



Estimating the Total and Regional Body Fat of Physically Active Men Is Not Appropriate for Sedentary Men

Supaporn Silalertdetkul^{1ABCDE}

¹Srinakharinwirot University

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

Corresponding Author: Supaporn Silalertdetkul, E-mail: ssilalertdetkul@gmail.com

Accepted for Publication: May 18, 2024

Published: June 30, 2024

DOI: [10.17309/tmfv.2024.3.06](https://doi.org/10.17309/tmfv.2024.3.06)

Abstract

Objectives. The reliability of predictive body fat equations remains unclear due to their inappropriate use across different subject cohorts and conditions. The objective of this study was to validate and cross-validate equations to predict total and regional body fat in young physically active males.

Materials and methods. Three hundred and five young male participants were divided into the following groups: active validation ($n = 165$), active cross-validation ($n = 70$), or sedentary cross-validation ones ($n = 70$). The study used a stratified random sampling based on weekly physical activity level. The total and regional body fat mass were measured using dual-energy X-ray absorptiometry (DEXA) after an overnight fast. Simultaneous measurements of height, body mass, skinfold thickness, body mass index, and body circumferences were taken. The total and regional body fat predictive equations were generated using multiple linear stepwise regression models. The coefficient of determination (R^2) and standard error of estimation (SEE) were calculated to examine the accuracy of the predictive equations. Furthermore, cross-validation groups were analysed.

Results. The percentage of total body fat, trunk fat, legs fat, arms fat, and body mass index of active cross-validation were found to be significantly lower than in the sedentary cross-validation groups. The total body fat percentage was highly associated with abdominal skinfold thickness ($r = 0.68-0.74$, $p < 0.001$), body mass index ($r = 0.55$, $p < 0.001$), and suprailiac skinfold thickness ($r = 0.67-0.71$, $p < 0.001$) in the active validation group. The predictive total and regional body fat equations of physically active men showed adjusted R^2 values ranging from 0.35 to 0.66, with standard error of estimation values between 2.74 to 4.35%. The standard error of estimation for the predictive percentage of total and regional body fat in the active cross-validation group was lower than in the sedentary cross-validation group.

Conclusions. The findings demonstrate that new predictive total and regional body fat equations can be used to accurately estimate body fat in healthy young active males under fast conditions.

Keywords: inactive men, young men, body composition, skinfold thickness, circumference.

Introduction

The body fat associated with cardiovascular diseases, diabetes, hypertension, and physical fitness (Chun, Suh, Byun, Park, & Shim, 2015; Ortega, Lavie, & Blair, 2016; Takeoka et al., 2016). Therefore, assessing body fat for monitoring and preventing health problems is essential. However, using an accurate instrument to measure body fat in the field can be expensive and inconvenient. Previous studies have shown that predictive equations for estimating

body fat in Western and Asian men have been developed (Ball, Cowan, Thyfault, & LaFontaine, 2014; Leahy, O'Neill, Sohun, Toomey, & Jakeman, 2013; Liu et al., 2015). It should be noted that most of the previous studies developed predictive total body fat equations. It has been reported that trunk fat mass is associated with cardiovascular diseases, arterial stiffness, and insulin resistance in men (Ganpule-Rao et al., 2013; Kouda et al., 2021; M. Lee et al., 2012). Therefore, it is important to assess not only total body fat but also regional fat mass. However, only a few studies developed predictive regional body fat equations from Caucasian men (Ritchie & Davidson, 2007; Scafoglieri et al., 2013). The validation of the predictive total and regional body fat equations developed

from Western and Asian men applied to Thai men is still unclear and needs to be examined. Conversely, equations for estimating total and regional body fat need to be developed and cross-validated for specific populations.

They correlate the percentage of body fat with ethnic differences (Davidson et al., 2011; Jensen et al., 2019; Stults-Kolehmainen et al., 2013), as demonstrated by its under-estimation and over-estimation when validating predictive body fat equations between Western and Asian men (Davidson et al., 2011; Hastuti, Kagawa, Byrne, & Hills, 2013). The predictive body fat equation developed from the Western population might not be appropriate for application to the Asian population. It has been demonstrated that body fat values are not consistent between young, middle-aged, and older-aged males (Coin et al., 2012; Ihasz, Finn, Lepes, Halasi, & Szabo, 2015; Larsson et al., 2015). Previous studies have shown that lower body fat was observed by active men compared to sedentary counterparts (Kyle, Morabia, Schutz, & Pichard, 2004; Scheers, Philippaerts, & Lefevre, 2013). Additionally, there is a relationship between sedentary time and visceral fat in men (Henson et al., 2015). Therefore, the predictive body fat equation developed by active men might not be suitable to apply to sedentary men. Additionally, the amount of food and water consumed before the assessment of body fat contributed to varying fat mass in different methods (Kerr, Slater, & Byrne, 2017). Consequently, the validity of predictive total and regional body fat equations might have been associated with participants' fasted or non-fasted states.

It has been demonstrated that body fat mass is associated with differences in ethnicity, age, food intake, and physical activity level (Coin et al., 2012; Jensen et al., 2019; Scheers et al., 2013). However, many previous studies have derived body fat equations using participants from across a range of ages, without providing food consumption status, and/or classification of the physical activity level (Leahy et al., 2013; D. H. Lee et al., 2017; Pongchaiyakul et al., 2005). Therefore, non-specific predictive body fat equations, which have been developed from the general male population, may be inaccurate in estimating body fat under certain conditions. Consequently, specific predictive total and regional body fat equations that represent males of a particular ethnicity, age range, and physical activity level, who have assessments taken in a fasted state, are required to provide a better estimation of total body and regional fat mass. Consequently, the objective of the present study was to validate and cross-validate predicted total body and regional fat equations of active young Thai males under fasted conditions.

Materials and Methods

Participants

Three hundred and five young Thai male participants provided their written informed consent to take part in this study, which was approved by the Institutional Research Ethics Committee. To separate the participants into sedentary and active groups, the participants were asked to complete PAR-Q (Physical Activity Readiness Questionnaire) and physical activity questionnaires. In the active group, participants performed regular physical activity for a duration of greater than 50 minutes and greater

than 3 times per week. In the sedentary group, participants performed physical activity for less than 30 minutes and less than 3 times per week. The participants' resting heart rate (Omron, Japan) and blood pressure (Omron, Japan) were also measured.

Study Design

They randomly divided participants into three groups; validation, cross-validation with an active group, and cross-validation with a sedentary group. Anthropometry and body fat mass were assessed after an overnight fast. Estimated total and regional fat mass equations were developed. The difference in fat mass between the predictive equations and the reference method was analyzed in the sedentary and active groups.

Assessment of the Reference Method

They performed a total body scan after an overnight fast using dual-energy X-ray absorptiometry (DEXA, Hologic Inc, United States) as the reference method. The procedure of the total body scan followed the manufacturers' guidelines. The total percentage of fat mass, and the regional fat mass of the trunk, arms, and legs, were recorded and analyzed.

Assessment of Anthropometry

Anthropometry measurements included height, body mass, and body circumferences, which were recorded after an overnight fast. In addition, the skinfold thickness of the biceps, triceps, vertical abdominal, transverse abdominal, suprailiac, chest, subscapular, mid-thigh, and medial-calf (Lange skinfold caliper, United States), were taken on both sides of the body (Lohman, Roche, & Martorell, 1991). Body mass index (BMI) was calculated using the ratio between body mass in kilograms and height in square meters. Chest, waist, abdominal, hip, arm, forearm, upper thigh, and calf circumferences were measured using a measuring tape (Swain et al., 2014). Waist and hip measurements were taken at the narrowest part of the waist, and the widest part of the hip, respectively, and the waist-to-hip ratio was subsequently determined.

Statistical Analysis

All data were analyzed using statistical software (SPSS Statistics for Windows, Version 22, Armonk, NY: IBM Corp). The sample size was calculated using multiple regression analysis (Dupont & Plummer, 1998). Based on a previous study (Ohta et al., 2017), the population of the regression equation was 150 men to provide an R^2 value between 0.867 to 0.932, and the standard error of estimation (SEE) between 0.18 and 1.44 kg (5.9-8.7%). The cross-validation sample size was calculated using a Bland-Altman plot (Bland & Altman, 2010) to determine the difference between the validation and cross-validation groups.

Paired t-tests were used to analyze differences between groups, with the relationship between parameters, were examined using the Pearson product-moment test. They analyzed the accuracy of the predictive body fat equations using the correlation coefficient (R^2) and the standard error

of estimation (SEE). They developed predictive equations of total and regional body fat mass using multiple linear stepwise regression models, derived from (1) body mass, skinfold thickness, and circumferences, and (2) body mass index and circumferences, respectively. The standard error of estimation was used to analyze the difference in fat mass between the predictive equations and the reference method. The waist and hip ratio was calculated from body circumferences. Data were presented as means \pm standard deviation and the α level of statistical significance was accepted at $p < 0.05$.

Results

Participant Characteristics

The participants' age, body mass, height, body mass index, waist-to-hip ratio, resting heart rate, resting blood pressure, and percentage of body fat, are shown in Table 1. There were no statistical differences in age, height, or blood pressure between the three groups ($p > 0.05$). The resting heart rate, body mass, body mass index, the percentage of total body fat, legs fat, and arms fat in the sedentary group were significantly higher compared to the active group ($p < 0.05$). There were no significant differences in age, height, waist-to-hip ratio, and blood pressure between the active and sedentary groups ($p > 0.05$; Table 1).

Relationship Between Variables

Total body fat mass was significantly correlated with body mass index, body mass, abdominal circumference, waist circumference, transverse abdominal skinfold thickness, vertical abdominal skinfold thickness, left suprailiac skinfold thickness, and suprailiac skinfold thickness ($p < 0.001$; Table 2).

The highly correlated total percentage of body fat with body mass index, transverse abdominal skinfold thickness, vertical abdominal skinfold thickness, and suprailiac skinfold thickness ($p < 0.001$; Table 2).

Table 2. The correlation (r) between total body fat mass, total percentage of body fat, and trunk fat mass with body mass index, body mass, abdominal circumference, waist circumference, and skinfold thickness (SF) in the validation active group

r	Total body fat mass	Total percentage of body fat	Trunk fat mass
Body mass index (kg/m^2)	0.71*	0.55*	0.71*
Body mass (kg)	0.67*	0.43*	0.66*
Abdominal circumference (cm)	0.57*	0.46*	0.55*
Waist circumference (cm)	0.56*	0.41*	0.55*
Left transverse abdominal SF (mm)	0.70*	0.74*	0.71*
Right transverse abdominal SF (mm)	0.55*	0.70*	0.54*
Left vertical abdominal SF (mm)	0.67*	0.68*	0.66*
Right vertical abdominal SF (mm)	0.67*	0.70*	0.67*
Left suprailiac SF (mm)	0.68*	0.67*	0.68*
Right suprailiac SF (mm)	0.69*	0.71*	0.69*

* Significantly associated between parameters ($p < 0.001$)

They significantly associated trunk fat mass with body mass index, body mass, waist circumference, abdominal circumference, transverse abdominal skinfold thickness, suprailiac skinfold thickness, and vertical abdominal skinfold thickness ($p < 0.001$; Table 2).

Predictive Body Fat Equations

Multiple linear stepwise regression revealed the predictive equations of percent body fat derived from; (1) body mass, body mass index, and circumferences,

Table 1. Participant characteristics of validation active group, cross-validation active and sedentary groups (mean \pm SD)

Indicators	Validation active group (n=165)	Cross-validation active group (n=70)	Cross-validation sedentary group (n=70)
Age (years)	20.00 \pm 1.0	19.00 \pm 1.09	20.00 \pm 1.26
Body mass (kg)	66.00 \pm 8.51	62.00 \pm 7.63	70.00 \pm 9.53*
Height (cm)	173.00 \pm 6.17	164.00 \pm 5.31	173.00 \pm 5.82
Body mass index (kg/m^2)	22.00 \pm 2.30	21.00 \pm 2.36	23.00 \pm 2.46*
Waist / Hip ratio	0.80 \pm 0.07	0.82 \pm 0.08	0.80 \pm 0.05
Systolic blood pressure (mmHg)	115.00 \pm 16.21	114.00 \pm 13.92	114.00 \pm 19.82
Diastolic blood pressure (mmHg)	71.00 \pm 15.09	71.00 \pm 13.96	75.00 \pm 14.74
Resting heart rate (beat/min)	68.00 \pm 12.00	66.00 \pm 12.13	71.00 \pm 10.77*
Total body fat (%)	15.00 \pm 4.88	15.00 \pm 5.25	24.00 \pm 6.36*
Trunk fat (%)	18.00 \pm 5.94	18.00 \pm 6.43	29.00 \pm 7.58*
Right leg fat (%)	15.00 \pm 4.86	14.00 \pm 5.09	23.00 \pm 5.95*
Left leg fat (%)	15.00 \pm 4.86	14.00 \pm 5.07	23.00 \pm 5.95*
Right arm fat (%)	9.00 \pm 3.64	8.00 \pm 3.96	16.00 \pm 6.09*
Left arm fat (%)	9.00 \pm 3.66	8.00 \pm 3.95	16.00 \pm 6.10*

* Significant difference between cross-validation active and sedentary groups ($p < 0.05$)

and (2) skinfold thickness and circumferences. Predictive equations of percent body fat exhibited adjusted R² values ranging between 0.35 to 0.66, with standard error of estimation (SEE) ranging between 2.74 to 4.85%. The percentage of total body fat, trunk fat, legs fat, and arms fat predictive equations are shown in Table 3.

Total and trunk fat mass predictive equations revealed adjusted R² values between 0.77 and 0.78 with a standard error of estimation between 1.09 and 1.93 kg.

Standard Error of Estimation

The standard error of estimation of equations for the percentage of total body fat in the sedentary cross-validation group (3.83-5.04%) was higher compared to the active cross-validation group (1.88 to 4.21%). In the active group, the standard error of estimation for the percentage fat equations in the active cross-validation of the trunk, legs, and arms, ranged between 2.56 to 4.21%, while in the sedentary group, the values ranged between 3.95 to 4.56%. The standard error of estimation for the percentage of total body fat, trunk fat, leg fat, and arm fat are presented in Table 3.

The standard error of estimation in the active cross-validation group for total and trunk fat mass in the sedentary group (1.67-3.84 kg) was lower compared to the active cross-validation group (2.09-3.82 kg).

Discussion

The percentage of total body fat and regional fat in the active men was significantly lower compared to the sedentary men. In the present study, we generated predictive equations for total and regional body fat using dual-energy X-ray absorptiometry as the reference method. The low standard error of estimation demonstrated the accuracy of the equations when applied to active men. Predictive body fat equations derived under fasted conditions from body mass, body mass index, circumferences, and skinfold thickness, may estimate the percentage of total and regional body fat in young Thai men who perform regular exercise.

Muscle mass and body fat mass influence and reflect physical performance (Drey et al., 2016; Guiraudou et al., 2015; Rodriguez, de la Rosa, Flores, Zuleta, & Briceno, 2012), with physical activity associated with body fat (da Silva et al., 2019; Scheers et al., 2013; Suminski, Patterson, Perkett, Heinrich, & Poston, 2019). Consistent with previous findings (Tarnus & Bourdon, 2006), we observed lower levels of body fat in the active compared to the sedentary group. In the present study, the percentage total and regional body fat predictive equations, which were developed from active participants, provided a lower standard error of estimation when applied to active men. This led to an underestimation of body fat when the equations were applied to the sedentary participants. In contrast to our findings, previous studies

Table 3. The predictive equations for the percentage of total body fat, trunk, legs, and arms are derived from skinfold thickness (SF), body mass index (BMI), and circumferences

%Fat	Equations	Adjusted R ²	SEE1	SEE2	SEE3
Total	$(0.313 \times \text{Left transverse abdominal SF}) + (0.512 \times \text{BMI}) - (0.133 \times \text{Left mid-thigh SF}) + (0.160 \times \text{Rt. suprailiac SF}) + (0.133 \times \text{Left triceps SF}) - (0.198 \times \text{Right biceps SF}) - 2.817$	0.66	2.85	2.17	5.04
Total	$(0.305 \times \text{Left transverse abdominal SF}) + (0.547 \times \text{BMI}) - (0.191 \times \text{Left mid-thigh SF}) + (0.152 \times \text{Right suprailiac SF}) + (0.103 \times \text{Left triceps SF}) - 3.519$	0.65	2.90	1.88	4.58
Total	$(\text{BMI} \times 1.015) + (\text{Abdominal circumference} \times 0.177) - (\text{Chest circumference} \times 0.269) - (\text{Left lower arm circumference} \times 0.854) + (\text{Waist circumference} \times 0.300) + (\text{Right upper arm circumference} \times 0.375) - 8.736$	0.45	3.63	3.37	3.83
Trunk	$(\text{BMI} \times 1.279) + (\text{Abdominal circumference} \times 0.183) - (\text{Left lower arm circumference} \times 1.178) + (\text{Right upper arm circumference} \times 0.483) - (\text{Chest circumference} \times 0.298) + (\text{Waist circumference} \times 0.392) - 11.322$	0.47	4.35	4.21	4.56
Right leg	$(\text{BMI} \times 0.970) + (\text{Abdominal circumference} \times 0.308) - (\text{Chest circumference} \times 0.239) - 9.080$	0.35	3.92	3.31	4.06
Left leg	$(\text{BMI} \times 0.969) + (\text{Abdominal circumference} \times 0.308) - (\text{Chest circumference} \times 0.239) - 9.093$	0.35	3.92	3.30	4.06
Right arm	$(\text{BMI} \times 0.714) + (\text{Abdominal circumference} \times 0.131) - (\text{Chest circumference} \times 0.196) - (\text{Left lower arm circumference} \times 0.608) + (\text{Waist circumference} \times 0.228) + (\text{Right upper arm circumference} \times 0.281) - 9.636$	0.43	2.74	2.58	3.95
Left arm	$(\text{BMI} \times 0.718) + (\text{Abdominal circumference} \times 0.130) - (\text{Chest circumference} \times 0.195) - (\text{Left lower arm circumference} \times 0.620) + (\text{Waist circumference} \times 0.232) + (\text{Right upper arm circumference} \times 0.284) - 9.815$	0.44	2.76	2.56	3.97

SEE1: Standard error of estimation for the validation group; SEE2: Standard error of estimation for cross-validation in the active group; SEE3: Standard error of estimation for cross-validation in the sedentary group

(Davidson et al., 2011; Henry, Ponnalagu, Bi, & Tan, 2018; Pongchaiyakul et al., 2005) have shown predictive total body fat equations to both underestimate and overestimate body fat compared to reference method when applied to sedentary and active men. Consequently, estimating body fat equations derived from a combination of sedentary and active participants may not be suitably applied to active young men. Our findings also imply that it's necessary to create more accurate body fat equations for sedentary males.

In the present study, we observed a lower percentage of fat located in the trunk, arms, and legs of active men compared to sedentary participants. This is consistent with previous studies presented that there is an association between visceral fat and sedentary time (Henson et al., 2015). Previous studies have developed equations to estimate body fat in the trunk, legs, and arms (Ritchie & Davidson, 2007; Scafoglieri et al., 2013). However, our present findings suggest that there was an underestimate of these predictive percentages of trunk fat equations in a previous study (Scafoglieri et al., 2013) compared to our predicted equations and reference method of both active and sedentary men. Compared to active and sedentary men in the present study, we observed a lower percentage of trunk fat and higher legs fat in the previous study (Scafoglieri et al., 2013). Therefore, there was a difference in fat distribution between the participants of this study and the previous study (Scafoglieri et al., 2013). The accuracy of predicted regional fat equations may be associated with body fat distribution which is a difference between the previous study and this study.

Skinfold thickness, in particular abdominal skinfold thickness, had the highest correlation with total body fat when measured using the reference method. Indeed, skinfold thickness has been highly correlated with body fat using dual-energy X-ray absorptiometry (Burns, Fu, & Constantino, 2019). In the present study, predictive body fat equations derived from skinfold thickness combined with body circumferences provided greater precision and accuracy than those derived from body circumferences combined with body mass index. In comparison with body mass index, estimating body fat from skinfold thickness provided a low standard error of estimation and a high mean body fat percentage compared with the 4-compartment model (Nickerson et al., 2018). In addition, we also observed visceral adipose tissue to be highly correlated with total body fat. However, it should be noted that measuring skinfold thickness might not be accessible or appropriate for many practitioners who need to assess body composition.

It has generated several predictive equations for estimating the percentage of body fat using Western populations (Durnin & Womersley, 1974; Jackson & Pollock, 1978). However, there are differences in the percentage of body fat, fat distribution, and skinfold thickness, between the Asian and Caucasian populations (Davidson et al., 2011; Stults-Kolehmainen et al., 2013). These morphological differences likely explain the higher body fat values obtained from equations derived from Asian men (Davidson et al., 2011; Henry et al., 2018) than presently observed. Therefore, it is apparent that ethnic differences exist, implying that predicted body fat equations generated by Western men may not provide accurate results. However, the percentage of body fat determined from equations created by the Thai population, aged between 20 and 84 years old (Pongchaiyakul et al., 2005),

was lower than the dual-energy X-ray absorptiometry reference method used in the present study. Therefore, it is likely that the precision of predictive body fat equations is largely determined by both ethnicity and age differences.

Previous studies have estimated body fat using equations based on data from young, middle, and older male participants (Henry et al., 2018; Leahy et al., 2013; Pongchaiyakul et al., 2005). Compared to the dual-energy X-ray absorptiometry reference method in our investigation, these studies have either overestimated (Henry et al., 2018) or underestimated (Pongchaiyakul et al., 2005) predictive total body fat values. Therefore, it is likely that the percentage of body fat equations, which are derived across broad age ranges, is not appropriate for predicting the body fat of young men. A previous study derived a body fat mass equation using Chilean males aged between 17 and 27 years (Campos, Carrillo, Fierro, Albornoz, & Cossio-Bolanos, 2018). Nevertheless, the standard error of estimation for estimated body fat mass was higher than we calculated.

Previously developed predictive body fat equations have not defined the participants' feeding or fasting state (Campos et al., 2018; Davidson et al., 2011). This is important to consider, as they associate body fat mass with the magnitude of food consumption before body fat assessment (Kerr et al., 2017). For this reason, predictive body fat equations developed from participants who were in a fed or mixed-state (Fast and fed state) of food consumption may be inaccurate in assessing body fat in overnight fasted participants. Whilst a predictive body fat equation has previously been developed using fasted-state participants, it formulated the equation from across a broad age range (Henry et al., 2018). This likely explains the overestimation in the percentage of body fat compared with the reference method used in this study.

Conclusions

The percentage of total body fat, leg fat, and arm fat in the active men was significantly lower compared to the sedentary men. Predictive body fat equations derived from skinfold thickness combined with circumference provided more precision and accuracy than those derived from circumference combined with body mass index. They may use our newly predicted fat equations to accurately estimate body fat mass in healthy active young Asian men who perform regular exercise. We developed a new predictive body fat equation, which could apply to active young men assessed in a fasting state. Our use of a validated and cross-validated method showed that whilst our equations could be accurately applied to young men who perform regular exercise, they were not suitable to be used with sedentary men. Therefore, the findings of this study emphasize the need to develop specific body fat equations to provide precise measurements of body fat across different ages, ethnicities, and physical activity levels.

Conflict of interest

The author declares that there is no conflict of interest.

Acknowledgments

We would like to thank all the participants who took part in this study. Funding for the conduct of this research was provided by the Faculty of Physical Education, Srinakharinwirot University.

References

- Chun, H., Suh, E., Byun, A. R., Park, H. R., & Shim, K. W. (2015). Epicardial fat thickness is associated to type 2 diabetes mellitus in Korean men: A cross-sectional study. *Cardiovascular Diabetology*, *14*(46), 1-7. <https://doi.org/10.1186/s12933-015-0210-7>
- Ortega, F. B., Lavie, C. J., & Blair, S. N. (2016). Obesity and cardiovascular disease. *Circulation Research*, *118*(11), 1752-1770. <https://doi.org/10.1161/circresaha.115.306883>
- Takeoka, A., Tayama, J., Yamasaki, H., Kobayashi, M., Ogawa, S., Saigo, T., . . . Shirabe, S. (2016). Intra-abdominal fat accumulation is a hypertension risk factor in young adulthood: A cross-sectional study. *Medicine*, *95*(45), e5361. <https://doi.org/10.1097/Md.00000000000005361>
- Ball, S., Cowan, C., Thyfault, J., & LaFontaine, T. (2014). Validation of a new skinfold prediction equation based on dual-energy X-ray absorptiometry. *Measurement in Physical Education and Exercise Science*, *18*(3), 198-208. <https://doi.org/10.1080/1091367X.2014.914518>
- Leahy, S., O'Neill, C., Sohun, R., Toomey, C., & Jakeman, P. (2013). Generalised equations for the prediction of percentage body fat by anthropometry in adult men and women aged 18-81 years. *British Journal of Nutrition*, *109*(4), 678-685. <https://doi.org/10.1017/s0007114512001870>
- Liu, X., Sun, Q., Sun, L., Zong, G., Lu, L., Liu, G., . . . Lin, X. (2015). The development and validation of new equations for estimating body fat percentage among Chinese men and women. *British Journal of Nutrition*, *113*(9), 1365-1372. <https://doi.org/10.1017/s0007114515000616>
- Ganpule-Rao, A., Joglekar, C., Patkar, D., Chinchwadkar, M., Bhat, D., Lubree, H., . . . Yudkin, J. (2013). Associations of trunk fat depots with insulin resistance, beta cell function and glycaemia--a multiple technique study. *PLoS One*, *8*(10), e75391. <https://doi.org/10.1371/journal.pone.0075391>
- Kouda, K., Fujita, Y., Ohara, K., Tachiki, T., Tamaki, J., Yura, A., . . . Iki, M. (2021). Associations between trunk-to-peripheral fat ratio and cardiometabolic risk factors in elderly Japanese men: Baseline data from the Fujiwara-kyo Osteoporosis Risk in Men (FORMEN) study. *Environmental Health and Preventive Medicine*, *26*(1), 35. <https://doi.org/10.1186/s12199-021-00959-9>
- Lee, M., Choh, A. C., Demerath, E. W., Towne, B., Siervogel, R. M., & Czerwinski, S. A. (2012). Associations between trunk, leg and total body adiposity with arterial stiffness. *American Journal of Hypertension*, *25*(10), 1131-1137. <https://doi.org/10.1038/ajh.2012.92>
- Ritchie, C. B., & Davidson, R. T. (2007). Regional body composition in college-aged Caucasians from anthropometric measures. *Nutrition & Metabolism*, *4*, 29. <https://doi.org/10.1186/1743-7075-4-29>
- Scafoglieri, A., Tresignie, J., Provyn, S., Marfell-Jones, M., George, K., Clarys, J. P., & Bautmans, I. (2013). Accuracy and concordance of anthropometry for measuring regional fat distribution in adults aged 20-55 years. *American Journal of Human Biology*, *25*(1), 63-70. <https://doi.org/10.1002/ajhb.22342>
- Davidson, L. E., Wang, J., Thornton, J. C., Kaleem, Z., Silva-Palacios, F., Pierson, R. N., . . . Gallagher, D. (2011). Predicting fat percent by skinfolds in racial groups: Durnin and Womersley revisited. *Medicine and Science in Sports and Exercise*, *43*(3), 542-549. <https://doi.org/10.1249/MSS.0b013e3181ef3f07>
- Jensen, B., Moritoyo, T., Kaufer-Horwitz, M., Peine, S., Norman, K., Maisch, M. J., . . . Bosy-Westphal, A. (2019). Ethnic differences in fat and muscle mass and their implication for interpretation of bioelectrical impedance vector analysis. *Applied Physiology Nutrition and Metabolism*, *44*(6), 619-626. <https://doi.org/10.1139/apnm-2018-0276>
- Stults-Kolehmainen, M. A., Stanforth, P. R., Bartholomew, J. B., Lu, T., Abolt, C. J., & Sinha, R. (2013). DXA estimates of fat in abdominal, trunk, and hip regions varies by ethnicity in men. *Nutrition & Diabetes*, *3*(3), e64. <https://doi.org/10.1038/nutd.2013.5>
- Hastuti, J., Kagawa, M., Byrne, N. M., & Hills, A. P. (2013). Development and validation of anthropometric prediction equations for estimation of body fat in Indonesian men. *Asia Pacific Journal of Clinical Nutrition*, *22*(4), 522-529. <https://doi.org/10.6133/apjcn.2013.22.4.14>
- Coin, A., Ruggiero, E., Giannini, S., Pedrazzoni, M., Minisola, S., Rossini, M., . . . Sergi, G. (2012). Trunk and lower limb fat mass evaluated by dual-energy X-ray absorptiometry in a 20-to 80-year-old healthy Italian population. *Annals of Nutrition and Metabolism*, *61*(2), 151-159. <https://doi.org/10.1159/000342086>
- Ihasz, F., Finn, K. J., Lepes, J., Halasi, S., & Szabo, P. (2015). Body composition comparisons by age groups in Hungarian adults. *International Journal of Morphology*, *33*(3), 850-854. <https://doi.org/10.4067/S0717-95022015000300007>
- Larsson, I., Lissner, L., Samuelson, G., Fors, H., Lantz, H., Naslund, I., . . . Bosaeus, I. (2015). Body composition through adult life: Swedish reference data on body composition. *European Journal of Clinical Nutrition*, *69*(7), 837-842. <https://doi.org/10.1038/ejcn.2014.268>
- Kyle, G. U., Morabia, A., Schutz, Y., & Pichard, C. (2004). Sedentarism affects body fat mass index and fat-free mass index in adults aged 18 to 98. *Nutrition*, *20*(3), 255-260. <https://doi.org/10.1016/j.nut.2003.11.019>
- Scheers, T., Philippaerts, R., & Lefevre, J. (2013). Objectively-determined intensity- and domain-specific physical activity and sedentary behavior in relation to percent body fat. *Clinical Nutrition*, *32*(6), 999-1006. <https://doi.org/10.1016/j.clnu.2013.03.014>
- Henson, J., Edwardson, C. L., Morgan, B., Horsfield, M. A., Bodicoat, D. H., Biddle, S. J., . . . Yates, T. (2015). Associations of sedentary time with fat distribution in a high-risk population. *Medicine and Science in Sports and Exercise*, *47*(8), 1727-1734. <https://doi.org/10.1249/MSS.0000000000000572>
- Kerr, A., Slater, G. J., & Byrne, N. (2017). Impact of food and fluid intake on technical and biological measurement error in body composition assessment methods in athletes. *British Journal of Nutrition*, *117*(4), 591-601. <https://doi.org/10.1017/S0007114517000551>
- Lee, D. H., Keum, N., Hu, F. B., Orav, E. J., Rimm, E. B., Sun, Q., . . . Giovannucci, E. L. (2017). Development and validation of anthropometric prediction equations for lean body mass, fat mass and percent fat in adults using the National Health and Nutrition Examination Survey

- (NHANES) 1999-2006. *British Journal of Nutrition*, 118(10), 858-866.
<https://doi.org/10.1017/s0007114517002665>
- Pongchaiyakul, C., Kosulwat, V., Rojroongwasinkul, N., Charoenkiatkul, S., Thepsuthammarat, K., Laopaiboon, M., . . . Rajatanavin, R. (2005). Prediction of percentage body fat in rural Thai population using simple anthropometric measurements. *Obesity Research*, 13(4), 729-738. <https://doi.org/10.1038/Oby.2005.82>
- Lohman, G. T., Roche, F. A., & Martorell, R. (1991). *Anthropometric standardization reference manual*. Champaign: Human Kinetics.
<https://doi.org/10.1249/00005768-199208000-00020>
- Swain, D. P., Brawner, C. A., Chambliss, H. O., Nagelkirk, P. R., Bayles, M. P., & Swank, A. M. (2014). *ACSM's resource manual for guidelines for exercise testing and prescription* (Seventh ed.). Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.
- Dupont, W. D., & Plummer, W. D., Jr. (1998). Power and sample size calculations for studies involving linear regression. *Controlled Clinical Trials*, 19(6), 589-601.
[https://doi.org/10.1016/s0197-2456\(98\)00037-3](https://doi.org/10.1016/s0197-2456(98)00037-3)
- Ohta, M., Midorikawa, T., Hikihara, Y., Masuo, Y., Sakamoto, S., Torii, S., . . . Kanehisa, H. (2017). Validity of segmental bioelectrical impedance analysis for estimating fat-free mass in children including overweight individuals. *Applied Physiology Nutrition and Metabolism*, 42(2), 157-165. <https://doi.org/10.1139/apnm-2016-0137>
- Bland, J. M., & Altman, D. G. (2010). Statistical methods for assessing agreement between two methods of clinical measurement. *International Journal of Nursing Studies*, 47(8), 931-936.
<https://doi.org/10.1016/j.ijnurstu.2009.10.001>
- Drey, M., Sieber, C. C., Degens, H., McPhee, J., Korhonen, M. T., Muller, K., . . . Rittweger, J. (2016). Relation between muscle mass, motor units, and type of training in master athletes. *Clinical Physiology and Functional Imaging*, 36(1), 70-76. <https://doi.org/10.1111/cpf.12195>
- Guiraudou, M., Maimoun, L., Dumas, J. M., Julia, M., Raingeard, I., & Brun, J. F. (2015). Body composition measured by bioimpedance segmental (BIAS) analysis and sprint performance in rugby players. *Science & Sports*, 30(5), 298-302.
<https://doi.org/10.1016/j.scispo.2015.08.002>
- Rodriguez, F. J. R., de la Rosa, F. J. B., Flores, A. A. A., Zuleta, M. F. L., & Briceno, F. R. (2012). Comparison of body composition and muscle mass body segment in students of physical education and sports of different disciplines. *International Journal of Morphology*, 30(1), 7-14.
<https://doi.org/org/10.4067/S0717-95022012000100001>
- da Silva, B. G. C., da Silva, I. C. M., Ekelund, U., Brage, S., Ong, K. K., Rolfe, E. D., . . . Horta, B. L. (2019). Associations of physical activity and sedentary time with body composition in Brazilian young adults. *Scientific Reports*, 9(1), 5444. <https://doi.org/10.1038/s41598-019-41935-2>
- Suminski, R. R., Patterson, F., Perket, M., Heinrich, K. M., & Poston, W. S. C. (2019). The association between television viewing time and percent body fat in adults varies as a function of physical activity and sex. *BMC Public Health*, 19(1), 736.
<https://doi.org/10.1186/s12889-019-7107-4>
- Tarnus, E., & Bourdon, E. (2006). Anthropometric evaluations of body composition of undergraduate students at the University of la reunion. *Advances in Physiology Education*, 30(4), 248-253.
<https://doi.org/10.1152/advan.00069.2005>
- Henry, C. J., Ponnalagu, S. D. O., Bi, X. Y., & Tan, S. Y. (2018). New equations to predict body fat in Asian-Chinese adults using age, height, skinfold thickness, and waist circumference. *Journal of the Academy of Nutrition and Dietetics*, 118(7), 1263-1269.
<https://doi.org/10.1016/j.jand.2018.02.019>
- Burns, R. D., Fu, Y., & Constantino, N. (2019). Measurement agreement in percent body fat estimates among laboratory and field assessments in college students: Use of equivalence testing. *PLoS One*, 14(3), e0214029.
<https://doi.org/10.1371/journal.pone.0214029>
- Nickerson, B. S., Esco, M. R., Bishop, P. A., Fedewa, M. V., Snarr, R. L., Kliszczewicz, B. M., & Park, K. S. (2018). Validity of BMI-based body fat equations in men and women: A 4-compartment model comparison. *Journal of Strength and Conditioning Research*, 32(1), 121-129.
<https://doi.org/10.1519/JSC.0000000000001774>
- Durnin, J. V., & Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged from 16 to 72 years. *British Journal of Nutrition*, 32(1), 77-97. <https://doi.org/10.1079/BJN19740060>
- Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. *British Journal of Nutrition* 40(3), 497-504. <https://doi.org/10.1079/BJN19780152>
- Campos, R. G., Carrillo, J. P., Fierro, A. A., Albornoz, C. U., & Cossio-Bolanos, M. (2018). Validation of equations and proposed reference values to estimate fat mass in Chilean university students. *Endocrinologia Diabetes Y Nutricion*, 65(3), 156-163.
<https://doi.org/10.1016/j.endinu.2017.11.008>

Оцінка загальної та регіональної жирової маси тіла фізично активних чоловіків — не є доцільною для чоловіків з гіподинамією

СупапORN Силалертдеткул^{1ABCDEF}

¹Університет Сринахарінвірот

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 3 табл., 41 джерело.

Мета дослідження. Достовірність прогностичних рівнянь для визначення вмісту жиру в організмі залишається незрозумілою через їх неналежне використання в різних когортах учасників дослідження та умовах. Метою цього дослідження була валідація та застосування методу перехресного затвердження (також відомо як перехресна валідація) рівнянь для прогнозування загального та регіонального вмісту жиру в організмі молодих фізично активних чоловіків.

Матеріали та методи. У дослідженні взяли участь триста п'ять молодих чоловіків, які були розподілені на такі групи: активна валідація ($n = 165$), перехресна валідація з високою фізичною активністю ($n = 70$) або перехресна валідація з низькою фізичною активністю ($n = 70$). Дослідження було проведено із застосуванням стратифікованої випадкової вибірки, що базувалася на щотижневому рівні фізичної активності. Загальна та регіональна жирова маса тіла вимірювалася за допомогою методу двоенергетичної рентгенівської абсорбціометрії (ДРА) після нічного голодування. Також проведено одночасні вимірювання показників зросту, маси тіла, товщини шкірної складки, індексу маси тіла та окружності тіла. Прогностичні рівняння загального та регіонального вмісту жиру в організмі були отримані шляхом застосування моделей множинної лінійної ступеневої регресії. З метою перевірки точності прогностичних рівнянь було розраховано коефіцієнт детермінації (R^2) і стандартна похибка оцінки (SEE). Крім того, проаналізовано групи перехресного затвердження.

Результати. Встановлено, що відсоток жирової маси тіла, жирових відкладень на тулубі, ногах, руках та індекс маси тіла в групі перехресної валідації з високою фізичною активністю був значно нижчим, ніж в групі перехресної валідації з низькою фізичною активністю. Показник відсотка загальної жирової маси тіла був тісно пов'язаний з товщиною шкірної складки черевної порожнини ($r = 0,68-0,74$, $p < 0,001$), індексом маси тіла ($r = 0,55$, $p < 0,001$) та товщиною шкірної складки над клубовою ділянкою ($r = 0,67-0,71$, $p < 0,001$) в групі активної валідації. Прогностичні рівняння загальної та регіональної жирової маси тіла фізично активних чоловіків показали скориговані значення коефіцієнта детермінації R^2 в діапазоні від 0,35 до 0,66, зі стандартною похибкою оцінки показників у межах від 2,74 до 4,35%. У досліджуваній групі перехресної валідації з високою фізичною активністю спостерігалися нижчі показники стандартної похибки оцінки прогнозованого відсотка загальної та регіональної жирової маси тіла, ніж у групі перехресної валідації з низькою фізичною активністю.

Висновки. Результати дослідження демонструють, що нові прогностичні рівняння загальної та регіональної жирової маси тіла можна використовувати для визначення точної оцінки жирової маси тіла у здорових молодих активних чоловіків в умовах підвищеної фізичної активності.

Ключові слова: чоловіки з низькою фізичною активністю, молоді чоловіки, композиція тіла, товщина шкірної складки, окружність.

Information about the authors:

Silalertdetkul, Supaporn: ssilalertdetkul@gmail.com; <https://orcid.org/0000-0003-0760-6702>; Department of Sports Science, Faculty of Physical Education, Srinakharinwirot University, 114 Soi Sukhumvit 23, Khlong Toei Nuea, Watthana, Bangkok 10110, Thailand.

Cite this article as: Silalertdetkul, S. (2024). Estimating the Total and Regional Body Fat of Physically Active Men Is Not Appropriate for Sedentary Men. *Physical Education Theory and Methodology*, 24(3), 388-395. <https://doi.org/10.17309/tmfv.2024.3.06>

Received: 30.04.2024. Accepted: 18.05.2024. Published: 30.06.2024

This work is licensed under a Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0>).