

Forearm Circumference and Handgrip Strength Asymmetry in Badminton Athletes: A Cross Sectional Study

Made Dwipa Indrayana¹, I Made Yoga Parwata², I Made Astika Yasa³, Agung Wahyu Permadi⁴

^{1,2,4}Physiotherapy Study Program, Faculty of Medicine, Universitas Dhyana Pura, Bali, Indonesia

³Professional Physiotherapy Study Program, Faculty of Medicine, Universitas Dhyana Pura, Bali, Indonesia

Corresponding author:

Name: Made Dwipa Indrayana

E-mail: dwipaindrayana8@gmail.com

Phone: 081338551238

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Abstract

Background: Badminton involves repeated unilateral use of the upper limb, which may be associated with side-to-side differences in anthropometric and functional characteristics.

Objective: To compare forearm circumference and handgrip strength between the dominant and non-dominant sides among badminton athletes in Denpasar and Badung.

Methods: This quantitative comparative cross-sectional study included 32 badminton athletes aged 18 to 25 years selected using purposive sampling. Forearm circumference was measured at the midpoint between the olecranon and radial styloid process using a nonelastic anthropometric tape. Handgrip strength was assessed with a Takei T.K.K. 5401 Grip D digital dynamometer. Descriptive statistics and paired samples t tests were reported at $p < 0.05$. Normality of paired differences was not assessed in the original analysis.

Results: Mean forearm circumference was 23.61 ± 2.03 cm on the dominant side and 21.69 ± 2.15 cm on the non-dominant side. Mean handgrip strength was 38.78 ± 7.51 kg and 32.18 ± 7.69 kg, respectively. Reported paired samples t tests showed significant differences in forearm circumference (mean difference 1.92 cm, $t = 19.20$, $df = 31$, $p < 0.001$) and handgrip strength (mean difference 6.60 kg, $t = 14.06$, $df = 31$, $p < 0.001$).

Conclusion: The studied athletes showed greater forearm circumference and handgrip strength on the dominant side. These findings describe side to side differences but do not establish that badminton participation caused the observed asymmetry.

Keywords

Badminton; Forearm; Hand Strength; Anthropometry; Racquet Sports

Introduction

Badminton is a racquet sport characterized by rapid changes of direction, repeated accelerations and decelerations, and the execution of technically demanding strokes. Upper limb function is central to stroke production because the racket is manipulated repeatedly during actions such as the smash, drive, drop shot, clear, and service. Consequently, physical characteristics of the hand and forearm may be relevant to the description and monitoring of badminton athletes.^{1,2}

The sport also involves a predominantly unilateral pattern of upper limb use because the racket is typically controlled with one hand. Repeated use of one side may be associated with differences between the dominant and non-dominant limbs.³ However, side specific differences cannot automatically be attributed to sport participation. Evidence from unilateral strength and skill training indicates that adaptations may also occur in the contralateral limb through cross education and other neural mechanisms.³ A cross sectional comparison therefore describes the pattern present at the time of measurement rather than demonstrating the cause of that pattern.

Forearm circumference is a practical anthropometric measure of the external dimension of the forearm. It may be useful for describing upper limb morphology, particularly when measurements are obtained using a standardized protocol. Nevertheless, circumference does not isolate muscle mass because the measurement also reflects bone, adipose tissue, skin, and other soft tissues. Standardized landmarking and measurement procedures are therefore important when side to side differences are examined.⁴

Handgrip strength provides a functional measure of maximal force production during gripping and is widely used in physical and clinical assessment. It is influenced by biological, anthropometric, and functional characteristics.^{5,6} Previous research has also shown associations between hand and forearm dimensions and grip related strength, although the magnitude and determinants of these relationships vary across populations.⁷ In badminton, grip related function is relevant to racket control and has been examined in relation to sport specific performance.⁸

Studies of badminton athletes have reported anthropometric and physical characteristics, while other work has examined grip strength or training related changes.^{4,9-11} However, the available literature represented in the present manuscript provides limited evidence describing both an anthropometric outcome and a functional strength outcome through paired dominant versus non dominant assessment within the same athletes. The contribution of the present study therefore lies in evaluating forearm circumference and handgrip strength as two paired outcomes within individuals rather than in the geographic setting alone.

The Denpasar and Badung athlete population provides a defined local context in which to document these side-to-side characteristics. Such data may support future work that incorporates training exposure, competition level, body composition, injury history, and performance outcomes. The present study did not collect or analyze those variables and therefore cannot determine whether the observed differences reflect training exposure, hand dominance, pre-existing anatomical characteristics, or a combination of factors.

From an applied perspective, paired assessment may also be useful because dominant and non-dominant values can be interpreted within the same individual rather than against a single population reference. This approach does not remove all sources of confounding, but it reduces the influence of differences in age, sex, body size, and other characteristics that vary between athletes.¹² At the same time, the meaning of an observed asymmetry depends on the outcome being measured and the context in which it occurs. A statistically significant side difference should not be equated with impairment, injury risk, or a requirement for corrective intervention unless those outcomes have been directly evaluated.^{6,8} This distinction is particularly important in cross sectional studies that describe existing characteristics without establishing temporal sequence or causation.

Accordingly, this study aimed to compare forearm circumference and handgrip strength between the dominant and non-dominant sides among badminton athletes in Denpasar and Badung. The two outcomes were prespecified as the primary outcomes of the study.

Methods

This study used a quantitative comparative cross-sectional design. The comparison was performed within participants, with measurements from the dominant and non-dominant sides treated as paired observations. Participants were active badminton athletes in Denpasar and Badung, Bali, Indonesia, recruited from GOR Balijaya, Lima Arena Badminton Courts, and GOR Satria Mandala Bakti. The recruitment period was not available in the supplied study records and is therefore not specified.

Participants were active badminton athletes aged 18 to 25 years. Eligible athletes trained regularly at least three times per week, used one dominant hand to hold the racket during badminton participation, and agreed to complete the study procedures and provide written informed consent. Athletes were excluded if they were currently experiencing or had experienced a severe upper limb injury involving the shoulder, elbow, or wrist during the previous 6 months; had a congenital abnormality or deformity involving the arm or hand; or were actively participating in another resistance-based sport, such as weightlifting, that could influence handgrip strength.

Thirty-five athletes were available and willing to participate before sample selection. An a priori sample size calculation was reported to have been performed using G Power for a paired samples t test, assuming a medium effect size of Cohen's $d = 0.5$, $\alpha = 0.05$, and statistical power of 0.80. The calculation indicated a minimum requirement of 27 participants. Allowing for a 15% dropout rate, the target sample was increased to 31 participants. Thirty-two eligible athletes were ultimately included, and all provided complete data for analysis. Three athletes from the accessible population were not included because the required sample size had already been achieved.

The primary outcomes were forearm circumference and handgrip strength, each measured on the dominant and non-dominant sides. Dominance was defined operationally as the hand routinely used to hold the badminton racket during training and competition. Dominance was determined by self-report through a brief interview before measurement. Athletes who routinely held the racket with the right hand were classified as right hand dominant, whereas those who routinely held it with the left hand were classified as left hand dominant.

Participant characteristics included age, sex, height, body weight, and body mass index. Training duration, weekly training volume, competition level, and other detailed training characteristics were not collected and were not included in the analysis.

Forearm circumference was measured using a nonelastic anthropometric tape with a precision of 0.1 cm. The anatomical site was standardized at the midpoint between the olecranon of the ulna and the radial styloid process. The distance between these landmarks was measured, and the midpoint was marked with a nonpermanent skin marker. Participants stood in a relaxed position with the forearm supinated. The tape was placed at the marked midpoint using the same procedure on the dominant and non-dominant sides.

Each side was measured three times, and the mean of the three measurements was used for analysis. All measurements were performed by the same examiner using the same instrument and standardized procedure. Formal intra examiner and inter examiner reliability testing was not performed in this study.

Handgrip strength was assessed using a Takei T.K.K. 5401 Grip D digital handgrip dynamometer (Takei Scientific Instruments Co., Ltd., Niigata, Japan). The instrument was checked for operational function before data collection and was zeroed before each measurement session. All measurements used the same device. The grip setting was adjusted to achieve a comfortable and appropriate grasp, with the proximal interphalangeal joints positioned optimally according to the manufacturer's recommendations.

Participants were assessed while standing upright. The tested arm was positioned beside the body with the shoulder in a neutral position, the elbow fully extended, the forearm in a neutral position, and the wrist in a neutral position. Participants were instructed to hold the device in the prescribed position and, after the command to begin, squeeze as strongly as possible for 3 to 5 seconds without moving the arm or trunk. Three trials were performed for each side with a 60 second rest interval between trials. The highest value was used as the maximal handgrip strength. The order of testing between the dominant and non-dominant sides was not randomized or otherwise documented in the original study records. All measurements were performed by the same examiner.

Participants received an explanation of the study objectives and measurement procedures and provided written informed consent before data collection. Height and body weight were measured, followed by assessment of forearm circumference and handgrip strength on both sides. Measurements were obtained using the standardized procedures described above. No missing measurements were reported, and all 32 included participants contributed complete data to the final analysis.

Descriptive statistics included the mean, standard deviation, minimum, and maximum. The original analysis reported Shapiro Wilk testing separately by sex and side. However, the relevant assumption for a paired samples t test concerns the distribution of within participant differences between the dominant and non-dominant measurements. The normality of these paired differences was not assessed in the original analysis, and the required results are not available for retrospective reporting. No formal outlier assessment was performed. Because there were no missing data, no imputation or other missing data procedure was required.

The reported paired samples t tests were retained for the two prespecified primary outcomes, using a significance level of $p < 0.05$. Mean differences were calculated directly from the reported descriptive means. Confidence intervals and standardized effect sizes were not available in the original statistical output and were not reconstructed. The statistical software used for the original analysis was not specified in the supplied records.

The study was approved by the Ethics Committee of Universitas Dhyana Pura under approval number 003702/KEP Universitas Dhyana Pura/2026. Written informed consent was obtained from all participants.

Results

The study included 32 badminton athletes aged 18 to 25 years. Men accounted for 24 participants (75.0%), and women accounted for 8 participants (25.0%). Most participants had a body mass index classified as normal, whereas 2 participants were classified as overweight. Participant characteristics are summarized in Table 1.

Table 1. Participant characteristics

Characteristic	Category	n	%
Sex	Men	24	75.0
	Women	8	25.0
Body mass index	Normal, 18.5 to 22.9	30	93.8
	Overweight, 23.0 to 24.9	2	6.3

BMI categories follow the Asian classification used in the original study dataset.

The two primary outcomes are summarized in Table 2. Mean forearm circumference was greater on the dominant side than on the non-dominant side. Mean handgrip strength was also greater on the dominant side.

Table 2. Descriptive statistics for the primary outcomes

Outcome	n	Dominant, mean $\pm$ SD	Non dominant, mean $\pm$ SD	Dominant range	Non dominant range
Forearm circumference, cm	32	23.61 $\pm$ 2.03	21.69 $\pm$ 2.15	19.80 to 28.30	18.50 to 26.70
Handgrip strength, kg	32	38.78 $\pm$ 7.51	32.18 $\pm$ 7.69	25.10 to 49.80	16.70 to 44.90

The reported paired comparisons are presented in Table 3. Forearm circumference differed by 1.92 cm between the dominant and non-dominant sides based on the reported means. The reported paired samples t test was statistically significant ($t = 19.20$, $df = 31$, $p < 0.001$). Handgrip strength differed by 6.60 kg, and the reported paired comparison was also statistically significant ($t = 14.06$, $df = 31$, $p < 0.001$).

Table 3. Reported paired comparisons between dominant and non-dominant sides

Outcome	Dominant mean	Non dominant mean	Mean difference	t	df	p
Forearm circumference, cm	23.61	21.69	1.92	19.20	31	<0.001
Handgrip strength, kg	38.78	32.18	6.60	14.06	31	<0.001

Mean differences were calculated directly from the reported descriptive means. Confidence intervals and effect sizes were not available in the original statistical output.

The original manuscript reported a non-dominant forearm circumference of 21.68 cm in one paired comparison table and 21.69 cm in the descriptive results. The present manuscript uses 21.69 cm consistently because this value is reported in the descriptive dataset and revised manuscript; the discrepancy should nevertheless be verified against the original statistical output before submission.

Discussion

The principal finding was that the dominant side had greater mean forearm circumference and greater mean handgrip strength than the non-dominant side among the studied badminton athletes. The reported mean side to side differences were 1.92 cm for forearm circumference and 6.60 kg for handgrip strength, and both paired comparisons were statistically significant.

The higher handgrip strength observed on the dominant side is compatible with the functional demands of badminton, in which one hand repeatedly controls the racket during stroke production. Handgrip strength reflects maximal gripping force and is influenced by biological and anthropometric factors.^{5,6} Previous badminton research has also examined grip strength in relation to sport specific performance, although performance was not assessed in the present study.⁸ The present findings should therefore be interpreted as a description of side-to-side strength differences rather than evidence that a particular level of grip strength improves badminton performance.

The greater forearm circumference on the dominant side should likewise be interpreted cautiously. Circumference is an external anthropometric dimension that incorporates muscle, adipose tissue, bone, skin, and other soft tissues. It cannot therefore be used as direct evidence of muscle hypertrophy.¹³ Standardized anthropometric procedures are important when comparing sides, and the midpoint protocol used in this study was intended to improve consistency of measurement.⁴ The observed difference may be compatible with morphological differences between the limbs, but the present measurements cannot identify the tissue responsible for the difference.

The within participant comparison is a methodological strength because measurements from the two sides were obtained in the same athletes, thereby reducing between participant variability when describing side to side differences. At the same time, the cross-sectional design does not establish whether repeated badminton participation produced the observed pattern. Hand dominance, previous physical activity, individual anatomy, and other unmeasured characteristics may also contribute. Evidence concerning cross education further indicates that unilateral training does not necessarily produce adaptations that are restricted entirely to the trained limb.³

The magnitude of the observed differences may be useful for descriptive monitoring, but the study did not establish a clinical or sport specific threshold for acceptable asymmetry. Statistical significance should therefore not be interpreted as evidence that the observed differences are harmful, clinically excessive, or associated with injury. The study also did not assess pain, injury incidence, sport performance, or response to a training intervention. Consequently, the results do not demonstrate that the asymmetry causes injury or that modifying the non-dominant side would improve performance or prevent injury.

Several limitations require consideration. The sample was relatively small and was selected purposively. Although recruitment sources, eligibility criteria, and the accessible participant pool were subsequently documented, the recruitment period was not available in the study records. Important potential confounders, including training duration, weekly training volume, competition level, body composition, and detailed previous physical activity, were not collected. The sample size calculation was documented retrospectively from the study record, but the analytical reporting remains incomplete because confidence intervals and standardized effect sizes were not available from the original output.

Measurement reproducibility was improved by using a defined anatomical landmark, repeated circumference measurements, the same instruments, and a single examiner. Nevertheless, formal examiner reliability testing was not performed, and the testing order of the dominant and non-dominant sides was not randomized or documented. The statistical assumption assessment also represents an important limitation. Normality was originally assessed by side and sex rather than for the within

participant differences required for a paired samples t test, and no formal outlier assessment was performed. The reported t statistics and p values were retained because no raw data or revised original output was available to support reanalysis.

Generalizability is limited to the characteristics of the studied sample, which comprised athletes aged 18 to 25 years, 75.0% of whom were men, from a specific regional context. Future studies should recruit larger and more diverse samples, prospectively document training exposure and competition characteristics, preserve complete statistical outputs, report confidence intervals and standardized effect sizes, and assess assumptions using paired differences. Longitudinal designs incorporating injury and performance outcomes would also help clarify the practical significance and possible determinants of side-to-side differences.

Conclusion

Among badminton athletes aged 18 to 25 years in Denpasar and Badung, the dominant side had greater mean forearm circumference and greater mean handgrip strength than the non-dominant side. The reported paired analyses showed statistically significant differences for both primary outcomes, with mean differences of 1.92 cm for forearm circumference and 6.60 kg for handgrip strength.

These findings provide a descriptive account of upper limb side to side differences within the studied athletes. They are compatible with possible influences of repeated unilateral sport use and hand dominance, but the cross-sectional design does not establish causality. The measurements used in this study also do not identify the tissue basis of the circumference difference, establish a clinically meaningful threshold of asymmetry, or demonstrate an association with injury or sport performance.

The findings may nevertheless provide baseline descriptive information for future monitoring of upper limb characteristics in comparable badminton populations when standardized procedures are used. Future research should incorporate larger and more representative samples, detailed training exposure, body composition and competition data, verified paired assumption testing, confidence intervals, standardized effect sizes, and longitudinal assessment of injury and performance outcomes. Such work is needed to determine the mechanisms, stability, and practical significance of the observed side to side differences.

Author Contribution

Made Dwipa Indrayana: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing Original Draft, Visualization, Project Administration.

I Made Yoga Parwata: Conceptualization, Methodology, Validation, Writing Review and Editing, Supervision.

I Made Astika Yasa: Methodology, Validation, Writing Review and Editing, Supervision.

Agung Wahyu Permadi: Methodology, Validation, Writing Review and Editing, Supervision.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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Ethics Statement

This study was approved by the Ethics Committee of Universitas Dhyana Pura, Bali, Indonesia, with approval number 003702/KEP Universitas Dhyana Pura/2026. Written informed consent was obtained from all participants before their participation in the study.

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