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SYSTEMATIC REVIEW AND META-ANALYSIS OF MEASURING ABDOMINAL SUBCUTANEOUS FAT THICKNESS USING AN ULTRASOUND

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ABSTRACT
Obesity prevalence is rising globally, including in Indonesia. Conventional methods (BMI, WHR, BIA) cannot directly measure subcutaneous fat thickness. Ultrasound (USG) offers a safe, non-invasive alternative. To evaluate the use of ultrasound in measuring subcutaneous fat thickness across all age groups. Articles were searched in ScienceDirect, Scopus, PubMed, Cochrane Library, and Google Scholar following PRISMA guidelines. A random-effects meta-analysis was performed using RevMan 5.4. Articles published from January 1, 2016, to December 31, 2025, using the keywords "subcutaneous fat" OR "adipose tissue" AND "ultrasonography" OR "ultrasound" AND 'reliability' OR "Intraclass Correlation Coefficient" OR "ICC"; out of 2,553 articles reviewed, 10. Ten cross-sectional studies across various age groups were analyzed. The pooled ICC was 0.99, indicating near-perfect reliability. Reliability was consistently high in children, adults, and the elderly. USG outperformed skinfold calipers and showed comparable results to MRI, with minimal measurement error (~1 mm). Heterogeneity was high due to differences in USG modes, populations, and operator expertise, but all studies reported reliability above the acceptable threshold. Funnel plot analysis showed high precision and no significant publication bias. Ultrasound is a highly reliable method for measuring abdominal subcutaneous fat thickness across all age groups, making it suitable for widespread application in research and clinical practice.

Keywords: abdomen; reliability; subcutaneous fat; ultrasound

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INTRODUCTION

The prevalence of obesity by 2030, it is estimated that nearly 3 billion adults (about 50% of the world's adult population) will be overweight or obese (Federation, 2025).The prevalence of obesity among people aged >18 years in Indonesia has increased from Body Mass Index (BMI) > 27 kg/m2 21,8% to 23,4% (Kemenkes, 2025). The increase in obesity is influenced by unhealthy lifestyles such as low physical activity and irregular eating patterns (Nugroho, 2020). The impact of obesity tends to increase the accumulation of subcutaneous fat compared to visceral fat (Arner et al., 2022) and is mostly stored in the abdomen (Liang et al., 2023). The parameter for determining obesity status uses the BMI by calculating weight and height (Widjaja et al., 2019). BMI measurement is a simple, practical, and fairly good method for estimating excess weight (Holmes & Racette, 2021). However, BMI cannot distinguish between body mass from muscle or fat with a low sensitivity value of 49.6% (Sommer et al., 2020). Additional anthropometric measurements such as the Waist-

to-Hip Ratio (WHR) can determine obesity status (Holmes & Racette, 2021), but it has a low sensitivity value of 53.61% and cannot distinguish between fat mass and muscle and bone mass (LI Ya Mei, 2021). A commonly used method for measuring body fat percentage in determining obesity is Bioelectrical Impedance Analysis (BIA), which works automatically and can provide body fat percentage assessments in a practical and relatively inexpensive manner (Samouda & Langlet, 2022).

BIA has good accuracy with a sensitivity value of 90% and is more accurate than BMI for determining overweight and obese individuals (Anwer et al., 2023). However, the weakness of BIA is that the measurement results vary (Wijayanti et al., 2018), depending on the amount of fluid in the body and it is unable to distinguish between visceral and subcutaneous fat (Hoffmann et al., 2023). Body fat percentage is a more accurate measure of obesity than BMI because it can directly assess fat levels (Trang et al., 2019). Accuracy in measuring body fat percentage is crucial for controlling body fat, determining obesity status, and planning diets (Wijayanti et al., 2018). Men with obesity have a subcutaneous fat thickness of 2.83 cm and women 3.68 cm (Uchida et al., 2024). Knowing that body fat levels are high, efforts should focus on reducing body fat levels, not just losing weight (Trang et al., 2019). In addition, there are skinfold calipers that can be used to measure subcutaneous fat thickness, but calipers tend to produce values that are much lower than the actual depth of subcutaneous fat tissue, with varying degrees of difference between body locations (Raab et al., 2022).

DXA (Dual-Energy X-Ray Absorptiometry) is the gold standard method for measuring body fat. However, it has drawbacks, including the need for expensive radiology equipment, exposure to radiation, and the requirement for trained personnel (Achamrah et al., 2018). Recent research shows that ultrasound (USG) is an alternative method that can assess subcutaneous and visceral fat with an Intraclass Correlation Coefficient (ICC) of 0.95 in adult women with normal weight and obesity in German (Hoffmann et al., 2023). The USG method has advantages such as no radiation, lower cost, portable, and more suitable for long-term monitoring (Neagu & Neagu, 2025). USG demonstrates high reliability with an excellent ICC value of 0.996 for measuring subcutaneous fat depth (Mechelli et al., 2019). Measuring subcutaneous adipose tissue with ultrasound is an alternative method for assessing cardiometabolic risk that is easy to apply in the field and superior to commonly used body indicators (Schmid-zalaudek et al., 2021).

In obesity, there is an accumulation of subcutaneous fat that reflects nutritional status and the amount of fat in the body. Parameters such as BMI, WHR, and BIA have the disadvantage of not being able to measure subcutaneous fat directly. Therefore, body fat measurement using ultrasound is essential to obtain accurate, safe data that can be used for long-term monitoring. However, there is no comprehensive synthesis of evidence regarding the reliability of ultrasound specifically for the adolescent population. The existing evidence is scattered across individual studies with varying measurement protocols. This systematic review aims to evaluate the reliability of ultrasound in measuring subcutaneous fat thickness in the abdomen.

METHOD

Study Design

This research study adopted the Preferred Reporting Items For Literature Review and Meta-analysis extension for Scoping Review (PRISMA-ScR) (Page et al., 2021). Original articles were searched using the Science Direct, Scopus, PubMed, Cochrane Library, and Google Schoolar databases with the keywords *("subcutaneous fat" OR "adipose tissue") AND (ultrasonography OR ultrasound) AND (reliability OR "Intraclass Correlation Coefficient" OR ICC)*. All articles obtained were then managed using Mendeley software (https://www.mendeley.com/download-reference-manager/windows) for reference management and duplication removal.

Inclusion criteria
Such original articles, cross-sectional study designs, articles published from January 1, 2016, to Desember 31, 2025, written in English, accessible, free, and full text, articles explaining ultrasound could measure subcutaneous fat with good reliability for humans.

Exclusion criteria
All articles were excluded from this study if ultrasound measurements were used for clinical purposes.

Study Criteria
Full-text articles were selected using the Population, Intervention, Comparison, Outcome, and Study Design (PICOS) (Roever, 2018), protocol to exclude the articles that did not meet the inclusion criteria.

Tabel 1.
Study Criteria PICOS

	Inclusion Criteria	Exclusion criteria
Population	children, adolescents, adults, and elderly	Studies in populations with specific medical conditions
Intervention	Ultrasound (A-mode or B-mode) to measure subcutaneous area	Ultrasound for other purposes (organ measurement, blood flow and elastography)
Comparison	Intra-rater, inter-rater, or test-retest reliability	No ICC values reported
Outcome	Intraclass Correlation Coefficient (ICC)	Only p-values reported without ICC values
Study design	Cross-sectional	Case control, RCT, cohort and Quasi-experimental

Search Strategy
The article search was conducted on February 11, 2026. The study eligibility and evaluation process were carried out collaboratively between NR and NHZ. The earlier researcher was responsible for evaluating five databases, which included searching, screening, and downloading all articles. Furthermore the NHZ helped evaluate the suitability of articles based on titles, abstracts, and eligibility criteria, and played a role in data analysis. Any differences of opinion between the two evaluators regarding the status of an article (whether it should be eliminated or not) were discussed to reach an agreement. If disagreement still arose, the final decision would be made by a third evaluator (DI).

Data Extraction and Synthesis
We evaluated the quality of the selected full-text articles and assessed the risk of bias using the Joanna Bring Institute Critical Appraisal Tool (JBI). This tool consists of 8 assessment items (Q1-8) https://jbi.global/critical-appraisal-tools. The selected articles were further analyzed by comparing the authors, study design, subjects, country, ultrasound location, ultrasound mode, and research findings. Next, the data were summed and averaged. Articles with scores below the average were considered to have a fairly high level of bias. Description of the answer score : Yes = 2; No = 1; and Unclear = 0.

Data Analysis
Data analysis in this study was performed using Review Manager (RevMan 5.4) software https://www.risetku.com/blog/revman. The purpose of this analysis was to assess the reliability of ultrasound (USG) in measuring subcutaneous fat using the pooled ICC value after Fisher's z transformation (95% CI), as well as to evaluate the level of heterogeneity (I^2) and the Q value to identify significant differences between studies through a forest plot. Additionally, a funnel plot was used to detect potential publication bias.

RESULT

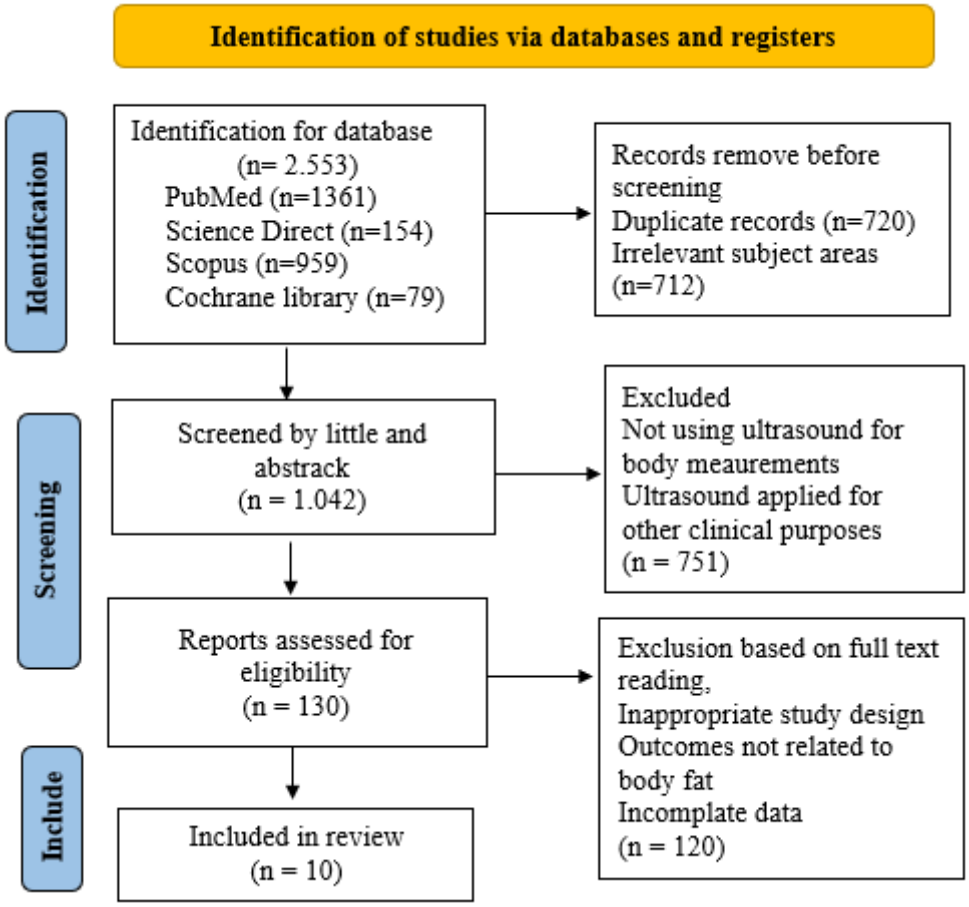

Figure 1 The PRISMA-ScR diagram

Tabel 2.
Description of the primary cross-sectional study included in the Sistematyc Review-meta-analysis

No	Author -Year	Country	Sample	Sex	Outcome	Result
1	(Hoffmann et al., 2022)	Germany	54 adults (aged 19-81 years)	Men =26 woman = 28	Abdomen, chest, back of thighs, hips, back, arms, and legs	There was a significant difference between SFT measurements using calipers (0.83 cm) and ultrasound (1.14 cm; p<0.001). Both were reliable, but ultrasound was more accurate, especially in the abdominal area, with an ICC of 0.940
2	(Kelso et al., 2019)	Germany	274 children aged 3-5 years	Boys = 144 Girl = 130	Upper and lower abdomen, erector spinae, distal triceps, brachioradialis, lateral thigh, front and medial calf	Subcutaneous fat thickness differed between boys and girls (5.3 mm vs. 6.3 mm; p<0.01) and was influenced by body mass, height, and gender. Ultrasound has very high reliability (ICC 0.994) and is therefore very accurate for children
3	(Ribeiro et al., 2020)	Brazil	30 adults (aged 18-37 years)	Men = 30	Abdomen, axillary, bicep brachii, calf, ceast, subcapular, subprailiac, thigh, tricep brachii	Subcutaneous fat measurement using A-Mode ultrasound with the ($IT_{(BM)}$) technique showed excellent reliability (ICC 0.960) at all anatomical points.

No	Author -Year	Country	Sample	Sex	Outcome	Result
4	(Benatti de Oliveira et al., 2024)	Brazil	150 older adults (aged 60 -86 years)	Men = 32 Woman = 118	Abdomen, axillary Biceps, brachii, calf Chest, subscapular Suprailiacus, thigh, triceps brachii	The ICC value for the thickness of the inner abdominal fat measured was ICC = 0.880)
5	(Wagner and Teramoto, 2020)	United States	80 young adults (aged 22-24 years)	Male = 48 Female = 32	Chest, abdomen, thighs, triceps, suprailiac	Inter-rater reliability was better for ultrasound than abdominal SKF (0.980 vs. 0.69).
6	(Störchle *et al*., 2017)	Austria	38 adults (aged 20-60 years)	Men = 26 Woman = 12	Upper abdomen, lower abdomen, erector spinae, distal triceps, brachioradialis, lateral thigh, front thigh, medial calf	ICC result of 0.990 ($p < 0.01$) with a standard error estimate of 1.1 mm for total SAT. For the normal BMI group, the median deviation was ≈ 0.43 mm (~1.1%) from the mean total SAT. For the overweight/obese group, the median deviation was ≈ 0.89 mm (~0.5%) from the total SAT.
7	(Kelso et al., 2020)	Germany	20 children (aged 3-6 years)	Boys = 8 Girls = 12	Upper abdomen, lower abdomen, erector spinae, distal triceps, brachioradialis, lateral thigh, front thigh, medial calf	Ultrasound measurements showed an ICC of 0.998. Total SAT thickness (including fibrous structures) varied between 25.7–86.4 mm, with an average of 48.1 ± 15.5 mm across all children.
8	(Müller et al., 2016)	Austria	12 adult athletes (aged 18-35 years)	Men = 6 Woman = 6	Upper abdomen, lower abdomen, erector spinae, distal triceps, brachioradialis, lateral thigh, front thigh, medial calf	The results showed that almost all variations could be explained by this method ($R^2 = 0.998$), with an average error of only about 0.55 mm. It has a value (ICC = 0.998), and 95% of the measurement results are within a difference of ±1 mm. The measured SAT thickness ranges from 10–50 mm
9	(Gao et al., 2025)	China	179 adults (aged 18-32 years)	Men = 79 Woman = 100	Intra-abdominal, pre-peritoneal, posterior right perinephric, suprailiac, abdominal subcutaneous, upper arm	ICC intra-rater 0.950 for three abdominal locations. However, inter-rater reliability showed wider variation r 0.874–0.958 for the same locations
10	(Chandler et al., 2020)	United States	17 adults (aged 25-30 years)	Male = 9 Female = 8	Triceps, subcapula, midaxilla, suprailliac, abdomen, interior thigh	Strong inter-rater reliability with ICC 0.980 for %BF measurements, with no significant differences between techniques ($p>0.10$)

After selecting article process, studies that met the inclusion criteria were then assessed for quality using the JBI Critical Appraisal Tools.

Tabel 3.
Critical Appraisal Checklist For Cross-Sectional Studies In Sistematyc Review and Meta-analysis

Author	Question Checklist								
	1	2	3	4	5	6	7	8	Total
Hoffmann et al., 2022	2	2	2	2	1	1	2	2	14
Kelso et al., 2019	2	2	2	2	0	0	2	2	12
Ribeiro et al., 2020	2	2	2	2	2	1	2	2	15
Benatti de Oliveira et al., 2024	2	2	2	2	1	1	2	2	14
Wagner and Teramoto, 2020	2	2	2	2	2	2	2	2	16
Störchle et al., 2017	2	2	2	2	0	0	2	2	12
Kelso et al., 2020	2	2	2	2	1	1	2	2	14
Müller et al., 2016	2	2	2	2	1	1	2	2	14
Gao et al., 2025	2	2	2	2	2	2	2	2	16
Chandler et al., 2020	2	2	2	2	1	1	2	2	14
Average									13,9

The average checklist score was 13.9 out of a maximum of 16 points. Two studies (Wagner and Teramoto, 2020; Gao et al., 2025) received the highest score of 16, indicating excellent methodological quality. The studies with the lowest scores were Kelso et al. (2019) and Störchle et al. (2017), both scoring 12. Most of the other studies fell within the 14–15 range, so overall, the methodological quality of the analyzed research can be categorized as good.

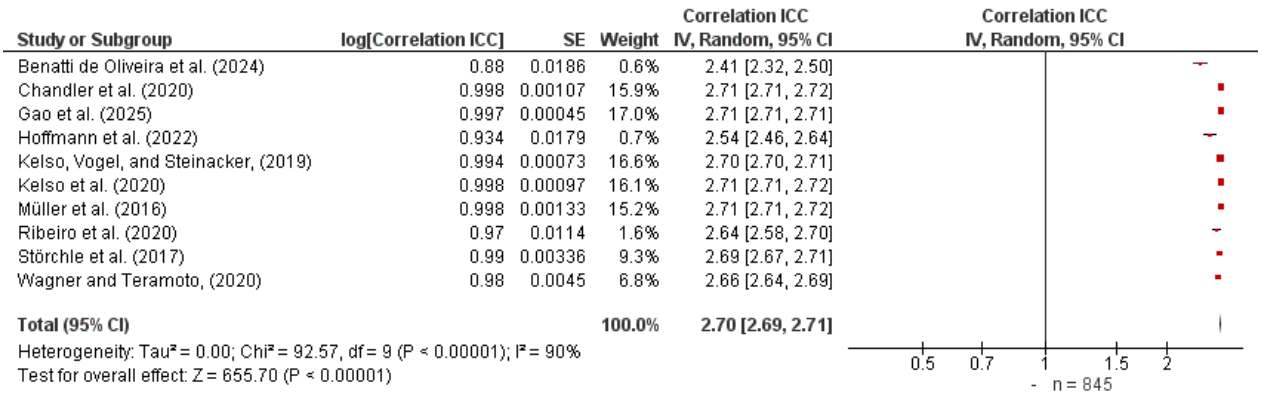

Figure 2 Forest Plot from 10 studies using random-effects model

A meta-analysis of several studies using a random-effects model yielded a pooled Fisher's z-score of 2.71 (95% CI: 2.69–2.71), indicating a very high level of statistical precision. When converted back to the ICC scale, this result is equivalent to a pooled reliability estimate of 0.99 (95% CI: 0.99–0.99). However, the heterogeneity test results indicate very high variability among studies, with an I^2 value of 90%. The Q statistic was recorded at 92.57 with df = 9 ($p < 0.00001$), confirming the presence of significant differences among studies. An I^2 value of 90% indicates that 90% of the total variation among studies is due to genuine heterogeneity, not sampling error.

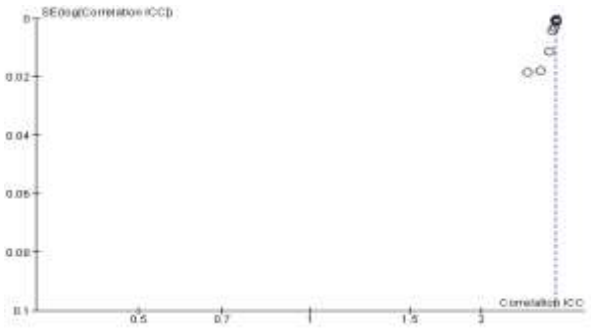

Figure 3 Standard Error Funnel Plot for publication bias assessment

The funnel plot shows that most studies have high precision and are concentrated around the pooled estimate. There appears to be no significant publication bias, but the asymmetrical distribution confirms the presence of high heterogeneity among studies.

DISCUSSION

This discussion aims to interpret and critically evaluate the findings of systematic reviews and meta-analyses regarding the reliability of ultrasound (USG) as a measurement tool for determining subcutaneous fat thickness, particularly in the abdominal region, while taking into account variations in study characteristics, populations, and factors that may influence measurement results.
The results of this systematic review and meta-analysis indicate that ultrasound (USG) has very high reliability in measuring subcutaneous fat thickness across various age groups, ranging from children to adults and the elderly. A pooled ICC value of 0.99 (95% CI: 0.99–0.99) confirms that USG is a consistent and nearly perfect method for generating measurement data. These findings are consistent with reports by Hoffmann et al. (2022) in adults (ICC 0.94), Kelso et al. (2019) in children (ICC 0.99), and Benatti de Oliveira et al. (2024) in the elderly (ICC 0.88), all of which demonstrate high reliability.

Ultrasound is more reliable than skinfold calipers, with an ICC value of 0.984 for ultrasound and only 0.693 for calipers (Wagner et al., 2020). When compared to MRI, ultrasound also yields excellent results: the average measurement difference is only about -0.13 ± 0.34 cm, with an ICC reliability of 0.966 in the abdominal region. This means that ultrasound is nearly equivalent to MRI in measuring two-dimensional subcutaneous fat thickness, but is more practical and cost-effective (Hoffmann et al., 2022). Ribeiro et al. (2020) also confirmed that measurement points in the abdomen have high reliability (ICC > 0.90), making ultrasound a reliable method for assessing subcutaneous fat in this body region. Measurements at specific body sites using ultrasound have been shown to be consistent, with very small errors (approximately 1 mm) in both individuals with a normal BMI and those with obesity (Störchle et al., 2017b). This indicates that ultrasound is capable of providing accurate and stable results in assessing subcutaneous fat. Compared to other methods such as BMI or WHR, ultrasound is more precise in depicting body fat distribution and is also useful in assessing cardiometabolic health risks (Sengeis et al., 2019)

In individuals with thick subcutaneous fat layers, ultrasound can still be used at lower frequencies. Although the tissue images are less sharp, measurement errors remain small (approximately 0.1–0.2 mm) and the results are consistent (Müller et al., 2016; Kelso et al., 2020). Accuracy remains high across all nutritional status groups when performed by trained operators; in fact, measurement errors are smaller in thick fat layers compared to thin ones (Störchle et al., 2017b). Differences in ultrasound modes are one of the factors contributing to the heterogeneity of results. Mode A, as in the study by Ribeiro et al. (2020), relies on peak amplitude, so the results are highly influenced by probe pressure and operator interpretation. Mode B produces clearer two-dimensional images, but results may vary when performed by less experienced operators (Chandler et al., 2020). Body mass, height, and gender in children explain 66% of the variance in subcutaneous fat thickness, as it is greater in higher body mass, shorter stature, and in females (Kelso et al., 2019). Females tend to have thicker subcutaneous fat, while males store more visceral fat (Gao et al., 2025).

The same measuring device (ultrasound) will be tested on populations with different physiological conditions, which statistically may increase heterogeneity between studies. To obtain high-quality and accurate data, operators must undergo special training. This training includes how to determine the measurement location, use ultrasound equipment, proper measurement techniques, and practice and discussion of results between operators (Müller et al., 2016). Risk of bias was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Tool, with a total score for all studies being 139. The average score obtained was 13.9. Studies with scores below the average were considered to have a higher potential risk of bias than studies with scores above the average. The forest plot

analysis shows that nearly all studies report very high ultrasound reliability. Although there are differences in results across studies, these are primarily due to variations in the types of ultrasound modalities used, population characteristics (such as age, sex, and BMI), and operator skill.

Nevertheless, all studies still demonstrate reliability above the acceptable standard. This means that despite differences between studies, the main conclusion remains clear ultrasound is a highly reliable method for measuring subcutaneous fat. Meanwhile, the funnel plot shows a relatively symmetrical distribution of studies concentrated around the pooled estimate, indicating high precision and the absence of significant publication bias. Although the number of studies is limited (n=10), these results support the conclusion that the meta-analysis is relatively free of publication bias. Overall, ultrasound has proven to be a superior method compared to BMI, WHR, and skinfold measurements, as it can directly measure abdominal subcutaneous fat with greater accuracy. Its high reliability, low risk of bias, and non-invasive nature make ultrasound suitable for use in both research and clinical practice. Furthermore, evidence from various studies indicates that ultrasound can be applied to all age groups, ranging from children to adults and the elderly, making it highly relevant for monitoring nutritional status and metabolic risk, including in Indonesia.

CONCLUSION

Ultrasound has proven to be highly reliable for measuring abdominal subcutaneous fat across all age groups. Compared to BMI, WHR, and skinfold callipers, ultrasound is more precise, non-invasive, and has a low risk of bias. Although there are differences among studies, all demonstrate high reliability. Given these advantages, ultrasound is suitable for use in both research and clinical practice, including for monitoring nutrition and metabolic risk in Indonesia.

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