The Relationship Between Proprioception and Badminton Player Shot Landing Accuracy

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Abstract

This research aims to examine the relationship between the proprioception of college-level badminton athletes and their accuracy in badminton tosses. The study utilizes five proprioception testing methods, including joint position sense, movement sense, force sense, and strength to assess the proprioception integrity of the athletes. The testing indicators include upper limb muscle proprioception, upper arm muscle proprioception, lower limb proprioception, kinesthetic proprioception, and upper limb kinesthetic accuracy. The results indicate significant differences ($P < 0.05$) in the force sensation of upper limb muscles among players with varying levels of skill in the high serve. Furthermore, a correlation exists between the force sensation of upper limb muscles and the accuracy of the forehand clear ($P > 0.05$). Significant differences ($P < 0.05$) were also observed in the force sensation of upper limb muscles among players at different skill levels in the forehand clear. The force sensation of upper limb muscles is correlated with hitting accuracy, suggesting its importance for the accuracy of shuttlecock landing locations during the stable phase of motion patterns. This paper provides substantial evidence that proprioception training can enhance the performance of badminton athletes and offers theoretical support for innovative selection methods in badminton sports.

Keywords: Proprioception, Badminton, Landing Accuracy, Reciprocal Relationship.

Introduction

In the sphere of badminton instruction and training within sports academia, the prevailing emphasis has been on the execution of shot-making skills, often neglecting the training directed towards the accuracy of shuttlecock placement. This oversight arises from an ingrained presumption among coaches which posits that the accuracy of shuttlecock placement fundamentally aligns with the competency level of the players, thereby considering them as inseparable entities. Such a belief tends to place a disproportionate focus on the phase of skill acquisition, whilst disregarding the outcomes of technical proficiencies, specifically the accuracy of shuttlecock placement and its affecting variables, such as proprioception. The researchers assert that accuracy remains pivotal to the successful implementation or the failure of performance skills, with each sport presenting unique accuracy prerequisites (Fleisig et al., 2009). Shuttlecock placement accuracy in badminton is deemed a critical gauge of a player's competency and adaptability across varied shot-making techniques. In light of this perspective, sports researchers strive to develop a highly reliable apparatus for evaluating the accuracy of shuttlecock placement in badminton. Nevertheless, scant exploration has been conducted from a psychological viewpoint on its influencing variables, particularly in respect to the role of proprioception within sports performance. It is detected that a strong ankle-foot proprioception correlated positively with operative levels within soccer. Despite a definitive association between sports performance and outcomes, the dualism inherent between them cannot be denied. Hence, examining the correlation between proprioception within sports and performance outcomes could have a tangible impact on ameliorating the successful rate of technical skill outcomes. Furthermore, it can deepen a coach's comprehension of the elements influencing shuttlecock placement accuracy, balance performance and technical skill outcomes during training sessions, thereby enhancing training efficiency in a substantial manner. Consequently, this study aims to probe the correlation between proprioception and shot placement accuracy amongst university badminton athletes and also endeavours to discern if there exist pronounced disparities in proprioception levels amidst players of divergent skill sets.

The study revealed a correlation between proprioception and the landing point accuracy of badminton shots. The researchers highlight that proprioception exerts its influence on the landing point accuracy of badminton shots during the phase of technical movement stabilization. Moreover, this influence is reciprocal. Current sports training methodologies fall short in

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addressing the gap in badminton proprioception training. These insights are significantly valuable for the development of proprioception training approaches and the enhancement of athlete selection methodologies. We propose that adopting a training philosophy focused on the long-term improvement of proprioceptive skills, integrated with comprehensive sports control, could serve as an effective strategy in fostering the development of essential technical skills within badminton. These findings hold importance not only for creating efficient athlete training programs but also for broadening the criteria for athlete selection (Radicchi & Mozzachiodi, 2016). This understanding could provide meaningful contributions to the selection processes used by scouts in identifying potential sports talents. The findings stress the need to update existing badminton training practices to include proprioception training, thereby promoting a holistic approach towards optimizing badminton performance and outcomes.

Literature Review

Proprioception, initially conceptualized by Charles Sherrington in 1907, is a key component in the control of human motion, motor learning, and skill development. It pertains to the sensory awareness of the relative positioning of various body parts and the forces exerted during movement. By serving as a fundamental aspect of motor coordination and control, proprioception facilitates individuals in possessing a sense of their body's spatial awareness and movement without exclusive reliance on visual cues. The range of proprioception includes inputs from muscle, joint, and skin receptors, assisting in body position and motion perception. Proprioception is a result of a complex interplay of sensory inputs and motor commands. It integrates peripheral signals originating from muscle spindles, Golgi tendon organs, skin, and joint receptors with the central inputs from efferent motor commands (Proske et al., 2012). Such collective sensorimotor signals allow individuals to perceive their body's position, motion, muscle strength, and the resultant effort. Importantly, proprioception plays a critical role in determining the conformance of actual movements with intended movements by comparing motor output with sensory feedback.

Understanding the role of proprioception in motor control is indispensable to grasp how the body senses its position, motion, and muscle strength. A prior study elaborates on the modulation along the proprioceptive pathway that extracts pertinent features of goal-directed movements, elucidating the integration of proprioceptive information into motor control and sensory representation. The brain uses proprioceptive information to regulate the body's shape, position, and motion, contributing to joint stability and motor coordination (Aman et al., 2015). Research also suggests that the nervous system utilizes kinesthetic information for controlling natural limb movements, emphasizing proprioception's role in motor control (Henry et al., 2019). Moreover, the function of motor commands in body proprioception stresses the integration of proprioceptive information in motor control (Riemann et al., 2002). The unconscious processing of proprioceptive signals indicates their function in the reflexive control of muscle tension and adjustments in posture, thereby accentuating their importance in motor control (Aman et al., 2015).

Studies have confirmed that athletes demonstrating proficiency in proprioception have a direct impact on enhancing their motor skills, with remarkable athletes often showing superior proprioceptive capabilities. There was also evidence to substantiate that superior elbow joint proprioceptive accuracy correlates with better performance in sports such as basketball, darts, and water polo competitions. Detailed investigation of proprioception's relationship with motor performance across different sports disciplines underscores the critical role proprioception plays in shooting accuracy in sports like basketball (Yılmaz et al., 2024). Furthermore, a research study examines the relationship between visual acuity, throwing technique, and sensory function among soccer players, demonstrating the sensory system's influence on athletic performance. Another similar study involving volleyball, badminton, and wrestling athletes reveals a significant correlation among body self-concept, athletic success, and kinesthetic proprioception, highlighting proprioception's importance in achieving athletic success. However, the precise relationship between proprioception and specific motor skill outcomes such as hitting accuracy remains unclear. This ambiguity is particularly significant in sports like badminton, where hitting accuracy is critical and also differentiates the technical skill outcomes.

For sports, there is a dearth of widespread testing methods for proprioception (Hillier, Immink, & Thewlis, 2015). As a preliminary step, clarification of the concept of proprioception testing for badminton athletes can help address issues related to the reliability and validity of the methodology. Several methods have been designed for proprioception testing, primarily based on features of proprioception like joint position, movement, and the degree and sensation of force and weight. Hillier et al. (2015) propose a categorization of three types of proprioception testing methods—joint position detection, passive movement detection, and passive movement direction discrimination. However, this view narrowly defines proprioception as the ability to assimilate sensory signals from mechanoreceptors to determine body position and spatial movement, overlooking the associations of external weight and force with muscle tension. From a perspective of external validity, testing methods involving active movements should be prioritized as they better resemble an individual's performance in natural environments. Thus, factors like strength reproduction and discrimination, muscle tension reproduction, weight discrimination, and kinesthetic discrimination should be considered during measurements. Vision is another significant source of non-movement system and cutaneous signals playing a role in proprioception. Visual input can provoke adjustments in proprioception, altering the fidelity of proprioceptive signals, thereby affecting testing accuracy (Bernier et al., 2007). The choice between active versus passive movement measurement depends on the research interest. If the focus is on the integrity of the sensory-motor integration processes, then active movement methods are suitable. Conversely, for the "purest" measurement of proprioceptive function, passive-induced joint movements are superior. Thus, our proposed tests for badminton athletes' proprioception, based on theories of force reproduction and discrimination, muscle tension reproduction, weight discrimination, and kinesthetic discrimination, will be presented in-depth in the subsequent chapter.

Building on the prior discussion, this investigation adopts an expansive notion of proprioception and meticulously curates a suite of five proprioceptive assessment techniques based on active dynamism (Dekeyzer, 2022). These carefully selected methodologies focus on evaluating proprioceptive indicators, including the sense of joint positioning, movement awareness, and the discernment of force and strength. This approach emphasizes a holistic perspective on proprioceptive integration within the realm of badminton. In alignment with the curriculum of the sports discipline, we have concentrated on two pivotal training maneuvers for this term—the forehand high lob and the forehand smash. The aim of this study is to explore the correlation between an athlete's sensorimotor perception and the landing point accuracy of their strokes, examining proprioception across various bodily aspects. Using theoretical insights, we have developed a comprehensive research schematic, depicted in Figure 1. We hope that this framework will provide a robust and definitive theoretical basis in the concluding sections of this literature review, offering both theoretical enlightenment and practical strategies for the future training of badminton contenders.

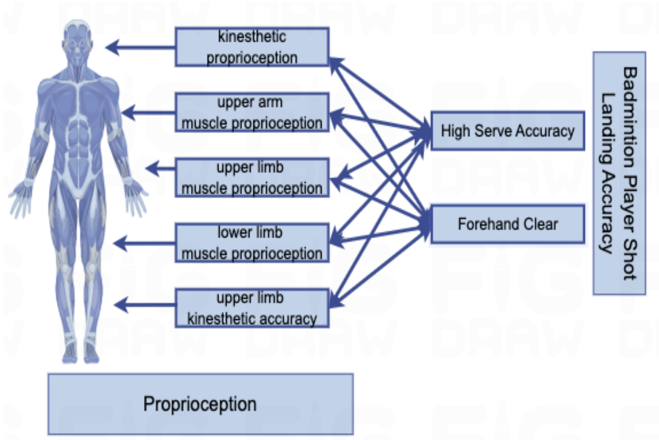

Figure 1: Model of the Relationship Between Proprioception and Motor Skills in Badminton Athletes.

Methodology

General Information

This investigation engaged 63 male students specializing in physical education from the College of Physical Education at Liaoning Normal University as research subjects. Each participant had undergone 64 hours of comprehensive badminton training. The demographic profile of the participants delineated an average age of 21.79±0.86 years, a mean height of 181.6±5.68 cm, and a mean weight of 74.1±10.92 kg.

Research on Psychological Test Methods

Through a detailed analysis of the forehand serve and high clear movement patterns in badminton, it has been identified that the upper limb, upper arm, and lower limb are primarily involved in these actions. This involvement is largely characterized by the lower limb initiating force before the shuttlecock contact, the upper limb leading the swing motion, and the upper arm exerting force during the contact phase. Within this dynamic framework, these body segments significantly contribute to the modulation of strength and the analytical positioning required for effective execution. Consequently, building on the foundational principles of the proprioception-motor perception incident (PK-smcs) theory, motor perception performance is elucidated across three distinct dimensions: presence, bodily awareness, and action preparedness. The dimension of presence is interconnected with the functional integration of the body's components and the immediacy of potential action, leading to the execution of strength sensory tests, positional analysis assessments, and movement stability evaluations on the upper limb, upper arm, and lower limb of the participants. This systematic approach allows for a focused investigation into the perceptual abilities that most significantly influence the proficiency in badminton technique. A comprehensive description of the specific testing modalities and the methodologies used for outcome processing is presented subsequently.

Testing Indicators and Methods

Upper Limb Muscle Proprioception

Before the test, participants held a Japanese TAK5101 hand dynamometer in their dominant hand and adjusted the grip for comfort. Standing with arms relaxed and palms facing inward, they squeezed with full force to measure maximum grip strength. Afterwards, they attempted to exert half this force three times. The variance between these trials and the half-force target was recorded as the upper limb proprioceptive error.

Upper Arm Muscle Proprioception

Before the test, subjects positioned themselves on a back dynamometer, feet 15cm apart, gripping the handle with forearms level and upper arms at 90-degree angles. They pulled up with maximum force for a peak force reading. With the same posture, they attempted half-force three times. The difference in these attempts was noted as the upper arm proprioceptive error.

Lower Limb Muscle Proprioception

Subjects stood on the base of the back dynamometer, facing away from it, with their upper body upright, knees bent to approximately 135 degrees, and hands gripping the bar (the bar slightly higher than the knees), with hands shoulder-width apart. Subjects then extended their legs with maximum force and the tester recorded the test value. Using the same grip method and posture, subjects perceived and exerted half of their maximum force for three trials. The tester recorded the error value between the three replicates and half of the maximum force as the error of lower limb muscle proprioception.

Kinesthetic Proprioception

Blindfolded subjects had their arms raised to a pre-set 110 degrees (BD-II-309 Instrument) and swung their arm until hitting the stopper, which was then removed for them to replicate the movement. The difference in three attempts from 55 degrees was recorded as the proprioceptive error, calculated against the 55-degree standard.

Upper Limb Kinesthetic Accuracy

Two circular targets named A and B were drawn on an A4 paper with a distance of 15 centimeters between them. The test paper was placed flat on a horizontal table. Under visual conditions, subjects started from point A and moved the pen tip to point B at a moderate, constant speed, and then returned to point A. This procedure was repeated three times for practice. During the formal test, subjects wore a blindfold and used the muscle sensation obtained during practice to perform the A and B positioning tests. Three trials were conducted, and the distance between the pen tip imprint and the centers of A and B targets was measured to calculate the average error.

Shot Placement Accuracy Test

This methodology brief outlines the scoring strategies used in two badminton tests titled 'Forehand Clear Landing Point Accuracy' and 'High Serve Landing Point Accuracy'. In the forehand clear test, players hit five forehand clears from the service area targeting left/right court halves. A target with five concentric circles was used to record where each shot landed. Points were given from two for landing on the innermost circle to six for the outermost, according to closeness to the center. In-bounds shots outside the circles scored one point; shots out-of-bounds scored none. The High Serve test also had participants performing high serves aimed at a one-meter-diameter target in the back court. Similar to the Forehand Clear test, points were awarded based on where the shuttlecock landed within the target area. Examiners tracked shuttlecock landing positions for both tests, with scores based on these observations.

Testing Procedures and Control Factors

Given that interactions between an individual and the environment can stimulate experiential activities, our entire testing process took place in the badminton hall. The tests occurred at Liaoning Normal University's School of Physical Education badminton hall, ensuring ample natural light. More importantly, we mitigated the impact of natural wind and managed ambient noise within the venue to obviate external influences on proprioception, including upper limb muscle proprioception, upper arm muscle proprioception, and lower limb proprioception. Considering the potential effect of players on the opposite court on participants' forehand Clear landing points (Investigating if an opponent’s presence impacts elite players’ high serve accuracy? A study on accuracy of badminton tosses for elite players), we employed a badminton serving machine. The testing team comprised seven graduate students and two professors, all of whom were thoroughly trained to grasp the aim and methods of the test beforehand. Recognizing the propensity for self-activity in social interactions, we assigned two undergrads to maintain order during the accuracy tests for forehand

Clear, high serve, and badminton toss. Furthermore, interactions between the subjects and testers were minimized.

Mathematical Statistics

Prior to the main analysis, normality checks were performed to ensure data conformed to the assumptions of parametric testing. Using SPSS 21.0 software, a Kolmogorov-Smirnov test confirmed the data followed a normal distribution, validating the use of Pearson correlation analysis and independent sample t-tests. Pearson correlation analysis was utilized to investigate the relationships between the landing point accuracy of forehand clear, the landing point accuracy of high serve, the landing point accuracy of badminton toss, and various proprioceptive measures including upper limb, upper arm, lower limb muscle proprioception, kinesthetic proprioception, and upper limb kinesthetic accuracy. Independent sample t-tests compared these proprioceptive measures across different performance groups for the forehand clear landing point accuracy, high serve landing point accuracy, and badminton toss landing point accuracy. A significance level of α = 0.05 was established for difference testing.

Research Results

Results of the Correlation Analysis between Proprioception and High Serve Landing Point Accuracy

The research was conducted to explore the connection between perceptual awareness and the landing point accuracy of high serves. A correlation analysis was performed on five test indicators of perceptual awareness and the landing point accuracy of high serves, as shown in Table 1. No correlation was discovered between the upper limb muscle proprioception and the landing point accuracy of high serves ($p>0.05$); there is no correlation between proprioception and the landing point accuracy of high serves ($p>0.05$); no correlation was found between the upper limb kinesthetic accuracy and the landing point accuracy of high serves ($p>0.05$); there is no correlation between the upper limb muscle proprioception index and the landing point accuracy of high serves ($p>0.05$); and there is no correlation between the lower limb proprioception index and the landing point accuracy of high serves ($p>0.05$). The results suggest that there is no significant link between the indicators of upper limb muscle proprioception, kinesthetic proprioception, upper limb kinesthetic accuracy, upper limb muscle proprioception, and lower limb proprioception, and the landing point accuracy of high serves.

Table 1

Correlation Analysis between Proprioception Ability and High Serve Landing Point Accuracy

Indicator	Correlation Coefficient	p-value
Upper Limb Muscle Proprioception	-0.16	>0.05
Upper Arm Muscle Proprioception	0.04	>0.05
Lower Limb Muscle Proprioception	-0.22	>0.05
Kinesthetic Proprioception	0.02	>0.05
Upper Limb Kinesthetic Accuracy	-0.17	>0.05

The study investigates the impact of skill levels on motor perception by analyzing variations in the proprioceptive abilities of players with differing levels of expertise. Based on their landing point accuracy of high serves, participants were categorized into a higher scoring group (30 individuals) and a lower scoring group (33 individuals).

Table 2

Comparison of Proprioceptive Abilities between Groups with Different Landing Point Accuracy in High Serve

Indicator	High-score Group (n=30)	Low-score Group (n=33)	Mean Difference	t-value	p-value
	M±SD	M±SD			
Upper Limb Muscle Proprioception	0.10±0.09	0.15±0.08	-0.05	-2.05	<0.05
Upper Arm Muscle Proprioception	4.97±3.43	4.37±2.72	0.59	0.76	>0.05
Lower Limb Muscle Proprioception	2.20±0.83	2.64±0.97	-0.44	-1.93	>0.05
Kinesthetic Proprioception	0.13±0.07	0.14±0.08	-0.01	-0.34	>0.05
Upper Limb Kinesthetic Accuracy	0.12±0.06	0.12±0.06	0.00	-0.64	>0.05

As Table 2 illustrates, the average upper limb muscle proprioception for the high serve landing point accuracy in the higher scoring group (0.10) is significantly lower by 0.05 compared to that of the lower scoring group (0.15), indicating significant differences ($p<0.05$). No significant differences in kinesthetic proprioception, upper limb kinesthetic accuracy, upper arm muscle proprioception, and lower limb proprioception were observed between the high and low scoring groups for the high serve ($p<0.05$).

This indicates that players with more precise landing points for their high serves have a better upper limb muscle proprioception ability.

Results of the Correlation Analysis between Proprioception and Forehand Clear Landing Point Accuracy

To analyze the correlation between motor perception and the landing point accuracy of forehand clears in sports, a correlation analysis was conducted using five test indicators of motor perception and the landing point accuracy of forehand clears. As Table 3 displays, there is a correlation between the measurement of upper limb muscle proprioception and the landing point accuracy of forehand clears ($p<0.01$). There is no correlation between kinesthetic proprioception and the landing point accuracy of forehand clears ($p>0.05$); no correlation exists between the upper limb kinesthetic accuracy and the landing point accuracy of forehand clears ($p>0.05$); there is no correlation between the upper arm muscle proprioception index and the landing point accuracy of forehand clears ($p>0.05$); and there's no correlation between the lower limb proprioception indicator and the landing point accuracy of forehand clears ($p>0.05$). The findings indicate that the better the players' upper limb muscle proprioception, the more precise the landing point of their forehand clears.

Table 3

Correlation Analysis between Proprioception and Landing Point Accuracy of Forehand Clear

Indicator	Correlation Coefficient	p-value
Upper Limb Muscle Proprioception	-0.48	<0.01
Upper Arm Muscle Proprioception	-0.02	>0.05
Lower Limb Muscle Proprioception	-0.18	>0.05
Kinesthetic Proprioception	-0.06	>0.05
Upper Limb Kinesthetic Accuracy	0.05	>0.05

The study explores the impact of the landing point accuracy of high clears on motor perception by examining variations in motor perception among players with different skill levels. Based on the landing point accuracy score of high clears executed with a forehand, participants were categorized into a high-score group (34 individuals) and a low-score group (29 individuals).

As indicated in Table 2, the average upper limb muscle proprioception in the high score group for the landing point accuracy of high clears executed with forehand (0.09) is 0.08 lower than the average in the low score group (0.17), displaying a significant difference ($p<0.01$). There were no significant differences in kinesthetic proprioception, upper limb kinesthetic accuracy, upper arm muscle proprioception, and lower limb proprioception between the high and low score groups for high clears executed with a forehand ($p>0.05$).

This indicates that players who achieve greater landing point accuracy in high clears exhibit superior upper limb muscle proprioception.

Table 4

Comparative Analysis of Proprioception Abilities between High-Score and Low-Score Groups Based on Landing Point Accuracy of High Clears

Indicator	High-score Group (n=34)	Low-score Group (n=29)	Mean Difference	t-value	p-value
	M±SD	M±SD			
Upper Limb Muscle Proprioception	0.09±0.07	0.17±0.09	-0.08	-3.6	<0.01
Upper Arm Muscle Proprioception	4.56±3.37	4.77±2.72	-0.21	-0.27	>0.05
Lower Limb Muscle Proprioception	2.36±0.97	2.51±0.88	-0.25	-0.64	>0.05
Kinesthetic Proprioception	0.13±0.07	0.14±0.08	-0.01	-0.49	>0.05
Upper Limb Kinesthetic Accuracy	0.13±0.07	0.11±0.05	0.02	1.07	>0.05

Discussion

Effects of Proprioception on the Landing Point Accuracy of High Serve in Badminton

Our exploration of the connections between various proprioceptive aspects and the landing point accuracy of forehand clears in badminton reveals that elements such as upper limb muscle proprioception, kinesthetic proprioception, upper limb kinesthetic accuracy, upper arm muscle proprioception, lower limb proprioception, and the landing point accuracy of high clears operate independently. As a result, we observe no notable correlations among these factors in performing forehand clears, suggesting an absence of a direct link between proprioceptive abilities and the landing point accuracy of shots (Nagai et al., 2013).

The core of these outcomes seems to stem from the inconsistency in players' proprioceptive abilities and their control over shot execution, which may diminish the landing point accuracy of their shots. The lack of consistent training limits players' mastery in executing shots to a broad, generic phase. In testing situations where landing point accuracy is emphasized, there's a departure from standardized movements and a unified technical method. This departure leads to test results that may not accurately reflect a player's true skills. Moreover, in the generalization phase of shot execution, despite inconsistency in technique, certain compensatory mechanisms are at work. These mechanisms can counterbalance impairments in proprioceptive abilities, allowing college athletes to accurately direct the shuttlecock towards the designated target. During this stage, proprioception does not critically impact the landing point accuracy of strikes. Therefore, at the initial phase of technical training, emphasizing the development of strong technical movement patterns is essential. Building a solid technical base before incorporating proprioceptive training is more likely to result in significant enhancements in the landing point accuracy of badminton shots.

Differences in Proprioception Among Badminton Athletes with Varying Proficiencies in High Serve

In a comparative analysis examining proprioceptive variations among badminton athletes of different skill levels, we observed no notable differences across variables such as kinesthetic proprioception, upper limb kinesthetic accuracy, upper arm muscle proprioception, or lower limb proprioception. However, a significant difference was identified in upper limb muscle proprioception between athletes who attained high and low landing point accuracy of forehand clears. This indicates that university athletes who demonstrate higher landing point accuracy of forehand clears possess superior upper limb muscle proprioception compared to those with lower scoring accuracy, which ostensively contributes to their enhanced proficiency in forehand clears (Yang et al., 2024).

This outcome can be attributed to the enhanced proprioceptive feedback from muscle exertion that accompanies improved technical skill in the athletes. As training progresses and technical prowess is honed, athletes develop a finer attunement to their muscle exertion. Those within the high-scoring bracket consistently exhibit more refined technical execution. Under such consistent movement patterns, adept perception and control of muscle exertion, along with kinesthetic and visual senses, culminate in more precise force deployment and better management of landing points during high clears. Our findings lay a strong foundation supporting. Researchers determined that unconscious proprioceptive signal processing, essential for reflex muscle tension control and posture adjustment, depends on the maturation of motor skills. In the training context, specifically when the athlete's forehand clear technique matures to a consolidation phase, incorporating exercises to advance upper limb muscle proprioception may prove advantageous for augmenting the landing point accuracy in shot placement.

Effects of Upper Limb Muscle Proprioception on the Landing Point Accuracy of Forehand Clears in Badminton

Statistical analyses exploring the connection between proprioception and the landing point accuracy of forehand clears in badminton indicate a substantial moderate relationship specifically between the proprioception of upper limb muscles and the landing point accuracy of forehand clears. The study discovers that proprioception, along with variables such as upper limb muscle proprioception, upper arm muscle proprioception, and lower limb proprioception, demonstrates independence from the landing point accuracy of forehand clears, with no significant correlations found among these aspects. This result suggests that enhancements in the proprioception of upper limb muscles could lead to improved landing point accuracy of forehand clears (Malwanage, Senadheera, & Dassanayake, 2022).

The underlying principle for this relationship is the pivotal role of proprioception in the upper limb muscles relative to the accuracy, joint stability, coordination, and balance required for executing forehand clears. Optimal proprioception in the upper limbs enables effective regulation of the arm's swing, the imparting of accurate direction, and the application of the whipping force critical for performing forehand clears. This ability allows the brain to finely calibrate muscle contractions and speed based on sensory feedback received about muscle tension and positioning, thus permitting athletes to produce precise force output and maintain control over their movements. Such an adaptive mechanism ensures consistency in the skilled performance of badminton strokes, especially concerning the landing points of the shuttlecock.

Given these findings, when upper limb muscle proprioception is recognized as a determinant of badminton practical skill outcomes, it provides coaches with a solid foundation for assessing and advancing athletes' performance. By evaluating variations in upper limb muscle proprioception, coaches can utilize this information to develop more specialized training strategies aimed at enhancing the landing point accuracy of badminton shots, thereby boosting overall gameplay.

Differences in Proprioception Among Badminton Athletes with Varying Proficiencies in Forehand Clear

This investigation aims to explore proprioception distinctions among badminton athletes of varying forehand clear proficiencies. The study finds no significant differences in kinesthetic proprioception, upper limb muscle proprioception, upper arm muscle proprioception, and lower limb proprioception. Nevertheless, notable differences in upper limb muscle proprioception emerge between athletes with high and low landing point accuracy of forehand clears (Buszard et al., 2020). College athletes exhibiting greater landing point accuracy of forehand clears demonstrate superior upper limb muscle proprioception, providing an advantage in forehand clear performance over their less proficient peers.

Further analysis confirms the reciprocal link between muscular effort sensation in the upper limbs and technical performance in forehand clears. Enhanced upper limb muscle proprioception contributes to skill refinement. These observations support a scientific basis for sports training selection and introduce new prospects for psychological coaching in badminton. Focusing on upper limb muscle proprioception in training is recommended for coaches to improve athletes' performance.

Traditional training, emphasizing repetition and target shuttlecock landing point accuracy, does not address the fundamental issue of upper limb muscle proprioception. By creating training programs that highlight proprioceptive feedback from muscle groups, coaches can uplift athletes' forehand clear skills.

Custom exercises, such as active joint repositioning and force sense refinement, promote proprioceptive and sensorimotor control enhancement. These methods seek to perfect movements and foster improved joint stability, coordination, and balance, offering practical training strategies to advance athletes' technical skills and overall badminton performance.

Conclusion

Our research outlines a significant correlation between proprioceptive awareness and the landing point accuracy of badminton shot placements, indicating that current methods for proprioceptive training may not effectively enhance the landing point accuracy of badminton toss. In the early stages of developing technical proficiency, exercises aimed at enhancing upper limb muscle proprioception are found to be crucial. As athletes further their technical skills, a reciprocal influence becomes apparent between upper limb muscle proprioception and the landing point accuracy of forehand clear shots. While badminton toss exercises improve technical execution and awareness of upper arm exertion, they do not sufficiently develop upper limb kinesthetic accuracy, which is vital for the landing point accuracy of shots. This deficiency could be attributed to the fact that instability during the initial phase of consolidating technical movements is not effectively counterbalanced through proprioceptive sharpness—rather, it is through the repetition of exercises that athletes' sense of muscle exertion is heightened. When technical movements mature, improved upper limb muscle proprioception contributes to better control over limb strength and joint stability, leading to more consistent shot executions aligned with desired trajectories.

This study emphasizes the need to enhance the efficacy of badminton training and refine the mechanisms for athlete selection. Coaches are advised to prioritize activating upper limb muscle proprioception during training. Setting a comprehensive training goal focused on the long-term improvement of proprioceptive abilities and overall motor control, by incorporating practices such as force sensation training, muscular strength exercises, and resistive vibration training, will significantly refine athletes' mastery of movement nuances, joint stability, and coordination, thereby aiding skill development. Moreover, integrating upper limb muscle proprioception as a psychological indicator in the early stages of athlete selection, and establishing a scientific evaluation framework, will improve the athlete selection process.

However, the study's reliability is limited by its reliance on technical skill assessments and field testing to gauge athlete skill levels, which raises concerns about the validity of such measurements. Additionally, the exclusion of gender as a variable in sample selection limits the general applicability of the results to female athletes.

In future work, we aim to expand our sample to include athletes of various genders, skill levels, and ages to enhance the robustness of our findings. Furthermore, pursuing more empirical research on sports interventions to examine the practical applications of proprioceptive training will elaborate its theoretical basis and contribute to establishing firm criteria for sports selection and evaluation.

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