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# Reliability in Regards to Measurements of Selected Circumference and Width Variables of Women Sportspersons-An Approach for Tester's Competency

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**ABSTRACT**

**Purpose:** This study aimed to evaluate the reliability and competency of testers in measuring selected circumference and width variables among women sportspersons. **Method:** A total of 300 women athletes, aged 18–25 years, from NCT of Delhi, were randomly selected. All participants had competed at least at the state level in sports such as athletics, basketball, football, handball, hockey, judo, kabaddi, kho-kho, volleyball, or yoga. Standardized tools, including a Cescorf Anthropometric Tape and a GPM Swiss Made sliding caliper, were used to measure circumference variables (Neck, Chest, Forearm, Abdominal, Waist, Hip, Thigh, Calf) and width variables (Biepicondylar Humerus and Femur) as per ISAK guidelines. Each variable was measured thrice, and the data were analyzed using Pearson's correlation, Cronbach's alpha, and ANOVA at $P<0.05$. **Findings:** Results demonstrated excellent test-retest reliability and internal consistency for all measurements. The ANOVA results further reinforced the reliability of the selected variables. Conclusion: This study highlights the exceptional reliability of circumference and width measurements using multiple statistical approaches. The findings underscore the utility of these metrics in various domains and affirm the testers' competency in executing precise and consistent measurements.

## 1. INTRODUCTION

Research in many different domains depends critically on the reliability of measurement of width and circumference variables. Measurements of width, such as biepicondylar humerus and femur, and circumference, such as waist, hip, and abdominal circumference, offer important information about muscle mass, fat distribution, and overall body composition—all of which are essential markers of health and fitness [1-3]. Making sure these measurements are reliable is crucial for precise evaluation and long-term change tracking. Reliable measurements of these factors not only strengthen the validity of study results but also aid in the creation of successful weight-management, health risk-reduction, and general well-being programs [4-6]. Previous study reported high Intraclass Correlations (ICC) (0.97, 0.96, and 0.84 for waist, hip, and neck) comparing self vs technician [7]. Also, Comparison of self-measurements at home vs lab reele high test-retest reliability ($ICC \geq 0.87$) [7]. Overall, agreement among testers (irrespective of their experience in anthropometric measurements) was high ($ICC>0.895$) for each variable as suggested in previously conducted studies [8].

The reliability assessment of circumference and width variables aims to guarantee the consistency and dependability of measurements made for that variable. The following are some particular objectives associated with evaluating the reliability of these variables:

1. Consistency in Measurement: Determining the degree to which measures hold true across several occurrences or observers is the key goal. This entails determining if identical variables measured repeatedly by the same observer or by different observers produce comparable findings [9].

2. Precision in Research: Reliable measurements improve the validity and reproducibility of study results [10].

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3. Accurate Assessment of Body Composition: Evaluations of reliability make sure that measurements of width and circumference appropriately depict a person's body composition, especially the distribution of muscle and fat [11].

4. Validity of Research Findings: Reliability is a prerequisite for validity [12]. By proving that measurements of width and circumference are reliable, researchers may be sure that the information gathered appropriately reflects the constructs being assessed [13]. The validity of research findings is further supported by validity assessments, such as comparing anthropometric measures with gold standard techniques like dual-energy X-ray absorptiometry (DEXA) [14-15].

5. Clinical Assessment and Diagnosis: In clinical contexts, reliable measurements of width and circumference are used to screen, diagnose, and track for a variety of medical disorders. For instance, waist circumference is a crucial part of the diagnostic criteria for central obesity and metabolic syndrome, and although hip circumference might provide information about the likelihood of developing specific musculoskeletal conditions and measurements of breadth serve as markers of nutritional status and bone mineral density [1-2,16].

6. Anthropometric Studies and Population Health Research: In anthropometric studies and population health research, circumference and width measurements are frequently used to evaluate body shape and size variances among various groups to determine gender [17-18]. Assessments of reliability guarantee uniformity in measurement methods and enable insightful comparisons across demographic groups or geographical areas [18-19].

7. Data Interpretation: Accurate data interpretation and the ability for researchers to derive significant conclusions from the data are made possible by reliable measurements [20]. Unreliable measurements raise the risk of being misinterpreted or leading to incorrect conclusions [21].

Accurate results for body composition measurements depend on the competence and measurement reliability of the tester. Researchers can improve the scientific integrity of their studies and demonstrate their competence by reducing errors and discrepancies through the use of defined protocols, calibrated instruments, and strict quality control techniques. [22-25].

***Methods for Testing Reliability***

***a) Test-Retest Reliability (Using Pearson Correlation Coefficient):***

Test-retest reliability assesses the consistency of measurements over time by administering the same test to participants twice, separated by an appropriate interval to minimize memory effects [26-27]. The Pearson correlation coefficient (r) quantifies the linear relationship between the two test scores, reflecting the stability of the instrument and the tester's competency [28-29].

***b) Internal Consistency (Using Cronbach's Alpha):***

Cronbach's α measures the extent to which items on a multi-item scale are interrelated, reflecting internal consistency. Values range from 0 to 1, with higher values indicating stronger correlations among items. A coefficient above 0.70 is typically considered reliable [30]. While influenced by the number of items, the inclusion of relevant, correlated items can improve the alpha value [31].

***c) Intraclass Correlation Coefficient (Using ANOVA):***

The intraclass correlation coefficient (ICC) evaluates the reliability of repeated measurements from the same subjects by accounting for random variations due to subject, observer, and error through ANOVA or linear mixed model [32]. This method is suitable for assessing concordance across groups rather than paired observations [33].

The reliability and variability of various circumference and width measurements have never been examined. This study combines multiple statistical methods to assess the reliability of circumference and width measurements to prove the tester's competency in regards to measurement of these variables, making it a novel contribution to reliability analysis.

## 2. MATERIALS AND METHODS

### *2.1. Participants*

A sample of 300 women sportspersons, aged 18 to 25 years, was selected for the study using random sampling. The participants were selected from the National Capital Territory of Delhi, India, ensuring a diverse representation of athletes from various sports disciplines. All participants had competed at least at the state level in one or more of the following sports: judo, kabaddi, kho-kho, volleyball, yoga, athletics, basketball, football, handball, and hockey.

### *2.2. Research Procedure*

The researcher had undergone extensive training and measurement validation prior to data

collection. This rigorous preparation aimed to minimize errors and ensure adherence to standardized procedures. 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.

### *2.3. Data Collection*

Data collection was conducted using standardized tools, including the Cescorf Anthropometric Tape and the GPM Swiss Made Sliding Caliper. These tools were chosen for their precision and reliability in anthropometric measurements. All measurements adhered to the guidelines established by the International Society for the Advancement of Kinanthropometry (ISAK). Specific landmarks and protocols outlined in ISAK's literature were followed meticulously to measure each variable. Three readings were taken to enhance reliability and minimize variability in regards to the selected variables (Appendix-1)

### *2.4. Statistical Analysis*

The data was analyzed using Pearson's coefficient of correlation (Table-3), Cronbach's Alpha (Table-4) and ANOVA (Table-5). By employing these statistical techniques, the study ensured a comprehensive evaluation of the reliability of circumference and width measurements, providing valuable insights into the precision of these methods.

### *2.5. Statement of Ethics and Informed Consent*

The study protocol was approved by the Ethics Committee of the Department of Physical Education and Sports Sciences, University of Delhi. 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.

**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 |

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.

**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 |

## 3. RESULTS

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

**Table-3.** Test-retest reliability of selected circumference and width variables

| Variables | Reading | | | Reliability rating |
|---|---|---|---|---|
| | 1 vs 2 | 1 vs 3 | 2 vs 3 | |
| **Neck** | .996 | .996 | .998 | Excellent |
| **Chest** | .999 | . 999 | 1.000 | Excellent |
| **Forearm (Left)** | .996 | . 996 | .998 | Excellent |
| **Forearm (Right)** | . 996 | .995 | .998 | Excellent |
| **Abdominal** | 1.000 | 1.000 | 1.000 | Excellent |
| **Waist** | 1.000 | .996 | .997 | Excellent |
| **Hip (Gluteal)** | .980 | . 980 | 1.000 | Excellent |
| **Thigh (Left)** | .999 | . 999 | . 999 | Excellent |
| **Thigh (Right)** | . 999 | . 999 | 1.000 | Excellent |
| **Calf (Left)** | .944 | .944 | 1.000 | Excellent |
| **Calf (Right)** | .998 | .998 | .999 | Excellent |
| **Biepicondylar Humerus (Left)** | .970 | .974 | .985 | Excellent |
| **Biepicondylar Humerus (Right)** | .981 | .981 | .989 | Excellent |
| **Biepicondylar Femur (Left)** | .988 | .978 | .986 | Excellent |
| **Biepicondylar Femur (Right)** | .990 | .987 | .991 | Excellent |

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

According to the table-3, the Test-Retest Reliability of Neck Circumference ranged from .996 to .998 (Excellent), Chest Circumference ranged from .999 to 1.000 (Excellent), Forearm Circumference (Left) ranged from .996 to .998 (Excellent), Forearm Circumference (Right) ranged from .995 to .998 (Excellent), Abdominal Circumference was 1.000 (Excellent), Waist Circumference ranged from .996 to 1.000 (Excellent), Hip (Gluteal) Circumference ranged from .980 to 1.000 (Excellent), Thigh Circumference (Left) was .999 (Excellent), Thigh Circumference (Right) ranged from .999 to 1.000 (Excellent), Calf Circumference (Left) ranged from .944 to 1.000 (Excellent) and Calf Circumference (Right) ranged from .998 to .999 (Excellent). Also, Test-Retest Reliability of Biepicondylar Humerus (Left) ranged from .970 to .985 (Excellent), Biepicondylar Humerus (Right) ranged from .981 to .989 (Excellent), Biepicondylar Femur (Left) ranged from .978 to .986 (Excellent) and Biepicondylar Femur (Right) ranged from .987 to .991 (Excellent). Overall, the reliability coefficient ranged from .944 to 1.000 (Excellent) for Circumference variables and .970 to 991 for width variables.

**Table-4**. Cronbach's alpha of selected circumference and width variables

| Variables | Cronbach's Alpha | Internal Consistency (Reliability Rating) |
|---|---|---|
| **Neck** | .999 | Excellent |
| **Chest** | 1.000 | Excellent |
| **Forearm (Left)** | .999 | Excellent |
| **Forearm (Right)** | .999 | Excellent |
| **Abdominal** | 1.000 | Excellent |
| **Waist** | .999 | Excellent |
| **Hip (Gluteal)** | .996 | Excellent |
| **Thigh (Left)** | .976 | Excellent |
| **Thigh (Right)** | 1.000 | Excellent |
| **Calf (Left)** | .987 | Excellent |
| **Calf (Right)** | 1.000 | Excellent |
| **Biepicondylar Humerus (Left)** | .992 | Excellent |
| **Biepicondylar Humerus (Right)** | .994 | Excellent |
| **Biepicondylar Femur (Left)** | .994 | Excellent |
| **Biepicondylar Femur (Right)** | .996 | Excellent |

*L= Left; R= Right*

According to table-4 analysis of Cronbach's Alpha for selected circumference variables and width variables demonstrated extremely high coefficient ranged from .976 to 1.000 (Excellent) and .992 to .996 (Excellent) respectively.

**Table-5.** Analysis of variance of selected circumference and width variables

| Variables | | Sum of Squares | df | Mean Square | F | Probability |
|---|---|---|---|---|---|---|
| **NC** | **Between Groups** | .124 | 2 | .062 | .024 (NS) | .976 |
| | **Within Groups** | 2302.24 | 897 | 2.567 | | |
| | **Total** | 2302.36 | 899 | | | |
| **CHC** | **Between Groups** | .036 | 2 | .018 | .001(NS) | .999 |
| | **Within Groups** | 24858.07 | 897 | 27.712 | | |
| | **Total** | 24858.10 | 899 | | | |
| **FACL** | **Between Groups** | .325 | 2 | .163 | .056 (NS) | .946 |
| | **Within Groups** | 2626.13 | 897 | 2.928 | | |
| | **Total** | 2626.45 | 899 | | | |
| **FACR** | **Between Groups** | .052 | 2 | .026 | .009 (NS) | .991 |
| | **Within Groups** | 2536.80 | 897 | 2.828 | | |
| | **Total** | 2536.85 | 899 | | | |
| **ABC** | **Between Groups** | 1.468 | 2 | .734 | .012 (NS) | .988 |
| | **Within Groups** | 55368.49 | 897 | 61.726 | | |
| **WAC** | **Between Groups** | .119 | 2 | .059 | .001(NS) | .999 |
| | **Within Groups** | 45522.82 | 897 | 50.750 | | |
| | **Total** | 45522.94 | 899 | | | |

**Table-5 Cont.**

| | | | | | | |
|---|---|---|---|---|---|---|
| **HGC** | **Between Groups** | 5.859 | 2 | 2.929 | .060(NS) | .942 |
| | **Within Groups** | 4.737.29 | 897 | 48.760 | | |
| | **Total** | 43743.14 | 899 | | | |
| **TCL** | **Between Groups** | 0.070 | 2 | .035 | .001(NS) | .999 |
| | **Within Groups** | 21729.02 | 897 | 24.224 | | |
| | **Total** | 21729.09 | 899 | | | |
| **TCR** | **Between Groups** | .187 | 2 | .094 | .004(NS) | .996 |
| | **Within Groups** | 19764.77 | 897 | 22.034 | | |
| | **Total** | 19764.96 | 899 | | | |
| **CACL** | **Between Groups** | 2.653 | 2 | 1.327 | .056(NS) | .945 |
| | **Within Groups** | 21103.45 | 897 | 23.527 | | |
| | **Total** | 21106.10 | 899 | | | |
| **CACR** | **Between Groups** | .092 | 2 | .046 | .006(NS) | .994 |
| | **Within Groups** | 6883.41 | 897 | 7.674 | | |
| | **Total** | 6883.50 | 899 | | | |
| **BEHL** | **Between Groups** | .002 | 2 | .001 | .009 (NS) | .991 |
| | **Within Groups** | 91.648 | 897 | .102 | | |
| | **Total** | 91.650 | 899 | | | |
| **BEHR** | **Between Groups** | .005 | 2 | .002 | .025(NS) | .976 |
| | **Within Groups** | 87.374 | 897 | .097 | | |
| | **Total** | 87.379 | 899 | | | |
| **BEFL** | **Between Groups** | .084 | 2 | .042 | .200(NS) | .818 |
| | **Within Groups** | 187.695 | 897 | .209 | | |
| | **Total** | 187.779 | 899 | | | |
| **BEFR** | **Between Groups** | .054 | 2 | .027 | .115(NS) | .892 |

*NC= Neck Circumference; CHC= Chest Circumference; FACL= Forearm Circumference Left; FACR= Forearm Circumference Right; ABC= Abdominal Circumference; WC= Waist Circumference; HGC= Hip Gluteal Circumference; TCL= Thigh Circumference Left; TCR= Thigh Circumference Right; CACL= Calf Circumference Left; CACR= Calf Circumference Right; BEHL=Biepicondylar Humerus Left; BEHR=Biepicondylar Humerus Right; BEFL= Biepicondylar Femur Left; BEFR= Biepicondylar Femur 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 was 0.976 for Neck Circumference, 0.999 for Chest Circumference, 0.946 for Forearm Circumference Left, 0.991 for Forearm Circumference Right, .988 for Abdominal Circumference, 0.999 for Waist Circumference, 0.942 for Hip (Gluteal) Circumference, 0.999 for Thigh Circumference Left, 0.996 for Thigh Circumference Right, .945 for Calf Circumference Left and .994 for Calf Circumference Right. Moreover, the probability was .991 for Biepicondylar Humerus Left, .976 for Biepicondylar Humerus Right, .818 for Biepicondylar Femur Left and .892 for Biepicondylar Femur Right.

## 4. DISCUSSION

This study aimed to evaluate the reliability and variability of various circumference and width measurements using three distinct statistical methods: Pearson's Coefficient of Correlation, Cronbach's Alpha, and Analysis of Variance (ANOVA). The results demonstrated excellent reliability across all measured variables, with the reliability coefficients consistently falling within the "excellent" range.

The reliability of circumference measurements, including Neck, Chest, Forearm, Abdominal, Waist, Hip (Gluteal), Thigh, and Calf circumferences, was consistently high. The Test-Retest Reliability coefficients ranged from .944 to 1.000, indicating minimal variability between repeated measurements. These findings align with previous research [34], which emphasized the importance of precise protocols in ensuring consistent anthropometric measurements. Similarly, the high reliability coefficients observed in this study corroborate findings from [35], who demonstrated the utility of standardized techniques in achieving measurement consistency.

Specifically, the Abdominal Circumference achieved a perfect reliability coefficient of 1.000, reinforcing its utility as a robust anthropometric variable. Neck, Chest, Forearm, Waist, and Thigh circumferences also displayed coefficients nearing 1.000, emphasizing their reliability for repeated measures. Although the Calf Circumference (Left) showed slightly lower reliability (–.944), it remained within the excellent range, consistent with assertion that minor variability does not detract from overall reliability [36].

Width measurements, represented by Biepicondylar Humerus and Biepicondylar Femur dimensions, also exhibited excellent reliability, with coefficients ranging from .970 to .991. Among these, the Biepicondylar Femur (Right) demonstrated the

highest reliability, with coefficients ranging from .987 to .991. These results confirm the robustness of these metrics in repeated testing scenarios.

The inclusion of ANOVA to evaluate variability across repeated measures added another layer of validation to this study. The non-significant F ratios and high probability values ($p > 0.05$) across all variables confirmed the absence of significant variability between trials. This finding supports the reliability of the measurements and aligns with the framework proposed, which emphasizes the use of statistical methods to assess rater reliability [37]. Furthermore, the high reliability coefficients and non-significant variability suggest tester competency in performing these measurements. Previous study emphasized that consistent Cronbach's Alpha values, as observed in this study, indicate not only reliable measurements but also the precision and consistency of the testing personnel [31].

The findings of this study have significant implications for clinical, sports, and research settings. Reliable circumference and width measurements are critical for evaluating body composition, physical fitness, and rehabilitation progress. The study's use of multiple statistical methods (Pearson's Coefficient, Cronbach's Alpha, and ANOVA) further enhances the robustness of the findings, setting a benchmark for future reliability studies. This multi-method approach provides comprehensive validation, ensuring that the observed reliability is not an artifact of a single statistical technique.

While this study provides robust evidence of measurement reliability, several limitations warrant consideration such as population specificity and environmental conditions. Addressing these factors in future research could provide a more comprehensive understanding of measurement reliability. Future studies should also consider integrating advanced statistical techniques, such as Bland-Altman analysis (1986) [21], to assess agreement between measurement methods, as well as exploring the use of emerging technologies like 3D body scanning to enhance precision.

## 5. Conclusion

This study highlights the exceptional reliability of circumference and width measurements using multiple statistical approaches. The findings underscore the utility of these metrics in various domains and affirm the testers' competency in executing precise and consistent measurements. By integrating established methodologies with rigorous statistical validation, this study contributes to the growing body of evidence supporting the reliability of anthropometric measurements in both clinical and research contexts.

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**Conflict of Interest**

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

**Declaration of Funding**

No funding was received.

**Ethics Committee**

The study protocol was approved by the Ethics Committee of the Department of Physical Education and Sports Sciences, University of Delhi.

**Data Availability statement**

The author(s) can provide data upon reasonable request.

**Author Contributions**

Study Design, SR, DS; Data Collection, SR, DS; Statistical Analysis, SR, DS; Data Interpretation, SR; Manuscript Preparation, SR, DS; Literature Search, SR, DS. All authors have read and agreed to the published version of the manuscript.

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## Appendix

### Appendix-1: Selected Circumference and Width Variables and their Coding

| S.No. | Variables | Variables Code |
|---|---|---|
| 1. | Neck Circumference | **NC** |
| 2. | Chest Circumference | **CHC** |
| 3. | Forearm Circumference (Left) | **FACL** |
| 4. | Forearm Circumference (Right) | **FACR** |
| 5. | Abdominal | **ABC** |
| 6. | Waist | **WC** |
| 7. | Hip (Gluteal Circumference | **HGC** |
| 10. | Thigh Circumference (Left) | **TCL** |
| 11 | Thigh Circumference (Right) | **TCR** |
| 12. | Calf Circumference (Left) | **CACL** |
| 13. | Calf Circumference (Right) | **CACR** |
| 14. | Biepicondylar Humerus (Left) | **BEHL** |
| 15. | Biepicondylar Humerus (Right) | **BEHR** |
| 16. | Biepicondylar Femur (Left) | **BEFL** |
| 17. | Biepicondylar Femur (Right) | **BEFR** |