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EVALUATING THE PREDICTIVE ACCURACY OF 4-SITE FAT CALIPER MEASUREMENTS TOTAL BODY FAT AND VISCERAL FAT ESTIMATION

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ABSTRAK

Pendahuluan: Penilaian komposisi tubuh, khususnya lemak total dan visceral, sangat penting dalam menentukan risiko kesehatan. Lemak visceral berhubungan erat dengan masalah metabolik dan penyakit kardiovaskular, tetapi pengukurannya sering memerlukan teknik pencitraan yang mahal seperti CT atau MRI. Metode kaliper lemak 4-titik merupakan alat sederhana dan hemat biaya untuk menilai lemak tubuh total, namun efektivitasnya dalam memprediksi lemak visceral masih belum diketahui. Studi ini membandingkan estimasi metode kaliper 4-titik dengan teknik pencitraan standar emas untuk menilai akurasi prediktifnya. Tujuan penelitian ini adalah mengevaluasi reproduksibilitas pengukuran berbasis kaliper terhadap lemak total dan visceral serta memberikan wawasan tentang penggunaannya dalam konteks klinis dan sumber daya terbatas. Hasil penelitian ini akan membantu praktisi dalam menerapkan teknik yang realistis untuk evaluasi kesehatan yang efektif. **Metode**: Studi cross-sectional ini dilakukan di Krendang (November 2024) dengan melibatkan 155 orang dewasa (18–60 tahun), dengan pengecualian individu dengan penyakit kronis, kehamilan, atau data yang tidak lengkap. **Hasil**: Kaliper triseps dan suprailiaka secara signifikan memprediksi lemak total dan subkutan regional ($p < 0{,}001$), tetapi tidak lemak visceral ($p = 0{,}777$; $p = 0{,}745$). Kaliper suprailiaka menunjukkan hubungan marginal dengan lemak lengan ($p = 0{,}050$). Hasil ini mendukung penggunaan pengukuran lipatan kulit sebagai alat yang andal untuk estimasi lemak subkutan. **Kesimpulan**: Kaliper triseps dan suprailiaka secara akurat memprediksi lemak subkutan tetapi tidak lemak visceral. Temuan ini menyoroti manfaatnya dalam pengaturan dengan sumber daya terbatas untuk memantau distribusi lemak, sekaligus menekankan perlunya pencitraan canggih untuk penilaian lemak visceral yang lebih akurat.

Kata Kunci: Kaliper lemak; Lemak tubuh; Lemak visceral

ABSTRACT

Introduction: *Assessing body composition, particularly total and visceral fat, is critical for determining health risks. Visceral fat is highly associated with metabolic problems and cardiovascular diseases, but measuring it often necessitates the use of costly imaging techniques such as CT or MRI. The 4-site fat caliper method, a simple and cost-effective tool for assessing total body fat, is extensively used, although its effectiveness in predicting visceral fat is unknown. This study compares the 4-site fat caliper method's estimates to gold-standard imaging techniques to assess their predictive accuracy. The study's goal is to assess the reproducibility of caliper-derived measurements for total and visceral fat, as well as to provide insights into their use in clinical and resource-limited contexts. These findings will assist practitioners in implementing realistic techniques for conducting effective health evaluations.* ***Methods:*** *This cross-sectional study, conducted in Krendang (November 2024), involved 155 adults (18–60 years), excluding those with chronic conditions, pregnancy, or incomplete data.* ***Results:*** *Tricep and suprailiac fat calipers significantly predicted total and regional subcutaneous fat ($p < 0.001$) but not visceral fat ($p = 0.777$; $p = 0.745$,* *respectively). Suprailiac calipers showed marginal association with arm fat (p = 0.050). These findings support skinfold measurements as reliable tools for subcutaneous fat estimation.* ***Conclusion:*** *Tricep and suprailiac fat calipers reliably predict subcutaneous fat but not visceral fat. These findings highlight their utility in resource-limited settings for monitoring fat distribution, while emphasizing the need for advanced imaging to assess visceral fat accurately.*

Keywords: *Body Fat; Fat caliper; Visceral fat*

1. INTRODUCTION

Body composition analysis is critical for understanding the distribution of body fat and its impact on general health (Sukkriang et al., 2021). Total body fat and visceral fat are particularly relevant indicators, with visceral fat closely associated with metabolic disorders, cardiovascular illnesses, and other chronic health issues (R. V. Shah et al., 2014b). Researchers and practitioners are constantly looking for trustworthy and accessible methods to estimate these fat components, particularly in contexts where advanced imaging technologies are unavailable (Després, 2007).

Skinfold measurements using fat calipers have become popular due to their convenience, cost, and non-invasive nature (Lewandowski et al., 2022). The 4-site fat caliper method, which measures skinfold thickness at four anatomical places, is a well-established technique for determining total body fat. However, it is questionable if it can effectively predict visceral fat. Current study emphasizes the need to determine if simple anthropometric methods such as measurement of subcutaneous fat with calipers can accurately capture visceral fat levels, which are normally measured using more complex techniques such as computed tomography (CT) or magnetic resonance imaging (MRI) (Chen et al., 2014; U. A. Shah et al., 2023).

This study investigates the predictive accuracy of the 4-site fat caliper method in assessing total body fat and visceral fat. It compares caliper-derived estimates to gold-standard imaging methods to assess their reliability in clinical and non-clinical scenarios. By focusing on the relationships between skinfold thickness and visceral fat, this study hopes to bridge the gap between advanced diagnostic methods and practical, cost-effective technologies.

The study's is to find the usefulness of fat calipers for health assessments, particularly in resource-limited situations. These findings will also help health practitioners and fitness professionals understand the benefits and limitations of this commonly used technology, opening the door for more successful strategies in body composition analysis and disease prevention.

2. METHODS

This cross-sectional study was carried out from January to December 2024 at Krendang. A total of 155 adult participants aged 18 to 60 were recruited using casual sampling. Inclusion criteria including participants had to be free of chronic conditions, pregnancies, or recent procedures that affected their body composition in order to be eligible. The exclusion criteria are uncooperative respondents, refusal to conduct the examination, and data incompleteness. All participants provided written informed consent.

Data were collected using two basic methods: skinfold measurements with a calibrated fat caliper and body composition analysis with the OMRON Body Composition Monitor HBF-375. Skinfold thickness was assessed at four anatomical places on the right side of the body including, biceps, triceps, suprailiac, and subscapular and were measured in millimeters (mm). To assure accuracy, a certified professional measured each site three times and reported the average value. The OMRON gadget assessed the following variables: total body fat (%), total visceral fat (%), total subcutaneous fat (%), trunk subcutaneous fat (%), arm subcutaneous fat (%), and leg subcutaneous fat.

The primary variables were total body fat (%) and visceral fat (%), as determined by the fat caliper method and the OMRON device. Secondary variables included subcutaneous fat in various body areas, all reported in percentages. Data were evaluated using statistical tools, with descriptive statistics used to summarize demographic and body composition information. Pearson's correlation and regression analyses were used to determine the association between skinfold measures (mm) and OMRON-derived fat estimates (%).

3. RESULTS AND DISCUSSION

The study included 155 individuals, including 92.9% women and 7.1% men. The average biceps fat caliper measurement was 5.71 mm, but the triceps fat caliper measurement was higher at 15.68 mm. The suprailiac region had the largest mean measurement (19.78 mm), followed by the scapular region (15.12 mm).

The findings revealed a mean total body fat of 33.13% and an average total visceral fat of 8.52%. The total subcutaneous fat was 29.20%, and the trunk subcutaneous fat was 25.23%. Among regional subcutaneous fat measurements, the arm had the largest proportion (43.87%), followed by the leg (40.35%). (Table 1)

Table 1. Respondents' Characteristics

Parameter	
Gender (%):	
- Women	144 (92.9)
- Men	11 (7.1)
Biceps fat caliper, mean (SD) mm	5.711 (4.32)
Triceps fat caliper, mean (SD) mm	15.68 (5.36)
Suprailiac fat caliper, mean (SD) mm	19.78 (7.11)
Scapular fat caliper, mean (SD) mm	15.12 (6.01)
Total body fat, mean (SD) %	33.13 (5.83)
Total visceral fat, mean (SD) %	8.52 (5.26)
Total subcutaneous fat, mean (SD) %	29.20 (7.52)
Trunk subcutaneous fat, mean (SD) %	25.23 (6.16)
Arm subcutaneous fat, mean (SD) %	43.87 (8.96)
Leg subcutaneous fat, mean (SD) %	40.35 (8.88)

The study looked at the relationships between fat caliper measures at different places (biceps, triceps, suprailiac, and scapular) and body fat characteristics determined with the OMRON Body Composition Monitor HBF-375. The triceps and suprailiac fat calipers had substantial positive correlations for total visceral fat ($p < 0.001$), whereas the scapular fat caliper had a lesser but still significant positive association ($p = 0.017$). There was no significant connection with biceps fat caliper measures ($p = 0.111$).

Triceps, suprailiac, and scapular fat caliper measures showed significant positive relationships with trunk subcutaneous fat ($p < 0.001$). Biceps fat caliper measurements revealed a substantial, but weaker, connection ($p = 0.001$). There was a substantial positive connection ($p < 0.001$) between arm subcutaneous fat and triceps and suprailiac fat calipers. The scapular fat caliper revealed a weaker but still significant association ($p = 0.033$), but the biceps fat caliper revealed no significant link ($p = 0.399$).

The triceps and suprailiac fat calipers had high positive associations ($p < 0.001$) with total body fat, while the scapular caliper showed a weaker but significant link ($p = 0.013$). Biceps fat caliper measurements did not produce statistically significant findings ($p = 0.121$). Suprailiac and triceps fat caliper measurements showed a significant positive correlation for total subcutaneous fat (p < 0.001). The scapular fat caliper had no significant correlation (p = 0.773), whereas the biceps fat caliper did not approach statistical significance (p = 0.312).

Table 2. Pearson Analysis of Fat Caliper with Body Fat Component according to OMRON Body Composition Monitor HBF-375

		Fat Caliper Biceps	Fat Caliper Triceps	Fat Caliper Suprailiac	Fat Caliper Scapular
Total body fat	Pearson Correlation	0.128	0.488**	0.356**	0.192*
Total visceral fat	Sig. (2-tailed)	0.111	<0.001	<0.001	0.017
Total subcutaneous fat	Pearson Correlation	0.273**	0.574**	0.605**	0.581**
Trunk subcutaneous fat	Sig. (2-tailed)	0.001	<0.001	<0.001	<0.001
Arm subcutaneous fat	Pearson Correlation	0.068	0.536**	0.317**	0.171*
	Sig. (2-tailed)	0.399	<0.001	<0.001	0.033
Total body fat	Pearson Correlation	0.125	0.560**	0.385**	0.200*
Total visceral fat	Sig. (2-tailed)	0.121	<0.001	<0.001	0.013
Total subcutaneous fat	Pearson Correlation	0.082	0.385**	0.158*	-0.023
Trunk subcutaneous fat	Sig. (2-tailed)	0.312	<0.001	0.050	0.773
Arm subcutaneous fat	Pearson Correlation	0.082	0.502**	0.289**	0.109
	Sig. (2-tailed)	0,308	<0.001	<0.001	0,177

The regression analysis examined the predictive relationship between tricep fat caliper measurements and various body fat components. Significant positive associations were observed for total body fat, total subcutaneous fat, trunk subcutaneous fat, arm subcutaneous fat, and leg subcutaneous fat, with all p-values < 0.001. These findings indicate that tricep fat caliper measurements are strong predictors of both overall and regional subcutaneous fat levels.

In contrast, the relationship between tricep fat caliper measurements and total visceral fat was not statistically significant, as evidenced by a p-value of 0.777. This suggests that tricep fat caliper measurements are less effective for estimating visceral fat compared to subcutaneous fat and total body fat.

Table 3. Conversion of Tricep's Fat Caliper to Body Fat Component

Parameter	**Triceps Fat Caliper In Millimeters (mm)**			
	Konstanta (B) (SE)	**Odds Ratio (SE)**	**p-value**	**Formula**
Total body fat	24,811 (1,271)	0,530 (0,077)	< 0,001	Y = 0,530 X + 24,811
Total visceral fat	-0,305 (1,076)	0,563 (0,065)	0,777 & < 0,001	Y = 0,563 X
Total subcutaneous fat	17,405 (1,586)	0,752 (0,096)	< 0,001	Y = 0,752 X + 17,405
Trunk subcutaneous fat	15,141 (1,276)	0,643 (0,077)	< 0,001	Y = 0,643 X + 15,141
Arm subcutaneous fat	33,771 (2,067)	0,644 (0,125)	< 0,001	Y = 0,644 X + 33,771
Leg subcutaneous fat	27,304 (1,919)	0,832 (0,116)	< 0,001	Y = 0,832 X + 27,304

*X is tricep fat caliper in mm

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The regression analysis evaluated the relationship between suprailiac fat caliper measurements and various body fat components. Significant positive relationships were found for total body fat, total subcutaneous fat, trunk subcutaneous fat, and leg subcutaneous fat, as indicated by p-values < 0.001. These results suggest that suprailiac fat caliper measurements are reliable predictors of these components.

For arm subcutaneous fat, the analysis also showed a significant relationship with a p-value < 0.001. However, an additional p-value of 0.050 suggests a marginal association, warranting cautious interpretation. In contrast, the relationship between suprailiac fat caliper measurements and total visceral fat was not significant, as indicated by a p-value of 0.745.

Table 4. Conversion of Suprailiac's Fat Caliper to Body Fat Component

Parameter	**Suprailiac Fat Caliper in Millimeters (mm)**			
	Konstanta (B) (SE)	**Odds Ratio (SE)**	**p-value**	**Formula**
Total body fat	27,355 (1,300)	0,292 (0,062)	< 0,001	Y = 0,292 X + 27,355
Total visceral fat	-0,326 (1,000)	0,447 (0,048)	0,745 & < 0,001	Y = 0,447 X
Total subcutaneous fat	22,562 (1,703)	0,335 (0,081)	< 0,001	Y = 0,335 X + 22,562
Trunk subcutaneous fat	18,621 (1,358)	0,334 (0,065)	< 0,001	Y = 0,334 X + 18,621
Arm subcutaneous fat	39,935 (2,114)	0,199 (0,101)	< 0,001 & 0,050	Y = 39,935
Leg subcutaneous fat	33,212 (2,031)	0,361 (0,097)	< 0,001	Y = 0,361 X + 33,212

*X is suprailiac fat caliper in mm

The study's findings show the predictive potential of tricep fat caliper measurements in determining various body fat components. The findings indicate that subcutaneous fat, particularly in specific body regions such as the trunk, arms, and legs, may be accurately predicted using simple anthropometric data. These findings are consistent with the known concept of skinfold thickness as a useful proxy for subcutaneous fat in body composition studies.

The high correlation between tricep fat caliper measures and subcutaneous fat components emphasizes the importance of localized fat deposits as indicators of overall body fat distribution (Hoffmann et al., 2022). Subcutaneous fat, which is located just beneath the skin, is controlled by genetic, hormonal, and environmental variables (Damayanti et al., 2019). Skinfold thickness measurement is a non-invasive, cost-effective tool for determining body composition, especially in resource-constrained environments where advanced imaging modalities such as dual-energy X-ray absorptiometry (DEXA) or computed tomography (CT) are not possible (Olutekunbi et al., 2018).

The predictive strength obtained for trunk and limb subcutaneous fat is consistent with studies demonstrating that fat storage patterns differ by body region.(Cui et al., 2022) Trunk fat, which is frequently associated with central adiposity, is a powerful predictor of metabolic and cardiovascular risk (R. V. Shah et al., 2014a). In contrast, limb fat, particularly in the arms and legs, gives extra information about peripheral fat distribution, which may have various physiological and clinical implications. These findings support the usefulness of region-specific skinfold measures in measuring fat deposition and associated health effects (Rios-Escalante et al., 2023a).

The relationship between fat storage patterns in different body regions and health outcomes is well-established in metabolic and clinical research. Trunk fat, which refers to the fat stored in the torso area, including the abdomen, chest, and back, is closely associated with central adiposity (Kwon et al., 2017). Central adiposity is a significant predictor of metabolic syndrome, encompassing insulin resistance, hypertension, dyslipidemia, and hyperglycemia, as well as cardiovascular diseases (CVD) (Swarup et al., 2024). This association is primarily due to the proximity of trunk fat to visceral fat, a metabolically active depot that promotes systemic inflammation and insulin resistance. Trunk fat can be assessed using skinfold measurements at sites like the suprailiac and subscapular regions, providing a practical and accessible tool for evaluating central adiposity (Rochlani et al., 2017).

In contrast, limb fat, stored in the arms and legs, provides insights into peripheral fat distribution, which has different physiological and clinical implications (Ferreira et al., 2004). Peripheral fat is generally less metabolically harmful and may even play a protective role by serving as a safe storage site for lipids, thereby preventing ectopic fat accumulation in vital organs such as the liver and pancreas (Porter et al., 2009). Additionally, limb fat contributes to thermoregulation and joint cushioning, particularly in the lower body (Minetto et al., 2021). It also reflects muscle-fat balance, which is critical for assessing conditions like sarcopenia (loss of muscle mass) or sarcopenic obesity. A reduction in limb fat is often observed in disorders like lipodystrophy, which is associated with metabolic disturbances, highlighting its importance in clinical evaluations (Liu et al., 2023).

Trunk fat is more metabolically active and linked to adverse health outcomes when excessive, whereas limb fat tends to be more inert and may have neutral or even protective effects on metabolic health (Jensen, 2008; Maher, 2010; Zhang et al., 2013). The balance between trunk and limb fat defines body fat distribution phenotypes, such as the "apple-shaped" android distribution (predominantly trunk fat) and the "pear-shaped" gynoid distribution (predominantly limb and lower body fat). Android distribution is associated with higher metabolic and cardiovascular risks, whereas gynoid distribution is linked to lower metabolic risks, showcasing the importance of regional fat distribution in health assessments (Blüher, 2020; Ma et al., 2023; Sánchez-López et al., 2013).

Skinfold measurements are valuable tools for assessing subcutaneous fat distribution in specific regions. Trunk fat can be measured using sites such as the suprailiac, subscapular, and abdominal skinfolds, while limb fat is assessed through biceps, triceps, thigh, and calf skinfolds (Sénéchal et al., 2013). Region-specific assessments provide detailed insights into fat storage patterns and their health implications, making them practical for clinical and fitness settings. These measurements also allow for monitoring changes over time, enabling the evaluation of interventions like weight loss programs or resistance training (Rios-Escalante et al., 2023a).

Interestingly, there is no significant association between tricep fat caliper measurements and visceral fat, highlighting the limitations of anthropometric methods in determining deeper, more metabolically active fat deposits (Aini & Ardiaria, 2022). Visceral fat, which is accumulated around internal organs, is not easily accessible through skinfold measurements and frequently requires imaging techniques such as CT or MRI for precise quantification (Pescatori et al., 2019). This constraint emphasizes the significance of using various evaluation methods to provide a complete understanding of body composition (Ryo et al., 2014).

The examination of suprailiac fat caliper measures demonstrates their usefulness as predictors of specific body fat components, particularly subcutaneous fat distribution across areas (Després et al., 2008). The suprailiac region, which is near the abdominal area, has subcutaneous fat deposits that are highly predictive of central fat storage (González Jiménez,

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2013). These findings support the well-known function of abdomen subcutaneous fat in influencing total adiposity and associated metabolic hazards (Fox et al., 2007).

The strong correlation between suprailiac fat caliper measurements and subcutaneous fat, including total, trunk, and leg subcutaneous fat, highlights the need of region-specific examinations (Demura & Sato, 2007). Subcutaneous fat in the trunk is especially important since it is associated with central obesity, a major risk factor for metabolic syndrome and cardiovascular disease (Neeland et al., 2013). The potential of suprailiac measures to predict trunk fat emphasizes its usefulness in assessing central adiposity in a cost-effective and non-invasive manner (Sniderman et al., 2007).

In contrast, the poorer association found between suprailiac fat caliper readings and arm subcutaneous fat demonstrates the variability of fat distribution (Rios-Escalante et al., 2023b). Peripheral fat, such as that found in the arms, can be regulated by a variety of physiological factors, including hormone levels and muscle mass (Frank et al., 2018). This contrast emphasizes the importance of measuring fat deposition at numerous sites to accurately reflect the complicated patterns that occur (Duren et al., 2008).

The lack of a significant association between suprailiac fat caliper measurements and visceral fat is consistent with previous research, which has shown that skinfold measurements are limited in detecting deeper fat deposits (Orphanidou et al., 1994). Visceral fat, which is found in the abdominal cavity around internal organs, is metabolically active and significantly associated with insulin resistance and inflammation (Janochova et al., 2019). Advanced imaging techniques such as CT or MRI remain the gold standard for measuring visceral fat, highlighting the limits of anthropometric approaches to body composition measurement (Wang et al., 2014).

4. CONCLUSION

The study emphasizes the predictive value of tricep and suprailiac fat caliper measures for subcutaneous fat distribution in different parts of the body. Tricep caliper measurements have a good correlation with subcutaneous fat in the trunk, arms, and legs, demonstrating their usefulness as non-invasive methods for measuring overall body composition. Similarly, suprailiac measures accurately predict subcutaneous fat, particularly in the trunk and legs, underscoring their utility in assessing central adiposity. These findings support the use of region-specific skinfold measurements to monitor fat deposition and associated health hazards, especially in resource-limited settings.

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