significant at the level of significance α=0.05 ($p < 0.05$). If the calculated p-value was less than 0.0001, it was presented as $p<0.05$. In other cases, its value is given, rounded to the nearest thousandth.

The research material was processed using a package of special computer programs MS Excel and STATISTICA 10.0 (StatSoft, USA).

Results

For timely correction of pedagogical influence, In the process of design of training classes for children of primary school age in a swimming sports club, the phase of initial swimming training and determining the effectiveness of the phased formation of new motor skills and abilities in an aquatic environment requires special attention. The estimation of primary schoolchildren's swimming fitness in the conditions of school sports club was carried out by means of the revised methodology of Obrazhei (2023) taking into account the reduced swimming skills of participants of the research during the entrance, operational and stage control.

We turned out that certain indicators for assessing the initial swimming skills of junior schoolchildren, such as squats in the water, the ability to perform a float and an asterisk, and especially holding the breath in the water and the ability to push off and slide, were low. On the other hand, the rate of growth dynamics of such indicators as the reaction to the unsupported position in the water and holding the breath in the water turned out to be lower compared to other indicators. At the same time, face diving and water squatting increased at an accelerated rate. However it should be stressed, that all the remaining indications were statistically significant ($76.6 < \chi^2$-Fridman < 122.94, de ; $p<0.05$) grew (Fig. 1).

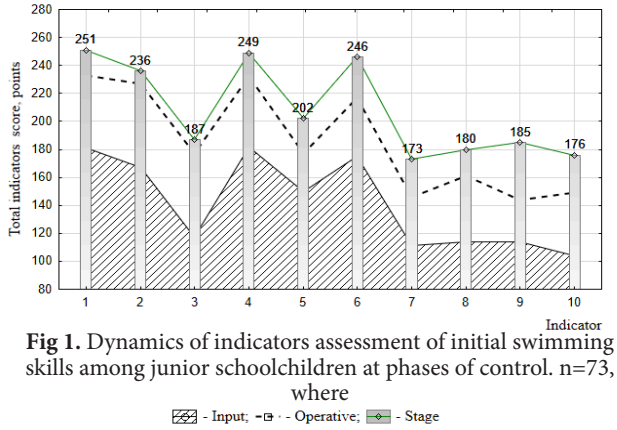

Fig 1. Dynamics of indicators assessment of initial swimming skills among junior schoolchildren at phases of control. n=73, where

1 – signs of hydrophobia; 2 – immersion of the face in the water; 3 – squats in the water; 4 – water entry skill; 5 - reaction to unsupported position in the water; 6 – reaction to water entering the eyes / nose; 7 – breath holding in water; 8 – the ability to perform a float; 9 – the ability to perform an asterisk; 10 – the ability to push off and slide; the meaning of the lines

It was established that, for example, reaching the maximum group scores were taken by junior schoolchildren for the following indicators: "Signs of hydrophobia" (251 points), "The skill of the entry into the water" (249 points) and "Reaction to water Getting in the eyes / nose" (246 points), and minimum – for the indicators "Breath holding under the water" (173 points) and "Ability to push off and slide" (176 points) (Fig. 1).

Individual initial swimming skills of junior pupils at the input stage were estimated from 10 to 36 and the average formation of initial swimming skills was 18.63 ± 5.10 points, during the operational control – from 13 to 40 – 24.75 ± 5.47 points, and at the end of the research – from 20 to

Table 1. Analysis of growth of group indicators of assessment initial swimming skills in schoolchildren (n=73)

Indicator / Control phase	The control stage			The value of the Friedman criterion	Average level of the dynamics series, points	Growth Δ, % / absolute growth, point			Average growth rate, %	Average absolute increase, points
	I	O	S			I/O	O/S	I/S		
Signs of hydrophobia	181	233	251	113.26*	221.7	28.7 / 52	7.7 / 18	38.7 / 70	17.8	35
immersion of the face in water	167	227	236	122.35*	210.0	35.9 / 60	4.0 / 9	41.3 / 69	18.9	35
Squats in water	117	177	187	122.86*	160.3	51.3 / 60	5.6 / 10	59.8 / 70	26.4	35
Water entry skily	182	232	249	108.63*	221.0	27.5 / 50	7.3 / 17	36.8 / 67	17.0	34
for the reaction to the unsupported position in the water	150	176	202	76.53*	176.0	18.0 / 27	14.1 / 25	34.7 / 52	16.0	26
reaction to water entering the eyes/nose	175	217	246	107.69*	212.7	24.0 / 42	13.4 / 29	40.6 / 71	18.6	36
Underwater breath holding	111	146	173	93.52*	143.3	31.5 / 35	18.5 / 27	55.9 / 62	24.8	31
Ability to perform float	114	161	180	104.94*	151.7	41.2 / 47	11.8 / 19	57.9 / 66	25.7	33
Ability to perform asterisk	114	144	185	107.35*	147.7	26.3 / 30	28.5 / 41	62.3 / 71	27.4	36
Ability to push off and slide	104	149	176	110.25*	143.0	43.3 / 45	18.1 / 27	69.2 /72	30.1	36
Total score, points	1360	1807	2030	146.0*	1732.0	32.9 / 447	12.3 / 223	49.3 / 670	22.2	335
Mean (x ± SD), points	18.63; 5.10	24.75; 5.47	27.81; 4.80							

Note: I/O, O/S, I/S – comparative analysis of the indicators depending on the phase of control, where I – initial, O – operational, S – staged control; * - with a proven statistically significant increase in the indicator according to the χ^2-Friedman criterion at the p-level of the significance of 0.05 and taking into account the degrees of freedom df = 2.

44 points – 27.81 ± 4.80 points. The statistically significant growth of primary schoolchildren's swimming skills under the influence of swimming lessons in school sports club was proved (χ^2-Friedman = 146; df=2; p<0.05). Statistically significant increase of individual indicators for the period between input and operative (T=0; z=7,4244; p<0,05) and between operative and stage control (T=0; z=8,4270; p<0,05) was revealed (Table 1).

As you can see from Table 1, during the study period, the average indicators of the initial swimming readiness of junior schoolchildren in the conditions of a school sports club ranged from 143.3 points for the ability to perform an asterisk to 221.7 points for signs of hydrophobia. It was revealed that at the end of the study, compared with the initial stage of the average growth rate of the indicator "The ability to push off and slide" in junior schoolchildren, was the maximum and amounted to 30.1%. At the same time, the minimum average growth rate was 16.0%, which was revealed by the reaction to an unsupported position in the water.

The analysis of changes in the indicators of the initial swimming readiness of younger schoolchildren in the conditions of the school sports club made it possible to trace the positive dynamics at each stage of control. Comparing the results of operational and input control, we found that the minimum increase of 18.0% was observed according to the results of the reaction to the unsupported position in the water, and the maximum – 51.3% – to squats in the water.

At the same time, the minimum increase at the stage control compared to the operational one was observed in the indicator "The ability to push off and slide" and amounted to 4.0%, and the maximum of 28.5% was stated in the ability to perform an asterisk. And at the end of the study, compared with the beginning of the increase in the indicators of basic swimming readiness of younger schoolchildren in the conditions of a school sports club, it varied from 34.7% in response to an unsupported position in the water to 62.9% in the ability of children to push off and slide in the water. We determined that the average absolute increase in indicators, showing how they changed on average at the control phases, ranged from 26 to 36 points (Table 1).

A statistically significant increase of all indicators of primary school pupils' swimming fitness in conditions of a school sports club for the period of research was established (76,5< χ^2-Friedman <122,9; df=2; p<0,05).

At the same time, a statistically significant increase in the general assessment of pupils' swimming fitness for the period of research was proved (χ^2-Friedman = 146,0; df=2; p<0,05). Besides, statistically significant increase of general assessment of swimming fitness of school swimming club visitors at the stage of operative control compared to the input one (T=0; z=7,4244; p<0,05), at the stage of stage control compared to the operative one (T=0; z=7,4244; p<0,05), and also at the stage of stage control compared to the input one (T=0; z=8,4270; p<0,05) was revealed.

Discussion

The issue of improving the health of primary school children has been a priority in numerous studies in recent years (Kemeryte-Ivanauskiene et al., 2022; Komaini et al.,

2022). The search for a solution to this issue has led to the discovery of the prospects for the implementation of the club form of primary school children's classes and the widespread use of swimming equipment (Lyashenko et al., 2012).

Instead, to achieve the maximum health effect, there is a need for systematic monitoring of children's swimming fitness, which makes the educational and training process manageable (Hartati et al., 2022).

In the course of the research differentiation of the content of children's swimming training was determined as one of the leading at the initial stage of training, where it is formation of the skills necessary for further stages (Bondar et al., 2009; Goncharova et al., 2020; Ivanyshyn et al., 2021; Santos-Garcia et al., 2022). It should be noted that the relevance of differentiating the content of the educational and training process of younger schoolchildren is aggravated in the conditions of the formation of groups of different ages, which is common when completing groups in school sports clubs (Limarenko, 2014; Oliynyk, 2020; Richards, 2022). Therefore, grouping children is important in building training classes, taking into account the level of their initial swimming readiness.

Studying and analysing the existing methods of pedagogical control, we drew attention to certain methods for assessing the initial swimming skills of younger students.

Regarding the assessment of primary schoolchildren's swimming fitness, scientists propose different methods of its evaluation (Limarenko, 2014). However, the existing methods assumed that pupils have already formed swimming skills. Therefore, to solve the tasks, in the course of the study, we revised the methodology for assessing the initial swimming skills of Obrazhei (2023) and took into account that at the beginning of the study not all participants could stay in the water, and some children had pronounced signs of water fear. At the same time, changes were made to the system of assessment of initial swimming skills by Obrazhey (2023), which are related to the avoidance of situations of water fear and direct assessment of the formed swimming skill. The tests of jumping into the water, the ability to slide and work with feet, the ability to slide and work with hands, the ability to swim in coordination were not used, which, in our opinion, creates an additional stressful situation for the contingent of children with no swimming skills. The reliability of the obtained system for assessing children's primary skills was proved by the Cronbach's alpha coefficient, which was 0.879.

Therefore, the swimming skills of school sports club visitors were assessed according to the indicators proposed by us during the entrance, operational and stage pedagogical control. The offered method of assessment allows to create an idea of the level of swimming fitness of children both at the initial stages of training and dynamics of training. At the same time the dynamics of those indicators which are leading at the initial stages of mastering swimming skills is controlled.

It is worth emphasizing that the study confirmed the data of Obrazhei (2023) about the low level of primary swimming skills in primary school children. However, the comparison of our results with those of Obrazhey (2023) is complicated by the different duration of the pedagogical experiment and its focus.

The most interesting from the point of view of assessment of initial swimming skills is proposed by Vogt & Staub (2020). It covers 19 aquatic specific skills and most accurately reflects a set of children's motor skills in swimming at the initial stages of classes. However, in our opinion, this system needs additional systematization and separation of the most important indicators due to the large time spent on its implementation.

Comparison of the obtained results with the research of Moura et al. (2021) proves that the authors used more control tests to assess the assessed aquatic motor skills (17 aquatic specific skills). At the same time, a significant number of motor tests according to this methodology are difficult to assess the initial level of swimming in children, namely feet-first entry, head-first entry, autonomy in a deep pool (legs and arms displacement), vertical buoyancy in deep water, deep water immersion. The actual data obtained in the "water entry skill" test (Moura et al., 2021) correspond to our results and prove their high values compared to other abilities. Instead, unlike the means of influence proposed by Moura et al. (2021), our study achieved statistically significant changes in the indicators of "immersion of the face and eye-opening", which is associated with significant attention to the use of means of reducing water fear and adaptation to the aquatic environment. We also support the author's opinion about the need to develop skills related to buoyancy and gliding in children at the initial stage of swimming training.

The main result of the study was to prove the positive impact of swimming lessons in a school sports club based on the study of the dynamics of individual and group indicators of swimming fitness of schoolchildren. Thus, it turned out that at the time of pedagogical control, the average indicators of pupils' swimming fitness ranged from 143 points for the ability to push off and glide in water to 221.7 points for signs of water fear. The maximum average growth rate of 30.1% was recorded for the children's ability to push off and glide in water, i.e. on average, this indicator increased by 30.1% in stages. At the same time, the lowest average growth rate of 16.0% was recorded for the indicator of pupils' reaction to unsupported position in water. This result can be explained by insufficient self-control of movements of school swimming club visitors, as well as by insufficient level of their physical fitness. Therefore, it is necessary to establish at what moment of the motor action a child makes a mistake and to determine what physical qualities need to be developed for the correct performance of the movement. Ago, the task is to develop additional exercises aimed at developing certain physical abilities in pupils of the school swimming club, which would provide an accelerated pace of improvement of the motor action "unsupported position in water". On the other hand, the reduced average growth rate of the indicator "skill of entering water", which amounted to 17.0%, is explained by the high assessment of children's skills at the stage of entrance control. In addition, it was found that such indicators as reaction to water getting into eyes/nose, ability to perform asterisk and ability to push off and slide in water on average increased by 36 points at each stage of pedagogical control during the study period.

At the same time, the study of literature data proves the existence of an integrated approach to the assessment of children's swimming fitness, for example, the system Scale to Measure Aquatic Competence in Children by Moreno-Murcia and Ruiz-Pérez (2008), Moreno-Murcia et al. (2020), which includes 23 items divided into three dimensions (socio-affective, cognitive, and motor). This approach of the author creates a comprehensive perception

of the child's physical condition and is not limited to the physical component. This approach can be considered as a prospect for future research.

Thus, the obtained theoretical and practical provisions of the assessment of children's initial swimming fitness can become an important tool for controlling the educational and training process in swimming.

Conclusions

On the basis of the theoretical analysis of the literature and taking into account own pedagogical experience, the indicators that determine the initial swimming fitness of visitors of the school sports club are proposed. In accordance with the main stages of mastering swimming skills, three stages of control are provided (input, operational, stage). It is established that under the influence of introduction of the offered organizational and methodical approaches to the construction of training classes of primary school age children in a sports club on swimming statistically significant ($p<0.05$) increased individual and group indicators of initial swimming fitness of children. It was determined that the increase of initial swimming skills for the period of research was 49.3 %, and the average rate of increase was 22,2 %. Except for the indicator "Ability to perform a star", indicators of children's initial swimming skills in the period between operational and entrance control grew at a faster pace in comparison with the period between stage and operational control. The maximum average growth rate of children's initial skills assessment at the end of the study compared to the beginning was recorded for the ability to push off and slide (30.1%), the ability to perform the star (27.4%), and squatting in the water (26.4%).

It is possible to state that pupils demonstrated positive dynamics by all indicators of swimming fitness. Statistically significant ($p<0,05$) improvement of all indicators of their swimming fitness for the studied period was proved, and also statistically significant ($p<0,05$) increase of general assessment of swimming fitness of visitors of school sports club on swimming. Besides, statistically significant ($p<0.05$) increase of pupils' swimming fitness at the stage of operational control compared to the input one and at the stage of stage control compared to operational control was recorded. Statistically significant ($p<0.05$) improvement of primary school pupils' results of control exercises at all stages of diagnostics of their initial swimming skills formation confirms positive influence of swimming lessons in school sports club.

Conflicts of interest

The authors declare no conflict of interest.

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ДИНАМІКА ПОЧАТКОВОЇ ПЛАВАЛЬНОЇ ПІДГОТОВЛЕНОСТІ МОЛОДШИХ ШКОЛЯРІВ У ШКІЛЬНОМУ СПОРТИВНОМУ КЛУБІ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 1 табл., 1 рис., 39 джерел.

Мета дослідження – оцінити вплив занять плаванням у шкільному спортивному клубі на початкову плавальну підготовленість дітей молодшого шкільного віку.

Матеріал і методи. У дослідженні взяли участь 73 учні молодших класів, яке проводилося на базі шкільного клубу спортивного плавання «Sportrend». У процесі дослідження використовувалися теоретичний аналіз науково-методичної літератури, для оцінки плавальної підготовленості молодших школярів в умовах шкільного спортивного клубу використано систему контрольних вправ О. Ображей, переопрацьовану із врахуванням контингенту дослідження, методи математичної статистики.

Результати. Запропоновано методику оцінки плавальної підготовленості молодших школярів в умовах шкільного спортивного клубу. Темп динаміки зростання таких показників як реакція на безопорне положення у воді та затримка дихання у воді, виявився нижчим порівняно з іншими показниками. Водночас, показники занурення обличчя у воду та присідання у воді зростали пришвидшеними темпами. Середній приріст початкових навичок плавання у дітей за період дослідження склав 49,3 %, а середній темп приросту становив 22,2 %. Максимальний середній темп приросту показників оцінки початкових навичок дітей наприкінці дослідження у порівнянні з початком зафіксовано за умінням відштовхуватись і ковзати (30,1 %), умінням виконувати зірочку (27,4 %), присіданням у воді (26,4 %).

Висновки. Статистично значуще ($p<0,05$) покращення результатів виконання молодшими школярами контрольних вправ на усіх етапах діагностики сформованості їх початкових плавальних навичок підтверджує позитивний вплив занять плаванням у шкільному спортивному клубі.

Ключові слова: плавання, діти молодшого шкільного віку, спортивний клуб, оцінка, плавальна підготовленість.

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ORIGINAL SCIENTIFIC ARTICLE

THE DIFFERENCES IN PHYSICAL ACTIVITY LEVELS OF MALE AND FEMALE UNIVERSITY STUDENTS

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Abstract

Study purpose. The aim of this study was to examine the levels of physical activity among undergraduates living in ADISU (Agency for the Right to University Study) residences in order to better understand their situations and highlight the differences between male and female students.

Materials and methods. Eighty participants between the ages of 18 and 28 were enrolled in this study. A questionnaire was given to each participant who was selected for the study in order to gather general data and measure physical activity levels.

Results. 60% of the students involved in this investigation are smokers; nonsmokers show a higher average than smokers, which indicates greater physical activity and higher frequency; 52.3% of female students declare not to practice any PA compared to 26.9% of male students; 9.3% of female students declare to practice PA < 1 time per week, while 15.4% of male students declare to practice PA < 1 time per week; 7.4% of female students declare to practice PA 1-2 times per week, while 3.8% of male students declare to practice PA 1-2 times per week; 25.9% of female students declare to practice PA 2-3 times per week, while 23.1% of male students declare to practice PA 2-3 times per week; finally, 3.7% of female students declare to practice PA > 3 times per week, while 30.8% of male students declare to practice PA > 3 times per week.

Conclusions. In conclusion, we think that studies like ours are essential for formulating plans to enhance students' wellbeing and their academic route inside universities.

Keywords: physical fitness, university students, undergraduate, sedentary, health, healthy lifestyle.

Introduction

The World Health Organization (WHO) has published the new guidelines to combat a sedentary lifestyle, which has worsened due to the pandemic, through physical activity. If the world's population were more active, more than 5 million deaths could be avoided every year. At a time when people are more at home due to Covid-19, the new WHO guidelines on physical activity and sedentary behavior highlight that anyone, of any age and ability, can be physically active and that every type of movement counts. Sadly, however, globally, 1 in 4 adults do not achieve recommended levels of physical activity globally (approximately 1 in 3 women and 1 in 4 men do not exercise enough to stay healthy) and more than 1 in 4 according to the WHO. 80% of the world's adolescents are insufficiently active. Between 2001 and 2016, in high-income countries, the percentage of those who did not practice enough physical activity increased by 5 points (from 31.6% to 36.8%). With the result that, in insufficiently active people, the risk of death increases by 20% to 30% compared to active people.

Previous research has revealed that unhealthy habits that are modifiable, such smoking, eating badly, not exercising, and drinking alcohol, each have a unique impact on the development of non-communicable diseases and early morbidity (Joseph et al., 2017; Liu et al., 2012; WHO 2010). Compared to older persons, young people, particularly university students, are more prone to lead unhealthy lives. The global epidemic of overweight, obesity, and sedentary

lifestyle is a serious public health problem because it has the potential to increase the prevalence of cancer, type 2 diabetes, metabolic disorders, and cardiovascular diseases (Hultgren et al., 201). When young people are attending college, adolescent-starting habits usually solidify and last until adulthood (Deasy et al., 2014). The effects of a number of different health-related risk factors have been studied in the past, but neither their clustering behaviors nor their synergistic effects in a university setting have been studied. However, a few studies (El Ansari et al., 218; Murphy et al., 2019; Brunet et al., 2010; Meader et al., 2016) suggest that unhealthy lifestyles frequently coexist with one another. The existence of such clustering may have significant implications for studies of morbidity and mortality as well as the design of preventative and health promotion initiatives because it implies that interventions should focus on the overall lifestyle rather than just one aspect. The development of strategies that lead to an increase in the diffusion of physical activity, through the activation of interventions of proven effectiveness, is a public health objective that can only be achieved through targeted health policies, shared objectives and identification of responsibilities. The positive effects of widespread physical activity (PA) at the community level are evident at both the social and economic levels. The community benefits not only in terms of a reduction in public health costs, an increase in productivity, better efficiency in schools, a reduction in absenteeism at work, but it would also record an increase in participation in recreational and relational activities. Promoting physical activity is therefore a priority public health action, often included in health plans and programming around the world. In the United States, in fact, the Healthy People 2010 program identifies physical activity as one of the main health objectives for the country.

The term "physical activity" (PA) refers to "any body movement produced by skeletal muscles that requires energy expenditure" (Caspersen et al., 1985), including those performed for recreation, transportation, or employment. Exercise, which is "a subtype of PA that is planned, structured, repetitive, and attempts to enhance or maintain one or more components of physical fitness," should not be confused with the term "PA" (World Health Organization 2010, 2018). Instead, the World Health Organization (WHO) defines physical inactivity as "not fulfilling the applicable physical activity recommendations" (World Health Organization 2010, 2018). Physical inactivity is a risk factor for the major non-communicable diseases (NCDs) that cause early death and disability in western countries, according to a growing body of epidemiological research (Cochrane et al., 2019; Tremblay et al., 2017).

Additionally, "any awake behavior characterized by an energy expenditure 1.5 metabolic equivalents" (Lee et al., 2012) is considered sedentary behavior. Sedentary lifestyles have been ranked as the fourth biggest cause of death globally (Gallè et al., 2020). In recent years, PA has largely been replaced by increasingly sedentary habits, particularly among children and young people, and possibilities for physical activity are gradually dwindling for adults and the elderly (Tremmel et al., 2017). Contrarily, it is generally known that PA can be used to prevent non-communicable diseases, promote psycho-physical health, and enhance quality of life in people of all ages and genders. Additionally, people who are physically active typically live longer than those who are not. Due to all of these advantages, PA may lower the direct and indirect expenditures associated with a sedentary lifestyle (WHO 2011). This is especially important when taking into account the aging of the population in industrialized nations, which is leading to an increase in the burden of chronic diseases (Gallè et al., 2020).

However, there is proof that anyone, regardless of age, who improves their level of physical activity can benefit from it, even after extended periods of inactivity. As a result, in recent years, the WHO, the European Union (EU), and national governments have focused their policy on promoting an active lifestyle. It takes a team effort from all sectors and disciplines to raise the PA level in the population since it calls for a holistic, culturally sensitive approach (Cochrane et al., 2019). In fact, PA promotion is crucial for everyone in society and should be approached from a variety of disciplinary and sectorial perspectives.

The aim of this study was to examine the levels of physical activity among undergraduates living in ADISU (Agency for the Right to University Study) residences in order to better understand their situations and highlight the differences between male and female students.

Materials and Methods

Eighty participants between the ages of 18 and 28 were enrolled in this study (Tab. 1). The Department of Clinical Experimental worked with ADISU Puglia (Agency for the Right to University Study) to identify all of the subjects, who were all University of Foggia students. The "Lifestyle & World life: enhancing your life while protecting the planet" project was taken up by all of the recruited participants. To do this, epidemiological study was carried out to determine the level of physical activity and way of life of the ADISU Residences. There were no exclusion standards used in this investigation. A questionnaire was issued to each individual re-recruited for the study to gather general information and physical activity levels. A survey was created using Google forms, which allowed for both open-ended and multiple-answer responses.

Table 1. Anthropometric characteristics

Parameters	Female	Male
Number (n)	54	26
Systolic pressure	124.25 mmHg ± 20.9	129.03 mmHg ± 19.8
Diastolic pressure	74.53 mmHg ± 13.1	76.92 mmHg ± 10.6
Height (cm)	162.2 ± 6.3	176.3 ± 8.2
Weight (kg)	61.9 ± 15.2	73.6 ± 13.5

Statistical analysis

The statistical analysis was performed by using IBM SPSS Statistics 23. All the variables related physical activity were analyzed by using descriptive statistic. The frequencies and distribution of the parameters investigated were reported. The multinomial logit model was performed to investigate the differences of the following variables: "SEX", "Smoker" and "Physical Activity". The analysis shows the clustering of the frequencies relative to the variable "Physical Activity Frequency" in each group.

Results

In this study, the statistical investigation, was conducted in 80 students at the University of Foggia. The sample is not equally distributed regarding the gender; in fact, as show in table one, 67.5% are female students and 32.5% are male students (Tab. 2).

Table 2. In this table were reported the frequencies of the variables

Sex	Frequency	Valid. Percentage	Cumulative Percentage
1	54	67.5	67.5
2	26	32.5	100
Total	80	100	

"SEX" (1= woman; 2= man)

Further analysis was performed to investigate the sample on smoking habit. The results shows that the 60% of the students involved in this investigation are smoker (Tab. 3).

Table 3. In this table were reported the frequencies of smoker students (Smoker: 1= yes; 2= no)

Smoker	Frequency	Valid. Percentage	Cumulative Percentage
1	32	40	40
2	48	60	100
Total	80	100	

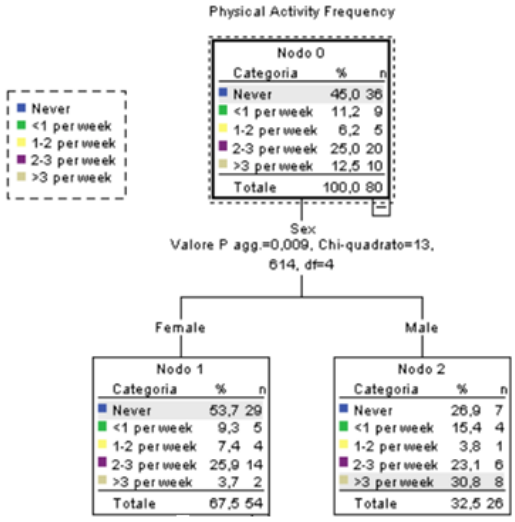

Fig. 1. Decision tree model analysis

Table 4. In this table were reported the differences between smoker and nonsmoker students

Smoker	Parameters	Physical Activity	Physical Activity Frequency
1	Mean	1.43	2.16
	N	32	32
	Minimum	1	1
	Maximum	2	5
	Std. Deviation	0.483	1.505
	Kurtosis	-1.629	-0.725
	Skewness	0.691	0.928
2	Mean	1.56	2.71
	N	48	48
	Minimum	1	1
	Maximum	2	5
	Std. Deviation	0.501	1.57
	Kurtosis	-2.018	-1.719
	Skewness	0.260	0.061
Total	Mean	1.48	2.49
	N	80	80
	Minimum	1	1
	Maximum	2	5
	Std. Deviation	0.503	1.559
	Kurtosis	-2.041	-1.544
	Skewness	0.102	0.373

(Smoker: 1= yes; 2= no; Physical Activity: 1= yes; 2= No; Physical activity frequencies: 1= never; 2= <1per week; 3= 1-2 per week; 4= 2-3 per week; 5= >3 per week).

Furthermore we also performed the investigation of the practice of physical activity in smoker group and non-smoker students (Tab. 4).

In the table above was reported the difference in average rates: in both cases, nonsmokers, shows a higher average than smokers, indicating greater physical activity and higher frequency. To get an overview of the variables, a summary descriptive table was presented (Tab. 5).

Another analysis performed was the "decision tree model" (Fig. 1). This further analysis highlights the different levels of physical activity practice in relation to gender differences. Furthermore the 52.3% of female students declare to not practice any PA compared to 26.9% of male students; the 9.3% of female students declare to practice PA <1 time per week, while the 15.4% of male students declare to practice PA <1 time per week; the 7.4% of female students

Table 5. This table show the descriptive statistics of the sample regarding the following parameters: Sex, Smoker, age and physical activity

Parameters	N	Minimum	Maximum	Mean	Skewness	Kurtosis
Sex	80	1	2	1.33	0.762	-1.457
Smoker	80	1	2	1.6	-0.416	-1.874
Age	80	18	28	21.21	1.121	1.477
Physical Activity	80	1	5	2.49	0.373	-1.544

There are two dichotomous variables "Sex" and "Smoker," one scalar variable "Age" (range 18 to 28 years) and the nominal variable "Physical Activity Frequency". Variables show positive skewness (except for the variable "Smoker"). (Sex: 1= woman; 2= man; Smoker: 1= yes; 2= no; Smoker: 1= yes; 2= no).

declare to practice PA 1-2 time per week, while the 3.8% of male students declare to practice PA 1-2 time per week; the 25.9% of female students declare to practice PA 2-3 time per week, while the 23.1% of male students declare to practice PA 2-3 time per week; Finally, the 3.7% of female students declare to practice PA >3 time per week, while the 30.8% of male students declare to practice PA >3 time per week.

Discussion

The main finding of this study are: 1) the 60% of the students involved in this investigation are smoker; 2) non-smokers, shows a higher average than smokers, indicating greater physical activity and higher frequency; 3) the 52.3% of female students declare to not practice any PA compared to 26.9% of male students; the 9.3% of female students declare to practice PA <1 time per week, while the 15.4% of male students declare to practice PA <1 time per week; the 7.4% of female students declare to practice PA 1-2 time per week, while the 3.8% of male students declare to practice PA 1-2 time per week; the 25.9% of female students declare to practice PA 2-3 time per week, while the 23.1% of male students declare to practice PA 2-3 time per week; Finally, the 3.7% of female students declare to practice PA >3 time per week, while the 30.8% of male students declare to practice PA >3 time per week. This study is important to verify the student's lifestyle to obtain detailed report to be able, if necessary, to propose improvement strategies. In fact, accordingly to WHO, adults (aged 18-64 years) Should also engage in muscle-strengthening activities at moderate or greater intensity that involve all major muscle groups on 2 or more days a week, as these provide additional health benefits. Should do at least 150-300 minutes of moderate-intensity aerobic physical activity; at least 75-150 minutes of vigorous-intensity aerobic physical activity; or an equivalent combination of moderate- and vigorous-intensity activity throughout the week. All individuals, especially older adults, should strive to engage in more than the advised amounts of moderate- to vigorous-intensity physical activity. Physical activity of any intensity can help lessen the negative effects of high levels of sedentary behavior on health (WHO 2018).

In actuality, consistent physical exercise, such as walking, cycling, wheeling, playing sports, or engaging in active leisure, has major positive effects on health. It is preferable to engage in some exercise than none. People can easily reach the necessary exercise levels by increasing their daily activity in relatively easy methods (Moscatelli et al., 2020). One of the main risk factors for non-communicable diseases mortality is physical inactivity. Compared to those who are appropriately active, those who are insufficiently active have a 20%–30% higher risk of dying. Exercise on a regular basis can: decrease the incidence of depression, hypertension, coronary heart disease, stroke, diabetes, various cancers (including breast cancer and colon cancer), falls, hip or vertebral fractures, and increase muscular and cardiorespiratory fitness. It also helps maintain a healthy body weight. Furthermore, our study, highlight the great percentage (60%) of smoker students.

More than 8 million people die each year from the tobacco epidemic, which is one of the greatest risks to global public health. This figure includes roughly 1.2 million fatalities from exposure to secondhand smoke (Global Burden of Disease 2019; Huang et al., 2014; Polito et al., 2019, 2020; Sperandeo et al., 2020; Di Maio et al., 2020). There is no level of cigarette exposure that is safe; all kinds of tobacco are toxic. The most prevalent method of tobacco consumption worldwide is cigarette smoking. Other tobacco goods include bidis, kreteks, cigars, cigarillos, roll-your-own tobacco, waterpipe tobacco, and numerous smokeless tobacco items. The economic consequences of tobacco use are large and include high medical expenses for treating diseases brought on by tobacco use as well as the lost human capital as a result of morbidity and mortality linked to tobacco use. Moreover, the smoke that is exhaled by the smoker as well as the smoke that is released from the burning end of a cigarette or other smoking devices (such bidis and water pipes) is referred to as second-hand tobacco smoke. There is no safe threshold of exposure to secondhand cigarette smoke because more than 4000 compounds have been found in tobacco smoke (Monda et al., 2017; Precenzano et al., 2017; Moscatelli et al., 2016; Maldonato 2018).

The Conference of the Parties to the WHO Framework Convention on Tobacco Control (WHO FCTC) has determined that the only effective strategy to fully protect people's health from the damaging effects of secondhand tobacco smoke is to have 100% smoke-free settings. Smoke-free regulations are popular because they don't hurt business and they help smokers stop while also protecting the health of non-smokers. Unfortunately, the results of our study, when compared to national data, are decidedly alarming since, according to the data of the "Report on smoking in Italy", presented on the occasion of World No Tobacco Day 2022 (World No Tobacco Day, 31 May), almost one in four Italians (24.2% of the population) is a smoker: a percentage that had never been recorded since 2006. After a long period of stagnation, this year we are witnessing an increase of 2 percentage points: in fact, smokers were 22% in 2019, the last year of the pre-pandemic survey. The trend observed in the three-year period 2017-2019 which saw a constant decrease in female smokers is not confirmed in 2022: this year, in fact, there is an increase in the percentage of smokers of both sexes. People who smoke cigarettes with heated tobacco are also on the increase: 3.3% in 2022 compared to 1.1% in 2019, but more than one in three people (36.6%) consider them less harmful than traditional ones.

Conclusions

This is the first investigation conducted in the University of Foggia students. The data revealed lower physical activity practices level and a higher number of smoker students. Given the results obtained, it would be appropriate to implement strategies capable of increasing sports practice and, at the same time, decreasing the number of smoking students. While our study is found to be important for student health implications, we believe it has some limitations. In fact, it would be advisable to increase the sample and compare the results between students who reside in university residential structures and those who instead reside in their own homes. Furthermore, the parameters could also be evaluated in relation to the year of the course attended. In conclusion, although our study has some limitations, we believe that surveys like ours are fundamental for setting strategies for improving the health of students and their educational path within universities.

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Conflict of interest

The authors declare that there is no conflict of interest.

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ВІДМІННОСТІ В РІВНЯХ ФІЗИЧНОЇ АКТИВНОСТІ СТУДЕНТІВ І СТУДЕНТОК УНІВЕРСИТЕТУ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 5 табл., 1 рис., 33 джерела.

Мета дослідження. Метою цього дослідження було вивчити рівні фізичної активності студентів, які мешкають у гуртожитках ADISU (Агентство з права на навчання в університеті), щоб краще зрозуміти їхні обставини та висвітлити відмінності між студентами та студентками.

Матеріали та методи. У цьому дослідженні взяли участь 80 учасників віком від 18 до 28 років. Кожному учаснику, відібраному для дослідження, було надано анкету для збору загальних даних та вимірювання рівня фізичної активності.

Результати. 60% студентів, залучених до цього дослідження, курять; некурці показують вищий середній показник, ніж курці, що вказує на більшу фізичну активність і більшу її частоту; 52,3% студенток заявляють, що не займаються жодною ФА порівняно з 26,9% студентів; 9,3% студенток заявляють, що займаються ФА < 1 разу на тиждень, тоді як 15,4%

студентів заявляють, що займаються ФА < 1 разу на тиждень; 7,4% студенток заявляють, що займаються ФА 1-2 рази на тиждень, тоді як 3,8% студентів заявляють, що займаються ФА 1-2 рази на тиждень; 25,9% студенток заявляють, що займаються ФА 2-3 рази на тиждень, тоді як 23,1% студентів заявляють, що займаються ФА 2-3 рази на тиждень; нарешті, 3,7% студенток заявляють, що займаються ФА понад 3 рази на тиждень, тоді як 30,8% студентів заявляють, що займаються ФА понад 3 рази на тиждень.

Висновки. Підсумовуючи, ми вважаємо, що дослідження, подібні до нашого, необхідні для складання планів покращення добробуту студентів та їхнього освітнього шляху в університетах.

Ключові слова: фізична підготовленість, студенти університету, студент, малорухливий, здоров'я, здоровий спосіб життя.

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ORIGINAL SCIENTIFIC ARTICLE

ANALYSIS OF FACTORS INFLUENCING THE MOTIVATION OF HUNGARIAN JUNIOR HANDBALL PLAYERS

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Abstract

Study purpose. In sports, just like in everyday life, motivation plays an important role in achieving individual goals. Motivation is an individual's decision to engage in certain activities and make various efforts to do so. Sports require a continuous, constant effort from individuals, so it is even more important here that the athlete has the necessary motivation. Without motivation, it is not possible to do sports at a high level in the long term. The aim of the study was to examine the sports motivation factors of handball players in the Hungarian junior classes. Handball is one of the most popular sports in Hungary. As a result, it can be said that, from the point of view of the long-term success of the sport, it is essential to know the factors that motivate youth athletes.

Materials and methods. We collected the data required for the research using a questionnaire. The research took place in the fall of 2022, with 190 youth athletes interviewed. During our research, we established that internal and external motivational factors are equally important for Hungarian youth handball players.

Results. With statistical calculations, we show a significant relationship between the athletes' motivation and the joy caused by sports, the avoidance of disappointment caused to the environment due to the cessation of sports, and the sports results achieved.

Conclusions. The results of the study will be a useful resource for those interested in the sport of handball, to better consider the motivational factors that help to understand the motivation of young athletes and which are important in order to consistently provide a high level of performance.

Keywords: Hungary, handball, motivation, physical education, young athletes.

Introduction

The role of sport and physical education has become more valued nowadays, as it can contribute to the realization of health, social and economic goals. In Hungary, the promotion of regular sports for young people also appears in the government strategy as a social goal. Accordingly, in recent decades, countless opportunities have opened up for young people to participate in various sports activities. Simultaneously with the spread of sport, research related to sport and athletes is playing an increasingly important role in international and domestic research. Researching the motivation of athletes is one of the central topics of sports psychology researchers. International research has been done on the reasons why individuals start a sport or why they don't continue a given sport, as well as what motivational factors affect athletes during sports activities (Jones, Mackay & Peters, 2006). Motivation is a factor that encourages a person's behavior and directs it in a certain direction. Individuals differ not only in their ability to perform a certain task, but also in their motivations and willingness to perform the task. Motivation is a kind of internal drive that affects the driving forces and needs that trigger and direct the efforts of individuals to achieve.

In sports, it is important to understand the motivations behind an individual's behavior, what triggers it and what modifies the athletes' behavior. The motivational factors that appear in individuals to play sports can be intrinsically motivated (for example, passion for sports, enjoyment of playing sports) and external factors (for example, reward, improved health, good appearance, the role of the environment). The aim of our study was to assess which motivational factors have

the greatest effect on youth handball players in Hungary. The obtained results can help to understand which motivational factors are important for young athletes.

The study of motivation has been a key area of interest for sport psychologists since the early 1990s. What motivates an athlete can depend on many factors. Some research has shown that the motivation of competitive athletes and those participating in leisure activities is different. In competitive sports, it is mainly the results achieved, while in leisure activities it is the enjoyment of the sport that motivates (Frederick & Ryan, 1993). However, according to Vazou et al. (2007), no matter what kind of sports activity we participate in, it is important to love and enjoy the chosen type of sport, because it can maintain the individual's motivational level in the long term. So, in the case of an athlete, internal motivation can be considered more effective in the long term. Athletes driven by internal motivation are able to give their maximum even when there is no stake in their performance or when no one is watching them. In the case of internal motivation, the individual pursues the sport for the joy of the sport and for the resulting enjoyment. During internal motivation, the athlete enjoys training and learning processes when he can learn new movements and skills (Thomas & Güllich, 2019). In the case of external motivation, the athlete is driven by various rewards or recognition from others, so the athlete is influenced by an external factor in maintaining motivation. If the individual's extrinsic motivation ceases, the motivated behavior will most likely cease as well. It can be said that the existence of external motivation is very important at the beginning of sports activities, as it increases performance. If used correctly, these motivational tools can be beneficial for athletes (Ridwan et al., 2022). Most athletes are motivated by goals such as winning an award or a tournament, which is outside of intrinsic motivation. The problem is caused when someone excessively focuses on external rewards, so the enjoyment of sports activities is lost, this can demotivate the athlete in the long term and negatively affect sports performance (Jõesaar et al., 2011). Like the aforementioned authors, Hoffmann (2007) collected and grouped possible motivations for sports according to motives. Such motives are the motive of winning, the motive of being together, the motive of health and fitness, and the motive of play and fun. In the case of a winning motive, individuals participate in various sports competitions because they want to test their skills and enjoy the positive feedback that comes from being a winner. The motive of being together makes the individual participate in sports with friends and enjoy playing sports together. In the case of the motive of health and fitness, the athlete participates in the given sport because of the positive effects provided by the given activity. In the case of the motive of play and fun, the joy caused by sport prompts the individual to perform the activity.

Individual and team sports participants may also have different motivational factors. Several international studies have investigated the differences between the motivation of individual and team sports participants. In their study, Benar and Loghmani (2014) compared the sports motivation and goal orientation of young athletes. Their results showed that individual athletes were more motivated for results than team athletes. According to Jakobsen (2014), the interest/enjoyment scores of athletes in team sports are higher than in individual sports, but he found no difference in the motivation to participate in sports in team and individual sports.

In sport psychology, two main motivational directions appear most often (Fenton et al., 2016; Méndez-Giménez et al., 2012), the Self-Determination Theory and the performance goal (goal orientation) theories. The self-determination theory is close to many theories, including the Basic Psychological Needs theory (Deci & Ryan, 2000). Self-determination theory focuses on the extent to which an individual's behavior is self-motivated. It deals with the motivations behind the decisions that individuals make without any external influence. It is coded in individuals to look for situations in which they can promote their self-development. According to the theory, all individuals have three innate basic needs, which are the following: independence (autonomy), competence and social relations. The individual tries to create a balance between the three basic needs. The essence of autonomy is that people should feel in control of their own behavior and goals. Competence includes all the innate needs that encourage us to acquire different skills and tasks. During social relationships, people need to know the feeling of attachment, what it is like to belong to others (Deci & Ryan, 2000).

Achievement motivation was defined by Maehr and Nicholls (1980) as "conformity to standards or virtuous intentions rather than superior talent". According to Achievement Goal Theory, athletes are motivated when they have a predetermined goal (Ntoumanis & Biddle, 1999). A well-defined goal has a strong motivating effect. If the athlete can identify with the predetermined goal, it means greater commitment for him, which has a positive effect on his performance. If the individual has set several goals for himself, it is important to establish a suitable sequence for their implementation. Two types of goals can be defined during the theory, there are task-oriented goals and so-called self-centered goals. We can speak of a task-oriented athlete if the individual sees himself as a benchmark and always emphasizes learning and development. These athletes are characterized by the need to improve their knowledge, as they want to perform better in line with their internal expectations (Duda & Whitehead, 1998). As a result, they set goals for themselves that will improve their abilities the most, because they believe that their abilities can be improved. These individuals evaluate their own competencies in a completely self-reflective manner. By striving for personal development, the athlete has a much more positive effect. On the other hand, if the athletes' goals do not match their abilities, instead of motivation, anxiety appears in their behavior, which will almost certainly reduce the effectiveness of their performance (Monteiro et al., 2018). We can talk about self-centeredness if the given athlete compares his own abilities with those of other athletes and thereby wants to receive positive feedback about his abilities. In contrast to task-oriented athletes, they believe that they cannot change their abilities, which is precisely why they want to prove that they are better than their teammates and opponents. They try to avoid situations where their abilities may be revealed. We can talk about failure-avoidance behavior if the athlete sets his goals below his abilities, since in this case he can jump the set task without much effort, so the possibility of failure cannot arise. This behavior is typical of those who are afraid of taking risks and fear of failure, as they feel that they would not be able to perform well. As a result of these goals, the athlete may develop anxiety and worry due to

the constant comparison (Nicholls, 1989). Thus, athletes who have a greater motivation to avoid failure achieve lower results than we would expect from them based on their potential and opportunities (Bratko et al., 2020).

According to some researchers (Côté, 1999; Strandbu et al., 2019; Duda, 2013), the environment also affects the athlete's actions. The environment has a significant impact on the athlete's attitude and personality development. Parents, friends and coaches play a decisive role in creating a motivational atmosphere (Castro-Sánchez et al., 2018). An environment that can properly motivate the athlete to achieve better performance is needed. However, it is important to emphasize that the most decisive actor in the motivational environment is the coach, since during his work he influences the athlete's motivations both directly and indirectly (Curran et al., 2015). The atmosphere created by the coach can have a positive or negative effect on the athlete (Bortoli al., 2014). Athletes' burnout syndrome is often caused by an inappropriate environment. The motivational climate is created by key individuals (e.g. parents and coaches) who influence the athletes and set goals and expectations for the athletes that also affect the individual's fears about sports (Gómez-López et al., 2020). Among the many environmental components that influence an athlete's motivation and subsequent performance, one of the most decisive factors is the quality of the relationship between the athlete and the coach (Mageau & Vallerand, 2003). Both the coach and the players must strive to build the right relationship for success and proper cooperation. Parties with a good relationship are much more successful than those with a bad coach-athlete relationship (Jowett & Wachsmuth, 2020). According to Jowett and Cockerill (2003), the establishment of a good relationship is vital, as it has a great impact on the athlete's motivation, as well as on the achievement of set goals and successes. The task-oriented environment emphasizes learning and development; thus the coach also has a positive effect on the player's development. In this environment, athletes can feel equal, as this atmosphere indicates to them that they equally contribute to the team's success and are an integral part of it. In such an environment, cooperation prevails and players believe that they all contribute to the team's success. On the other hand, in the case of a performance-oriented environment, the focus is on defeating and surpassing competitors. In this environment, it is typical for the coach to single out those players who are better than their peers, giving them special attention, thus illustrating that they must always give their best performance to the competitors, and also encourages them to compete with each other. Gives little positive feedback and is less supportive with athletes. The results achieved are not recorded as the success of the team as a whole, but those of the players who perform better than their peers.

In the following, the main results of our own research will be presented. In our research, we set out to define and analyze a less researched segment, the motivational factors of youth handball players.

Materials and methods

The main goal of the research was to assess the factors affecting the sports motivation of Hungarian youth handball players. During the research, we used the Participation Motivation Questionnaire (PMQ) developed by Gill, Gross, & Huddleston in 1983 as a starting point. Our final questionnaire contained 47 questions. The questionnaire was sent out on a national level among youth handball players. The survey took place in the fall of 2022, and a total of 190 evaluable questionnaires were returned. The survey was completely anonymous, which we also assured our respondents. In addition to demographic questions, the questionnaire included questions related to the motivation of athletes. During our research, we modified the 3-point Likert scale of the original PMQ questionnaire and used a 7-point scale in order to collect more accurate answers. 1 represented the statement "Not at all true", while 7 represented the statement "Completely true".

In Hungary, youth players are divided into 3 classes (I. II. III.) in both men's and women's fields. It is possible to participate in the first and second divisions by promotion or by remaining, while sports organizations can openly apply for the third division if they meet the given criteria. We sent the questionnaire to all teams of the first and second division by e-mail. Before sending out the questionnaire, we contacted the team leaders by e-mail, phone and social media and asked them to participate in the research.

The IBM SPSS statistics 26 program was used to analyze the data. To verify the research hypotheses, we run an analysis of variance. The essence of this is what effect our low measurement level variable (independent) has on the high measurement level variable (dependent). As a general rule, we accepted that the relationship is 0.0-0.2 weak, 0.2-0.5 medium, and 0.5-1.0 strong. Furthermore, we also examined significant differences between the independent variables.

After a detailed study of the studies presented in the literature review, we formulated 3 research hypotheses:

H1: A significant relationship can be shown between the motivation of young handball players and the feeling of joy caused by the sport.

H2: A significant relationship can be shown between the feeling of guilt caused by quitting sports and the disappointment of the young athletes' environment.

H3: A significant relationship can be shown between the motivation of young handball players and the sports results achieved.

A summary of the demographic data is presented in Table 1. 190 people participated in the survey, of which 69 (36.3%) were boys and 121 (63.7%) were girls. Analyzing the age composition, it can be said that most of the respondents fell into the 16 and 18 age category, 41.5 percent of all respondents were from this age group. 40 people (21.1%) played in the Youth I. division, the fewest respondents in the Youth III. dropped out of class, 24 people (12.6%). The number of first-class players was 72 (37.9%), our second-class players were 66 (34.8%), while the proportion of third-class players was 27.3% (52 people). A significant number of our respondents started playing sports on their own initiative, 133 of them (70.0%). It is also worth highlighting the 24 people (12.6%) who started the sport because of friends, as well as 18 people (9.5%) who started playing handball because of family.

Results

During our research, we examined how the independent variables established in our hypotheses affect the dependent

Table 1. Profile of the sample (n = 190)

Varibale		N	%
Gender	Male	69	36.3
	Female	121	63.7
Age	12-15 years	64	33.7
	16-18 years	79	41.6
	19-20 years	47	24.7
Class	I. class	72	37.9
	II. class	66	34.8
	III. class	52	27.3
Years spent by playing sports	0-5 years	37	19.5
	5-10 years	129	67.9
	More than 10	24	12.6
Reason of starting playing sport	Friends	24	12.6
	Family	18	9.5
	Own motivation	133	70.0
	Other	15	7.9
Total		190	100.0

variables. Significant differences between low-level variables (independent) were also examined. Our low-level variables were created from high-level variables, not proportionally, but by dividing the 7-point Likert scale into 3 parts. The first two values (1-2) were the first group, the values 3-5 were in the second group, and the values 6 and 7 formed the third group. Since there were large differences between our independent variables in all cases, we first examined normality, which was met in all cases.

Table 2. Welch robust test of equality of means

	Statistica	df1	df2	Sig.
Happiness caused by sport results	9.040	2	107.009	0.000

a. Asymptotically F distributed.

For unmotivated players, the joy caused by sports reached an average of 1.87, while this average was 2.91 for moderately motivated players and 3.35 for highly motivated players (Table 3).

Since the homogeneity is broken, we examine the results of the Games-Howell (Table 4) test. It is clear that unmotivated players differ from moderately motivated players by 1.037 average points in absolute value (p = 0.025, standard error = 0.388). Between unmotivated and highly motivated players, this difference in absolute value is 1.478. There was also a significant difference between moderately motivated and highly motivated players, the difference in absolute value was 0.441. Based on the results of the tests, we accept our first hypothesis.

The second hypothesis of our research was aimed at examining the relationship between the feeling of guilt caused by quitting sports and the disappointment of the young athletes' environment. Based on the literature, we assumed that it is important for adolescent athletes what their environment thinks. Many people want to live up to their environment, including the coach, family, and friends, and the desire to prove themselves in sports is stronger because of them. When examining our second hypothesis, we first examined the homogeneity of variance, which (p=0.000) was damaged, so in this case we also performed the Welch test (Table 5), in which case the relationship between the two variables was verified (p=0.000). Based on our study, it can

Table 3. Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
	38	1.87	1.614	0.262	1.34	2.40	1	7
Moderately motivated	74	2.91	1.953	0.227	2.45	3.36	1	7
Motivated	78	3.35	2.082	0.236	2.88	3.82	1	7
Total	190	2.88	2.011	0.146	2.59	3.17	1	7

Table 4. Games-Howell test for phase-wise comparison among the means

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Games-Howell	Unmotivated	Moderately motivated	-1.037*	0.346	0.010	-1.86	-0.21
		Motivated	-1.478*	0.352	0.000	-2.32	-0.64
	Moderately motivated	Unmotivated	1.037*	0.346	0.010	0.21	1.86
		Motivated	-0.441	0.327	0.372	-1.22	0.33
	Motivated	Unmotivated	1.478*	0.352	0.000	0.64	2.32
		Moderately motivated	0.441	0.327	0.372	-0.33	1.22

*. The mean difference is significant at the 0.05 level.

Table 5. Welch robust test of equality of means

	Statistica	df1	df2	Sig.
Dissapointment of the environment of athletes	27.955	2	102.595	0.000

a. Asymptotically F distributed

be said that the strength of the relationship between the two factors examined is medium (r=0.490).

The average environmental frustration was 2.84. For those who do not feel guilty about quitting sports, the frustration of the environment is 1.75, while for those who feel moderately guilty about quitting sports, the frustration of the environment is 3.08. An average of 4.28 environmental frustrations characterized the athlete's environment for those athletes who felt guilty about quitting sports (Table 6). The obtained results confirmed our assumption that a significant part of the youth athletes are motivated to continue the sport because they would like to respond to their environment.

Since homogeneity is broken, we examined the results of the Games-Howell test. There was also a significant difference between the groups here. There was a difference of 1.335 in absolute value between those who did not feel guilty about quitting sports and those who felt moderately guilty about quitting sports (p = 0.000, standard error = 0.315). An average difference of 2,533 was detected between those who do not feel guilty and those who stop playing sports with a significant feeling of guilt. Between those who felt moderately and significantly guilty, the average difference was 1.198 in absolute value (Table 7).

Based on the evaluation of the above data, we also accept the second hypothesis.

Our third hypothesis, which we created after studying the literature, assumed that a significant relationship can be shown between the motivation of young handball players and the sports results achieved. Even in this hypothesis test, the homogeneity of variance was damaged (p=0.000), so we used the previously proven Welch's test (Table 8) to show the significant relationship between the two variables (p=0.000). During the examination of the strength of the relationship (r=0.385), a relationship of medium strength was shown.

Table 8. Welch robust test of equality of means

	Statistica	df1	df2	Sig.
Happiness caused by sport results	16.918	2	116.910	0,000

a. Asymptotically F distributed

Table 6. Descriptive Statistic

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
No guilt	79	1.75	1.454	0.164	1.42	2.07	1	7
Moderate guilt	61	3.08	1.865	0.239	2.60	3.56	1	7
Guilt	50	4.28	2.330	0.330	3.62	4.94	1	7
Total	190	2.84	2.110	0.153	2.54	3.14	1	7

Table 7. Games–Howell test for phase-wise comparison among the means

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Games-Howell	No guilt	Moderate guilt	-1.335*	0.289	0.000	-2.02	-0.65
		Guilt	-2.533*	0.368	0.000	-3.41	-1.65
	Moderate guilt	No guilt	1.335*	0.289	0.000	0.65	2.02
		Guilt	-1.198*	0.407	0.011	-2.17	-0.23
	Guilt	No guilt	2.533*	0.368	0.000	1.65	3.41
		Moderate guilt	1.198*	0.407	0.011	0.23	2.17

*. The mean difference is significant at the 0.05 level

Table 9. Descriptive Statistic

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Unmotivated	60	1.90	1.446	0.187	1.53	2.27	1	7
Moderately motivated	74	2.92	1.834	0.213	2.49	3.34	1	7
Motivated	56	3.88	2.265	0.303	3.27	4.48	1	7
Total	190	2.88	2.011	0.146	2.59	3.17	1	7

Table 10. Welch robust test of equality of means.

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Games-Howell	Unmotivated	Moderately motivated	-1.019*	0.283	0.001	-1.69	-0.35
		Motivated	-1.975*	0.356	0.000	-2.82	-1.13
	Moderately motivated	Unmotivated	1.019*	0.283	0.001	0.35	1.69
		Motivated	-.956*	0.370	0.030	-1.84	-0.08
	Motivated	Unmotivated	1.975*	0.356	0.000	1.13	2.82
		Moderately motivated	.956*	0.370	0.030	0.08	1.84

*. The mean difference is significant at the 0.05 level

The average value of happiness caused by sports results was 2.88. In the case of unmotivated players, this was 1.90, in the case of moderately motivated players, it was 2.92, while in the case of motivated players, this average was 3.88 (Table 9). Based on these, it can be stated that the sports results achieved play a role in the motivation of the examined athletes and in their long-term maintenance.

Examining the significant difference between the groups, we analyzed the Games-Howell table. There was a significant difference between the three groups. There was an average difference of 1.019 in absolute value between the happiness caused by sports results of unmotivated and moderately motivated players ($p = 0.006$, standard error = 0.324). The average difference between unmotivated and motivated players was 1.975 in absolute value, while the average difference between moderately motivated and motivated players was 0.956 in absolute value.

Based on the above results, we also accept the third hypothesis, according to which a significant relationship can be demonstrated between the motivation of youth athletes and the feeling of happiness caused by the achieved sports results.

In our own study, it was confirmed that both internal and external motivational factors influence athletes, even junior athletes.

Discussion

The aim of this study was to (a) assess the motivational factors of Hungarian junior handball players and (b) formulate development proposals for those involved in the topic. During our own investigations, the analysis of both internal and external motivational factors was presented. Our first study focused on the intrinsic motivation of athletes. In line with other international researches, we managed to prove that the joy caused by sport is important for Hungarian junior handball players. Intrinsic motivation comes from within, is completely self-determined, and is characterized by an interest in and enjoyment of participating in sports (Vallerand, 2007). The same conclusion was reached by Hagger and Chatzisarantis in their 2007 study, according to which the enjoyment of sports activities is an important factor in the motivation of athletes. The existence of internal motivation is also important in order to achieve long-term goals. Athletes who can identify with the values offered by sport are able to provide high performance in the long term (Almagro et al., 2020). According to Weiss et al. (2012), the athlete's level of interest in sports is related to how much someone enjoys the sports activity, the more someone enjoys sports, the longer they will play sports. Our second hypothesis, according to which there is a connection between the athlete's motivation and his environment, was also proven. In many cases, the participants in the study were juveniles and were highly dependent on their parents for moral and financial support. Extrinsic drives include many factors that can motivate athletes, including social inclusion, health and good looks, achievement, rewards, money, sponsorship, fame, parents, coaches and the friends. In the course of our research, we investigated the role of the athlete's wider environment among the external motivational factors: the coach, family, and friends in the motivation of junior athletes. According to the results obtained, the sense of guilt that characterizes the athlete when he stops playing sports and thereby disappoints his environment is related to the motivation of the respondents. Our results are also supported by Lassalle et al.'s 2018 study, in which they found that the support, help and encouragement of family members motivates their young relatives in sports activities. In their study, Morgan and Giacobbi (2006) emphasize that successful athletes are born with a combination of favorable factors, such as genetics, and supportive environmental factors, including the support of family, coaches, and teammates. A 2004 study by Wolfden and Holt found that both coaches and parents play an important role in the lives of athletes. Similarly, in their study, Scanlan et al. (2003), believe that the level of encouragement provided by the family and the wider environment is very important for the sports performance of young athletes. Our third and last hypothesis was also proven, according to which a relationship can be shown between the achieved sports results and the motivation of Hungarian junior handball players. In sports, especially in competitive sports, athletes strive for the best possible performance, every athlete wants to perform well and win. Athletes do their best to achieve individual and, where applicable, team goals, which requires continuous and high-level motivation (Šmela et al., 2017). According to Mallet and Hanrahan, in their 2004 study, one of the self-defining behaviors of athletes is that they have strong motivation, persistence and strong desires to achieve personal goals.

The attitude of junior Hungarian handball players towards sports is influenced by many factors, such as the enjoyment caused by sports activities, the sports results achieved and the family or environmental support, which

have a significant impact on the motivation of young athletes, therefore the professionals working with young athletes must jointly identify these factors that trigger and maintain motivation must be taken into account.

Conclusions

The analysis of motivational factors is one of the fastest growing research areas in the field of sports psychology. The aim of our study was to examine what motivational factors affect the sports activities of Hungarian junior handball players. All three hypotheses set up during our research were accepted, and we showed that the motivational factors of junior handball players are multifaceted. Based on the obtained results, it can be stated that in addition to the internal motivational drive of athletes, which means the joy given by sports, the environment and the sports results achieved also play an important motivating role.

Our research has certain limitations, including the small sample size, the lack of similar studies for other sports, with which we could compare our results, thus gaining a broader perspective on the motivational factors of handball players. Despite these limitations, however, our study provides new results for those interested in the topic. Those active in junior age groups, including primarily coaches, must pay attention to the role of these motivational factors. It is important to make them aware that beyond the internal motivation of young athletes, the fact that the results achieved, even if they are not so great, definitely have a motivating effect on the young athletes, and that the family and the environment of the athletes also have a motivating role, therefore very a supportive and motivating atmosphere is important.

Given the paucity of studies on junior athletes, there are many opportunities for future research in this area. It would be interesting, for example, to extend the research to other sports, as well as to prepare further surveys and analyzes on the satisfaction of junior handball players with the sport, as well as the effect of the atmosphere between coaches and athletes on motivation.

Conflict of interest

The authors declare that there are no conflicts of interest.

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АНАЛІЗ ФАКТОРІВ, ЯКІ ВПЛИВАЮТЬ НА МОТИВАЦІЮ УГОРСЬКИХ ГАНДБОЛІСТІВ-ЮНІОРІВ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 10 табл., 37 джерел.

Мета дослідження. У спорті, як і в повсякденному житті, мотивація відіграє важливу роль у досягненні індивідуальних цілей. Мотивація – це рішення людини займатися певною діяльністю та докладати для цього різноманітних зусиль. Спорт вимагає від людей безперервних, постійних зусиль, тому тут ще важливіше, щоб у спортсмена була необхідна мотивація. Без мотивації неможливо займатися спортом на високому рівні в довгостроковій перспективі. Метою дослідження було вивчити фактори спортивної мотивації гандболістів юніорських класів Угорщини. Гандбол – це один із найпопулярніших видів спорту в Угорщині. У результаті можна сказати, що з погляду довгострокового успіху цього спорту важливо знати фактори, які мотивують молодих спортсменів.

Матеріали та методи. Необхідні для дослідження дані ми зібрали за допомогою анкети. Дослідження проводилося восени 2022 року, опитано 190 молодих спортсменів. Під час нашого дослідження ми встановили, що внутрішні та зовнішні мотиваційні фактори однаково важливі для угорських молодих гандболістів.

Результати. За допомогою статистичних розрахунків ми показуємо статистично значущий зв'язок між мотивацією спортсменів і радістю, яку дарує спорт, уникненням розчарування, спричиненого оточенням через припинення занять спортом, і досягнутими спортивними результатами.

Висновки. Результати цього дослідження стануть корисним ресурсом для тих, хто цікавиться гандболом, щоб краще розглянути мотиваційні фактори, які допомагають зрозуміти мотивацію молодих спортсменів і які є важливими для постійного забезпечення високого рівня спортивних показників.

Ключові слова: Угорщина, гандбол, мотивація, фізичне виховання, молоді спортсмени.

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REVIEW ARTICLE

CURRENT TRENDS AND ISSUES INVOLVING SCREEN TIME AND PHYSICAL ACTIVITY ENGAGEMENT AMONG SCHOOL STUDENTS: A THEMATIC REVIEW

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Abstract

Study purpose. Physical inactivity and excessive screen time engagement among school-aged children is a global issue which is known to be linked with sedentary lifestyle. Several studies were conducted about sedentary behavior among children, but still lacking is a review paper that analyzes the current trends and issues on physical inactivity and excessive screen time. This study aims to identify the current issues and trends on physical activity and screen time among school students discussed in the articles published from 2018-2022.

Materials and methods. Quantitative and qualitative methods were used in this study. Quantitative approach was used to explain the trends and statistics in terms of literatures geographical dissemination and specified topic or themes developed within the period from 2018 to 2022. Qualitative approach was implemented to establish patterns and themes. This study generates themes and patterns from the articles published from 2018 to 2022. Thirty articles were included via database searched from SCOPUS, SportsDiscus and PubMed.gov. Thematic analysis was done using ATLAS.ti 22.

Results. Five main themes were generated: 1) behavioral impact; 2) engagement level: age and gender specific; 3) association to socio-economic status; 4) impact on adiposity; and 5) school curriculum role.

Conclusions. Excessive screen time and physical inactivity have a diverse effect on young populations health. Understanding the patterns and themes generated in this study will be of great help in terms of designing a program of activity that will counter measure the negative effect associated with sedentary lifestyle.

Keywords: screen time, physical activity, sedentary lifestyle, children.

Introduction

Physical inactivity is one of the current health global concerns among children. Majority of the school students are experiencing this phenomenon. According to Zhu et al. (2019) sedentary lifestyle among children was significantly high globally. In connection to that, World Health Organization (2020) created a guideline for physical activity and sedentary behavior. Recommended engagement time for physical activity among children and adolescents was at least average of 60 minutes per day and less than 2 hours of spending time on screen as well Bull et al. (2020). Compliance and other related factors to the movement guidelines become a popular topic to explore across the globe.

Despite of being one of the concerns in child's development over previous decade, managing the lifestyle in terms of being active and lessening the screen engagement time among society was still an issue Scully et al., (2022). Movement guidelines were made to address the public health issue about inactivity but the pattern of non-compliance was still emerging (Moitra et al., 2021). Meeting the recommended movement guidelines was still a problem in the community. Seems that society was normalizing the trends among school students as they accept that the said phenomena was part of kid's and youths' daily life or activities. Hashem et al. (2018) describes that excessive screen time and inability to engage in movement exercises was extremely integrated in current technologically advance community. According to Ngantcha

et al. (2018) several activities by adolescents are connected and achieved through the use of technology such as internet and gadgets. Kids nowadays consider gadget use as significant part of their daily activities (Kidokoro et al., 2022)

Vast improvement on technology that provides advance gadgets and web applications that capture young populations interest will be additional factor for sedentary lifestyle (Wang et al., 2018). Recent studies shows that negative health related impact among children was linked to sedentary behavior, studies identified duration of exposure to gadget and movement engagement time as its main contributors (Zhang et al., 2020). Supported by Toledo-Vargas et al. (2020) stated that children and youth development was significantly affected by screen time engagement and being inactive and Zhang et al., (2020) concluded that unfavorable health consequences are linked to children physical activity engagement level.

Overall, these phenomena warrant a better understanding that can help to achieve the improvement that researchers and health practitioners were aiming which is compliance to the movement guidelines and managing the negative effect associated to sedentary lifestyle. Most of the articles recommend to develop an intervention program or activities specifically designed and anchored to the factors that affects inactivity. Therefore, this review was driven by the impression that managing physical activity and screen time engagement must be an issue and factor specific to be effective. There is a limited review article on current issues and trends on sedentary behavior. Hence, the purpose of this paper is to examine current issues and patterns in physical activity and screen time among school students' literature from 2018 – 2022 to provide knowledge and understanding on dealing inactivity and gaining insights for possible future studies.

Therefore, this study aims to generate themes according to issues and patterns that have been discuss in physical activity and screen time among school students' literature from 2028-2022 through following research question:

RQ: What are the current issues and trends on physical activity and screen time among school students discussed in the articles published from 2018 – 2022?

Materials and methods

Articles that serve as to be the main data for this review were gathered via SCOPUS, SportsDiscus, PubMed.gov searches. Mendeley was also used to organized the metadata needed in the review.

According to Braun & Clarke (2008), thematic analysis is the process of recognizing the pattern and establishing themes trough in-depth reading on the topic. Reviewing themes with the use of ATLAS.ti that was introduced by Zairul (2020) intends to analyse themes within the sets of literature. ATLAS.ti 22 was use in analysing themes across papers that were selected to identify the pattern and issues in physical activity and screen time engagement among school students. This paper aims to investigate the findings for possible reference in future sedentary behaviour studies and related fields.

Inclusion criteria was set for literature selection: 1) published from year 2018 to 2022; 2) participants was school students; 3) published in a journal and full text article; 4) English as language. Literature search through data bases, SCOPUS, SportsDiscus and PubMed.gov were done using search string as shown in table 1.

Screen time, gadget use, screen dependen*, physical activity, play, sports, game, exercise, child, prevalence, occurrence and inciden* were the key words sought in the literature search. Searching was performed on June 24, 2022 and had 1,285 articles in the results. Scopus data base generated 278 literatures, SportsDiscuss data base resulted 423 articles and PubMed.gov data base produced 584 research works.

Searched articles from SCOPUS and SportsDiscus was downloaded in excel file and word file for PubMed.gov as the data base don't have the feature of downloading articles in excel file. Abstract screening was performed for the first phase of literature selection. From the initial set of articles, 1,225 documents were excluded for not meeting the set criteria. Therefore, the remaining documents were move to the second phase of selection process which is full article screening. During this phase, 30 articles were excluded due to 1) not meeting the required participants which is being school students, 2) being incomplete paper, and 3) being inaccessible. Consequently, 30 articles were included for the review in this study (Figure 1). Remaining papers were uploaded to Mendeley to organize the data included for the review process. Metadata created in Mendeley was transferred to ATLAS.ti 22 for thematic review.

Qualitative and quantitative perspective were used to attain the results of this article. Establishing theme was done through qualitative approach, initial phase was through coding, followed by categorizing and pattern recognition so that it can be generated at different extent (Braun & Clarke, 2008). Quantitative approach was used to describe

Table 1. Search string from SCOPUS, SportsDiscus and PubMed.gov

SCOPUS	TITLE-ABS-KEY ((("screen time" OR "gadget use" OR "screen dependen*") AND child* AND (prevalence OR occurrence OR inciden*) AND ("Physical activity" OR play OR sports OR game OR exercise))) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (LANGUAGE , "English"))	278
SportsDiscus	("screen time" OR "gadget use" OR "screen dependen*") AND child* AND (prevalence OR occurrence OR inciden*) AND ("physical activity" OR play OR sports OR game OR exercise)	423
PubMed.gov	("screen time" OR "gadget use" OR "screen dependency" OR "screen dependent") AND child OR children AND (prevalence OR occurrence OR incidence OR incident) AND ("physical activity" OR play OR sports OR game OR exercise)	584

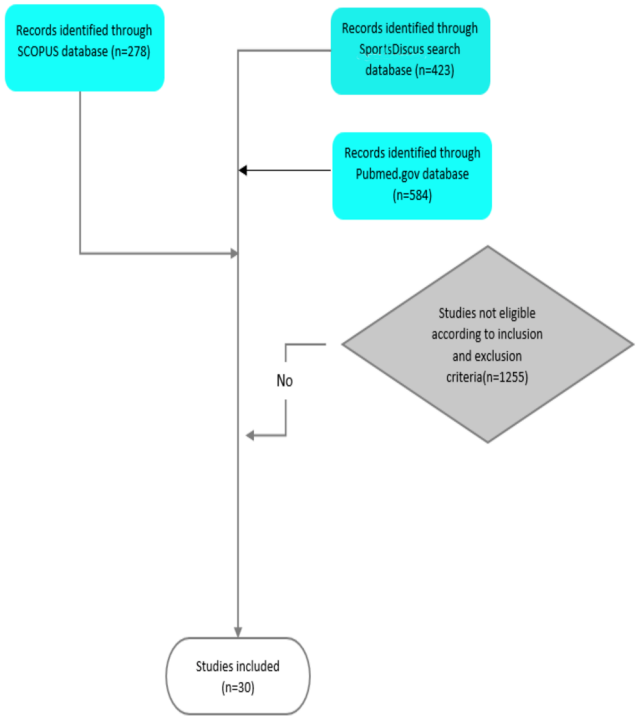

Fig. 1. Inclusion and Exclusion criteria for the selection process in thematic review

the trends and statistics in terms of literatures geographical dissemination and specified topic or themes developed within the year 2018 to 2022.

Results and discussions

Themes and patterns are discussed in this section. Literature geographical (research locale) dissemination, publication frequency by year and published documents per periodical were discussed in quantitative section as well as identifying most word used in 30 articles.

Themes and trends were identified through qualitative approach, 9 codes emerged during the initial coding of the 30 articles. Possible association and similarities in context on different codes were identified and merged some codes which was necessary. After thorough analysis of the preliminary codes, 5 themes and patterns were generated in ATLAS.ti 22 (Table 2).

Quantitative reports

During the initial phase of the review, the most frequent used words from 30 articles in word cloud impression shown in Figure 2 were "time" (1,737) which is the most mentioned, followed by "children" (1,583 times) and "physical" appeared 1543 times, "adolescent" gives 1512, "activity" 1363, "screen" 1290, "health" 1,259 and "school" 853. This analysis provides preliminary idea of what are main concerns and topics discussed in included literatures.

Patterns were analysed by geographical dissemination of literatures by country shown in Figure 3. This analysis shows that sedentary behaviour is a global issue, 26

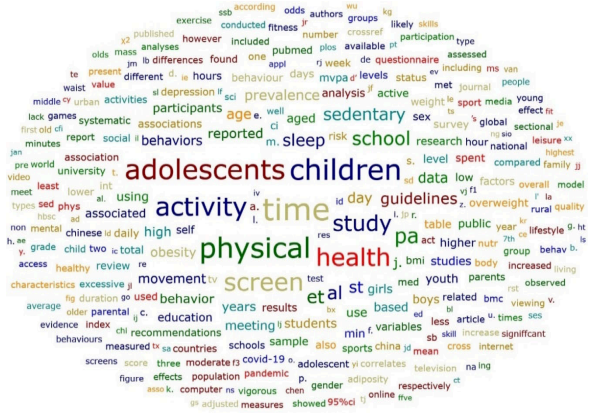

Fig. 2. Word cloud impression from 30 literatures

countries conducted research about physical activity and screen time within the year 2018 to 2022. China has the highest number of published articles (5) followed by Brazil, France and Germany with three publications. European countries (13 – Belgium, Czech Republic, Slovakia, France, Germany, Hungary, Ireland, Italy, Lithuania, Poland, Portugal, Romania, Slovenia, Spain) have the highest interest in conducting studies about sedentary lifestyle followed by Asia (Australia, Bangladesh, China, Hongkong, India, Iran, Israel, Japan, Kuwait), South America (Brazil, Chile, Colombia) and Russia having 9, 3, and 1 paper published respectively.

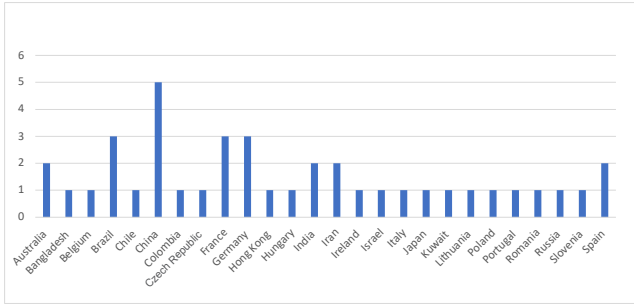

Fig. 3. Geographical dispersal of the research locale by country (2018-2022)

Included in the analysis was the current trend of published paper that discussed the five central themes generated during qualitative analysis (Table 2). The theme "engagement level: age and gender specific" was the most discussed, it was deliberated 16 times, next was "impact on adiposity" which was discussed 13 times and followed by "association to socio-economic status", "school curriculum role", and "behavioural impact" being highlighted in the discussion 12, 8, and 7 times respectively. The following central themes will be discussed in details in qualitative report section.

Added to the papers analysis was the pattern of which journals authors published their work regarding physical activity and screen time as well as the quantity of documents issued per year (table 3). According to the data, BMC Public Health and Journal of Physical Activity and Health was the most prevalent accepting 6 papers from 2018-2022. Table

Table 2. Thematic review of physical activity and screen time from 2018-2022

Themes	2018	2019	2020	2021	2022	Total
Behavioural impact	1	1	0	3	2	7
Engagement level: age and gender specific	5	2	2	4	4	16
School curriculum role	0	1	0	1	1	3
Association to socio-economic status	4	0	3	2	3	12
Impact on adiposity	1	1	2	2	0	13
Total	11	5	7	12	10	45

Table 3. Number of articles per periodical (2018-2022)

Source title	2018	2019	2020	2021	2022	Total
Applied Physiology, Nutrition and Metabolism	1					1
BMC Pediatrics				1		1
BMC Public Health	1	1	2	1	1	6
BMJ Open	1					1
European Journal of Pediatrics					1	1
European Journal of Sports Science				1		1
Frontiers in Pediatrics					1	1
Health Science Report				1		1
Healthcare (Switzerland)				1		1
International Journal of Adolescence and Youth				1		
International Journal of Environmental Research and Public Health					1	1
International Journal of Public Health					1	1
Journal of Exercise Physiology online		1				1
Journal of Physical Activity and Health	4		2			6
Journal of Sport and Health Science			1			1
Journal of Sports Science	1					1
Journal of Tropical Pediatrics		1				1
PLoS ONE				1		1
Scientific Reports			1			1
Sports	1					1
Total	9	3	6	7	5	30

also shows that 2018 has the greatest number of papers published (9 articles), next was 2021 with 7 papers followed by 2020, 2022 and 2019 having 6, 5, and 3 academic literatures published respectively.

Qualitative Reports

Central themes were identified from a thorough qualitative analysis. Figure 4 shows the overall network on how to identify the issues and patterns on physical activity and screen time engagement among school students through thematic review. Preliminary phase of analysis provided 9 initial codes, possible association and similarities in context on different codes were identified and merged some codes which was necessary. After thorough analysis of the preliminary codes, 5 themes and patterns were generated.

What are the current issues and trends on physical activity and screen time among school students discussed in the articles published from 2018-2022?

Theme 1: Behavioural impact

Figure 5 shows the results of extensive analysis of behavioral impact as one of the central themes generated. School students' behavior was discussed in 7 literatures as one of its focal points being affected by physical activity and screen time engagement.

Childhood stage is one of the crucial parts for behavioral development. According to Schaan et al. (2018) managing the impact of screen engagement to emotional well-being was vital to youth. More so, Toledo-Vargas et al. (2020) stated that children and youth development was significantly

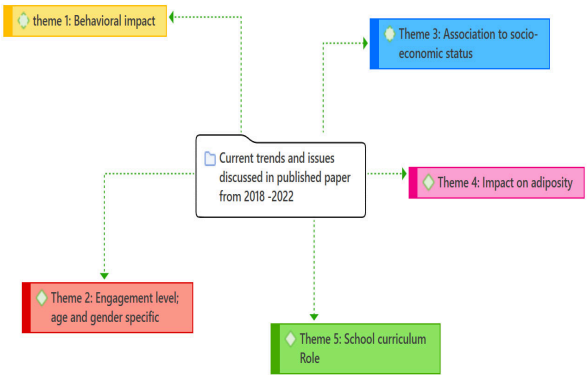

Fig. 4. Overall network for current trends and issues in physical activity and screen time among school students discussed in published litearature from 2018-2022

affected by screen time engagement and being inactive. This was supported by Rashid et al., (2021) who cited that screen activities were identified to be a prominent factor on emotional well-being status.

According to Taheri et al. (2019), inactivity and excessive screen time were link to behavioral effect among children, "depression, anger, worthlessness, confusion, anxiety and worry" are the negative impacts on child attitude. In the study conducted by Ngantcha et al., (2018) predictors of screen time (ST gadget used was associated to bullying behaviors, depression symptoms and lower life satisfaction. Additionally, excessive screen time has a negative association to depression symptoms (Moitra et al., 2021) excess screen time (ST. Similar findings was concluded by Hutzler et al. (2021) that attitude towards screen engagement was linked to violent behavior. Moreover, according to Rashid et al. (2021) excessive screen time has negative impact on students' behavior such as being irritability and hopelessness.

According to Kidokoro et al. (2022) types of screen activities should be consider in terms of behavioral impact association i.e. online platforms and applications such as games affects female middle school age student and watching videos on internet have negative effect on primary school students. On the other hand, physical activity was reported to be independently associated to behavioral impact, compliance to physical activity recommendation can decrease the occurrence of depression among secondary high school students (Kidokoro et al., 2022). This was supported by Taheri et al. (2019) which stated that negative behavioral effect was lesser among school students who actively engage on physical activity than those who do not, therefore, author concluded that engagement on movement exercises or activities has a positive impact on managing the undesirable effect on young populations behavior.

Articles from 2018 to 2022 that focuses on physical activity and screen time among school students included their discussions on behavioral impact. However, Taheri et al. (2019) posed a notion that there is a need for strong justification that excessive screen time is a main contributor for negative impacts on children and adolescents' behavior. According to Breidokienė et al., (2021) children in many countries might be engaged in more sedentary behavior and have limited possi-bilities to access the necessary level of physical activity to maintain their physical and mental health. The aim of this study was to explore the relationships between child sedentary behavior, physical activity, mental and physical health, and parental distress in a sample of Lithuanian children aged 6-14 years during the COVID-19 pandemic lockdown in March–June 2020. Parents of 306 children (52.9% female gadget use was not associated to the negative effect on students' behavior during pandemic, home environment that is majority affected by parents' actions was its main factor. This suggests that future studies can dig deeper in this particular issues.

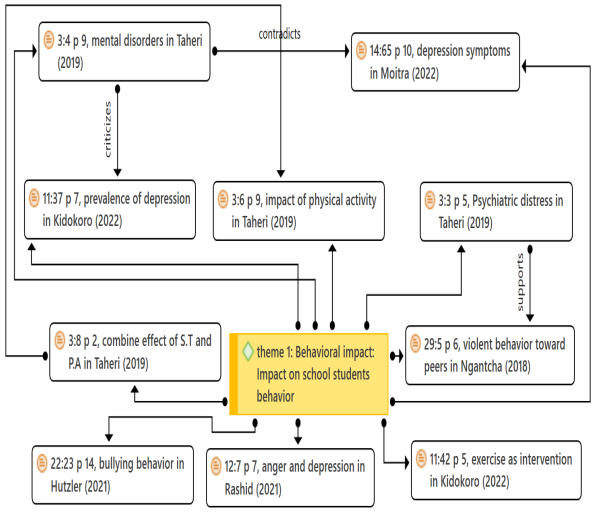

Fig. 5. Network of the behavioural impact theme

Theme 2: Engagement level: age and gender specific

This theme was the most discoursed by the authors, child developmental stage by age and gender (Figure 6) was discussed 17 times in the reviewed articles. Literatures shows that physical activity and screen time among school students were link to age and gender which revealed mixed conclusions and results.

Physical activity by gender

It was discussed that boys were more inclined to physical activity rather than girls. This was supported by Hashem et al. (2018), pointed out that physical activity engagement was higher in male than female. Similarly, Chen et al. (2018) discussed that during adolescence, girls have an issue of meeting the recommended time for physical activity and screen time, also found out that male was inclined to physical activity engagement than girls. Additionally, it was pointed out that male engage on physical activity compare to female (De Araújo et al., 2018; Tadiotto et al., 2019)BMI-z, waist circumference (WC. Hansen et al. (2022) screen time, and sleep affect the health of children and adolescents. This study described the national prevalence estimates of German youth aged 9 to 18 years who meet PA, screen time, and sleep guidelines alone and in combination and examined the associations of demographic and personal characteristics with adherence to guidelines. Data from a 2019–2020 German student survey were used (n = 15,786 also found out that male has the high tendency to meet the movement guideline recommendation.

Screen time by gender

According to Rashid et al. (2021), gender factor has a strong link in screen time engagement. In the study of Moitra et al. (2021) excess screen time (ST results pointed out that screen time was more prevalent in girls than boys. Similarly, Zhu et al. (2019) concluded that male was most likely to meet physical activity recommendation but not for screen time. On the contrary, Hardy et al. (2018) stated that gender is not a factor in terms gadget used and its association to well-being during adolescent stage. This implies that association varies when gender and age were considered as its factor.

Physical activity by age

Results of the literature shows the following pattern of physical activity during adolescents. Hardy et al. (2018) discussed that movement exercise and its impact was considerable during adolescent stage. Similarly, Scully et al. (2022) stated that compliance to physical activity among adolescent is a problem. However, this was contradicted by the results in the study conducted by Chen et al. (2018) discussing that the age is not considerable aspect when it comes to inactivity among school students.

Screen time by age

Prevalence of excessive screen time in relation to school students age was observed by the authors during adolescence. Hardy et al. (2018) pointed out that gadget used was prevalent to adolescent compare to children. Additionally, it was discussed that excessive screen time was prevalent in adolescent (Moitra & Madan, 2022 and screen addiction behaviors in 10-15 years old adolescents in Mumbai during the COVID-19 pandemic and 2; Schaan et al., 2018). Similarly, study conducted by Rubín et al. (2020) stated that young

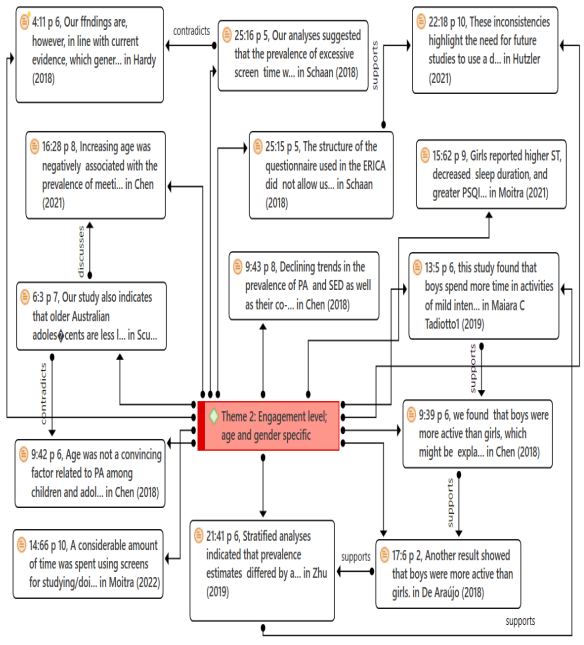

Fig. 6. Network of engagement level: age and gender specific theme

population are most likely to comply on physical activity and screen time guidelines compare to teen ager.

To address the issue on compliance of movement guidelines. Chen et al. (2018) suggests that approaches in increasing physical activity and limiting screen time must be plan and organized according to gender needs and assessments. Similarly, intervention must be based on gender and age specific to increase its effectivity (Kidokoro et al., 2022).

Theme 3: Association to socio-economic status

Socio-economic status discussed in the literatures were parents educational background, family income and community location classification (Figure 7).

Understanding the role and impact of socio-economic status in compliance to movement guideline is important. According to Chen et al. (2021), socio-economic status among factors linked to sedentary lifestyle was difficult to amend. However, awareness on different social and economic condition is significant to understand its association to sedentary lifestyle together with its undesirable health impact (Hashem et al., 2018).

Parents educational background

Family, including parental attributes had a significant role in achieving or meeting the movement guideline recommendation (Rubín et al., 2020). According to Rashid et al. (2021) screen time was affected by higher socio -economic status such as education level. Similarly, screen time engagement and participation in physical activity by school students was greatly affected by parent's educational background (Chen et al., 2021). This was supported by Hashem et al. (2018) who specified that excessive screen time was linked to mother's educational background and pointed out that educational background of father was not linked to inactivity. Educational level may also be associated to movement guideline awareness, (Chen et al., 2021; Wang et al., 2018), discussed that parent's awareness on the limit and suggested number of hours in terms of physical activity and screen time engagement has positive link. More so, Ngantcha et al. (2018) predictors of screen time (ST stated that guidance from parents is a vital factor in terms of managing and controlling excessive screen time engagement.

Family income

Having full access to digital technology devices and internet can be consider as one of the causes for excessive screen time. Rashid et al. (2021) concluded that screen time was affected by higher socio -economic status such as income. Similarly, Chen et al. (2021) stated that screen time engagement and participation in physical activity by school students was greatly affected by parent's salary. Additionally, (predictors of screen time (STGonzález et al., 2022; Ngantcha et al., 2018)predictors of screen time (ST stated that excessive screen time was highly prevalent to students coming from rich families than to those children come from low-income family. Also, according to Zhang et al. (2020) health problem linked to sedentary lifestyle was associated to income level of the family.

Economic status of the community

According to Schaan et al. (2018) economic classification of the community was linked to screen time engagement. Being a developed country plays a role in terms of decrease compliance in physical activity for them having an extensive improvement on technology (Hashem et al., 2018). Zhang et al. (2020) found out children from urban part was most likely to be affected by health-related impact brought by sedentary lifestyle. In another study, Toledo-Vargas et al. (2020) stressed out that some communities were having a hard time to meet the recommended guidelines for movement and associating it to being a low-income community. Similar to study conducted by Scully et al. (2022) who stated that high prevalence of inactivity was observed to among school students living socio -economic deprived community. More so, Rashid et al. (2021) found out that community economic classification has a substantial effect in terms of screen time engagement.

According to Chen et al. (2021), socio-economic status among factors linked to sedentary lifestyle was difficult to amend. Therefore, participation of the community leaders and authorities in planning and organizing intervention strategies is important.

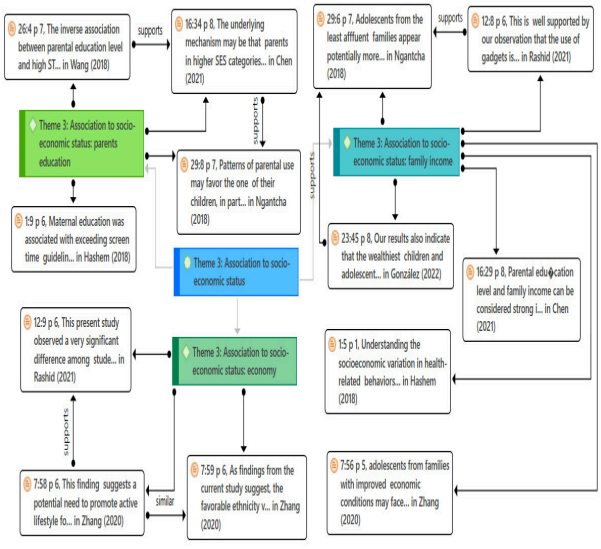

Fig. 7. Network of association to socio-economic status theme

Theme 4: Impact on adiposity

Another theme generated in this review was about children adiposity (Figure 8). Authors investigated the association of physical activity and excessive screen time among school students' weight.

According to Hadianfard et al. (2021) school students experiencing excessive screen time and being sedentary were most likely to gain weight. Similarly, Taheri et al. (2019) reported that being inactive and prolong gadget use was associated to being overweight. Another study supports the previous findings that Sedentary lifestyle i.e. inactivity and excessive screen time was associated to adiposity (Moitra et al., 2021) excess screen time (ST).

Movement guidelines were recommended by group of health professionals to manage or control childhood obesity. Engagement on movement exercises or activities have positive effect in overweight and obesity prevention (Cabanas-Sánchez et al., 2019). Compliance on the active lifestyle recommendation is a factor in managing child's weight. This was supported by Shi et al. (2020) stated that compliance in movement guidelines was an indicator to body mass index (BMI) and Zhang et al., (2020) concluded that adiposity was linked to recommendation non-compliance. Therefore, sedentary behavior such as physical inactivity and screen time engagement must be examined dependently. According to (Chen et al., 2021), physical activity was not a significant predictor for childhood adiposity, but combination of physical activity and screen behavior instead.

Another factor that the authors identify was habit of eating during excessive screen time. González et al. (2022), reported that eating during gadget used was link to adiposity. Similarly, Wang et al. (2018) stated that food advertisement during screen engagement might be a factor in consuming unhealthy foods that was link to childhood adiposity.

However, several authors contradict that compliance to movement guidelines is a significant factor in childhood obesity. O'brien et al. (2018) concluded that compliance to movement guidelines was not an indicator of middle school students body mass index (BMI). Similarly, Cabanas-Sánchez et al. (2019) concluded that prolong gadget used was not the significant factor contributing to being overweight.

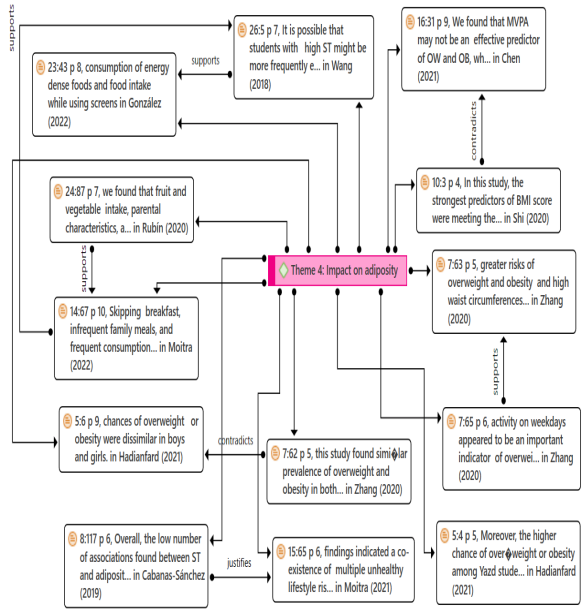

Fig. 8. Network of impact on adiposity theme

Theme 5: School curriculum role (Figure 9)

Physical education aims to achieve fitness through body movement such as engaging on physical exercise, organize sports and daily activities that requires energy. Low level of compliance in movement guidelines among school students was one of the pressing issues towards health. Authors of selected literatures discussed the possible role of schools in counter measuring the sedentary lifestyle and its effect to children.

According to Moitra et al. (2021) excess screen time (ST) schools can play a significant role in promoting physical

activities such as constructing and integrating specific approaches to physical education curriculum, providing student support in term of sports facilities availability as well as coaching

and counseling. This was supported by Kovacs et al. (2022) few data on how the COVID-19 pandemic and restrictions affected children's physical activity in Europe have been published. This study examined the prevalence and correlates of physical activity and screen time from a large sample of European children during the COVID-19 pandemic to inform strategies and provide adequate mitigation measures. An online survey was conducted using convenience sampling from 15 May to 22 June, 2020. Parents were eligible if they resided in one of the survey countries and their children aged 6-18 years. 8395 children were included (median age [IQR], 13 [10-15] years; 47% boys; 57.6% urban residents; 15.5% in self-isolation, stated that the schools must have an organized activity that will contribute to the compliance of recommended movement guidelines among school students. Aside from participation to structured physical activities, awareness and understanding the context of sedentary lifestyle is important for effective counter measure strategies. Similarly, Zhang et al. (2020) pointed reinforcing physical activity engagement among school students can be integrated to physical education subjects and suggested that rural schools to have improve operation in open space activities.

Kovacs et al. (2022) few data on how the COVID-19 pandemic and restrictions affected children's physical activity in Europe have been published. This study examined the prevalence and correlates of physical activity and screen time from a large sample of European children during the COVID-19 pandemic to inform strategies and provide adequate mitigation measures. An online survey was conducted using convenience sampling from 15 May to 22 June, 2020. Parents were eligible if they resided in one of the survey countries and their children aged 6-18 years. 8395 children were included (median age [IQR], 13 [10-15] years; 47% boys; 57.6% urban residents; 15.5% in self-isolation reported that physical education lessons play a huge role in keeping school students engage in physical activities, specifically during pandemic, active participation in physical education has significant association in complying the recommended movement guidelines. Due to prevalence of inactivity among school students, promotion of physical activity engagement is starting to gain attention as curriculum agenda (Hutzler et al., 2021). Similarly, Zhu et al. (2019) pointed out that results from previous literatures suggests that school's curriculum and approaches towards sedentary lifestyle plays a significant part.

Association of academic excessive screen time to school students' health was also discussed. According to Breidokienė et al. (2021) children in many countries might be engaged in more sedentary behavior and have limited possi-bilities to access the necessary level of physical activity to maintain their physical and mental health. The aim of this study was to explore the relationships between child sedentary behavior, physical activity, mental and physical health, and parental distress in a sample of Lithuanian children aged 6-14 years during the COVID-19 pandemic lockdown in March-June 2020. Parents of 306 children (52.9% female, excessive academic related gadget used was link to adverse outcome on health. Additionally, Hadianfard et al., (2021) stated excessive engagement on homework among school students have a negative association on health. Nevertheless, non-academic screen time and school subjects related gadget used is another context for sedentary lifestyle that might be discuss in future researches.

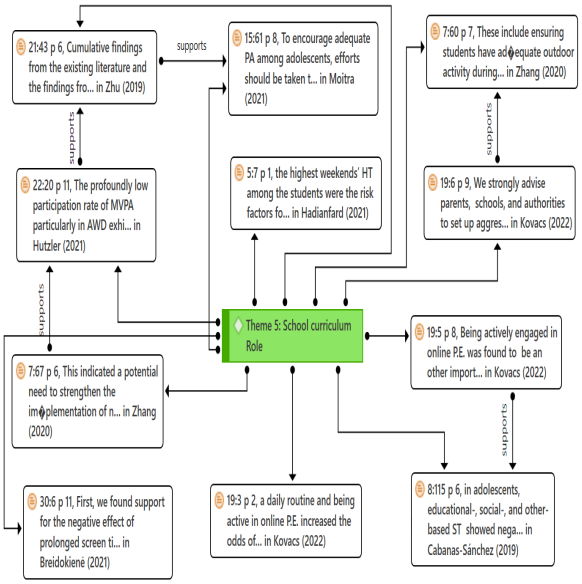

Fig. 9. Network of school curriculum role theme

Conclusions and future study

This paper highlights the current issues and patterns in physical activity and screen time engagement among school students. Sedentary lifestyle is a current health global issue among children. Movement guidelines were crafted to counter measure the effect of prolong gadget used and inactivity. The result shows that non-compliance to active lifestyle recommendation was still prevalent among school students. Despite of global interest to the topic, there is a limited review paper that focus on the current issues and pattern of sedentary behaviour. This article found out that recent literatures focused on the factors of having sedentary lifestyle and its influence to young populations health. Effect of excessive screen time to individuals' behaviour is one of the focal interests from the authors and due to mixed research outcomes, this warrants exploration for future studies. Findings on the patterns to engagement level: age and gender specific, suggests that strategies and approaches to promote physical activities and counter-measure the negative health impact of excessive screen time must be gender and age specific. Further, socio-economic issue can be address in partnership with community leaders and authorities. Additionally, contradicting results from adiposity and screen time engagement suggests that there is a need to investigate this factor in upcoming researches. Lastly, school curriculum is another factor that capture the authors interest in terms of promoting healthy and active lifestyle. It is suggested that strategies must be integrated to physical education and school framework as well. In summary, future study should explore on how would the generated issues and patterns can be integrated to a large-scale intervention program and test its effectivity as well.

Acknowledgment

We express our appreciation to those who support us for this study be possible.

Conflict of interest

The authors declare that they have no conflict of interest.

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СУЧАСНІ ТЕНДЕНЦІЇ ТА ПРОБЛЕМИ, ПОВ'ЯЗАНІ З ПРОВЕДЕННЯМ ЧАСУ ПЕРЕД ЕКРАНОМ ТА ЗАНЯТТЯМИ ФІЗИЧНОЮ ДІЯЛЬНІСТЮ СЕРЕД ШКОЛЯРІВ: ТЕМАТИЧНИЙ ОГЛЯД

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 3 табл., 9 рис., 31 джерело.

Мета дослідження. Відсутність фізичної активності та надмірне проведення часу перед екраном серед дітей шкільного віку є глобальною проблемою, яка, як відомо, пов'язана з малорухливим способом життя. Було проведено кілька досліджень щодо малорухливої поведінки дітей, але досі немає оглядової статті, у якій аналізують поточні тенденції та проблеми, пов'язані з відсутністю фізичної активності та надмірним часом перед екраном. Метою цього дослідження є визначення поточних проблем і тенденцій стосовно занять фізичною діяльністю та проведення часу перед екраном серед школярів, які обговорюються в статтях, опублікованих у 2018–2022 роках.

Матеріали та методи. У цьому дослідженні використовували кількісні та якісні методи. Кількісний підхід використовували для пояснення тенденцій і статистичних даних щодо географічного поширення літератури та визначеної теми чи тем, розроблених протягом 2018–2022 років. Якісний підхід застосовували для встановлення шаблонів і тем. У цьому дослідженні теми та шаблони генерують зі статей, опублікованих з 2018 по 2022 рік. Тридцять статей було включено через базу даних за пошуком із баз даних SCOPUS, SportsDiscus та PubMed.gov. Тематичний аналіз виконували за допомогою програмного забезпечення ATLAS.ti 22.

Результати. Було згенеровано п'ять основних тем: 1) вплив на поведінку; 2) рівень залучення: залежно від віку та статі; 3) асоціація з соціально-економічним статусом; 4) вплив на ожиріння; 5) роль шкільної програми.

Висновки. Надмірне проведення часу перед екраном і відсутність фізичної активності по-різному впливають на здоров'я молоді. Розуміння шаблонів і тем, згенерованих у цьому дослідженні, буде корисним для розробки програми активності, яка стане заходом протидії негативному впливу, пов'язаному з малорухливим способом життя.

Ключові слова: час перед екраном, фізична активність, малорухливий спосіб життя, діти.

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REVIEW ARTICLE

EFFECTS OF POST-ACTIVATION PERFORMANCE ENHANCEMENT ON COMPETITIVE SWIMMERS' PERFORMANCE: A SYSTEMATIC REVIEW

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Abstract

Study purpose. The aim of this systematic review was to evaluate the effects of post-activation potentiation/post-activation performance enhancement (PAP/PAPE) warm-up protocols on swimmers' performance.

Materials and methods. The searches were carried out on the electronic database PubMed, Scopus, Web of Science, and EBSCO platforms. Studies from 2010 to May 2022 related to PAP/PAPE and its effect on swimming performance in swimmers aged between 18 and 35 were included.

Results. Nine of 333 studies were included in this review. In two studies, peak thrust improved by 13% to 19% for PAP vs non-PAP and by 3% on performance. One study showed improvements by 10% on speed and speed fluctuation in 25 m all-out PAP vs non-PAP. Rate of force development (RFD) 15 m maximum effort was higher for dry land warm up (DLWU) than swimming warm up (SWU). One study had higher velocity in 5 m for repetition maximum warm-up (RMWU) and eccentric fly-wheel warm-up (EWU) vs SWU. One study demonstrated enhancements for upper-body PAP (UBPAP), low-body PAP (LBPAP) and MIX (UBPAP/LBPAP) vs warm up based on general exercises (GEN) in time to 25 m freestyle (T25FS). Two studies found improvements for band squats PAP compared to swimming specific warm up (SSWU) in time to 15 m. One study demonstrated that PAP trial (PAPT) was faster than control time trial (CTT) in 50 m and 100 m freestyle trial. Dive velocity (DV) was faster for RMWU/EWU vs SWU. One study showed significant increase in power vertical force (PVF) and power horizontal force (PHF) after the PAP vs SSWU.

Conclusions. PAP/PAPE is one more tool that can be beneficial if adapted to the conditions of swimmers, controlling fatigue levels, where it is performed (land or water), and most importantly, described by many coaches, the specificity of movement.

Keywords: post-activation potentiation, post-activation performance enhancement, swimming performance.

Introduction

The investigation about the swimming sport performance is important to analyze swimmer´s progression and stability between competitions and races, helping coaches define realistic goals and select appropriate training methods to optimize performance. There are a countless training methods and systems to improve swimming performance, whereas warming up before physical exercise is commonly accepted as fundamental previous practice to optimize performance (Aagaard et al., 2002; Barbosa et al., 2020; Beato et al., 2019). However, specifically in swimming, studies on the effects of warming are scarce, which could be due to the pool

environment, which has high humidity and temperature, which increases the complexity of the warm-up procedure (Neiva et al., 2014). Swimming is a complex sport where the whole body as a whole participates in propulsion, with the upper body being in charge of up to 90% of it (De Martino & Rodeo, 2018). Propulsive power in the freestyle is 80% for the stroke and 20% for the kick (King, 1995), which makes it important to know where to focus the main activation in the work leading up to the main activity. The warm-up is specifically intended to: 1) improve muscle dynamics in order to be less prone to injury and 2) prepare the athlete for the demands of exercise (Shrier, 2008). Additionally, 1° increase in body temperature may slightly increase tolerance to muscle failure and should generally be until there is some sweating (Cohen et al., 2015; Cuenca-Fernandez, Batalha et al., 2020; Cuenca-Fernandez, Gay et al., 2020). There are many types of warm-ups, which can be active or passive (Aagaard et al., 2002). Passive warming refers to raising body temperature with objects external to the body, such as a hot shower, warm pillows, or saunas (Shrier, 2008), while active warming is basically raising body temperature by physical activity that generally involves non-specific movements such as jogging, cycling and/or calisthenics (Prentice & Shellock, 1985). One of the widely used warm-up methods in sports is post-activation potentiation (PAP). PAP is a physiological phenomenon associated with an acute improvement in muscle performance after a protocol of neuromuscular, mechanical, and biomechanical changes that may temporarily induce performance enhancement, but the exact underlying mechanism is not fully understood (Beato et al., 2019). The most strongly supported explanation for the effects of PAP relates to the large number of cross-bridges as a result of myosin regulatory light chain phosphorylation during muscle contraction (Beato et al., 2019; Boullosa et al., 2018). In addition, it is proposed that PAP is the result of increased sensitivity of contractile proteins to calcium (Ca2+), released from the sarcoplasmic reticulum, the result of a cascade of events leading to an improvement in muscle response (Cuenca-Fernandez et al., 2017; De Martino & Rodeo, 2018). In recent years, the taxonomy of this term has been modified, in order to find one that best suits the characteristics of this type of pre-performance activation.

PAPE is the term that has come to replace PAP since when talking about PAP it only refers to a physiological mechanism responsible for improving performance in warm-up (Boullosa et al., 2018). The reasons behind this dualism (PAP vs PAPE) refer to the association of PAP with verification of evoked contraction, which, in turn, would be related to phosphorylation of myosin regulatory light chain (MLC) during a very short period of time (<5 min) (Cuenca-Fernandez et al., 2017). On the contrary, PAPE would be associated with increases in voluntary performance, mainly as a consequence of other potential mechanisms (for example, temperature, water content) in longer time windows (>5 min) (Blazevich & Babault, 2019). This review will refer to PAP/PAPE as one, since the investigations of potentiation protocols are referred to the PAP concept and the newer ones as PAPE. Studies on the effects of warming are scarce, specifically in swimming, which could be due to the pool environment with high humidity and temperature, increasing the complexity of warm-up procedure (Neiva et al., 2014).

Swimming is a complex sport where the whole body as a whole participates in propulsion, with the upper body being in charge of up to 90% of it (De Martino & Rodeo, 2018). In the freestyle, propulsive power is 80% for the stroke and 20% for the kick (King, 1995), indicating that main activation in the work should correspond to the main activity. Most of the few studies about swimming warm-ups provided information on temperature of the aquatic environment, training with elastic bands (dry), warm-up effects in different distance protocols and intensities (Czelusniak et al., 2021), but the information related to swimming warm-ups PAP/PAPE is limited, but not in other sports, where over the past decade have demonstrated positive changes in performance, particularly in sprint or highly power-derived events (Seitz & Haff, 2016).

PAP/PAPE protocols are increasing popularity in swimming sport, being a good solution for shorter periods for activation, because the competition environment tends to have a long waiting time between warm-up and competition. It is also necessary to consider the distances in which a PAP/PAPE protocol can have an effect, since the tests of longer duration and/or greater distance require resistance to force and not mainly maximum explosive speed in short periods (Boullosa et al., 2018).

Given the few knowledge about the effect of swimming warm-ups PAP/PAPE on swimmer´s performance and the swimming warm-ups PAP/PAPE could be a positive method to implement in competition. The objective of the following systematic review aimed to evaluated the effects of PAP/PAPE warm-up protocols on swimmer´s performance.

Materials and methods

Search strategy and study selection

This review aligns with the Preferred Reporting Items for Systematic Reviews and MetaAnalyses (PRISMA) guidelines (Page & Moher, 2017) and was registered with the International Prospective Register of Systematic Reviews (PROSPERO) (registration number: CRD42022340696). The searches were carried out in the following electronic database platforms from the year 2010 to May 2022 PubMed, Scopus, Web of Science, and EBSCO. The search strategy was not limited by language and included the following keywords: (1) Postactivation Performance Enhancement and post activation potentation; (2) Swimmers and (3) Swimming performance (Table 1). For the search of these keywords, the boolean term (AND) and (OR) was used, such as example "Post activation Performance Enhancement OR Post activation Potentation AND swimmers AND swimming performance" (Table 1).

The selection procedures are shown in Figure 1 and the total references were obtained and stored on an EndNote (EndnoteX9, Thomson Reuters, San Francisco, California) database. Then, the duplicates were removed and a filter of articles by titles and abstracts was carried out. After that, the remaining articles were completely analysed and those that did not meet the inclusion criteria were eliminated. Finally, an integral reading and analysis of all the articles that entered the review was made (Figure 1). No authors were contacted for obtaining further information whenever there was data missing.

Eligibility criteria

Studies were considered eligible if they met all the following criteria: a) The research involved an intervention study with acute effect, where the PAP/PAPE characteristics (the type of movements involved, intensity, volume, work-to-recovery ratio (WRR) between PAP/PAPE and trial and duration of the intervention) and control group warm-up protocols were given; b) The PAP/PAPE response were evaluated in swimming pool by maximum speed trial (m/s or total time race) and collecting other swimming performance variables (Rate of Force Development (RFD) and/or power-output (PO); c) Randomized designs with controlled trials (RCT) and RCT Crossover trials were considered. Groups may be mixed or only one sex; d). Outcome measures involved post warm- up, with any swimming race style (From start race up to 5, 15, 25, 50 or 100 m evaluated in race time); e) Participants of 18 to 35 years healthy and without diagnosed disease or injury; f) Articles with focus reviews, papers published in conference, dissertations, thesis or in non-peer-reviewed journals were excluded; g) Only research involving humans and written in English and Spanish were considered.

Study selection

The selection criteria were based on the on the population, intervention, comparison and outcomes (PICO) criteria used to define the characteristics of the included studies. The inclusion was evaluated according to the criteria (PICO): Population: Studies with competitive level athletes aged between 18 and 35 years. Intervention: Studies that analyze the effects of PAP/PAPE on the performance of swimmers. Comparator: Studies with active control group of specific swimming warm-up and/or traditional No-PAP/PAPE; Study design: studies RCTs and RCT crossover were included. Outcomes: Measures involved post warm-up, with any swimming race style or derive swimming race (From start race up to 5, 15, 25, 50 or 100 m evaluated in race time). Exclusion: Studies that present supplementation, doping, pathologies, injuries and/or injuries in the last 6 months. Also reviews, dissertations, theses, non-peer-reviewed journals, conference citations, and/or commentaries were excluded. One author completed the screening and selection of studies in May 2022. First, duplicates were removed and titles and abstracts were examined to identify studies that met the inclusion criteria. Second, the full texts of the eligible studies based on the screened studies were read by three authors (EM, AB and LF) to determine their final inclusion. Disagreements between the three reviewers were resolved through a consensus meeting between the four authors in October 2022. Finally, articles on acute PAP/PAPE effects on swimmers and swimming performance were included in this review. Figure 1 provides an overview of the selection process.

Data extraction process and data synthesis

The full texts were analyzed and after confirming the eligibility criteria, the following data were extracted: (a) First authors name, publication year, and country of data collection; (b) Participants age and sample size by group; (c) Study design and/or group assignment; (d) Characteristics of PAP/PAPE intervention (exercises intensity in individual maximus repetition percentage, sets, repetitions); (e) Characteristics of control group warm up intervention and (f) Main findings result related to pre-defined outcomes from the experimental group and control group, comparing each other. Data from the included studies were extracted independently by one reviewer (EM), consulted to other researchers (AB and LF) and any discrepancies were resolved by consulting a third reviewer (TRA).

Assessment of risk of bias

Three authors (EM, AB, LF) assessed study quality according to the PEDro scale (Maher et al., 2008) in each included study, shown in Table 2. Any disagreements were discussed with a third reviewer (TRA) until consensus was reached. The total PEDro score is obtained by adding points describing the quality of papers, classified with following score points: 9-10 (excellent), 6-8 (good), 4-5 (fair), and ≤3 (poor).

Results

Study selection

The search strategy yielded a total of 333 references, 17 were eliminated due to duplicates, 299 were removed by title and three by abstract. Four articles were removed by inclusion criteria (two for mean age and two for study type). Then, one articles were eliminated for other reasons described in figure 1. Nine articles were included for the presented review (Figure 1). Table 1 summarizes the characteristics and results of the study.

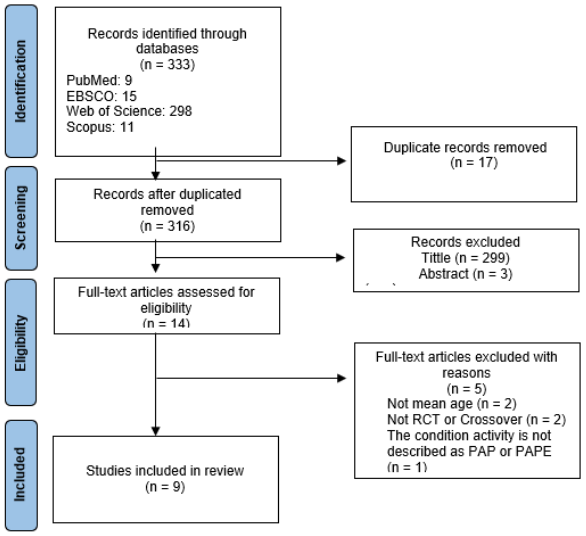

Fig. 1. PRISMA flow diagram of each stage of the study selection about the effects of post-activation potentiation/post-activation performance enhancement (PAP/PAPE) warm-up protocols on swimmer´s performance

Studies description

All the included articles assessed the effects of a PAP/PAPE activation protocol on swimming performance variables; an overview of the included studies is provided in Table 1. The present review found that the number of participants

Table 1. Summary table of studies

Author/Year/ Country/Study Type	Sample	Experimental Group intervention	Control Group intervention	Assessments	Main Results
Barbosa et al., 2020 Portugal Crossover RCT	n= 12 CS ♂= 12 Age= 23.50 ± 3.35 years old	PAP: 700 mt + 5 min recovery + PAP 2x5 one arm Band pull /2 min recovery between arm sets	non-PAP: 1400 mt	25-m all out.	Peak thrust and mean thrust were better for PAP group vs non-PAP group. Speed and speed fluctuation have no significant differences
Cuenca-Fernández et al., 2020a Spain RCT	n= 20 CS ♂= 11 Age= 18.02 ± 1.39 years old	400 mt SWU + DLWU (3 pull over al 85% 1MR)	SWU: 400 mt (2×50-m front crawl swim (12'5 fast/12'5 smooth)	15-m ME.	RFD showed to be higher after DLWU compared to SWU. The force, acceleration and power values were lower in DLWU compared to SWU
Cuenca-Fernández et al., 2020b Spain RCT	n= 14 CS ♂= 7 ♀= 7 Age= 18.37 ± 1.41 years old	PAPE: 1 x 4 ME arm-pull similar to arm-stroke + swimming start position movement (Yo-Yo Squat).	SWU: 400 m assorted styles + two block start + 4 min dynamic stretching	50-m ME.	15 m time and speed were better for PAPE comparing to SWU but to in other distances
Cuenca-Fernández et al., 2018 Spain Crossover RCT	n= 17 CS ♂= 11 Age= 18.42 ± 1.39 years old	RMWU: 1 x 3 85% 1 RM lunge + 1 x 3 85% 1RM arm stroke EWU: 1 x 4 Fly-Wheel. (Lower and upper limbs)	SWU: 400-m standard warm up + dynamic stretching	50m trial ME	BT: No differences DD: No differences DV: EWU Faster than SWU and RMWU UUSASS: No differences UUSAT: No differences T5-50M: T5 faster in both activation protocols compared SWU. No differences between protocols in 50M T25M: No differences between protocols V5M-: V5 faster in both activation protocols vs SWU V50M: no differences between protocols.
Hancock et al., 2015 United States RCT	n= 30 CS ♂= 15 ♀= 15 Age= 19-22 years old	PAPT: 900 mt WU + PAP (1 x 4 x 10-m swim using dynamic resistive sprints while attached to a Total Performance Power Rack)	CTT: 900 mt WU + 100 mt sprint	100-m freestyle ME	PAP trial was significantly faster than control trial for the first 50-m, second 50-m and 100-m
Kilduff et al., 2011 England Crossover RCT	n= 9 CS ♂= 7 ♀= 2 Age= 22 ± 2 years old	PAP (1 x 3 - 87% 1MR) squats	1.300-m specific WU	PVH and PHF in Time to 15-m ME	No significant difference between SS performance PAP stimulus compared to the DS preceded by the SSWU regard time to 15 m. Significant increase in both PVF and PHF after the PAP stimulus warm-up vs SSWU.
Ng et al., 2020 Egypt Crossover RCT	n= 16 CS ♂= 16 Age= 22.13 ± 3.84 years old	PAP warm-up: 700 mts + 2 x 5 CMJ	No PAP warm-up: 1400 m	25-m all out	Peak thrust increased by 15% in PAP vs non-PAP. Large and significant differences in speed and speed fluctuation in 10% in PAP compared with non-PAP
Sánchez et al., 2020 Spain Counterbalanced RCT	n= 10 CS ♂= 11 Age= 20,8 ± 4,7 years old	COM: 900-m freestyle (2 x 400-m/4x25-m sprint) UBPAP: COM + 3 min recovery + 1 x 6 eccentrics high pull MV. LBPAP: COM + 3 min recovery + 1 x 6 eccentric ½ squat MV. UBPAP/LBPAP mix: COM + 3 min recovery + 1 x 6 eccentric high pull MV + 1 x 6 eccentric ½ squats MV.	GEN: 5 min Upper and Lower body Dynamic stretching + 450-m freestyle 70-80% MHR	25-m freestyle ME	COM, UBPAP, LBPAP and UBPAP/LBPAP mix faster than GEN COM + PAP (UBPAP/ LBPAP mix) were no differences in effect in T25FS

Table 1 (continued)

Autor/year/Study Type	Sample	Experimental Group intervention	Control Group intervention	Assessments	Main Results
Waddingham et al., 2018 England Crossover RCT	n= 11 CS ♂= 8 ♀= 3 Age= 18–22 years old	1: Band Squats (3x3) 2: Weighted Jumps (3x3) 3: Drop jump 45-cm (2x5)	SSWU 400-m swims 4x50 kick/drill 4x50 freestyle, rest 15 s (1-build, 2-25 fast/25 easy, 3-easy, and 4-pace) 2x15 m start race condition	15-m swimming start ME	15-m start times were significantly quicker in the band squat protocol compared with the sport-specific warm-up condition

BT: Block time; CMJ: countermovement jump; CS; Competitive swimmers; CTT: Control time trial; DD: dive distance; DLWU: Dry land warm up; DS: dive start; DV: dive velocity; ; EWU: eccentric fly-wheel warm-up; GEN: warm up based on general exercises; LBPAP: Lower body PAP; m: metros; ME: Maximum effort; MHR: Maximum heart rate; MR: Maximum repetitions; MV: Maximum velocity; PAP; Post activation potentiation; PAPE; Post activation performance enhancement; PAPT: PAP trial; PHF: power horizontal force; PVF: power vertical force; RMWU: Repetition maximum warm-up; RCT: Randomized controlled trial; RFD: rate of force development; SS: Swimming start; SSWU: swimming specific warm up; SWU: standard warm-up; T5M-50M: time to 5 and 50-m; T25M: time to 25-m; T25FS: Time to 25 m freestyle; UBPAP: Upper body PAP; UUSAT: underwater undulatory swimming after turn; UUSASS: Underwater Undulatory Swimming After swim start; V5-V50M: Velocity to 5-m and 50-m; WU: Warm up; ♂, boys; ♀, girls.

in each study ranged from 9 to 30, with ages ranging from 18 to 26 years. These studies were conducted in England (Neiva et al., 2014; Page & Moher, 2017), Spain (Maher et al., 2008; McCrary et al., 2015; McGowan et al., 2015; Ørtenblad et al., 2000) United State (Hancock et al., 2015), Egypt (Ng et al., 2020), Portugal (Barbosa, Jia Wen Yam, Danny Lum, 2020). All the included studies evaluated and compared the acute warm up PAP/PAPE effects with a control group which performed a traditional warm-up. All participants were informed about the study procedure and an introducing session was provided to familiarization in a different day previous their assessments.

The type of exercise intervention consisted in submaximal singles efforts session protocols compared with a traditional swimming warm up protocol. In terms of the recovery between warm up and trial, different times were given to each swimmer in order to obtain their best recovery duration, within a range between 15 secs to 12 min. Additionally, the swimming variables assessed: were 15-m start; FT; T5M; T15M; T25M; T50M; T100M; BT; SS performance; DS; PVF; PHF; BT; RFD; DD; DV; UUSASS; UUSAT; V5M; V50M. Two studies assessed different performance swimming variables in order only to obtain the arm-pull in front-crawl performance while the legs held a pull-buoy (Barbosa, Jia Wen Yam, Danny Lum, 2020) and the flutter kick using a kickboard on hands (Ng et al., 2020). Two studies (MacIntosh et al., 2012; Ng et al., 2020) measured swimming variables; Peak thrust and speed and speed fluctuation in 25 m all-out. Peak thrust improved 13% to 19% (MacIntosh et al., 2012; Ng et al., 2020), only 3% on performance (MacIntosh et al., 2012) and have no differences on speed and speed fluctuation in 25 m all-out (MacIntosh et al., 2012) while in other study improvement by 10% (Ng et al., 2020). One Study (Maffiuletti et al., 2016) assessed the rate of force development and power in 15 m maximum effort, where experimental group (DLWU) showed to be higher than active control (SWU) when is performed in dryland, but not in force, acceleration and power values, which could not improve performance. Two studies found improvements on time to 15 m (Maher et al., 2008; Page & Moher, 2017). Two studies (McCrary et al., 2015; Neiva et al., 2014) showed no significative differences in the same distance (15 m) for experimental groups (EWU and RMWU) vs active control group (SWU). The same study (Cuenca-Fernández et al., 2019) showed that EWU and RMWU groups were faster than SWU on time to 5 m. One study (Sánchez et al., 2020) demonstrated enhances in experimental groups (UBPAPA, LBPAP and MIX) vs active control group (GEN) in 25 m speed (T25FS). Two studies (Maher et al., 2008; McCrary et al., 2015) found no differences in 25 m and 50 m between experimental group (PAP/PAPE; RMWU; EWU) vs active control group (SWU). One study (Hancock et al., 2015) demonstrated that PAP/PAPE was faster than control trial in 50 m and 100 m freestyle trial. One study (Cuenca-Fernández et al., 2019) had higher velocity in 5 m for experimental conditions (RMWU and EWU) vs active control condition (SWU). One study (Cuenca-Fernández et al., 2019) did not show differences between protocols in velocity for 50 m. One study (McCrary et al., 2015) had no differences in BT, DD. DV was faster, UUSASS and UUSAT had no differences between experimental groups and control active group. One study (Kilduff et al., 2011) showed significant increase in both PVF and PHF after the PAP/PAPE stimulus warm-up vs control active group (SSWU).

Discussion

The purpose of this systematic review was to evaluate the effects of PAP/PAPE and on swimming performance. PAP/PAPE is a relatively new phenomenon in sport and exercise science, which provides coaches with a good tool with which to impact sport and performance (Sarramian et al., 2015). It was found that the type of PAP/PAPE protocols (dryland, water, upper body, lower body or a combination of the two limbs, etc.) had effect on performance. Yet, in all studies, it was found that after PAP/PAPE warm-up, protocol swimmers improve at least one swimming variable on swimming performance. As is already known, the warm up is a well-accepted activity in most sport and impacts

Table 2. Quality assessment/ PEDRo Scale

Criteria:	Selection				Comparability			Outcomes					
Studies:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Score**	**Quality**
Waddingham et al., 2018	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6	Good
Hancock et al., 2015	Y	Y	N	Y	N	N	N	Y	Y	Y	N	5	Fair
Kilduff et al., 2011	Y	Y	N	Y	N	N	N	Y	Y	Y	N	5	Fair
Cuenca-Fernández et al., 2018	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6	Good
Ng et al., 2015	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6	Good
Sánchez et al., 2020	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6	Good
Cuenca-Fernández et al., 2020a	Y	N	N	Y	N	N	N	Y	Y	Y	N	4	Fair
Cuenca-Fernández et al., 2020b	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6	Good
Barbosa et al., 2020	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6	Good

PEDro score is obtained by adding points describing the quality of papers, for example, 9–10 (excellent), 6–8 (good), 4–5 (fair), and ≤3 (poor), Yes (Y); No (N). Maher CG, Moseley AM, Sherrington C, Elkins MR, Herbert RD. A Description of the Trials, Reviews, and Practice Guidelines Indexed in the PEDro Database. PhysTher 2008; 88(9): 1068–77.

the body's physiology and primes the athlete to perform at a high intensity with a lower risk of injury (Bishop, 2003). Understanding the specific impact, a warm-up and specifically PAP/PAPE and swimming performance has on time would benefit both coaches and swimmers.

Peak thrust, speed and speed fluctuation in 25 m all-out

In-water test, using arm-pull in front-crawl, while lower-limbs were held by a pull-buoy on a 25 m all-out bout, the findings were that after PAP/PAPE sets, have a large improvement in arm-pull thrust (about 13% to 19%) and a small improvement in performance (almost 3%) when a one arm band pull for each arm PAP/PAPE protocol was applied. Variables commonly used to characterize thrust are strongly correlated (50–75% of variance). Peak thrust and mean thrust were better for PAP/PAPE group vs non-PAP group (Barbosa et al., 2020). Speed and speed fluctuation have no significant differences (Barbosa et al., 2020). In other study (Ng et al., 2020), the researchers assessed front-crawl flutter kick while only holding on to a kickboard after a PAP/PAPE protocol vs Non-PAP/PAPE situation. There was a medium-large enhancement of the kicking thrust in 15,14% (peak thrust) and whereas kinematics and performance improved by 10% (speed and speed fluctuation) after a warm-up that includes PAP/PAPE sets comparing to non-PAP/PAPE situation. In one study (Takagi & Wilson, 1999) using differential pressure sensors on a triathlete, swimming at 0.8 m/s, thrust was noted as ranging between 20–40 N with each arm-pull. In another study, selecting the same set-up, but at 0.90 m/s, authors reported peak force ranging between 35-50 N. The peak force of an US Olympic champion, swimming at 1.66 m/s, was estimated to be 175 N by 3D video analysis and vector computation (Schleihauf et al., 1988). In another study, also on an US Olympic champion, but not reporting the swim speed, the peak thrust in the upsweep was 134N (Higdon, 1979). Conversely, using a tethered technique, the mean thrust and peak thrust were 39N and 158N, respectively (Higdon, 1979). A coupled biomechanical smoothed particle hydrodynamics fluid model estimated a peak force of 250–300 N at 1.45–1.47 m/s, on a highly-skilled Australian swimmer (Cohen et al., 2015). Therefore, if benchmarked with literature, and having as reference the competitive level of the swimmers recruited and the swim speed, thrust values are within the expected range. Although both studies were performed holding a pull-buoy between legs and other using a kickboard on hands, these are variables that could determinate the swimming performance and the mechanisms of pull-arm thrust and flutter kick on swimmers to improve race in competition. If a sprinter races the 100 m freestyle in 50 s, a 2.5–3.0% improvement in performance translates to a 0.98–1.25 s reduction in the final race time. Converting a d=0.18 to percentile gain, it represents a 7% improvement. I.e., everything else being equal, undergoing PAP/PAPE can lead to moving up 7 places in a ranking featuring 100 contenders. According to some studies (De Martino & Rodeo, 2018; King, 1995), the upper-limbs are 90% involved in thrust power and for freestyle is a 80%, while only a 20% for lower limbs, which could not explain the different small results in speed and speed fluctuation by Barbosa et al (Barbosa et al., 2020) when the potentiation protocol is targeting to upper limbs, whereas in lower limbs PAP/PAPE protocols, the speed and speed fluctuation were faster than control (Ng et al., 2020). Therefore, both upper and lower limbs are relevant to improve the swimming performance in race, especially in 25 m distance as evidenced before. It is important to understand due to the large amounts of variables that it is possible to extract, one may wonder how redundant are they. I.e., if these variables can be interpreted interchangeably. More studies are needed to give a conclusion about the different styes and distances.

Rate of force development and power in 15 m maximum effort

Rate of force development (RFD), which is derived from the force or torque time curves recorded during explosive voluntary contractions (Aagaard et al., 2002) hereafter also referred to as rapid or ballistic actions is increasingly evaluated to characterize explosive strength of athletes. In swimming performance could be relevant to develop the RFD to produce fastest movement during the race. In the study Cuenca Fernandez et al. (Cuenca-Fernandez, Batalha, et al., 2020), RFD showed to be higher after DLWU compared to SWU. The force, acceleration and power values were lower in DLWU compared to SWU when the potentiation protocol was performed in dryland. The force, acceleration and power values were lower in DLWU compared to SWU. Therefore, potentiation responses were present after the resistance warm-up, but they were not accompanied by PAP/PAPE effects. however, there are several reasons to discuss why it would be inappropriate to link the effects provided by DLWU with this response mechanism. first of all, as muscle biopsy was not conducted to verify the phosphorylation levels (Vandenboom, 2017), it prevented a conclusion favoring the presence of PAP/PAPE effects. Thus, the results of this study were based on an alternative interpretation provided by the encoder dynamic recordings The peaks reached in force and velocity after SWU were not achieved after DLWU, which seems to be lower average values on these variables. At this point, it is important to note that the RFD in this study was calculated as the slope of the force-time curve. Therefore, the reduction of the slope within the stroke-cycle produced a shorter time to reach the peak, which could result in higher RFD. This fact has been reported in other studies (Blazevich & Babault, 2019; Maffiuletti et al., 2016), where apparent RFD increases did not produced performance enhancements. Mechanic factor are very important to improve the performance in race. This study (Cuenca-Fernandez, Batalha, et al., 2020) concluded that an improvement in RFD is not enough to enhance the velocity, force, acceleration and impulse in 15 m ME, and the water mechanisms are not transferred from DLWU warm up. The improvement of RFD led in fastest strokes but also could explain the shortest length strokes. These could explain the reduction in velocity, acceleration, force and impulse.

Time to 5 m, 15 m, 25 m, 50 m and 100 m freestyle

Cuenca-Fernández et al. (Cuenca-Fernández et al., 2019) found a great improvement in the first meter's race to 15 m under two PAP/PAPE protocols (EWU and RMWU). Time to 5 m was faster in both activation protocols compared SWU (Cuenca-Fernández et al., 2019). The results obtained suggested that protocols based on PAP/PAPE could generate improvements in the first 15 m. Waddingham (Waddingham et al., 2021) also concluded that 15 m start times were significantly quicker in the band squat protocol compared with the sport-specific warm-up condition. However, because of either fatigue or a modification in the swimming patterns, the final performance obtained with the experimental protocols (RMWU and EWU) in Cuenca-Fernández et al (Francisco Cuenca-Fernández et al., 2019) was not better than that obtained with the SWU.

In other studies (Kilduff et al., 2011; Ng et al., 2020) there were not significant differences between SS performance PAP/PAPE stimulus compared to the DS preceded by the SSWU regard time to 15m. It is important to mention that one of the studies did not evaluated the whole body swimming performance, but only assessed the flutter kick performance, which could be relevant in only a 20% of propulsion in freestyle (De Martino & Rodeo, 2018; King, 1995). Cuenca-Fernández et al. (Cuenca-Fernandez, Gay et al., 2020) also found a performance improve at 15 m after the PAP/PAPE in eccentric machine, compared to the standard situation, but not in the subsequent meter marks. However, PAP/PAPE benefits are most effective when a rest period is provided between conditioning exercise and competitive activity (Seitz & Haff, 2016). Reasoning that makes sense if we look at the model proposed by Sale (Sale, 2004), since fatigue and potentiation are two inherent responses to contractile activity and the predominance of one over the other can have a crucial influence on performance. In trained athletes, this state of fatigue can dissipate relatively quickly, while the state of phosphorylation can last up to 5-8 minutes while waiting for the aforementioned maximum muscle contraction to be required by the body.

The other distances did not show significative differences. In the beginning the race, some gains on performance as a consequence of the PAP/PAPE warm-ups were registered on the block. For instance, the improvement on diving velocity after EWU showed that swimmer's flight was longer and faster. In addition, this improved performance was transferred to the swimming time and velocity at the beginning of the race (5 and 10 m marks), where the swimmers have just entered the water and have not executed actions other than gliding or underwater swimming. No differences were found between protocols in 50 m, time to 25 m (MacIntosh, Robillard & Tomaras, 2012; Maffiuletti et al., 2016), this could be due to the great fatigue accumulate after both experimental conditions resulting in a deteriorated kinetics and kinematics variable. Rest interval between conditioning exercise and measurement of performance outcome is also a point of contention in the determination of the most effective use of PAP/PAPE. In Cuenca-Fernández et al (Cuenca-Fernández et al, 2018), only 6 min was given between the potentiation protocol and trial, and a recent meta-analysis indicates that a rest interval of 8–12 minutes provides the greatest benefit, which could explain the reduce of performance (Hancock et al., 2015). In other hand, Hancock et al. (Hancock et al., 2015) noticed that 6 minutes of rest between the conditioning swims, and the 100-m swim was adequate to enhance swim performance. However, some have suggested that true muscle potentiation dissipates as quickly as 5 minutes after a conditioning exercise (MacIntosh et al., 2012).

Hancock et al. (Hancock et al., 2015) has shown that not only 100-m freestyle performance can be improved as a result of a PAP/PAPE loading protocol performed before the event, also the first and seconds 50 m race. For the 100 m race the mean time for the PAP/PAPE trial was significantly faster than the mean time for the control trial when the activation protocol was 4 set of 10 m swimming with an individualized weight being tethered to a system pulley adapted machine. In addition, the PAP/PAPE trial showed a trend for improvement in the first 50-m of 0.26 seconds over the control trial, which is a large margin in

sprint swimming where races are routinely decided by tenths and hundredths of a second. The results for the second 50-m split were similar to those of the first, with the PAP/PAPE trial being 0.27 seconds faster than the control trial. It may be hypothesized that the warm up environment plays an important role in the PAP/PAPE protocol and if is applied in swimming pool could be more effective for the swimmer´s sensibility water. Sanchez et al. (Sánchez et al., 2020) demonstrated that pre competition activation protocols based on eccentric contractions performed for upper limbs, lower limbs or mix enhances the swimmer´s men performance in T25EL when added and comparing to a general warm-up. In this sense, the lower volume performed in GEN (500-m) compared to the other protocols (900-m) could have negatively influenced the metabolic changes necessary to improve performance in T25 m (Neiva et al., 2014). However, their PAP/PAPE effect is not observed when added to a specific competition warm-up. Pre-competition activation protocols directed at the upper, lower, or upper + lower limbs seem to offer similar effects, although the latter (combined upper + lower limbs) require more demand and, therefore, could be less efficient.

Velocity in 5 and 50 m

Cuenca-Fernández et al. (Cuenca-Fernández, et al., 2018) assessed the velocity up to 50 m. The results showed that higher velocity was obtained to 5 and 10 m with both experimental protocols EWU and RMWU compared with the SWU protocol. No differences in velocity were found at any point between 15 and 50 m between the 3 protocols applied. It could be concluded the same as before. The lack of fatigue tolerance plays an important role in performance. Although, it does exist an improvement in the first swimming performances speed, the lack of capacities to keep the velocity up to the end of the race or more than 10 m, could be due the need of adaptation to the stimulus and fatigue tolerance. If we observed the result obtained in another study (Cuenca-Fernandez, Gay et al., 2020), after the 6 weeks training, following the application of the PAP/PAPE warm-up, the starting speed increased and swimming time and speed improved at 25, 40 and 50 meters, which suggests that the subjects were capable of attaining a better balance between fatigue and potentiation.

Block time, dive distance, dive velocity, underwater undulatory swimming after swim start, underwater undulatory swimming after turn

According to Cuenca-Fernández et al. (Cuenca-Fernández et al., 2018), and though BT and DD showed no differences, the analyses of the DV and takeoff angle yielded superior values, i.e., faster and higher values, with the experimental protocols, specifically after EWU. In the study was not possible to discern if improvements at start came because swimmers changed the takeoff angle or because lower limbs muscles were potentiated. Nonetheless when the kinetics variables were measured, some improve in performance as a consequence of the PAP/PAPE warm-ups were registered on the block. For instance, some improvement on DV after EWU showed that swimmer's flight was longer and faster. DV demonstrated to be faster for EWU than SWU and RMWU (Cuenca-Fernández et al., 2018), which could be due the differences between PAP/PAPE protocols, where the improvement was seen after the eccentric protocol, this is according to a study (Cuenca-Fernandez, Gay et al., 2020) which analyzed the relationships between specific strength training using an inertia training machine and swimming performance. It was found significant improvements at the 100 m marks, which were associated with the gains in strength and power caused by the training. This study (Cuenca-Fernández et al., 2018), experimented with the effects of a standard warm-up on performance in a speed swimming test compared to a PAP/PAPE warm-up which included specific maximum strength exercises executed on an eccentric training machine. The total distance during underwater undulatory swimming was similar between the 3 protocols studied, both after the swimming start and after the turn. These results in this study (Cuenca-Fernández et al., 2018), could be explained because the warm up protocols are not focus in the whole-body specific technique, specifically, underwater, resulting in a not one-hundred percent transferrable ability to water.

Power vertical force and power horizontal force

Measuring the PVF and PHF is important to understand the starting block in swimming performance and the forces from both variables. The result of starting block jump to the pool comes from PVF and PHF average forces and can be useful for swimmers in SS. The measures were obtained from a star block platform with a 10° elevation. In a study (Kilduff et al., 2011) there was a significative increase in both PVF and PHF after the PAP/PAPE stimulus warm-up vs SSWU. However, there were not differences in 15 m SS between conditioning protocols and standard or individualized race specific warm up. Although these two variables showed an enhancement in the jump from the block start, the results suggested that those variables (if are well-trained) could be relevant to improve the total time race, especially in 15 m race. Breed and Young (Breed & Young, 2003) identified CMJ performance as being significantly related to flight distance attained via grab, swing, and rear- weighted track starts. An additional finding there is a strong negative correlation between lower body strength and time to 15 m. The mechanisms behind the link between strength and starting performance (e.g., power) are probably multi-factorial in nature. For example, heavy-resistance training has been shown to induce hypertrophy within the high force–generating type II fiber isoforms (West et al., 2011) and concomitantly increase the size and number of the sarcoplasmic reticulum (Ørtenblad et al., 2000), thus increasing the rate of release and reuptake of calcium, and improving muscle contraction and relaxation rate (Ross & Leveritt, 2012) all of which would be positive adaptations for increasing power in the swim start. Also, there is a strong relationship between lower body strength and PVF and PHF indicating the important role force production plays in swim starts; this is further supported by the relationship between lower body strength and time to 15 m.

Limitations

One of the important limitations observed in this systematic review is related to the lack of statistical informa-

tion from a meta-analysis, which could limit the precision of the data to give an exact conclusion of the results. On the other hand, the change of nomenclature from PAP to PAPE was a limitation for the understanding of both concepts, where some researches the potentiation and performance improvement effect were only referred as PAP, instead, now the PAP effect has been widely explained by an increase in the phosphorylation of the myosin light chain that occurs in type II muscle fibers, with or without effects in performance enhancement. Therefore, for the newest researches from 2019, PAP effect by its self, does not explain the whole performance enhancement resulting from the changes in other variables such as: changes in temperature, flexibility, technique and phycological activation, etc., which PAPE does. For these reasons, these concepts (PAP/PAPE) as one was a limitation.

Conclusions

The present systematic review, concluded that PAP/PAPE is one more tool that can be beneficial if it is adapted to the conditions of swimmers (competitive level), controlling fatigue levels, the environment where it is performed (land or water), and most importantly still, described by many coaches worldwide, the specificity of the movement. The most favorable results of the PAP/PAPE in the current review are from movements that focus on swimming gestures, such as: the lunge in the jump height at the start of the platform, the first meters of swimming in a "fly-wheel" device and specific swimming works on a pulley adapted for the so-called "stroke" or swimming arm movement, and when the trial were short distances like 15 m in SS. The negative effect in conditioning protocols were when there was not an adaptation long or middle-term training period for PAP/PAPE and when the fatigue was higher in trial after potentiation protocols. An important aspect in order to obtain benefits from the potentiation protocol is when after the PAP/PAPE stimulus, a time of at least 8 minutes is carried out to guarantee recovery from the fatigue given before the competition or swimming test.

Practical applications

It is common to see swimmers perform different types of warm-ups for training and competitions through ballistic stretching, increasing their breathing and heart rate, or clapping the difficulty of their chest or extremities. Although many of these protocols are common (not being the objective of this review), swimmers are required to integrate protocols that have been studied and proven by sports science and not reject an extra activation protocol. It is recommended that coaches and swimmers include PAP/PAPE in their training protocols, at least for short sprints, and/or to improve the first meters and, finally, based on the results given in this review. The exercises with which they were carried out and saw benefits in the PAP/PAPE can be integrated and adapted to the training as a method of transfer to the aquatic environment, and above all, that the systematic training of the potentiation protocols is trained for at least 6 weeks for it to be adapted to the needs of the swimmers and their tolerance to fatigue.

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Conflict of interest

The author has no conflicts of interest to declare.

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ВПЛИВ ПОСТАКТИВАЦІЙНОГО ПОСИЛЕННЯ РЕЗУЛЬТАТИВНОСТІ НА РЕЗУЛЬТАТИВНІСТЬ ПЛАВЦІВ, ЯКІ ЗМАГАЮТЬСЯ: СИСТЕМАТИЧНИЙ ОГЛЯД

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Реферат. Стаття: 12 с., 2 табл., 1 рис., 43 джерела.

Мета дослідження. Метою цього систематичного огляду було оцінити вплив протоколів розминки постактиваційної потенціації/постактиваційного посилення результативності (PAP/PAPE) на результативність плавців.

Матеріали та методи. Пошуки проводили в електронній базі даних на платформах PubMed, Scopus, Web of Science та EBSCO. Були включені дослідження, опубліковані з 2010 року до травня 2022 року, пов'язані з протоколом розминки PAP/PAPE та його впливом на результативність плавання у плавців віком від 18 до 35 років.

Результати. До цього огляду були включені дев'ять із 333 досліджень. У двох дослідженнях максимальна короткочасна тяга покращилася на 13% – 19% для PAP порівняно з не-PAP і на 3% щодо результативності. Одне дослідження показало покращення на 10% швидкості та коливань швидкості на дистанції 25 м із повним застосуванням PAP порівняно з не-PAP. Швидкість зростання сили (RFD) на дистанції 15 м з максимальним зусиллям була вищою для розминки на суші (DLWU), ніж для розминки під час плавання (SWU). Одне дослідження показало вищу швидкість на дистанції 5 м для розминки з повторним максимумом (RMWU) і розминки на ексцентричному маховому колесі (EWU) порівняно з розминкою під час плавання (SWU). Одне дослідження продемонструвало покращення для PAP верхньої частини тіла (UBPAP), PAP нижньої частини тіла (LBPAP) і змішаного протоколу розминки MIX (UBPAP/LBPAP) порівняно з розминкою на основі загальних вправ (GEN) у часі на дистанції 25 м вільним стилем (T25FS). Два дослідження виявили покращення для присідань зі стрічковим еспандером за протоколом розминки PAP порівняно зі спеціальною розминкою для плавання (SSWU) у часі на дистанції 15 м. Одне дослідження продемонструвало, що спроба за протоколом розминки PAP (PAPT) була швидшою за контрольну спробу на час (CTT) на дистанції 50 м і 100 м вільним стилем. Швидкість занурення (DV) була вищою для RMWU/EWU порівняно з SWU. Одне дослідження показало значне збільшення вертикальної складової сили (PVF) і горизонтальної складової сили (PHF) після PAP порівняно з SSWU.

Висновки. Протокол розминки PAP/PAPE – це ще один інструмент, який може бути корисним, якщо його адаптувати до фізичних кондицій плавців, контролюючи рівні втоми, середовища його виконання (земля чи вода), а головне, описане багатьма тренерами, специфіки руху.

Ключові слова: постактиваційна потенціація, постактиваційне посилення результативності, результативність плавання.

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REVIEW ARTICLE

TIPS FOR STATISTICAL TOOLS FOR RESEARCH METHODS IN EXERCISE AND SPORT SCIENCES

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Abstract

Study purpose. The increasing amount of research in Exercise and Sport Sciences emphasized the use of increasingly heuristic statistical tools appropriate to the aim in terms of qualitative, quantitative, and qualitative-quantitative data. Often, a lack of knowledge of statistical tools and their appropriateness for data analysis, especially between the use of parametric and non-parametric statistical techniques, is encountered by researchers. This requires the indispensable use of statistical experts, who, for the comprehensive understanding of the research design, need the use of human and economic resources that could probably be used differently and more efficiently. The aim of this study was to provide a list of the most used statistical methods in Exercise and Sport Sciences, focusing on the distinction between parametric and non-parametric statistical processing for both quantitative and qualitative research.

Materials and methods. The method was the literature review with argumentative elaborations concerning the validity of the use of the statistical tools.

Results. A total of 22 statistical tools, both parametric and non-parametric, were found: 5 useful to test relationship, 7 to compare two groups and 10 to compare two or more groups. For each statistical tool, a scientific paper related to Exercise and Sport Sciences was collected.

Conclusions. These data allow developing potential guidelines, applying to Exercise and Sport Sciences, for the rigorous model of research projects with a systematic use of statistical processing in the complete hypothesis of the study.

Keywords: statistical analysis, parametric, non-parametric, guidelines, researchers, training.

Introduction

The increasing amount of research in the Exercise and Sport Sciences (ESS) field emphasized the use of increasingly heuristic statistical tools appropriate to the aim in terms of qualitative, quantitative, and qualitative-quantitative data. The ability to assess performance, using tests, to derive information related to the effectiveness of training protocols, to determine the relationship between certain parameters, or simply to get feedback on the state of the athlete is a quality that is increasingly in demand in the sports field (Rojas-Valverde et al., 2020). Statistical and methodology errors are very common in sports science research (Sainani & Chamari, 2022). Expert researchers in the field of ESS often lack adequate formation in the use of statistical tools and their appropriateness for data analysis, especially among the use of parametric and non-parametric statistical techniques.

Another problem concerns the recruitment by journals of peer reviewers who are responsible for improving the quality of manuscripts for publication by eliminating serious methodological errors (Altman, 2002; Schroter et al., 2008). Journals do not check the competence of peer reviewers, who often pass over the statistical section, because they do not consider themselves capable to give an opinion about it. As a result, several manuscripts may be published with a statistical misapplication, which is replicated by other researchers, starting a vicious cycle that results in the publication of manuscripts with a low methodological quality. For example, a very common basic error is not reporting the assumption of data normality, a necessary requirement for the application of parametric tests (Kamuk, 2020). In fact, in case of non-normally distributed data, non-parametric statistics should be applied. Inappropriate use of

statistical tools leads to misinterpretation of data (Mishra et al., 2019).

To overcome these problems, the scientific literature recommended increasing the collaboration among researchers and statisticians. Including experienced statisticians in the research team could help improve the design and quality of data analysis. In a systematic review conducted by Sainani et al. (2021), only 13.3% of the articles selected in 2019 in ESS field had a co-author affiliated with a department of biostatistics, statistics, data science, data analysis, epidemiology, mathematics, computer science, or economics. Very often, this collaboration did not seem to be successful. Difficulties in communication may arise because statisticians, in most cases, were not experts in the ESS field epistemology (Raiola et al., 2018; Raiola, 2019ab; Raiola, 2020). As a result, they must argue with the researcher for a different interpretation of the results obtained from statistical processing. In fact, statisticians tend to be more cautious regarding the interpretation of the data or a statistical significance. Thus, the full understanding of the research design required the use of human and economic resources that could probably be used differently and more efficiently. Another suggestion to overcome this problem was to improve statistical training within ESS degree programs (Sainani et al., 2021). The literature suggested that to improve the quality of research, a change at the institutional level was needed (Smaldino & McElreath, 2016). Researchers can attempt to learn applied statistics through university lectures, but also through guidelines with practical examples in the ESS field. This would also save human and economic resources.

Consequently, the aim of this study was to provide a list of the most used statistical methods in the ESS field, focusing on the distinction between parametric and non-parametric statistical processing for both quantitative and qualitative research. The utility was to provide guidelines to researchers, so as to facilitate the choice of statistical tool, based on the objective to be achieved through practical examples in ESS field.

Materials and methods

Materials for analysis

The method was the literature review with argumentative elaborations concerning the validity of the use of the statistical tool. Scholar was used as a database to search the articles, who are selected based on the author's area of expertise (ESS). The keywords used were "sports science" "training" "exercise" "statistics" "parametric" "non-parametric".

Organization of the study

After the article of interest was identified, we proceeded with the analysis of the research method, going on to identify the variables examined, the statistical tool and the objective of the study. Correlational, comparative and experimental studies were included. Descriptive studies were excluded because they did not involve the use of statistical tests.

Methods of analysis

Synoptic tables schematized the characteristics of the included studies with their statistical tools. Specifically, statistical tools, both parametric and non-parametric, with their own assumptions and a practical example in ESS field, were reported.

Results

About 22 articles were examined. For each statistical tool (parametric and non-parametric) a scientific article relating to ESS was selected. Statistical tools, with their meaning, assumptions to be met and an example of a study in the ESS field are included in tables, divided into three categories: testing relationships, comparing two groups, comparing more than two groups. Table 1 showed the statistical tools

Table 1. Statistical tools to test relationships

	Aim	Assumption	Statistical tool	Example
Testing relationships	To measure the strength and direction of relationship between 2 v.	Linearity; normality; no sig. outliers; 2 related continuous v.	Pearson	To assess the relationship between the different COD tests (Pereira et al., 2018).
		NPA; monotonic relationship; at least 1 ordinal v.	Spearman	To examine the association between BMI and MC (Lopes et a., 2012).
		NPA; monotonic relationship; ordinal/continuous v.; small sample size	Kendall	To explore the correlation between anxiety, motivation, and others c.v. (Ruffault et al., 2020).
	Predictive analysis to explain the relationship between 1 d.v. and 1/ more i.v.	Linearity; normality; no sig. outliers; independence; homogeneity of variances; large sample size; quantitative/ dichotomous i.v.	Regression	To assess the predictive capacity of psychological profile on competitive anxiety, moods and self-efficacy in handball players (Reigal et al., 2020).
	To test the relationship between 2 v.	NPA; independence; large sample size (Chi Square); low sample size (Fisher); 2 categorical v. (at least of 2 levels)	Chi Square / Fisher	To compare differences in inclusion perceptions between 2 types of dancesport athletes and sociodemographic factors (Aliberti et al., 2022).

Note: BMI, body mass index; COD, change of direction; d.v., dependent variable; i.v., independent variable; MC, motor coordination; NPA, non-parametric assumptions; v, variable /s

Table 2. Statistical tools to compare two groups

	Aim	Assumption	Statistical tool	Example
Comparing 2 groups	To compare the sample mean with a standardized/hypotetical value	Normality; no sig. ouliers; independence; 1 continuous d.v.	One Sample t-test	To determine the difference between the mean/median of motor score with a standardized value (Alsaedi, 2020).
	To compare the median sample with a standardized/hypotetical value	NPA; 1 continuous v.	Wilcoxon One Sample Signed-Rank test	
	To compare the mean differences between 2 paired measurements/ conditions or 2 halves/side of a subject	Normality; no sig. outliers; 1 continuous d.v.; 1 i.v. (2 categorical levels); related groups	Paired Samples t-test	To determine the difference between pre-post running in terms of jump height (Yu et al., 2020).
	To compare the medians between 2 paired measurements/ conditions	NPA; related groups; 1 ordinal/continuous d.v.; 1 i.v. (2 categorical levels)	Wilcoxon Signed-Rank test	To compare the function of the dominant and non-dominant hands (Armstrong & Oldham, 1999).
	To compare the mean differences between 2 different groups	Normality; no sig. outliers; independence; homogeneity of variances; 1 continuous d.v.; 1 i.v. (2 categorical levels); unrelated groups	Independent Samples t-test	To investigate the effects of latin dance (respect to non latin-dancers) on postural control, stability, and dynamic balance (Kiliç & Nalbant, 2022).
	To compare the mean ranks between 2 different groups	NPA; independence; 1 continuous/ordinal d.v.; 1 i.v. (2 categorical levels); unrelated groups	Mann–Whitney U test	To examine the impact of gender on hand dexterity (Haward & Griffin, 2002).
	To test differences on a dichotomous d.v. between 2 related groups	NPA; 1 dichotomous d.v.; 1 categorical i.v. with 2 related groups	McNemar's test	To compare the score of some questionnaires assessing physical activity, quality of life and sleep before and during pandemic (Wingerson et al., 2021).

Note: d.v., dependent variable; i.v., independent variable; NPA, non-parametric assumptions; v, variable /s

that have the objective of testing relationships between variables, including Pearson, Spearman, Kendall, Regression and Chi Square/Fisher.

Table 2 contained the statistical tools intended to compare two groups, including One Sample t-test, Wilcoxon One Sample Signed-Rank test, Paired Samples t-test, Wilcoxon Signed-Rank test, Independent Samples t-test, Mann–Whitney U test and McNemar's test.

Table 3 showed the statistical tools aimed to compare two or more groups including One-way ANOVA, Kruskal-Wallis One-way ANOVA, One-way repeated measures ANOVA, Friedman test, Cochran's Q test, One-way ANCOVA, Two-ways ANOVA, Two-way repeated measures ANOVA and multivariate analysis, comprising One-way MANOVA and One-way MANCOVA.

Discussion

The present literature review aimed to collect the most used statistical tools, both parametric and non-parametric, in ESS field, explaining their meaning, usefulness and requirements for use, concluding with an application example for each one. We started from the simple relationship to the comparison of two or more groups. The first step, when collecting data, is the calculation of descriptive statistics, which allow us to collect, summarize and interpret data through coefficients, including central tendency and dispersion indices, and the observation of graphs. This step allows us to figure out which statistical tool to choose if our goal is to go beyond describing the data. The next step is inferential statistics, which allow us to generalize the results obtained from data collected on a sample to the population from which it was drawn. They are used to test hypotheses and to make population estimates. There are two types of tests: parametric and non-parametric. The choice depends on the objective, the nature of the data and the testing of assumptions. Parametric tests, to be applied require several assumptions, as shown in the tables, the most important of which are normality of data, homogeneity of variances, and a large enough sample. When the data violate one of the assumptions, non-parametric tests, also called distribution-free, are used.

1. Pearson correlation (r) is a parametric measure that produces a correlation coefficient that measures the strength (±1) and direction (increasing/decreasing) of linear relationships between pairs of continuous variables. The non-parametric counterpart is the Kendall or Spearman coefficient for nonnormal distributions by calculating ranks of the data (Akoglu, 2008). It is therefore useful for testing how one variable varies as the other varies, such as between different ability tests or between coordination and body mass index (BMI) (Lopes et al., 2012; Pereira et al., 2018).

2. Regression analysis is a predictive analysis to explain the relationship between a dependent variable and one or more independent variables, for example the capacity of psychological profile on competitive anxiety, moods, and

Table 3. Statistical tools to compare two or more groups

	Aim	Assumption	Statistical tool	Example
Comparing more than 2 groups (1 i.v.)	To compare the mean differences of more than 2 groups	Normality; no sig. outliers; independence; homogeneity of variances; 1 i.v. (2/more categorical levels); 1 continuous d.v.	One-Way ANOVA	To test the differences in postural control in 3 groups: judoists, dancers and CON group (Perrin et al., 2002).
	To compare the mean ranks of more than 2 groups	NPA; independence; 1 i.v. (2/more categorical levels);1 ordinal/continuous d.v.	Kruskal-Wallis One-Way ANOVA	To verify the impact of age (3-level) on performance of the Moberg Pick-Up Test (Amirjain et al., 2007).
	To compare the mean differences between 2/more related groups	Normality; no sig. outliers; sphericity; 1 continuous d.v.; 1 i.v. (2/more categorical levels); related groups	One-way repeated measures ANOVA	To investigate the effect of an 11-week intervention of classical ballet and contemporary dance training on hip extensor flexibility and strength (Di Pasquale & Wood, 2017).
	To compare the mean ranks of 2/more related groups	NPA; 1 group measured 3/more times; 1 ordinal/continuous d.v.	Friedman test	To compare humor subscales of 3 basket matches (Pinto et al., 2022).
	To test differences on a dichotomous d.v. between 3/more related groups	NPA; related groups; large sample size; 1 dichotomous d.v.; 1 i.v. (3/more categorical levels)	Cochran's Q test	To test the changes in physical activity and its importance in 3 different time-points in elderly (Lefferts et al., 2022).
	To test the adjusted mean differences between 2/more i. groups (unrelated) on a d.v.	The same of one way-ANOVA + 1/more continuous cov.; linearity between cov. and d.v.; homogeneity of regression slopes; homogeneity of cov.	One-way ANCOVA	To compare the changes in agility between 2 groups, EXP (plyometric) and CON, using pre-test scores as covariate (Chtara et al., 2017).
Comparing more than 2 groups (2 i.v.)	To compare the mean differences between groups split into 2 factors	The same of one-way ANOVA + 2 i.v. (2/more categorical levels)	Two-ways ANOVA	To compare changes in YBT-LQ among athletes with gender and sports classification (one vs. multiple) as i. factors (Gorman et al., 2012).
	To compare the mean differences between related groups split into 2 factors	The same of one-way repeated measures ANOVA + 2 within-subjects factors (2/more categorical levels)	Two-ways repeated measures ANOVA	To compare the effect of a 12-week low-volume HIIT training (EXP and CON) on body composition, strength, balance, and mobility (García-Pinillos et al., 2019).
Comparing i. groups on more than 1 d.v.	To simultaneously compare the means of multiple d.v. across 2/more i. groups	Normality; no sig. outliers; homogeneity; large sample size; indipendence; 2/more continuous d.v.; 1 i.v. (2/more categorical levels)	One-way MANOVA	To determine differences in SMS subscales between competitive and non-competitive windsurfers (Modroño & Guillén, 2016).
	To simultaneously compare the adjusted mean differences of multiple d.v. across 2/more i. groups	The same of one-way ANCOVA + 2/more continuous d.v.	One-way MANCOVA	To examine difference between medallist and non medallist fencers in anthropometry, PP and MC, using maturity and chronological age as cov. (Norjali et al., 2018).

Note: CON, control; cov., covariate /s; d.v., dependent variable; EXP, experimental; HIIT, high intensity interval training; i.v., independent variable; MC, motor coordination; NPA, non-parametric assumptions; PP, physical performance; sig., significant; SMS, sport motivation scale; v, variable /s; YBT LQ, Lower Quarter Y Balance Test

self-efficacy in handball players (Reigal et al., 2020). Then there are different types of regressions depending on the variables collected and the objective.

3. Chi Square is a non-parametric independence test that crosses two variables through a cross table with the objective of testing for dependence. It is useful for processing questionnaire responses or comparing differences in perceptions between two samples. One example is to analyze differences in perceptions between athletes with and without disabilities toward sports inclusion (Aliberti et al., 2022). Fisher's test has the same function but is used when there is a value less than 5 in the adjacency table. The Chi Square is often accompanied by Phi (φ), Cramer's V (V) or odds ratio (OR), to quantify the strength of the association identified (Kim, 2017).

4. Several t-test students were found. The first is the one-sample t-test, useful to compare the sample mean with a standardized/hypothetical value. The non-parametric is Wilcoxon One Sample Signed-Rank test. The most used measure of effect size for a t-test is the Cohen's d (Cohen, 1998).

5. The paired dependent samples t-test compares the mean differences between two paired measurements/ conditions or two halves/side of a subject. For example, it can be used to test for the existence of a difference in pre-test post-test scores, difference in measurements taken under two different conditions in the same subject, difference in measurements taken from two halves or sides of a subject. The analogous non-parametric test is the Wilcoxon Signed-Ranks test.

6. The independent samples t test compares the mean differences between two different groups. The non-parametric versions s the Mann-Whitney U test. An example can be comparing postural control, stability, and dynamic balance in Latinists versus non-Latinists (Kiliç & Nalbant, 2022).

7. McNemar test is used to test differences on a dichotomous variable between two related groups. Practically, it measures the consistency in responses across two variables for example the difference in dichotomous answers of some variables before and during pandemic (Wingerson et al., 2021).

8. One-way ANOVA compares the means of two or more independent groups. For example, it is used to test for differences in postural control in three different groups of athletes (Perrin et al., 2002). Only in the case of significance is the post hoc test such as, for example, the Bonferroni post-hoc considered because the ANOVA is an omnibus test, i.e., it does not specify between which groups there is significance; consequently, post hoc allows for rotational comparisons between groups. The analogous non-parametric test is the Kruskal-Wallis One-way ANOVA. Partial eta squared (η2) is the most commonly way to measure the effect size of different variables in ANOVA models (Richardson, 2011).

9. One-way ANOVA with repeated measures is used to compare three or more groups composed of the same subjects. For example, it can be useful when we want a pre - in itinere and post intervention group, like three basket matches, to verify the changes in humor (Pinto et al., 2022). The non-parametric version is the Friedman test.

10. Cochran's Q test is used to determine whether there are differences on a dichotomous dependent variable (2-level like yes/no) between three or more related groups. For example, it is used in longitudinal studies (differences over time). An example would be to test the changes in physical activity practice and its importance in three different time-points (Lefferts et al, 2022).

11. One-way ANCOVA (analysis of covariance) is an extension of one-way ANOVA to incorporate a covariate. The covariate is a variable that can influence the results, consequently, it is included in the statistical calculation to control for it. An example of a covariate might be the pretest score of a physical test, when the objective of the study is to compare the changes in agility between two groups (Chtara et al., 2017).

12. Two-way ANOVA is used to test the interaction between the two independent variables, for example the gender and sports classification, on the dependent variable, like balance test (Gorman et al., 2012). Then, the ANOVA can be three-way or more-way, depending on the number of independent variables.

13. Two-way ANOVA for repeated measures is used to compare mean differences between groups that have been divided on two within-subjects' factors. It is one of the most widely used instruments in experimental studies with pre-test post-test design with control group. An example of a study is testing the effect of a 12-week low-volume HIIT training (experimental and control group) on body composition, strength, balance, and mobility (García-Pinillos et al., 2019) where the two within-subjects variables are time x conditions.

14. Finally, we have included an example of multivariate analysis, starting with the one-way MANOVA, used to determine whether differences exist between independent groups on more than one continuous dependent variable. One example is to test the differences between competitive and non-competitive windsurfers on sports motivational scale score (Modroño & Guillén, 2016). MANOVA can be two or more way, depending on the number of independent variables.

15. One-way MANCOVA, on the other hand, is an extension of the one-way MANOVA that incorporate a covariate, like ANCOVA. An example is to examine the difference between medalist and non-medalist fencers in physical performance, coordination, and anthropometry, using maturity and chronological age as covariate (Norjali et al., 2018).

Conclusions

This study collected the most useful statistical tools in the ESS field by explaining their meaning, assumptions, non-parametric version, and a practical example for a better understanding of their application. Future studies could further explore the application of each statistical tool in the ESS field. An institutional change is required to better prepare future researchers by proposing university courses (D'Elia, 2019; D'Isanto, 2019; D'Isanto et al., 2022) aimed to improve the knowledge and application of statistical tools according to the objective. Meanwhile, these data allow the predisposition of potential guidelines, applying to ESS, for the rigorous model of research projects to systemic utilize of statistical processing in the complete hypothesis of the study. Furthermore, the study aims to urge researchers to first investigate the nature of the data, and then test the assumptions necessary to be able to apply a statistical tool, which may be parametric or non-parametric.

Conflict of interest

The authors declare no conflict of interest.

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ПОРАДИ ЩОДО СТАТИСТИЧНИХ ІНСТРУМЕНТІВ ДЛЯ МЕТОДІВ ДОСЛІДЖЕННЯ В ГАЛУЗІ ФІЗИЧНИХ ВПРАВ І СПОРТИВНИХ НАУК

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 12 с., 2 табл., 1 рис., 43 джерела.

Мета дослідження. Зростаюча кількість досліджень у галузі фізичних вправ і спортивних наук надала особливого значення використанню дедалі більш евристичних статистичних інструментів, які відповідають меті з погляду якісних, кількісних та якісно-кількісних даних. Часто дослідники стикаються з браком знань про статистичні інструменти та їх придатність для аналізу даних, особливо між використанням параметричних і непараметричних статистичних методів. Це вимагає обов'язкового залучення статистичних експертів, які для всебічного розуміння схеми проведення дослідження потребують використання людських та економічних ресурсів, які, імовірно, можна було б використати інакше та ефективніше. Метою цього дослідження було наведення переліку статистичних методів, які найчастіше використовують у галузі фізичних вправ і спортивних наук, зосереджуючи увагу на відмінності між параметричною та непараметричною статистичною обробкою як для кількісних, так і для якісних досліджень.

Матеріали та методи. Методом був огляд літератури з аргументованими уточненнями щодо обґрунтованості використання таких статистичних інструментів.

Результати. Загалом було знайдено 22 статистичні інструменти, як параметричні, так і непараметричні: 5 корисних для перевірки наявності зв'язку, 7 – для порівняння двох груп і 10 – для порівняння двох або більше груп. Для кожного статистичного інструменту була підібрана наукова стаття, пов'язана з фізичними вправами та спортивними науками.

Висновки. Ці дані дозволяють розробити потенційні рекомендації, що стосуються фізичних вправ і спортивних наук, для суворої моделі дослідницьких проектів із систематичним використанням статистичної обробки в повній гіпотезі дослідження.

Ключові слова: статистичний аналіз, параметричний, непараметричний, рекомендації, дослідники, навчання.

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ІНСТРУКЦІЇ ДЛЯ РЕЦЕНЗЕНТІВ

Цей журнал є рецензованим. Оригінальні наукові статті, повідомлення та огляди надсилаються для розгляду одному з рецензентів. Рецензування відбувається за подвійною сліпою схемою. Статті, які мають позитивні оцінки приймаються до публікації. Редакція журналу залишає за собою право внести зміни до тексту, щоб відповідати стандартам стилю журналу та мови.

Головний редактор журналу визначає відповідність статті профілю журналу, вимогам до оформлення і направляє її на рецензування фахівцю, що має найбільш близьку до теми статті наукову спеціалізацію. Рецензування проходить за подвійною сліпою схемою.

У кожній статті у процесі рецензування завжди розглядаються:

- етичні аспекти;
- оригінальність твору;
- важливість інформації;
- чіткість та зрозумілість тексту;
- доцільність використання методів дослідження;
- інтерпретація результатів;
- обґрунтованість висновків.

Типовий період, необхідний для проведення рецензування складає 4 тижні.

Етичні принципи у діяльності рецензента

Рецензент здійснює неупереджене фахове рецензування поданої до розгляду статті на основі таких принципів:

- рецензент повинен поважати інтелектуальну власність авторів, і розглядати рукопис статті, що надійшов на рецензування, як конфіденційний, який не можна передавати для ознайомлення або обговорення третім особам, які не мають на це повноважень від редакції;
- рецензент зобов'язаний давати об'єктивну оцінку викладеним результатам дослідження, персональна критика автора неприпустима;
- у разі конфлікту інтересів з автором, слід повідомити про це редактора з проханням виключити його з процесу рецензування даної статті.

Політика щодо плагіату

Редакція журналу вважає неприйнятним наявність плагіату в статтях (оприлюднення у письмовій або електронній формі наукових результатів, отриманих та оприлюднених іншими особами, як результатів власного дослідження та/або відтворення опублікованих текстів інших авторів без відповідного посилання).

У статтях не допускається:

- копіювання та оприлюднення виконаної іншим автором роботи як своєї;
- дослівне копіювання фрагментів тексту (від фрази до набору речень) без належного оформлення цитування;
- внесення незначних правок у скопійований матеріал (переформулювання речень, зміна порядку слів в них тощо) та без належного оформлення цитування;
- переказ своїми словами чужих думок, ідей або тексту без належного оформлення посилання на джерело.

Обов'язковим є посилання на власні, раніше опубліковані роботи.

Редакція відхиляє поданий рукопис, якщо він містить запозичення з інших публікацій без належного цитування, та може скасувати публікацію за скаргою в плагіаті.

Як підготувати рецензію?

Попередній огляд

Перш ніж прийняти або відхилити запрошення на рецензування, розгляньте такі питання:

- Чи відповідає стаття вашій спеціалізації? Приймайте запрошення, якщо ви впевнені, що можете надати якісний огляд.
- Чи є у вас конфлікт інтересів? Дайте відповідь на це питання.
- Чи є у вас час? Рецензування може вимагати багато часу – перш ніж приймати запрошення, переконайтеся, що ви можете виконати роботу до вказаного строку.

Дайте відповідь на запрошення, як тільки ви зможете. Затримка відповіді сповільнює процес розгляду матеріалу. Якщо ви відхилите запрошення, за можливості, надайте пропозиції альтернативних рецензентів.

Якщо ви приймаєте запрошення, то ви повинні розглядати матеріали як конфіденційні документи. Це означає, що ви не можете поділитися ними з ким-небудь без попереднього дозволу редактора. Оскільки експертний огляд є конфіденційним, ви також не повинні передавати інформацію про рецензію будь-кому без дозволу редакторів та авторів.

По-перше, прочитайте статтю, а потім зробіть перерву. Розгляньте статтю з власної точки зору. Переконайтеся, що ви знаєте критерії оцінки статті, запропоновані журналом.

Огляд

Ваша рецензія допоможе редакторові вирішити, чи слід публікувати статтю. Важливою є ваша загальна думка та висновки про статтю. Ваші коментарі повинні бути доброзичливими та конструктивними, а також

не містити жодних особистих зауважень чи особистих даних, включаючи ваше ім'я.

Важливо надати інформацію про будь-які наявні недоліки. Ви повинні пояснити ваше судження, щоб як редактори, так і автори, могли повною мірою зрозуміти ваші коментарі.

Контрольний список

Оцініть такі аспекти статті: (якщо відповідь «Ні», будь ласка, за можливості, запропонуйте покращення в полі «Інформація для авторів»)

- Чи заголовок точно відображає зміст тексту?
- Чи чітко зазначено мету?
- Чи суттєвий внесок у розробку зазначеної проблеми робиться цією статтею?
- Чи розкриває стаття мету дослідження?
- Чи логічно викладений матеріал статті?
- Чи висвітлена в анотації суть статті, анотація є інформативною та лаконічною?
- Чи висновки автора адекватні експериментальному матеріалу?

Надайте конкретні коментарі та пропозиції, зокрема, щодо оформлення, назви, опису, вступу, гіпотези та/або предмету дослідження, матеріалів і методів, статистичної обробки матеріалів, результатів, обговорення, висновків, мови та посилань.

Якщо ви вбачаєте прояви академічної недоброчесної, обговоріть свої підозри з редактором, надайте якомога докладнішу інформацію.

Ваша рекомендація

Коли ви даєте рекомендацію, то обираєте одну з категорій, які використовуються для класифікації статті:

- прийняти подання;
- необхідні виправлення;
- необхідне додаткове рецензування;
- до іншого видання;
- відхилити подання.

Остаточне рішення

Головний редактор вирішує, чи прийняти чи відхилити статтю. Редактор, перш ніж прийняти рішення, зважить всі погляди та може зажадати третю думку або попросити автора переглянути документ. Видавнича система надає користувачам повідомлення про остаточне рішення.

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