ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 17, Issue, 06, pp.33282-33287, June, 2025
DOI: https://doi.org/10.24941/ijcr.49109.06.2025

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

RELIABILITY AND TESTER'S COMPETENCY OF SELECTED SKINFOLD MEASUREMENTS OF FEMALE NON-SPORTSPERSON (A BILATERAL APPROACH)

Sukanya Rawat[1]* and Dhananjoy Shaw[2]

[1]Department of Physical Education and Sports Sciences, University of Delhi, Delhi, India
[2]Indira Gandhi Institute of Physical Education and Sports Sciences, University of Delhi, Delhi, India

ARTICLE INFO

Article History:
Received 09th March, 2025
Received in revised form
21st April, 2025
Accepted 19th May, 2025
Published online 24th June, 2025

Keywords:

Skinfold, Harpendon Caliper, Reliability, Tester's Competency, Bilateral, Femalenon-Sportspersons.

***Corresponding author:** *Sukanya Rawat*

ABSTRACT

Objective: The main aim of this study was to assess the reliability and tester competency in measuring selected skinfold thickness among female non-sportsperson, with a specific focus on bilateral (left and right side) comparisons. ***Methods:*** A total of 200 female non-sportsperson, aged 18 to 25 years not having a proper sports background, were randomly selected from the National Capital Territory (NCT) of Delhi, India. Skinfold thickness was measured for the landmarks including chin, cheek, biceps, triceps, mid-axillary, forearm, subscapular, 10th rib, abdomen, suprailiac, supraspinale, medial thigh, and medial calf, on both the left and right sides of the body. The selected measurement was recorded three times using a Harpenden skinfold caliper by following the standard procedures prescribed by ISAK. The reliability and internal consistency of the measurements were analysed using the Pearson's coefficient of correlation, Cronbach's alpha, and analysis of variance (ANOVA). ***Results:*** The findings revealed excellent test-retest reliability and internal consistency across all measured sites on both sides of the body. Pearson's correlation coefficients exhibitedexcellent correlation between repeated measurements of each skinfold. Cronbach's alpha values were consistently excellent, indicating strong internal consistency. ANOVA results further supported the statistical reliability of the measurements across three trials. ***Conclusion:*** The study concludes excellent reliability and tester competency in regards to bilateral skinfold measurements using standardized procedures. This research contributes a novel approach by applying Pearson's correlation, Cronbach's alpha, and ANOVA altogether to assess the reliability of measurement, along with a comprehensive bilateral analysis.

Citation: Sukanya Rawat and Dhananjoy Shaw. 2025. *"*Reliability and tester's competency of selected skinfold measurements of female non-sportsperson (a bilateral approach)*". International Journal of Current Research, 17, (06), 33282-33287.*

INTRODUCTION

The analysis of body composition is a significant component in evaluation of health, monitoring of nutritional status and preventive health care. Among the various methods available, measurement of skinfold thickness remains one of the most cost-effective, practical and widely used field methods for evaluating subcutaneous fat and overall body fat percentage (1, 2). Despite the growing availability of advanced imaging techniques such as dual-energy X-ray absorptiometry (DEXA) and bioelectrical impedance analysis (BIA), skinfold caliper measurements continue to be a reliable alternative in clinical, community, and research settings—provided that standardized techniques and skilled testers are employed (1, 3, 4). Although extensive amount of research has focused on the reliability of skin fold measurements in sportsperson populations, there remains a significant gap in the literature focusing non-sportsperson, general female populations. The female who are not actively involved in organized sports or planned fitness programs may show different body composition patterns, variability in fat distribution and response to anthropometric assessments (5-7). Therefore, establishing the reliability of skinfold measurements of female non-sportsperson is very necessary for providing valid data in public health screenings, clinical assessments and longitudinal health studies. A significant but often ignored aspect in body composition research is the consideration of bilateral (left and right side) skinfold measurements. Most researches evaluate skinfold assessment of one side of the body specially the right, based on convenience or convention (4, 8, 9). However, individual differences in body fat distribution between the left and right sides may exist because of the factors such as handedness, asymmetrical physical activity or postural habits (8, 10). Evaluation of bilateral measurements provides a more comprehensive understanding of body fat distribution and allows for more precise and personalized evaluation. So far, this area remains underexplored in current literature, particularly in non-sporting female populations. The accuracy and reliability of these measurements are majorly dependent on tester's competency. To obtain valid and reliable results, proper identification of landmark, consistent pinching of skinfold and correct placement of caliper are the main important factors to be kept in mind while measurement of skinfold thickness (11). Novice or inconsistent testers can produce significant measurement error, which undermines the validity of the data. Therefore, evaluating the tester's competency to produce reliable measurements across trials and across both sides of the body is important for establishing confidence in the method. There are a number of tests available to measure the reliability of the data measured. The test-retest reliability that make use of Pearson Coefficient of Correlation to measure reliability. The Pearson Coefficient of Correlation (r) is employed to evaluate the consistency between the two trials of measurement.

A high correlation (r > 0.80) proves that the tester is competent to obtain accurate results. Although, low correlation shows inconsistency and emphasizes the need for proper training of the researcher (12, 13). Cronbach's Alpha is a statistical method to assess internal consistency by measuring how reliably a tester achieve consistent results across multiple trials. A high value (≥ 0.70) shows that the measurements performed by tester are reliable, showing their competency (14-16). Intraclass Correlation Coefficient (ICC) which is evaluated using ANOVA, measures the consistency of a tester's measurements across multiple trials. A high ICC (≥ 0.80) shows that the tester consistently produces reliable results, confirming their competency (17, 18). The main objective of this study is to determine the reliability of selected bilateral skinfold measurements in female non-sportspersons using standardized procedures. Furthermore, the study emphasizes the critical role of tester competency in achieving reliable anthropometric assessments, thereby contributing to best practices in body composition evaluation for broader population groups. By making use of the advanced reliability tests like ICC, Cronbach's Alpha, and Pearson's r, it confirms that the results are applicable to real-world health assessments of female non-sportsperson.

MATERIALS AND METHODS

The study was conducted on a sample of 200 female non-sportspersons age ranged from 18 and 25 years, from National Capital Territory (NCT) of Delhi, India. Participants were selected by using a random sampling method from colleges and residential areas. No participant was engaged in any structured sports and games training or any professional physical activity programs. Informed consent was obtained from all participants before performing the study and ethical approval was obtained from the institutional ethics committee. Skinfold thickness was measured at selected anatomical landmarks on both the left and right sides of the body, following the International Society for the Advancement of Kinanthropometry (ISAK) protocols. The skinfold sites included are mentioned in Appendix-1. Measurements were performed using a Harpenden skinfold caliper that is well known for its precision and reliability in anthropometric research.

The measurement was taken three time for each selected site. All measurements were obtained by the same trained researcher to remove inter-tester variability and to evaluate intra-tester reliability. The tester did proper training in anthropometric measurement techniques as per ISAK. Before collecting the data collection, the tester performed rigorous practice to calibrate measurement reliability and refine technique, ensuring accuracy, proper landmark identification and consistent application of caliper pressure. The following statistical analyses were used to evaluate the reliability and internal consistency of the measurements and proving tester's competency: Pearson's correlation coefficient (r) to evaluate the relationship between the measurements, Cronbach's alpha (α) to assess internal consistency between trials and Analysis of Variance (ANOVA) to examine variability within and between measurement trials. All statistical analyses were conducted using SPSS and significance levels were set at $p < 0.05$.

Table 1. Reliability Rating by Kirkendall *et al* (1987)

Value or Reliability Coefficient	Reliability Grading
0.00 to 0.59	Unacceptable
0.60 to 0.79	Average
0.80 to 0.89	High
0.90 to 1.00	Excellent

Table 2. Internal Consistency Reliability Rating by Cronbach (1971)

Cronbach's Alpha	Internal Consistency
<0.5	Unacceptable
0.5 to 0.6	Poor
0.6 to 0.7	questionable
0.7 to 0.8	Acceptable
0.8 to 0.9	Good
>0.9	Excellent

The table 1 and 2 were used for interpreting the reliability whereas the probability of 'F' ratio was used for the interpretation of 'F' value for reliability.

RESULTS AND DISCUSSION

The results have been documented in the table-3 to 5.

Table 3. Test-Retest Reliability of Selected Skinfold Measurements of Female Non-Sportsperson

Variables	Reading			Reliability rating
	1 vs 2	1 vs 3	2 vs 3	
Chin	.997	.995	.995	Excellent
Cheek (L)	.996	.988	.991	Excellent
Cheek (R)	.989	.979	.985	Excellent
Biceps (L)	.994	.992	.994	Excellent
Biceps (R)	.996	.994	.996	Excellent
Triceps (L)	.927	.920	.996	Excellent
Triceps (R)	.997	.993	.992	Excellent
Axilla/ Mid-Axilliary(L)-	.998	.997	.997	Excellent
Axilla/ Mid-Axilliary (R)-	.997	.995	.997	Excellent
Forearm (L)	.988	.982	.991	Excellent
Forearm (R)	.991	.984	.988	Excellent
Subscapular (L)	.990	.990	.997	Excellent
Subscapular (R)	.997	.995	.996	Excellent
Skinfold At 10th Rib (L)	.995	.991	.995	Excellent
Skinfold At 10th Rib (R)	.995	.986	.986	Excellent
Abdominal (L)	.997	.997	.998	Excellent
Abdominal (R)-	.999	.998	.999	Excellent
Suprailliac/Illiac Crest (L)	.998	.998	.998	Excellent
Suprailliac/Illiac Crest (R)	.999	.998	.999	Excellent
Supraspinale/ Illiospnale (L)	.997	.995	.997	Excellent
Supraspinale/Illiospinale (R)	.995	.996	.997	Excellent
Medial Thigh (L)	.990	.990	.998	Excellent
Medial Thigh (R)	.998	.998	.999	Excellent
Medial Calf (L)	.986	.984	.996	Excellent
Medial Calf (R)	.996	.996	.996	Excellent

**. Correlation is significant at the 0.01 level (1-tailed).

According to the table-3, the Test-Retest Reliability of Chin Skinfold ranged from .995 to .997 (Excellent), Cheek Skinfold Left ranged from .988 to .996 (Excellent), Cheek Skinfold Right ranged from .979 to .989 (Excellent), Biceps Skinfold Left ranged from .992 to .994 (Excellent), Biceps Skinfold Right ranged from .994 to .996 (Excellent), Triceps Skinfold Left ranged from.920 to .996 (Excellent), Triceps Skinfold Right ranged from .992 to .997 (Excellent), Axilliary Skinfold Leftranged from .997 to .998 (Excellent), Axilliary Skinfold Right ranged from .995 to .997 (Excellent), Forearm Skinfold Left ranged from .982 to .991 (Excellent), Forearm Skinfold Right ranged from .984 to .991 (Excellent), Subscapular Skinfold Left ranged from .990 to .997 (Excellent), Subscapular Skinfold Right ranged from .995 to .997 (Excellent), Skinfold at 10th Rib Left ranged from .991 to .995 (Excellent), Skinfold at 10th Rib Right ranged from .986 to .995 (Excellent), Abdominal Skinfold Left ranged from .997 to .998 (Excellent), Abdominal Skinfold Right ranged from .998 to .999 (Excellent), Illiac Crest/ Suprailliac Skinfold Left was .998 (Excellent),Illiac Crest/ Suprailliac Skinfold Right ranged from .998to .999 (Excellent), Illiospinale/ Supraspinale Skinfold Left ranged from .995 to .997 (Excellent), Illiospinale/ Supraspinale Skinfold Right ranged from .995 to .997 (Excellent), Medial Thigh Skinfold Left ranged from .990 to.998 (Excellent), Medial Thigh Skinfold Right ranged ranged from .998 to .999 (Excellent), Medial Calf Left ranged from .984 to .996 (Excellent), Medial Calf Right ranged was .996 (Excellent). Overall, the reliability coefficient ranged from.927 to .999(Excellent) for skinfold variables.

Table 4. Cronbach's Alpha of Selected Skinfold Variables of Female Non-sportsperson

Variables	Cronbach's Alpha	Internal Consistency (Reliability Rating)
Chin	.998	Excellent
Cheek (L)	.997	Excellent
Cheek (R)	.995	Excellent
Biceps (L)	.998	Excellent
Biceps (R)	.998	Excellent
Triceps (L)	.982	Excellent
Triceps (R)	.998	Excellent
Axilla/ Mid-Axilliary(L)-	.999	Excellent
Axilla/ Mid-Axilliary (R)-	.999	Excellent
Forearm (L)	.996	Excellent
Forearm (R)	.996	Excellent
Subscapular (L)	.997	Excellent
Subscapular (R)	.999	Excellent
Skinfold At 10th Rib (L)	.998	Excellent
Skinfold At 10th Rib (R)	.996	Excellent
Abdominal (L)	.999	Excellent
Abdominal (R)-	1.000	Excellent
Suprailliac/Illiac Crest (L)	.999	Excellent
Suprailliac/Illiac Crest (R)	1.000	Excellent
Supraspinale/ Illiospnale (L)	.999	Excellent
Supraspinale/Illiospinale (R)	.999	Excellent
Medial Thigh (L)	.997	Excellent
Medial Thigh (R)	.999	Excellent
Medial Calf (L)	.996	Excellent
Medial Calf (R)	.999	Excellent

L= Left; R= Right

According to analysis of Cronbach's Alpha for selected skinfold variables in table-4 demonstrated extremely high coefficient ranged from .982 to 1.000 (Excellent).

Table 5. Analysis of Variance of Selected Skinfold Variables of Female Non-sportsperson

Variables		Sum of Squares	df	Mean Square	F	Sig.
CHISKF	Between Groups	.965	2	.482	.073(NS)	.930
	Within Groups	3948.390	597	6.614		
	Total	3949.354	599			
CHESKFL	Between Groups	2.080	2	1.040	.181(NS)	.834
	Within Groups	3424.960	597	5.737		
	Total	3427.040	599			
CHESKFR	Between Groups	1.434	2	.717	.154(NS)	.858
	Within Groups	2787.227	597	4.669		
	Total	2788.661	599			
BSKFL	Between Groups	3.308	2	1.654	.177(NS)	.838
	Within Groups	5578.014	597	9.343		
	Total	5581.322	599			
BSKFR	Between Groups	1.304	2	.652	.066(NS)	.936
	Within Groups	5916.461	597	9.910		
	Total	5917.765	599			
TSKFL	Between Groups	2.063	2	1.032	.041(NS)	.960
	Within Groups	15182.522	597	25.431		
	Total	15184.585	599			
TSKFR	Between Groups	1.205	2	.602	.023(NS)	.977
	Within Groups	15540.787	597	26.031		
	Total	15541.992	599			
AXSKFL	Between Groups	8.897	2	4.448	.136(NS)	.872
	Within Groups	19456.337	597	32.590		
	Total	19465.233	599			
AXSKFR	Between Groups	2.663	2	1.331	.041(NS)	.960
	Within Groups	19546.830	597	32.742		
	Total	19549.493	599			
FASKFL	Between Groups	1.512	2	.756	.108(NS)	.898
	Within Groups	4189.834	597	7.018		
	Total	4191.347	599			
FASKFR	Between Groups	2.517	2	1.258	.168(NS)	.845
	Within Groups	4464.628	597	7.478		
	Total	4467.145	599			
SSSKFL	Between Groups	2.576	2	1.288	.044(NS)	.957
	Within Groups	17582.517	597	29.451		
	Total	17585.093	599			
SSSKFR	Between Groups	2.772	2	1.386	.045(NS)	.956
	Within Groups	18198.811	597	30.484		
	Total	18201.583	599			
SKF10RL	Between Groups	2.197	2	1.099	.053(NS)	.948
	Within Groups	12391.256	597	20.756		
	Total	12393.453	599			
SKF10RR	Between Groups	2.622	2	1.311	.055(NS)	.946
	Within Groups	14224.589	597	23.827		
	Total	14227.211	599			
ASKFL	Between Groups	1.616	2	.808	.012(NS)	.988
	Within Groups	40250.790	597	67.422		
	Total	40252.406	599			
ASKFR	Between Groups	2.212	2	1.106	.017(NS)	.984
	Within Groups	39984.752	597	66.976		
	Total	39986.963	599			
ICSKFL	Between Groups	2.032	2	1.016	.013(NS)	.987
	Within Groups	45394.733	597	76.038		
	Total	45396.765	599			
ICSKFR	Between Groups	2.878	2	1.439	.020(NS)	.980
	Within Groups	42828.860	597	71.740		
	Total	42831.738	599			
ISSKFL	Between Groups	3.517	2	1.758	.050(NS)	.951
	Within Groups	20822.696	597	34.879		
	Total	20826.213	599			
ISSKFR	Between Groups	4.682	2	2.341	.069(NS)	.933
	Within Groups	20277.833	597	33.966		
	Total	20282.515	599			
MTSKFL	Between Groups	7.991	2	3.995	.069(NS)	.933
	Within Groups	34465.197	597	57.731		
	Total	34473.188	599			
MTSKFR	Between Groups	.810	2	.405	.006(NS)	.994
	Within Groups	39460.997	597	66.099		
	Total	39461.807	599			
MCSKFL	Between Groups	.103	2	.051	.002(NS)	.998
	Within Groups	15606.185	597	26.141		
	Total	15606.288	599			
MCSKFR	Between Groups	1.726	2	.863	.031(NS)	.969
	Within Groups	16581.141	597	27.774		
	Total	16582.867	599			

CHISKF=Chin Skinfold Left; CHESKFL=Cheek Skinfold Left: CHESKFR= Cheek Skinfold Right; BSKFL=Biceps Skinfold Left; BSKFR= Biceps Skinfold Right; TSKFL= Triceps Skinfold Left; TSKFR= Triceps Skinfold Right; AXSKF= Axilliary Skinfold Left; AXSKFR= Axilliary Skinfold Right; FASKFL = Forearm Skinfold Left; FASKFR=Forearm Skinfold Right; SSSKFL= Subscapular Skinfold Left; SSSKFR=Subscapular Skinfold Right; SKF10RL= Skinfold at 10^{th} Rib Left; SKF10RR=Skinfold at 10th Rib Right; ASKFL= Abdominal Skinfold Left; ASKFR=Abdominal Skinfold Right;ICSKFL=Suprailliac/Illiac Crest Skinfold Left; ICSKFR=Suprailliac/Illiac Crest Skinfold Right; ISSKFL=Supraspinale/ Illiospnale Skinfold Left; ISSKFR=Supraspinale/ IlliospnaleSkinfold Right; MTSKFL=Medial Thigh Skinfold Left; MTSKFR=Medial Thigh Skinfold Right; MCSKFL= Medial Calf Skinfold Left; MCSKFR=Medial Calf Skinfold Right Df= Degree of freedom NS=Not Significantly Different at 0.05 level

According to the table-5 'F' Ratio are not significant. The probability were .930 for CHISKF, .834 for CHESKFL, .858 for CHESKFR, .838 for BSKFL, .936 for BSKFR, .960 for TSKFL, .977 for TSKFR, .872 for AXSKFL and .960 for AXSKFR, .898 for FASKFL, .845for FASKFR, .957 for SSSKFL, .956 for SSSKFR, .948 for SKF10RL, .946 for SKF10RR, .988 for ASKFL, .984 for ASKFR, .987 for ICSKFL, .980 for ICSKFR, .951for ISSKFL, .933 for ISSKFR, .993 for MTSKFL, .994 for MTSKFR, .998 for MCSKFL, .969 for MCSKFR. The present study was conducted to assess the test-retest reliability of bilateral skinfold measurements in female non-sportspersons and to evaluate the tester's competency in obtaining consistent and reliable measurements. The results of the study showed the test-retest correlation coefficients ranging from .927 to .999 (Excellent) across all the selected bilateral skinfold sites, confirming high measurement replicability in selected population. The observed reliability coefficients are consistent with prior research emphasizing the value of technical proficiency in anthropometric assessments rather than the physical characteristics of the sample being measured (11). In addition to Pearson's correlation, the use of Cronbach's Alpha further validated the internal consistency of the repeated skinfold measurements. The alpha values ranged from .982 to 1.000, clearly indicating excellent internal consistency. These findings are in line with the study conducted by Stomfai *et al*. (2011) (20). that confirm that the three repeated measures taken at each anatomical site were consistent with one another, reducing the random error and further highlighting the tester's proficiency. Analysis of Variance (ANOVA) was also employed to further support the findings and to find out whether any statistically significant differences existed between the three repeated measurements. The results presented that 'F' ratios were not statistically significant across all variables, with p-values ranging from .834 to .998. These non-significant p-values further confirms the consistency and uniformity of the measurements across trials and support the absence of measurement error across repetitions. The study conducted by De Zepetnek *et al*. (2021) (21) supports the above statement. These results collectively underscore the competency of the tester, whose consistent methodology aligned with the International Society for the Advancement of Kinanthropometry (ISAK) protocols. The proper training of the tester is essential for measurement reliability, particularly for skinfold assessments that rely on accurate landmark identification, uniform caliper application, and consistent tissue grasping techniques as suggested by Norton *et al*. (1996) (11). An additional strength of the present study is its inclusion of bilateral measurements that is, assessing skinfolds on both the left and right sides of the body. Generally, anthropometric measurements have highlighted right-side measurements for the sake of consistency and simplicity as suggested in the previously conducted studies (4, 8, 9). However, the present study has pointed out the significance of examining left-right symmetry or asymmetry in fat distributions. This study shows high reliability on both sides of the body which suggests that bilateral assessments are easy to conduct, meaningful, and scientifically justified in non-sports female. Overall, the study provides a comprehensive evaluation of measurement reliability by using a multi-method statistical approach, integrating Pearson's correlation, Cronbach's alpha, and ANOVA. The convergence of all three statistical techniques provides strong evidence of both the precision and consistency of skinfold measurements and affirms that, when performed by a well-trained anthropometrist, skinfold assessment is a highly reliable method for evaluating body composition in general populations, including those with no history of sports training.

CONCLUSION

This study concluded that bilateral skinfold measurements in female non-sportspersons can be produced with excellent reliability when executed by a trained and competent tester using standardized procedures. High test-retest correlation coefficients (.927 to .999), strong internal consistency (Cronbach's Alpha: .982 to 1.000), and non-significant ANOVA results assure the reliability of measurements between the three trials. However, the study has some limitations such as use of a single tester, a small sample size and the absence of comparison with gold-standard body composition methods. Future study should explore inter-tester reliability, include more diverse populations, and validate skinfold data against advanced techniques such as DEXA, BODPOD and MRI etc. Furthermore, the study also suggests that assessing both sides of the body is not only feasible but also valuable in anthropometric evaluation. These findings highlight the importance of formal training in anthropometry. Also, it supports the use of skinfold caliper measurements as a reliable tool and technique for body composition assessment in female non-sportspersons.

Acknowledgement: We are immensely grateful to all the participants who have participated in the study.

Funding Information: No funding was received.

Ethics Approval Statement: Approval for this study was sought from Ethics Committee of Department of Physical Education and Sports Science, University of Delhi.

Informed Consent: Informed consent was obtained by all the subjects involved in the study. They were also informed of their rights throughout the study, in accordance with the Declaration of Helsinki.

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

Author's contribution & Statement: The authors confirm contribution to the paper as follows: study conception and design: SR and DS; data collection: SR; analysis and interpretation of results: SR and DS; draft manuscript preparation: SR and DS. Both authors reviewed the results and approved the final version of the manuscript. DS gave the insight for the data analysis and make correction in writing the article.

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Appendix

Appendix-1: Selected Skinfold Variables and their Coding

S.No.	Variables	Variables Code
1.	Chin Skinfold	CHISKF
2.	Cheek Skinfold (L)	CHESKFL
3.	Cheek Skinfold (R)	CHESKFR
4.	Biceps Skinfold (L)	BSKFL
5.	Biceps Skinfold (R)	BSKFR
6.	Triceps Skinfold (L)	TSKFL
7.	Triceps Skinfold (R)	TSKFR
10.	Axilla/ Mid-Axilliary Skinfold (L)	AXSKFL
11	Axilla/ Mid-Axilliary Skinfold (R)	AXSKFR
12.	Forearm Skinfold (L)	FASKFL
13.	Forearm Skinfold (R)	FASKFR
14.	Subscapular Skinfold (L)	SSSKFL
15.	Subscapular Skinfold (R)	SSSKFR
16.	Skinfold At 10th Rib Skinfold (L)	SKF10RL
17.	Skinfold At 10th Rib Skinfold (R)	SKF10RR
18.	Abdominal Skinfold (L)	ASKFL
19.	Abdominal Skinfold (R)	ASKFR
20.	Suprailliac/Illiac Crest Skinfold (L)	ICSKFL
21.	Suprailliac/Illiac Crest Skinfold (R)	ICSKFR
22.	Supraspinale/ Illiospnale Skinfold (L)	ISSKFL
23.	Supraspinale/Illiospinale Skinfold (R)	ISSKFR
24.	Medial Thigh Skinfold (L)	MTSKFL
25.	Medial Thigh Skinfold (R)	MTSKFR
26.	Medial Calf Skinfold (L)	MCSKFL
27.	Medial Calf Skinfold (R)	MCSKFR
L=Left;R=Right		

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