

Upper Arm Circumference and Handgrip Strength Differences in Male Badminton Athletes

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Abstract

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

Objective: To compare upper arm circumference and handgrip strength between the dominant and non-dominant sides in male badminton athletes from Denpasar and Badung, Bali.

Methods: This quantitative observational comparative study used a within-subject cross-sectional design. Twenty-four male badminton athletes aged 18–25 years were recruited through purposive sampling. Dominance was defined as the hand routinely used to hold the racket during training and competition, based on self-report. Upper arm circumference was measured three times on each side at the midpoint between the acromion and olecranon, and the mean was analyzed. Handgrip strength was assessed three times per side using a Takei TTK 5401 dynamometer, with the highest value analyzed. The original analysis used paired sample t-tests.

Results: Mean upper arm circumference was 28.42 ± 2.23 cm on the dominant side and 26.27 ± 2.21 cm on the non-dominant side. Mean handgrip strength was 42.62 ± 3.73 kg and 36.05 ± 3.50 kg, respectively. Both comparisons were statistically significant ($p < 0.001$). Normality of paired difference scores, 95% confidence intervals, and paired effect sizes were unavailable.

Conclusion: Upper arm circumference and handgrip strength were significantly greater on the dominant side. These findings describe cross-sectional side to side differences and do not establish causation, longitudinal adaptation, clinical significance, or injury risk.

Keywords

Badminton; Hand Strength; Anthropometry; Upper Arm; Muscle Strength; Athletic Performance

Introduction

Badminton is a widely practiced racket sport characterized by intermittent high-intensity activity, rapid changes in direction, explosive movements, and repeated execution of technically demanding strokes.¹ Successful performance requires the integration of physical capacities, including endurance, agility, power, muscular strength, and sport-specific technical skill.² Evidence from recent research indicates that structured physical training programs may influence several performance-related characteristics in badminton players, highlighting the importance of understanding the physical demands associated with the sport and the characteristics that may differ among athletes.²

From a biomechanical perspective, badminton requires coordinated movement of the entire body, while the upper limb holding the racket plays a central role in the execution of strokes such as serves, clears, drives, drops, and smashes.³ The opposite upper limb also contributes to balance, body positioning, and movement coordination during stroke preparation and execution.³ Consequently, the two upper limbs are exposed to different functional demands. Repeated use of the racket-holding limb may produce an asymmetric pattern of mechanical loading that differs from sports in which both upper limbs are exposed to more similar movement and loading demands.^{4,5} Such differences provide a relevant basis for examining whether measurable side-to-side differences are present in anthropometric and functional characteristics among badminton athletes.

Repeated mechanical loading is associated with neuromuscular and morphological responses, although the magnitude and nature of these responses depend on factors such as training characteristics, exercise intensity, volume, frequency, and individual biological variation.⁶ Muscle size is also related to force-producing capacity, although this relationship is influenced by muscle architecture, neural factors, the specific muscle assessed, and the method and location of measurement.⁷ In this context, upper arm circumference can serve as a simple anthropometric measure for describing differences between the dominant and non-dominant upper limbs.⁸ However, upper arm circumference should not be interpreted as a direct measure of muscle mass, muscle cross-sectional area, or muscle hypertrophy because the measurement reflects the contribution of multiple tissues within the measured region.⁸

Handgrip strength provides a complementary functional measure of upper limb force generation.⁹ In badminton, the repeated use of the racket-holding hand during training and competition may contribute to differences in functional characteristics between the two sides. Previous studies have reported side-specific differences and muscular asymmetry among badminton athletes.^{10,11} However, the findings across studies are not necessarily uniform because athletes may differ in age, sex, competitive level, training exposure, duration of participation, measurement protocols, and operational definitions of limb dominance. Mhaske et al. also demonstrated that hand dominance does not necessarily result in a consistent advantage across all measures of hand function.¹² Therefore, the presence and magnitude of side-to-side differences should be interpreted within the methodological and population-specific context of each study.

Inter-limb asymmetry has received increasing attention in sports science because differences between sides may be relevant to physical profiling and performance assessment.¹³ Nevertheless, the presence of a measurable asymmetry does not automatically establish clinical significance or indicate an increased risk of injury. Thresholds for asymmetry have been discussed in the sports literature, but their interpretation depends on the outcome measured, testing procedure, athlete population, and context in which the asymmetry is evaluated.^{13,14} A statistically significant difference between two sides should therefore be distinguished from a clinically meaningful difference. Importantly, the present study did not assess injury occurrence, pain, tendon pathology, functional disability, or other clinical outcomes. Accordingly, any observed differences in upper arm circumference or handgrip strength cannot be interpreted as evidence of injury risk or as proof that asymmetry is harmful.¹³

Although previous research has examined muscular and functional asymmetry in badminton athletes, the available literature demonstrates substantial variation in participant characteristics and measurement approaches.^{10–12} In addition, relatively limited information is available regarding the simultaneous comparison of upper arm circumference and handgrip strength within the same participants in local club-level badminton populations. Examining these two outcomes together may provide a broader description of side-specific characteristics because upper arm circumference represents an anthropometric measure, whereas handgrip strength represents a functional measure. A within-subject comparison is particularly useful for this purpose because each participant serves as their own reference, thereby reducing some sources of variability attributable to differences between individuals.

The present study focused on male badminton athletes aged 18 to 25 years who were recruited from badminton training facilities in Denpasar and Badung, Bali. The study was designed as a cross-sectional comparison between the dominant and non-dominant upper limbs. In this study, the dominant side was defined as the side routinely used by the athlete to hold the racket during badminton training and competition, based on self-report obtained before measurement. This operational definition was selected because the racket-holding limb is directly exposed to the sport-specific demands associated with repeated stroke execution.

Therefore, the objective of this study was to compare upper arm circumference and handgrip strength between the dominant and non-dominant sides in male badminton athletes from Denpasar and Badung, Bali. The study aimed to describe the side-to-side differences observed at the time of assessment. Because of the cross-sectional design, the findings were not intended to establish that hand dominance, badminton participation, or training exposure caused the observed differences, nor were they intended to determine the clinical significance or injury implications of those differences.

Methods

This quantitative observational comparative study used a within-subject cross-sectional design to compare upper arm circumference and handgrip strength between the dominant and non-dominant upper limbs of the same participants. Data collection was conducted at Lima Arena Badminton Courts, Badung, Bali, on 27 May 2026. In this study, the comparison factor was upper limb side, categorized as dominant or non-dominant, while the primary outcomes were upper arm circumference and handgrip strength.

Participants were recruited from active badminton athletes in Denpasar and Badung who trained at GOR Baliyaya, Lima Arena Badminton Courts, and GOR Satria Mandala Bakti. The reported source population consisted of approximately 200 athletes identified through a survey of badminton training facilities in Denpasar and Badung. Facilities were included in the recruitment source when they provided training for prospective or active badminton athletes and met the study requirements. A total of 24 athletes who met the established eligibility criteria were included through purposive sampling.

The inclusion criteria were male badminton athletes aged 18 to 25 years, participation in more than two competitions, absence of serious injury during the previous 6 months, a healthy condition at the time of assessment, and willingness to participate by providing written informed consent. Participants were excluded if they had a current injury, had not participated in training during the previous 2 months, or were considered unhealthy at the time of measurement. The final sample of 24 participants was obtained based on the application of these eligibility criteria, which were intended to select active athletes with sufficient badminton experience. However, no *a priori* sample size calculation or other statistical sample size determination was performed. Therefore, the sample size was determined through purposive sampling based on the predefined inclusion and exclusion criteria rather than statistical power estimation.

The dominant side was defined as the upper limb routinely used by the athlete to hold the racket during badminton training and competition. Dominance was determined through self-report obtained during a brief interview before the measurements were performed. Athletes who routinely used the right hand to hold the racket were categorized as right-side dominant, whereas those who routinely used the left hand were categorized as left-side dominant. This operational definition was used because the racket-holding limb is directly involved in repeated sport-specific actions and is exposed to the primary mechanical demands associated with badminton stroke execution.

Upper arm circumference was measured on both the dominant and non-dominant sides using an Onemed measuring tape with a length of 150 cm and a reported resolution of 0.1 cm. For each measurement, the participant stood upright. The arm to be measured was initially flexed to approximately 90°, after which the midpoint between the acromion and olecranon was identified and marked. The arm was then returned to a relaxed position alongside the body and was free from clothing that could compress the measurement area. The measuring tape was placed around the marked midpoint without excessive tightening or looseness. Each side was measured three times using the same procedure, and the mean of the three measurements was used for statistical analysis.

Handgrip strength was assessed on both sides using a Takei TKK 5401 digital handgrip dynamometer. During testing, participants stood upright with the shoulder positioned close to the body, the elbow flexed to approximately 90°, and the wrist maintained in a neutral position while gripping the dynamometer. Participants were instructed to squeeze the device with maximal effort for approximately 2 to 4 seconds without allowing the instrument to contact another part of the body. Three trials were performed for each side, with an interval of approximately 20 to 30 seconds between trials. The highest value obtained from the three trials was used for analysis.

The order of dominant and non-dominant side assessment was randomized. However, upper arm circumference was always measured before handgrip strength. All measurements were performed using the same instruments to maintain consistency across participants. The measuring tape and handgrip dynamometer were not recalibrated specifically by the researcher before data collection because both instruments were laboratory equipment from the Physiotherapy Study Program. Before use, their physical condition and operational function were checked according to laboratory procedures. Before each measurement session, the handgrip dynamometer was checked to ensure that the digital display returned to zero and that no operational malfunction was evident. The instruments were maintained as laboratory equipment and were considered suitable for use according to routine laboratory management procedures.

Descriptive statistics were used to summarize participant characteristics and measurement outcomes. The original analysis assessed the distribution of the dominant and non-dominant measurements separately using the Shapiro–Wilk test. Paired-sample t-tests were subsequently used to compare upper arm circumference and handgrip strength between the dominant and non-dominant sides. Statistical significance was reported as $p < 0.001$ for both paired comparisons. The available Shapiro–Wilk results were $p = 0.107$ and $p = 0.203$ for dominant and non-dominant upper arm circumference, respectively, and $p = 0.057$ and $p = 0.292$ for dominant and non-dominant handgrip strength, respectively.

However, the normality assumption relevant to a paired-sample t-test concerns the distribution of the paired difference scores rather than the separate distributions of each side. Normality testing of the dominant minus non-dominant difference scores was not performed in the original analysis and could not be added retrospectively from the available statistical output. Similarly, the available materials did not provide a verified mean difference, 95% confidence interval, or paired effect size. These parameters were therefore not reconstructed or estimated because doing so could introduce unsupported assumptions into the statistical results. The statistical findings presented in this study should consequently be interpreted within the limitations of the original analysis.

Written informed consent was obtained from all participants before participation. The author confirmation materials also include evidence that ethical review was obtained. However, the exact name of the approving ethics committee, approval number, and approval date or period must be transcribed directly from the original ethical approval document before final submission to ensure complete and verifiable reporting. No external funding was received for this study.

Results

A total of 24 male badminton athletes aged 18 to 25 years were included in the analysis. The participant characteristics and the distribution of the primary measurement outcomes are summarized in Table 1. The sample was predominantly composed of 18-year-old athletes, accounting for 11 participants (45.8%), followed by athletes aged 19 years, who accounted for 6 participants (25.0%). All participants were male. Based on the body mass index categories reported in the original dataset, 22 participants (91.7%) were classified as having normal body mass index and 2 participants (8.3%) were classified as overweight.

The distribution of upper arm circumference also differed between the dominant and non-dominant sides. On the dominant side, half of the participants had measurements between 25.0 and 27.9 cm, whereas 29.2% and 20.8% had measurements between 28.0 and 30.9 cm and 31.0 and 33.0 cm, respectively. On the non-dominant side, the largest proportion of participants had measurements between 23.0 and 25.9 cm. The categorical distribution is presented descriptively and is intended to complement the continuous outcome analysis.

The original dataset also categorized handgrip strength into poor, below average, and average groups. However, the source and population basis for the cut-off values were not sufficiently documented in the available materials. Although the author confirmed that the classification was based on a reference range for athletes aged 18 to 29 years, the specific source and exact cut-off values were not provided. Therefore, these categories are not presented as validated classifications in the revised main results. The continuous handgrip strength values were retained as the primary basis for statistical comparison.

Table 1. Participant characteristics and descriptive distribution of upper arm circumference

Characteristic	Category	n (%)
Age, years	18	11 (45.8)
	19	6 (25.0)
	20	2 (8.3)
	21	1 (4.2)
	22	2 (8.3)
	23	1 (4.2)
	25	1 (4.2)
Sex	Male	24 (100)
Body mass index	Normal	22 (91.7)
	Overweight	2 (8.3)
Upper arm circumference, dominant side	25.0 to 27.9 cm	12 (50.0)
	28.0 to 30.9 cm	7 (29.2)
	31.0 to 33.0 cm	5 (20.8)
Upper arm circumference, non-dominant side	23.0 to 25.9 cm	11 (45.8)
	26.0 to 28.9 cm	9 (37.5)
	29.0 to 31.0 cm	4 (16.7)

Note: Percentages may not total exactly 100 because of rounding.

The distributional assessment performed in the original analysis is presented in Table 2. Shapiro–Wilk testing was conducted separately for the dominant and non-dominant measurements. All reported p-values were greater than 0.05, indicating that none of the individual measurement distributions showed statistically significant evidence of deviation from normality according to the reported tests. However, these results do not directly establish the normality of the paired difference scores, which is the assumption relevant to the paired-sample t-test.

Table 2. Shapiro–Wilk test results for individual dominant and non-dominant measurements

Variable	n	Shapiro–Wilk W	p-value
Upper arm circumference, dominant side	24	0.9319	0.107
Upper arm circumference, non-dominant side	24	0.9443	0.203
Handgrip strength, dominant side	24	0.9194	0.057
Handgrip strength, non-dominant side	24	0.9515	0.292

Note: The reported normality tests were conducted for the individual measurements. Shapiro–Wilk testing of the paired difference scores was not available in the supplied statistical output.

The continuous descriptive results for the two primary outcomes are presented in Table 3. Mean upper arm circumference was greater on the dominant side than on the non-dominant side, with values of 28.42 ± 2.23 cm and 26.27 ± 2.21 cm, respectively. A similar pattern was observed for handgrip strength. The dominant side had a mean handgrip strength of 42.62 ± 3.73 kg, whereas

the non-dominant side had a mean value of 36.05 ± 3.50 kg. These descriptive findings consistently indicated higher mean values on the dominant side for both the anthropometric and functional outcomes.

Table 3. Descriptive comparison of upper arm circumference and handgrip strength

Outcome	Dominant side, mean $\pm$ SD	Non-dominant side, mean $\pm$ SD
Upper arm circumference, cm	28.42 ± 2.23	26.27 ± 2.21
Handgrip strength, kg	42.62 ± 3.73	36.05 ± 3.50

SD: standard deviation.

The paired comparisons from the original statistical analysis are presented in Table 4. Upper arm circumference differed significantly between the dominant and non-dominant sides, with a reported t-value of 22.03, 23 degrees of freedom, and $p < 0.001$. Handgrip strength also showed a statistically significant difference, with a reported t-value of 11.91, 23 degrees of freedom, and $p < 0.001$. Thus, according to the original paired analysis, both primary outcomes were significantly greater on the dominant side.

Table 4. Paired comparison of dominant and non-dominant upper limb outcomes

Outcome	Comparison	t	df	p-value
Upper arm circumference	Dominant vs non-dominant	22.03	23	<0.001
Handgrip strength	Dominant vs non-dominant	11.91	23	<0.001

Note: The original statistical materials contained additional values reported as 27.35 ± 2.47 for upper arm circumference and 39.34 ± 4.89 for handgrip strength. Their statistical meaning could not be verified from the available output and they were therefore not relabeled or interpreted as mean differences in this revision. Verified mean differences, 95% confidence intervals, and paired effect sizes were not available and are not reported.

Overall, the available results demonstrate statistically significant side-to-side differences in both upper arm circumference and handgrip strength among the 24 participants. However, the magnitude and precision of these differences cannot be fully evaluated because the original statistical output did not provide a verified mean difference, 95% confidence interval, or paired effect size. In addition, normality testing for the paired difference scores was unavailable. These limitations do not alter the descriptive values or the reported paired test results but should be considered when interpreting the strength and precision of the observed differences.

Discussion

The present study compared upper arm circumference and handgrip strength between the dominant and non-dominant upper limbs of 24 male badminton athletes aged 18 to 25 years. The principal finding was that both outcomes were greater on the dominant side according to the descriptive data and the reported paired-sample t-test results. Mean upper arm circumference was 28.42 ± 2.23 cm on the dominant side compared with 26.27 ± 2.21 cm on the non-dominant side. Similarly, mean handgrip strength was 42.62 ± 3.73 kg on the dominant side and 36.05 ± 3.50 kg on the non-dominant side. Both paired comparisons were reported as statistically significant at $p < 0.001$. These findings indicate measurable side-to-side differences in the assessed anthropometric and functional outcomes at the time of measurement.

The observed difference in upper arm circumference is consistent with the asymmetric functional demands of badminton. The dominant upper limb is repeatedly involved in holding and controlling the racket and executing sport-specific movements, whereas the non-dominant limb performs different roles during movement coordination and stroke preparation.^{4,5} Previous research has also described side-specific muscular characteristics among badminton athletes, including differences in muscle volume between dominant and non-dominant upper limbs.¹¹ Therefore, the present findings are broadly consistent with literature indicating that athletes participating in sports with asymmetric loading patterns may demonstrate measurable differences between sides.^{4,5}

Nevertheless, the greater upper arm circumference observed on the dominant side should not be interpreted as direct evidence of greater muscle mass or muscle hypertrophy. Upper arm circumference is an anthropometric measurement influenced by multiple tissues and does not directly quantify muscle cross-sectional area or muscle volume. Although muscle size may be associated with force-producing capacity, this relationship is influenced by factors including muscle architecture, neural activation, measurement location, and the specific characteristics of the muscle being assessed.⁷ Exercise-related muscle remodeling provides a plausible physiological context for side-specific differences, but the cross-sectional design of the present study cannot determine whether the observed differences developed as a consequence of badminton training.⁶ Other unmeasured factors may also have contributed to the observed measurements.

Handgrip strength was likewise greater on the dominant side. This finding is compatible with the functional demands imposed on the racket-holding limb, which is repeatedly required to generate and control grip force during badminton activities. Previous studies have reported muscular imbalance and side-specific functional differences among badminton athletes.^{10,11} However, findings concerning hand dominance and grip strength are not necessarily consistent across populations and measurement procedures. Mhaske et al. reported that hand dominance does not uniformly result in superior performance across all measures of hand function.¹² Differences between studies may therefore reflect variation in participant age, competitive level, training history, cumulative training exposure, testing instruments, testing posture, familiarization procedures, and operational definitions of dominance.¹²

The statistical significance of the observed differences should also be distinguished from their magnitude and potential practical or clinical importance.¹⁵ Although both paired comparisons were reported as statistically significant, the available statistical output did not provide a verified mean difference, 95% confidence interval, or paired effect size. Consequently, the precision and standardized magnitude of the observed differences cannot be fully evaluated from the available data. In addition, normality testing was performed for the dominant and non-dominant measurements separately rather than for the paired difference scores, which represent the assumption most directly relevant to the paired-sample t-test.¹⁶ The reported statistical results should therefore be interpreted as evidence of differences within the original analysis while acknowledging the limitations in the available statistical documentation.

The present findings should not be interpreted as evidence of clinical significance or increased injury risk.¹³ The study did not assess injury occurrence, pain, tendon pathology, functional disability, or other clinical outcomes. Although previous studies have discussed inter-limb asymmetry in relation to athletic performance and injury, the interpretation of asymmetry depends on the population, outcome, measurement method, and magnitude of the difference.^{13,14} Therefore, the statistically significant side-to-side differences observed in this study cannot be directly translated into evidence of harmful asymmetry or a predictor of injury.^{13,14}

From a practical perspective, the results suggest that measurements of upper arm circumference and handgrip strength may differ between the dominant and non-dominant sides of male badminton athletes. These outcomes may therefore be useful as descriptive components of athlete physical profiling when interpreted alongside other relevant information, such as training history,

competitive characteristics, sport-specific performance measures, and clinical or functional assessments. However, the present findings do not provide sufficient evidence to recommend compensatory or corrective training solely on the basis of the observed side-to-side differences. Decisions regarding training modification should be supported by broader individual assessment and evidence linking specific asymmetry patterns with meaningful performance or clinical outcomes.

The within-subject design represents a strength of this study because each athlete served as their own comparison, thereby reducing some variability associated with differences between participants. In addition, both primary outcomes were assessed directly on the dominant and non-dominant sides using the same instruments. However, several limitations should be considered. The sample was limited to 24 male athletes aged 18 to 25 years recruited through purposive sampling from badminton facilities in Denpasar and Badung. No a priori sample size calculation was performed, which limits the statistical justification for the final sample size. In addition, detailed information regarding the number of athletes screened, the number excluded at each stage, and the specific recruitment flow was not available.

Further limitations relate to measurement and statistical procedures. Although the measurement procedures were clarified through author confirmation, the instruments were not recalibrated specifically by the researcher before data collection. The available quality-control information was limited to routine laboratory maintenance, operational checks, and verification that the handgrip dynamometer returned to zero before measurement sessions. Furthermore, the study did not report study-specific reliability testing. Potential measurement and order effects therefore cannot be completely excluded. The statistical interpretation is also limited by the absence of normality testing for paired difference scores and the unavailability of verified mean differences, 95% confidence intervals, and paired effect sizes.

Several potentially relevant participant and training characteristics were not measured or included in the analysis. These include training duration, training frequency, cumulative training exposure, competitive level, previous injury history beyond the stated eligibility criteria, and racket-related characteristics. Consequently, dominance or badminton participation cannot be considered the sole explanation for the observed differences. Future research should use prospectively justified sample sizes, transparent recruitment flow reporting, standardized and reproducible measurement procedures, complete paired statistical reporting, and effect estimates with confidence intervals. Longitudinal studies may further clarify whether side-to-side differences change over time and whether particular asymmetry patterns are associated with meaningful performance or clinical outcomes.

Overall, the present study demonstrates that upper arm circumference and handgrip strength differed between the dominant and non-dominant sides among the participating male badminton athletes. The findings should be interpreted as cross-sectional observations rather than evidence of causation, physiological adaptation, clinical impairment, or injury risk. The results provide descriptive information regarding side-specific characteristics in this study population while also highlighting the importance of rigorous methodological and statistical reporting in future investigations.

Conclusion

Among the 24 male badminton athletes included in this study, upper arm circumference and handgrip strength were significantly greater on the dominant side than on the non-dominant side according to the reported paired-sample comparisons ($p < 0.001$ for both outcomes). These findings demonstrate measurable side-to-side differences in anthropometric and handgrip performance measures at the time of assessment.

However, the results should be interpreted within the limitations of the cross-sectional design and the available statistical documentation. The study does not establish that badminton participation, hand dominance, or training exposure caused the observed differences. It also does not provide evidence regarding clinical significance, functional impairment, or injury risk. In addition, the magnitude and precision of the differences could not be fully evaluated because verified mean differences, 95% confidence intervals, paired effect sizes, and normality testing of the paired difference scores were not available.

Overall, the findings provide descriptive evidence of side-specific differences in upper arm circumference and handgrip strength in this population of male badminton athletes. Future studies should use prospectively justified sample sizes, transparent recruitment procedures, standardized measurement protocols, and complete paired statistical reporting to clarify the magnitude, development, and practical relevance of these differences.

Author Contribution

I Komang Gede Artha Guna: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing Original Draft, Project Administration.

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

Ni Luh Made Reny Wahyu Sari: Methodology, Validation, Investigation, Writing Review and Editing.

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

All authors have read and approved the final version of the manuscript.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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Ethics Statement

This study was conducted in accordance with the ethical principles for research involving human participants. Written informed consent was obtained from all participants before their participation in the study. Participants were informed about the purpose and procedures of the study and voluntarily agreed to participate.

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