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The Effect of Knee Tuck Jump and Jump-To-Box Plyometric Training on Female Students' Leg Muscle Strength and Flexibility in Volleyball Extracurricular Activity

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Abstract

Study purpose. This study aimed to investigate the effects of Knee Tuck Jump or Jump to Box plyometric training and to determine their effectiveness in increasing leg muscle strength and flexibility in female students participating in volleyball extracurriculars.

Materials and methods. This study used a quasi-experimental design. Twenty-four female students were randomly selected as samples and then divided into two categories: 12 students receiving Knee Tuck Jump training (age: 17.08±0.51) and 12 students receiving Jump to Box training (age: 17.00±0.60). All participants performed the initial and final tests using the Vertical Jump and sit-and-reach tests. To analyze the data, the t-test was used to determine the differences in variables between the pretest and posttest in the experimental group.

Results. In the Knee Tuck Jump group, a significant improvement in VJ ($p = 0.000$) and sit-&-reach tests ($p = 0.000$) was observed. In addition, Knee Tuck Jump was considered to be more effective in increasing the students' flexibility, because the t value of sit-&-reach test (14.075) was higher than that of VJ (13.811).

Similarly, the Jump to Box group also showed a significant improvement in VJ ($p = 0.000$) and sit-&-reach ($p = 0.000$) tests. However, Jump to Box was deemed to be more effective in increasing the students' leg muscle strength, as the t value of VJ (26.086) was higher than that of sit-&-reach test (9.594).

Conclusions. Based on the research findings, it can be concluded that plyometric exercises, specifically KTJ and JB, have a significant and positive impact on the lower limb muscle strength and flexibility in female students participating in volleyball extracurricular activities. Despite both demonstrating significant positive effects, KTJ training is more effective in improving flexibility compared to JB, while JB is more effective in enhancing lower limb muscle strength compared to KTJ.

Keywords: plyometric training, flexibility, volleyball, female student.

Introduction

Volleyball demands a unique skill to land the ball in the opponent's area, and to achieve maximum performance, the players must be in top physical condition (Bompa & Carrera, 2015; M. Silva et al., 2014). Athlete performance, particularly in sporting events, is greatly improved by physical condition. Athletes will benefit from being in good physical shape as they learn sports techniques. The primary objective of enhancing sports performance is the capacity of personally trained athletes (Gozzoli et al., 2023). Forearm pass, overhand pass, serve, smash and block are some examples of basic individual skills in the game of volleyball (Zahálka et al., 2017). These individual basic skills all utilize various motor skills and abilities such as jumping, swinging or various ways of movement as well as strength, agility, flexibility and reaction speed (Lehnert et al., 2017).

According to the components of physical condition, volleyball players need endurance, speed, strength, power, flexibility, and agility (Charitonidis et al., 2019). Each player in an international men's volleyball match makes more than 250 jumps during the course of the five sets, according to

match analysis (Martinez, 2017). According to Vlantes & Readdy (2017), the team and the volleyball players themselves will benefit from having a good jump, making it advantageous to have a strong physical power component in volleyball games.

Furthermore, power training is frequently used in volleyball, which is regarded as a very explosive and fast-paced activity (A. F. Silva et al., 2019). One of the most crucial skills to master to become a competent or experienced player in volleyball is jumping. The ability to jump high is necessary for success when performing a smash. Physical components like leg muscle power and flexibility are required to increase smashing skills. Leg muscle power affects jumps during smashing and blocking (Hammami et al., 2022). At the same time, flexibility is also needed to support athletes in performing smashes. According to Hu et al. (2022), the degree of a joint's flexibility determines how well it can carry out specific movements. Additionally, Zhao & Liu (2022) stated an athlete's speed, strength, and explosive power can all be improved to various degrees by training flexibility. Flexibility is therefore required when blocking and striking the ball. In a volleyball match, a good smash will result in points by dropping the ball in the opponent's area. The players must also be in decent physical shape to achieve strong smash results. According to A. F. Silva et al. (2019), it is necessary to make efforts to increase physical quality through various training methods in order to obtain maximum processing in volleyball games, particularly boosting leg muscle power and flexibility in every volleyball game.

The plyometric approach is one exercise strategy for boosting power (Slimani et al., 2016). Plyometrics is one of the training techniques that trainers are frequently requesting to increase the physical component of power, especially in sports that require the use of the legs or arms. However, its effect on flexibility has not been investigated. Additionally, plyometric exercise involves training by umping or bouncing using the limbs (Davies et al., 2015). The knee tuck jump exercise, which is performed in a sequence of quick, explosive jumps, is one example. The gastrocnemius, gluteals, quadriceps, hamstrings, and hip and thigh flexors are among the muscles that develop in this exercise (Clark et al., 2018). Another example is the jump-to-box exercise, which is the exercise of jumping onto a block box and then jumping back down to the back using the starting position and both legs together (Saparia et al., 2020).

Based on the explanation above, this research aimed to reveal the effect of plyometric training on strength and flexibility. Specifically, it compared the effect of plyometric knee tuck jump and jump to box exercises on increasing the students' strength and flexibility. Because the students participated in extracurricular volleyball activities, they could be categorized as unprofessional volleyball players (beginners).

Materials and methods

Participants

Twenty-four students from one senior high school who joined volleyball extracurriculars agreed to participate in this research. After a preliminary assessment using the vertical jump and sit-and-reach, the participants were then randomly split into two groups, one received plyometric training in the knee tuck jump (KTJ) and one received jump to box (JB). Table 1 displays the characteristics of the students. All students had no experience in weight training. They were initially given an explanation of the benefits and risks that could occur if they took part in the training in this research. Then, they provided written consent to the experimental procedures.

Table 1. Participant's physical characteristics

Variables	Knee Tuck Jump (n = 12)	Jump To Box (n = 12)
	Mean ± SD	Mean ± SD
Age	17.08±0.51	17.00±0.60
Height (m)	1.56±0.01	1.57±0.02
Weight (kg)	44.25±6.20	48.33±6.12
BMI	18.11±2.43	19.71±2.45

Experimental design

This study was designed to answer two questions: (1) Is there an effect of plyometric knee tuck jump and jump-to-box exercises on strength and flexibility? (2) Is plyometric knee tuck jump training more effective for increasing strength and flexibility? To investigate these questions, twenty-four students were randomly assigned to one of the two training groups: KTJ (n = 12) and JB (n = 12). This research used a quasi-experimental design. The two experimental groups trained twice a week for 6 weeks using only plyometric knee tuck jump (KTJ) and jump to box (JB) exercises with their own body weight and using equipment in the form of a 40cm high box. The following are the characteristics of the training program in this research

Table 2. Characteristics of the training program*

Indexes		KTJ (S × R × I)	JB (S × R × I) (cm)
Week 1	TS1	2 × 6 × 30"	2 × 6 × 30" × 40cm
	TS2	3 × 6 × 30"	3× 6 × 30" × 40cm
Week 2	TS3	2 × 8 × 30"	2 × 8 × 30" × 40 cm
	TS4	3 × 8 × 30"	3 × 8 × 30" × 40cm
Week 3	TS5	2 × 10 × 1'	2 × 10 × 1' × 40cm
	TS6	3 × 10 × 1'	3 × 10 × 1' × 40cm
Week 4	TS7	4 × 8 × 2'	4 × 8 × 2' × 40cm
	TS8	4 × 10 × 2'	4 × 10 × 2' × 40cm
Week 5	TS9	4 × 12 × 2'	4 × 12 × 2' × 40cm
	TS10	4 × 15 × 3'	4 × 15 × 3' × 40cm
Week 6	TS11	5 × 15 × 4'	5 × 15 × 4' × 40cm
	TS12	5 × 15 × 3'	5 × 15 × 3' × 40cm

*note: TS: Training session; KTJ: Knee tuck jump; JB: Jump to Box (cm); S × R × I: Set × Repetitions × Interval (minute)

Testing procedure

The testing session was conducted for each participant in the same condition, without injury, and not following

a match or a period of intense training at the same location and time (about an hour). During testing, body composition was also assessed. The participants were verbally strongly encouraged to exert their maximum effort. They were also recommended to stretch for roughly 10 minutes prior to the test.

Vertical Jump (VJ)

VJ is used to evaluate lower body strength in the vertical plane in an indirect manner (Banda et al., 2019). The tools used were a board attached to the wall at a height of 150 to 350 cm, powdered chalk (talcum powder or flour), and a blackboard eraser. To carry it out, first the fingertips were smeared with lime powder or magnesium carbonate, then the participant stood upright near the wall, feet together, scale board to the left or right. Next, the hand near the wall was lifted straight up, the palm of the hand was placed on a scaled board, thereby leaving a reach mark. Participants started with a bent knee posture and the dominant hand or arm was raised in a vertical position and the other arm was hanging at the side of the body and was not permitted to swing the arm to help with jumping momentum. Then the participants jumped as high as possible while tapping the board with their fingertips to leave a mark. The assessment is the difference in jumping achievement minus standing achievement. The participants got two opportunities to do this test. The best results were recorded.

Sit and Reach

Flexibility was assessed using sit and reach test. The subjects sat with their feet approximately hip-wide against the testing box. They kept their knees extended and placed the right hand over the left, and slowly reached forward as far as they could by sliding their hands along the measuring board. The participants got two chances to do the test and the best results were recorded.

Statistical analysis

In analyzing the data, the following tests were used:

(1) Normality test to find out whether the data were normally distributed. The test used was the Shapiro-Wilk test;

(2) Homogeneity test to find out whether the variations in the population were the same or not. The homogeneity of variance test was carried out to test the similarity of the variances of the pretest and posttest experimental group data. To test the homogeneity, the Levene's Test with the F test was used. The homogeneity test was carried out to determine whether the data distribution (variance) of the two experimental groups was not heterogeneous, in the sense that they had balanced traits or characteristics so that they were suitable for comparison (van Breukelen & Candel, 2021). The data distribution (variance) of the two experimental groups was declared homogeneous if the Levene test results showed a significance value of $p>0.05$;

(3) The t-test was carried out to determine whether there were differences in variables between the pretest and posttest in the experimental group. A difference could be stated if the significance value was less than 0.05 ($p < 0.05$). The data obtained from the initial test (pretest) and final test (posttest) were analyzed descriptively statistically using the t-test using the SPSS version 27 with a significance level of 5% or 0.05.

Results

Pre-Test Results

A statistical picture is shown in Table 3 based on assessments of students' strength and flexibility before knee tuck jump or jump to box training. Based on the table, it can be seen that in the knee tuck jump group the students had an average strength value of 27,916 and flexibility with an average value of 23,495. Meanwhile, in jump to box group, the average strength value was 26.9167 and the average flexibility value was 19.050.

Table 3. Statistical Description of Pre-Test Score

Indexes	Knee Tuck Jump group pre-test score (n = 12)		Jump to Box group pre-test score (n = 12)	
	Strength	Flexibility	Strength	Flexibility
Mean	27.9167	23.4950	26.9167	19.0500
Median	28.0000	22.8600	27.0000	19.0500
Std. Deviation	1.88092	3.77132	2.23437	2.54000
Variance	3.538	14.223	4.992	6.452
Range	6.00	12.70	7.00	7.62
Minimum	25.00	17.78	23.00	15.24
Maximum	31.00	30.48	30.00	22.86

Post-Test Results

Table 4 shows descriptive data from the results of measuring strength and flexibility after treatment was given, namely knee tuck jump and jump to box exercises.

Table 4. Statistical Description of Post-Test Score

Indexes	Knee Tuck Jump group post-test score (n = 12)		Jump to Box group post-test score (n = 12)	
	Strength	Flexibility	Strength	Flexibility
Mean	37.5833	32.1792	40.3333	26.2083
Median	38.0000	32.9000	40.5000	25.2500
Std. Deviation	1.44338	2.83929	1.82574	3.79867
Variance	2.083	8.062	3.333	14.430
Range	5.00	11.00	6.00	12.00
Minimum	35.00	26.00	37.00	22.00
Maximum	40.00	37.00	43.00	34.00

After the treatment it can be seen that in knee tuck jump group the students had an average strength value of 37.5833 and average flexibility value of 32.1792. Meanwhile, in jump to box group, the students' average strength value was 40.3333 and their average flexibility value was 26.2083. Therefore, it may be considered that the jump to box exercise is more helpful for increasing strength, while the knee tuck jump exercise is more effective for increasing flexibility. However, these descriptive data need to be strengthened in order for them to provide a substantial and meaningful answer to the hypothesis.

Normality Test Results

The Shapiro-Wilk test was used to test the normality. Table 5 explains that all data were normally distributed because all results got significant values below 0.05.

Table 5. Normality Test Results

Group	Variables	Pre-test		Post-test	
		s-w	P	s-w	p
KTJ	V-Jump	0.944	0.552	0.960	0.780
	Sit & Reach	0.933	0.411	0.936	0.453
JB	V-Jump	0.962	0.811	0.955	0.713
	Sit & Reach	0.906	0.187	0.866	0.058

Homogeneity Test Results

The Levene Statistic test was performed to test the homogeneity. Tabel 6 shows that all data were homogeneously distributed because all results obtained significant values below 0.05

Table 6. Homogeneity Test Results

Groups	Variables	Levene Statistic	p
KTJ	V-Jump	.478	.497
	Sit & Reach	1.128	.300
JB	V-Jump	.337	.567
	Sit & Reach	1.064	.313

Hypothesis Testing

Hypothesis testing was then conducted after the data passed the prerequisite test, indicating that the data were homogeneous and normally distributed. The purpose of this study was to determine whether plyometric knee tuck jump and jump to box exercises had an impact on strength and flexibility and to determine which activity was more successful at doing so. The following are the results of the Paired Sample T-test to answer the hypothesis in this research.

According to Table 7, knee tuck jump group had a significant improvement in vertical jump because the p-value was less than 0.05 and the t statistic was positive. Additionally, there was a significant improvement in sit and reach because the p-value was below 0.05 and t statistic was positive. Therefore, it can be concluded that Knee tuck jump is more effective to increase the students' flexibility because the t statistic of Sit and reach (14.075) was higher than that of Vertical jump (13.811).

Similarly, in jump to box group, a significant improvement was observed in vertical jump as the p-value was less than 0.05 and t statistic was positive. Similar improvement was also seen in sit and reach because, once again, the p-value was below 0.05 and t statistic was positive. However, jump to box exercise is considered more effective to improve the students' leg muscle strength because the t statistic of Vertical jump (26.086) was higher than that of sit and reach (9.594).

Discussion

The effects of Jump to Box plyometric training on leg muscle strength and flexibility

Plyometric exercises are designed to enhance neuromuscular coordination by conditioning the neural system and increasing movement automaticity when engaged in activity. As a result, activity automation is known to be created, strengthening motor patterns, which boosts neural efficiency and enhances neuromuscular performance (Davies et al., 2015). Plyometrics is known as a stretch-shortening cycle, or mitotic stretch reflex, where a muscle is loaded into an eccentric contraction (lengthening), followed immediately by a concentric contraction (shortening) with the result that the muscle that was stretched before the contraction will contract more forcefully. Plyometrics also include vigorous and explosive training exercises to activate the fast response and elastic properties of the major muscles in the body. Thus, implementing a specific strength and conditioning program in volleyball can significantly help prevent injuries and improve performance.

Since volleyball players place a high value on being able to jump vertically, it is thought that using plyometric training techniques to increase this capacity may enhance volleyball player performance (Çankaya et al., 2018). A study by Mroczek et al. (2018) has found that plyometric training contributes to optimizing landing mechanisms, improving extrinsic muscle control and increasing knee flexion and hamstring activity.

The variety of exercises is another crucial element that might impact the efficacy or scope of the advantages of plyometric intervention. In this research, the jump to box exercise was utilized to train the students' strength and flexibility. According to the findings of this study, using such exercise significantly influences the students' leg muscle strength and flexibility. This finding is strengthened by the

Table 7. Results of Hypothesis Testing

Variables		Test	KTJ Group			JB Groups		
			Average	t count	p value	Average	t count	p value
Strength	V-Jump	Pretest	37.58	13.811	0.000	40.33	26.086	0.000
		Posttest	27.91			26.91		
Flexibility	Sit & Reach	Pretest	32.17	14.075	0.000	26.20	9.594	0.000
		Posttest	23.49			19.05		

study by Gjinovci et al. (2017) which found plyometric training (which included jump to box exercise) more effective than skill-based conditioning in increasing the conditioning capacity of female senior volleyball players with the results of the plyometric group significantly reducing body mass (Effect Size [ES] difference; average 1% change before and after measurement), and improved their performance in S20M (moderate ES; 8%), MBT (very large ES; 25%), CMJ (large ES; 27%), and SBJ (moderate ES; 8%).

In addition, a significant effect of jump to box training was observed on the students' flexibility with a significant value of 0.000. This is in line with the study by Ramírez-delaCruz et al. (2022) which found that plyometric training increased the thickness, pennation angle and length of the muscle fascicles evaluated. Additionally, plyometrics is an effective tool for increasing tendon stiffness and improving jumping performance and lower body strength. According to Arntz et al. (2022), plyometric jump training can cause skeletal muscle hypertrophy, regardless of age and gender. There is evidence of a relatively greater effect in non-athletes compared to athletes.

Although jump to box exercise was observed to significantly impact the students' vertical jump and flexibility, this exercise is deemed to be more effective to increase the students' leg muscle strength because the t statistic of Vertical jump (26.086) is higher than that of Sit and reach (9.594). Since vertical jumps are not the only thing that volleyball players do, future research on volleyball players must include a variety of vertical jump tests to compare the various effects of plyometric training on player performance, particularly in volleyball players. Additionally, it is necessary to assess how various programs affect players who are more experienced and skilled.

The effects of plyometric Knee Tuck Jump training on leg muscle strength and flexibility

The range of motion that may be performed without injuring a joint or group of joints is determined by flexibility, which is a feature fundamental to bodily tissue (Pate et al., 2012). The sit and reach test is used to measure spinal flexibility and hamstring muscle length (Cornbleet & Woolsey, 1996). According to studies by Idrizovic et al. (2018) and Turgut et al. (2016), plyometric training improves flexibility in women under 16. However, on the other hand, flexibility ability as measured by sit and reach in middle school students is considered to reduce vertical jump ability. Refuting previous research findings, Ozgul (2018) revealed that static, dynamic and PNF flexibility training improved the vertical jump performance of basketball and volleyball players. Research by Yildiz et al. (2020) revealed that, static stretching increased flexibility but decreased the athletes' jumping performance.

A study by Skaggs et al. (2015) which compared the individual and combined effects of plyometric training programs and dynamic stretching on muscle strength, endurance, and flexibility in female collegiate volleyball players, showed that plyometric training improved some of these neural functions and dynamics, so it could be concluded that stretching increased muscle temperature, stimulated nervous system and increases muscle elasticity, thereby increasing flexibility by 10.29%.

This research has found that plyometric training using the Knee Tuck Jump method which is carried out systematically with the correct frequency and intensity can increase the students' leg muscle strength. A significant improvement was seen in the students' vertical jump as the p-value was below 0.05 and the t statistic was positive. Furthermore, similar improvement was observed in the students' sit and reach test because the p-value was below 0.05 and the t statistic was positive. Therefore, it can be concluded that Knee tuck jump exercise is considered more effective to improve the students' flexibility since the t statistic of Sit and reach (14.075) is higher than that of Vertical jump (13.811). This can happen because the knee tuck jump training mechanism emphasizes the maximum height achieved by pushing the leg up and forward quickly, especially by training the flexors and extensors of the thigh and hip in relation to muscles such as the iliacus, sartorius, gracilis, biceps, femur, semitendon, gluteus muscle, semi-membrane, gluteus major and minor. This repetitive jumping movement will contract the leg muscles and increase the size and number of muscle cells and leg muscle fibers which will indirectly have an effect on increasing flexibility. Flexibility depends on several factors such as joint structure, body muscles, flexibility of capsule and collagen tissue, strength and evenness of joints of bony structures, intramuscular and intermuscular coordination, age, psychology, environmental conditions, level of training, fatigue and warming up. Furthermore, to support this study's findings, a study by Tsolakis & Bogdanis, (2012) found that there was an increase in hip flexion ROM (~12.6%), but there was a significant decrease in CMJ performance of 5.5% due to long duration static stretching treatment. This static stretching or lowering effect still occurs for a moment when doing a tuck jump. Furthermore, CMJ's performance returned to its initial performance (initial measurement) only after performing tuck jumps for 8 minutes.

Future studies should look at the range of motion during plyometric training in order to identify the factors most likely to increase participants' flexibility. Additionally, it is necessary to assess how various programs affect professional and skilled players.

Conclusions

Based on the study' findings, it can be concluded that Knee Tuck Jump and Jump to Box plyometric exercises have a positive and significant influence on the beginner female volleyball players' leg muscle strength and flexibility. Although both have a significant positive effect, Knee Tuck Jump training is more effective at increasing flexibility, while Jump to Box is more effective at increasing leg muscle strength. Further research needs to be carried out to further strengthen this research's findings by investigating the effects of both exercises on experienced and more professional players.

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Conflict of interest

The authors guarantee that no conflicts of interest exist.

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Вплив пліометричного тренування стрибків із підтягуванням колін до грудей та стрибків на коробку (пліобокс) на показники сили м'язів ніг та гнучкості у студенток в процесі позааудиторних занять з волейболу

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

Реферат. Стаття: 8 с., 7 табл., 33 джерела.

Мета дослідження. Метою цього дослідження було вивчити вплив пліометричного тренування стрибків із підтягуванням колін до грудей або стрибків на коробку (пліобокс) та визначити їх ефективність у зростанні показників сили м'язів ніг та гнучкості у студенток, які беруть участь у позааудиторних заняттях з волейболу.

Матеріали та методи. У цьому дослідженні використано квазіекспериментальний метод. Двадцять чотири студентки були відібрані методом рандомізації, а потім розподілені на дві категорії: 12 студенток, які виконували тренування зі стрибків із підтягуванням колін до грудей (вік: 17,08±0,51) та 12 студенток, які виконували тренування зі стрибків на коробку (вік: 17,00±0,60). Всі учасниці виконували початкові та підсумкові випробування, виконуючи вертикальний стрибок та тест на гнучкість sit-and-reach (спосіб вимірювання загальної гнучкості тіла при згинанні тулуба вперед, сидячи на підлозі з витягнутими вперед руками). Для аналізу даних було застосовано t-критерій для визначення відмінностей у показниках варіації змінних між претестом і посттестом в експериментальній групі.

Результати. У групі, що виконувала вправи зі стрибків із підтягуванням колін до грудей, спостерігалося значне покращення показників результативності у тесті з виконання вертикального стрибка (p=0,000) та тесті на гнучкість sit-and-reach (p=0,000). Крім того, стрибок із підтягуванням колін до грудей виявився більш ефективним в рамках зростання показників гнучкості студенток, оскільки t-статистика (значення) тесту на гнучкість sit-and-reach (14,075) була вищою, ніж при виконанні вертикального стрибка (13,811).

Аналогічним чином, група, яка виконувала вправи зі стрибків на коробку (пліобокс) також показала значне поліпшення результативності у тесті з вертикального стрибка (p=0,000) та тесті на гнучкість sit-and-reach (p=0,000). Однак, стрибок на коробку виявився більш ефективним у зростанні показників сили м'язів ніг студенток, оскільки t-значення вертикального стрибка (26,086) було вищим, ніж при виконанні тесту на гнучкість sit-and-reach (9,594).

Висновки. На основі результатів дослідження можна зробити висновок, що пліометричні вправи, зокрема стрибки із підтягуванням колін до грудей та стрибки на коробку, мають значний позитивний вплив на показники сили м'язів нижніх кінцівок та гнучкості у студенток, які беруть участь у позааудиторних заняттях з волейболу. Незважаючи на те,

що обидві вправи демонструють значні позитивні результати, тренування зі стрибків із підтягуванням колін до грудей є більш ефективним для поліпшення показників гнучкості порівняно з виконанням стрибків на коробку, тоді як стрибок на коробку є більш ефективним для підвищення показників сили м'язів нижніх кінцівок порівняно з виконанням стрибків із підтягуванням колін до грудей.

Ключові слова: пліометричне тренування, гнучкість, волейбол, студентка.

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