

RESEARCH ARTICLE

Improving Low-Serve Accuracy in Badminton Using Fine Motor Strengthening with Instructional Video and Proprioceptive Training

Kim Rayan Reyes

Lourdes College, Inc., Cagayan de Oro City, Philippines

✉ Correspondence: kim.reyes@lccdo.edu.ph

RECEIVED May 6, 2026

PUBLISHED June 15, 2026

CITE AS Reyes, K. R. (2026). Improving low-serve accuracy in badminton using fine motor strengthening with instructional video and proprioceptive training. *USFD Journal of Physical Education Pedagogy & Sports Performance*, 2(2), 171-179. <https://doi.org/10.64339/USFD-h41ssm74>

ACCEPTED May 13, 2026

DOI 10.64339/USFD-h41ssm74

ABSTRACT

The low serve is a fundamental badminton skill that reflects a player's control, precision, and ability to strategically initiate play. However, inconsistent execution highlights the need for effective training interventions, leading this study to examine the effects of fine motor strengthening exercises with instructional videos and of proprioceptive training exercises on participants' low-serve accuracy. A quasi-experimental, non-equivalent pretest-posttest active comparator design was employed, involving 60 participants (30 per group). Low-serve accuracy was measured using an adapted badminton service accuracy test focusing on the low serve. Results revealed that participants initially demonstrated a good level of low-serve accuracy; significant within-group improvements were observed in both groups, indicating that each intervention was effective in enhancing performance; and ANCOVA results showed no significant difference between the two groups after controlling for pretest scores, indicating that fine motor strengthening exercises with instructional videos and proprioceptive training exercises were comparably effective in improving posttest performance. These findings suggest that guided instruction and sensorimotor-based training approaches are effective routes to improving low-serve accuracy, and that the choice between them can be guided by available resources. It is recommended that Physical Education practitioners incorporate structured instructional videos and proprioceptive drills alongside skill training to enhance accuracy outcomes. The study supports motor learning and coordination theories and provides practical implications for enhancing skill instruction in Physical Education.

KEYWORDS badminton, low-serve accuracy, fine motor strengthening, proprioceptive training, instructional video

INTRODUCTION

Badminton low-serve accuracy is a critical skill because it influences rally control, limits the opponent's attacking options, and supports tactical advantage during game initiation. A well-executed low

serve should pass just above the net and land near the short service line, forcing a defensive return and shaping the early phase of the rally (Indarto *et al.*, 2023; Vial *et al.*, 2020; Williyanto *et al.*, 2021). However, maintaining service precision under pressure remains difficult because performance may be affected by anxiety, technical errors, unstable racket control, and shuttle trajectory problems (Beckmann *et al.*, 2021; Caballero *et al.*, 2021; Costa *et al.*, 2024; Pan *et al.*, 2024). Although repetitive drills and audiovisual training are commonly used, their effects on serving performance remain inconsistent, suggesting the need for more targeted and skill-specific approaches (Gómez *et al.*, 2020).

Existing studies show that successful badminton players demonstrate greater serve variation, better low-serve accuracy, and stronger tactical awareness (Gómez *et al.*, 2020). Biomechanical evidence also indicates that postural stability, coordinated body movement, and balance control contribute to effective service execution (Irawan *et al.*, 2022; Pan *et al.*, 2024). Beyond physical mechanics, perceptual and cognitive factors such as visual guidance, imagery, and confidence may also improve racket-sport skill execution (Parimi *et al.*, 2024). These findings suggest that low-serve accuracy depends not only on repeated practice but also on fine motor control, perceptual learning, proprioceptive regulation, and neuromuscular coordination.

Despite these developments, limited research has examined interventions that directly combine fine motor strengthening with instructional video support, and proprioceptive training for badminton low-serve accuracy, particularly among school-based and developing athletes. Most available studies focus on technical drills, psychological interventions, or general conditioning in isolation (Gómez *et al.*, 2020; Parimi *et al.*, 2024). In the Philippine school and grassroots context, badminton remains popular, yet training often emphasizes repetitive serving drills with less attention to grip stability, wrist-forearm coordination, body balance, and proprioceptive control (Indarto *et al.*, 2023; Williyanto *et al.*, 2021). This gap highlights the need for context-specific, evidence-based interventions for Filipino student-athletes.

To address this gap, the present study examined two skill-linked intervention approaches for improving badminton low-serve accuracy: fine motor strengthening exercises with instructional videos and proprioceptive training exercises. The fine motor strengthening program included finger resistance-band extensions, tennis-ball squeezes, and wrist flexion-extension with dumbbells to improve grip stability, wrist control, and racket handling (Biao & Lu, 2023; Chen *et al.*, 2024; Labott & Donath, 2023). Instructional videos were integrated to provide visual models of proper movement execution and support observational learning (Li *et al.*, 2024). Proprioceptive training included single-leg balance with eyes closed, dynamic lunge with shuttle toss, and star excursion balance drills to enhance balance, postural control, joint stability, and neuromuscular coordination relevant to serving performance (Shafiq *et al.*, 2024; Winter *et al.*, 2022; Yilmaz *et al.*, 2024).

Grounded in Social Cognitive Theory, Schema Theory, and Sensory Integration Theory, the study assumes that badminton low-serve accuracy can be improved through interventions that strengthen visual modeling, motor schema development, and sensory-motor regulation. Specifically, the study evaluated the participants' low-serve accuracy levels, determined whether significant differences existed between pretest and posttest performance, and compared which intervention was more effective in improving low-serve accuracy. By testing these interventions through a quasi-experimental, non-equivalent pretest-posttest active comparator design, the study contributes to Physical Education and Sports Science by offering practical, theory-based strategies for developing badminton serving accuracy among student-athletes.

Statement of the Problem

This study aimed to assess the effectiveness of selected fine-motor and proprioceptive training interventions in improving low-serve accuracy in badminton, a fundamental skill that significantly influences game initiation and point construction. Specifically, the study aims to answer the following research questions:

1. What is the participants' badminton low-serve accuracy levels?
2. Do the low-serve accuracy levels of the two groups significantly differ before and after the interventions?
3. Which of the interventions is more effective in improving low-serve accuracy in badminton?

Hypotheses

To objectively examine the effects of the training interventions on badminton low-serve performance, this study is guided by null hypotheses that test both within-group and between-group differences in accuracy outcomes:

Ho₁: There is no significant difference between participants' pretest and posttest low-serve accuracy scores.

Ho₂: None of the two interventions is more effective in improving the participants' low-serve accuracy in badminton.

METHODS AND MATERIALS

This study employed a quasi-experimental, non-equivalent pretest-posttest active comparator design with two groups to examine the effects of fine motor strengthening and proprioceptive training on low-serve accuracy in badminton. Random assignment was not feasible; thus, intact groups were used, with baseline differences statistically controlled in the analysis. Rather than comparing an intervention against a no-treatment or passive control, the design used an active comparator approach in which both groups received a distinct, evidence-based intervention—fine motor strengthening with instructional videos versus proprioceptive training—so that the two active conditions could be compared directly. The participants were Grade 7 students (aged 12–14 years) from a public secondary school in Misamis Oriental. Inclusion criteria required that participants have at least 6 months of badminton experience, be physically fit to participate, and obtain parental consent and student assent. Students were excluded if they reported a musculoskeletal injury within the past 6 months, pain levels exceeding 2/10 on the Visual Analog Scale, neurological or vestibular conditions, or participation in specialized badminton training.

Low-serve accuracy was assessed using a target-based badminton serving test adapted from established skill assessments. A designated target area was positioned in the opponent's forecourt, just beyond the short service line. Each participant performed 10 trials from the left service court and 20 from the right, using their dominant hand and a legal serving technique. Scoring was based on shuttlecock landing position within predefined zones, with scores ranging from 5 points (central target) to 1 point (outer zones), while faults or out-of-target serves received 0 points. The final score was computed as the mean across all trials (range: 0–5), reflecting accuracy and consistency. The instrument demonstrated face validity through expert evaluation and acceptable reliability, with Spearman-Brown coefficients of approximately 0.74–0.75 projected from a pilot try-out to inform the number of trials, when sufficient trials were administered.

Following ethical approval and institutional permission, baseline data were collected via a standardized pretest administered in a controlled gymnasium setting, with uniform equipment, instructions, and scoring procedures. Participants were then assigned to one of two intervention groups: (1) fine motor strengthening with an instructional video, and (2) proprioceptive training. The intervention period lasted

eight weeks, with sessions conducted three times per week for approximately 30 minutes under the supervision of the researcher and a Physical Education teacher.

The fine motor strengthening program consisted of finger resistance-band extensions, tennis-ball squeezes, and wrist flexion-extension with dumbbells, targeting hand, wrist, and forearm musculature to improve grip stability and racket control. The video-based group received visual demonstrations of correct technique, movement sequencing, and common errors. The proprioceptive training group performed balance and coordination exercises, including single-leg balance with eyes closed, dynamic lunges with a shuttle toss, and star-excursion balance drills, aimed at enhancing postural control, joint position sense, and neuromuscular coordination.

All sessions incorporated warm-up and cool-down routines, and participants were monitored for safety throughout the intervention. Upon completion of the training period, a posttest was administered using the same procedures as the pretest to ensure measurement consistency.

Data analysis included descriptive statistics (mean, standard deviation, frequency, and percentage) to summarize performance levels. Paired-samples t-tests were conducted to determine significant pretest-posttest changes within each group. To compare the effectiveness of the interventions while controlling for baseline differences, analysis of covariance (ANCOVA) was applied using pretest scores as covariates. When a significant difference was detected, a pairwise comparison of adjusted means was used to identify the direction of the group difference. Additionally, effect sizes (Cohen’s d and partial eta squared) were calculated to determine the magnitude and practical significance of the observed effects.

RESULTS

Problem 1. What is the participants’ badminton low-serve accuracy levels?

Table 1 presents the distribution of participants' badminton low-serve accuracy levels before and after the interventions for the two groups.

Table 1. Frequency, Percentage, Mean, and Standard Deviation Distribution of the Participants’ Badminton Low Serve Accuracy Levels Before and After the Interventions

Range	Interpretation	Fine Motor Strengthening w/ Instructional Videos				Proprioceptive Training Exercises			
		Pretest		Posttest		Pretest		Posttest	
		f	%	f	%	f	%	f	%
4.1 - 5.0	Outstanding	0	0	0	0	0	0	0	0
3.1 - 4.0	Very Good	0	0	19	63.33	0	0	17	56.7
2.1 - 3.0	Good	25	83.33	11	36.67	23	76.7	13	43.3
1.1 - 2.0	Fair	5	16.67	0	0	7	23.3	0	0
0 - 1.0	Poor	0	0	0	0	0	0	0	0
Total		30	100	30	100	30	100	30	100
Mean		2.42		3.14		2.31		3.11	
Interpretation		Good		Very Good		Good		Very Good	
SD		0.30		0.19		0.25		0.22	

Based on the mean scores, both groups initially demonstrated a “Good” level of performance during the pretest, with mean values of 2.42 for the Fine Motor Strengthening with Instructional Video group and 2.31 for the Proprioceptive Training group. After the intervention, improvements were observed in both groups. The Fine Motor Strengthening with Instructional Video group increased to a mean of 3.14, while the Proprioceptive Training group improved to 3.11, both interpreted as “Very Good.” Furthermore, the standard

deviation values slightly decreased in the posttest for the Fine Motor Strengthening with Instructional Video ($SD = 0.19$) and Proprioceptive Training ($SD = 0.22$) groups, indicating more consistent performance among participants after the interventions.

Problem 2. Do the low-serve accuracy levels of the two groups significantly differ before and after the interventions?

Ho₁: There is no significant difference between participants' pretest and posttest low-serve accuracy scores.

The results of the paired-samples t-test comparing pre- and post-test scores for the two intervention groups are presented in Table 2. Before the paired samples t-test, normality was checked with the Shapiro-Wilk test and Q-Q plots. Both groups' difference scores did not significantly deviate from normality, with p-values: Fine Motor Strengthening with Videos ($W=0.962$, $p=.348$), and Proprioceptive Exercises ($W=0.975$, $p=.692$). All p-values exceeded 0.05, confirming normality. Q-Q plots supported this, showing data points aligned with the diagonal. Thus, the paired-samples t-test was appropriate.

The findings reveal that both groups demonstrated statistically significant differences between their pretest and posttest scores. For the Fine Motor Strengthening Exercises with Instructional Videos group, a computed t-value of -11.80 and a p-value of <0.001 indicate a highly significant difference. The effect size (Cohen's $d = -2.154$) suggests a very large magnitude of change. The Proprioceptive Training Exercises group also exhibited a significant increase in performance, from a mean of 2.31 (Good) to 3.11 (Very Good), with a t-value of -15.32 and a p-value of <0.001. The effect size ($d = -2.797$) reflects a very large effect, indicating substantial improvement following the intervention.

Table 2. Paired Samples t-test for Pre-Test and Post-Test Scores in Fine Motor Strengthening Exercises With Instructional Videos and Proprioceptive Training Exercises

Group	Test	M	Interpretation	SD	t	p	Cohen's d
Fine Motor Strengthening Exercises With Instructional Videos (n=30)	Pre-test	2.42	Good	0.30	-11.80*	<0.001	-2.154
	Post-test	3.14	Very Good	0.19			
Proprioceptive Training Exercises (n=30)	Pre-test	2.31	Good	0.26	-15.32*	<0.001	-2.797
	Post-test	3.11	Very Good	0.22			

*Significant at 0.05 two-tailed alpha level. M = mean, SD = standard deviation, t = t statistic, p = probability value, Cohen's d = effect size.

The results show significant differences in scores between pretest and posttest in both groups. Thus, the null hypothesis (H_{01})—that there is no significant difference between participants' pretest and posttest low-serve accuracy scores—is rejected. Both interventions, fine motor strengthening with instructional videos and proprioceptive training, effectively improved low-serve accuracy in badminton. The large effect sizes suggest these improvements are both statistically and practically significant.

Problem 3. Which of the interventions is more effective in improving low-serve accuracy in badminton?

Ho₂: None of the two interventions is more effective in improving the participants' low-serve accuracy in badminton.

Table 3. ANCOVA Summary Table for Posttest Scores with Pretest Scores as Covariate

GROUPS	Adjusted Mean	Interpretation	F(1,57)	p	Partial η^2
Fine Motor Strengthening w/ Instructional Videos	3.133	Very Good	0.083	0.774	0.001
Proprioceptive Training Exercises	3.118	Very Good			

Adjusted Mean = estimated marginal mean controlling for the pretest covariate; F = F statistic; p = probability value; partial η^2 = effect size.

*Significant at 0.05 two-tailed alpha level. M = mean, SD = standard deviation, t = t statistic, p = probability value, Partial η^2 = effect size

Lastly, regarding which of the two interventions is more effective at improving low-serve accuracy in badminton, Table 3 presents the ANCOVA results comparing posttest low-serve accuracy scores among the two intervention groups, controlling for pretest scores. Before ANCOVA, key assumptions were checked. Levene's Test showed a non-significant result, $F(1,58) = 0.319$, $p = .574$, indicating equal variances between the two groups. The residuals were approximately normal, as the Q-Q plots showed, and the descriptive statistics had low coefficients of variation (0.059–0.070), suggesting good within-group consistency. With equal group sizes ($n = 30$) and the homogeneity-of-variance assumption met, the use of ANCOVA was appropriate.

The analysis yielded a non-significant result, $F(1,57) = 0.083$, $p = .774$, indicating no significant difference between the two groups' adjusted posttest means after accounting for initial performance levels. The relatively low standard deviations in the posttest scores suggest more consistent performance following both interventions. The reported partial eta squared (partial $\eta^2 = 0.001$) indicates a negligible effect size, meaning that the type of intervention explained almost none of the variance in posttest scores once pretest differences were controlled. Although the Fine Motor Strengthening with Instructional Videos group obtained a slightly higher adjusted posttest mean ($M = 3.14$) than the Proprioceptive Training group ($M = 3.11$), this difference was too small to be statistically meaningful.

DISCUSSION

The findings of the study demonstrate that badminton low-serve accuracy among participants was initially at a generally "good" level in both intervention groups during the pretest, suggesting that the participants possessed foundational serving competence prior to the intervention period. However, the posttest results revealed notable performance improvements, particularly among participants exposed to Fine Motor Strengthening Exercises with Instructional Videos and Proprioceptive Training Exercises, both of which advanced from "good" to "very good" levels. This pattern suggests that while baseline skill was relatively comparable, interventions that combined physical conditioning with either visual instructional support or sensory-motor regulation provided strong developmental gains. These results align with existing evidence that service precision in badminton depends not only on repetitive execution but also on coordinated neuromuscular efficiency, perceptual guidance, and motor adaptation (Indarto *et al.*, 2023; Pan *et al.*, 2024; Parimi *et al.*, 2024).

The significant pretest-to-posttest improvement in the Fine Motor Strengthening Exercises with Instructional Videos group supports Social Cognitive Theory, which emphasizes the role of observational learning, modeled performance, and self-efficacy in skill acquisition. Instructional videos likely enhanced participants' ability to internalize proper serve mechanics by providing repeated visual demonstrations of grip, wrist action, shuttle contact, and body positioning, thereby strengthening cognitive representation of movement patterns (Li *et al.*, 2024). Combined with hand, wrist, and forearm strengthening, this approach may have optimized racket control and precision through both muscular adaptation and improved technical

awareness. Similar findings have been reported in sport pedagogy literature, where visual-based instruction enhances technical consistency and accelerates motor learning beyond physical drills alone (Caballero *et al.*, 2021; Li *et al.*, 2024).

The strong improvement observed in the Proprioceptive Training Exercises group also reinforces Schema Theory and Sensory Integration Theory by highlighting the value of sensory feedback, balance regulation, and body-position awareness in refining complex motor tasks. Low serves require subtle force modulation, stable posture, and accurate spatial judgment, all of which are strengthened through proprioceptive conditioning. Exercises such as balance drills, dynamic lunges, and star excursion movements may have improved participants' kinesthetic awareness and postural control, allowing for more consistent shuttle placement and smoother motor execution (Shafiq *et al.*, 2024; Winter *et al.*, 2022; Yilmaz *et al.*, 2024). This finding is consistent with biomechanical studies showing that badminton performance is influenced by lower-body stability and sensorimotor integration, particularly in precision-based technical actions (Irawan *et al.*, 2022; Pan *et al.*, 2024).

These patterns suggest that strengthening grip and wrist musculature is most effective when paired with complementary inputs: muscle capacity can support execution, but precision sports such as badminton also require movement calibration, timing accuracy, and cognitive-perceptual reinforcement (Biao & Lu, 2023; Chen *et al.*, 2024). In the present study, fine motor strengthening was delivered together with instructional video modeling, which may have helped participants correct subtle technical errors, while proprioceptive training emphasized body control and joint position sense—each providing the calibration that strengthening alone would not supply.

The ANCOVA findings indicated that, after controlling for baseline performance differences, the two interventions did not differ significantly in their effect on posttest low-serve accuracy (partial $\eta^2 = 0.001$, a negligible effect). In other words, neither intervention was more effective than the other; both moved participants from a Good to a Very Good level and produced large within-group gains. This comparability is itself practically meaningful for Physical Education and coaching contexts because it provides flexibility in intervention design: schools or coaches with limited technological access may emphasize proprioceptive drills, while settings with audiovisual resources may adopt video-assisted fine motor training, with confidence that either route can improve low-serve accuracy (Gómez *et al.*, 2020; Parimi *et al.*, 2024).

Hence, the findings contribute to badminton pedagogy by demonstrating that effective low-serve development extends beyond isolated physical drills and benefits from integrated approaches that address muscular strength, visual learning, or proprioceptive control. The study supports the assumption that precision in badminton is multidimensional, requiring coordinated interaction among cognitive, biomechanical, and sensory systems. For Physical Education teachers and grassroots badminton coaches, the results suggest that intervention programs should intentionally incorporate either structured instructional modeling or proprioceptive-based movement tasks to maximize skill acquisition. By contextualizing these findings within school-based badminton development, the study expands practical evidence for designing more responsive and theory-grounded training programs that improve technical performance through integrated, skill-specific training (Indarto *et al.*, 2023; Li *et al.*, 2024; Shafiq *et al.*, 2024).

CONCLUSION

The study concludes that badminton low-serve accuracy improved after the implementation of the intervention programs. In both the Fine Motor Strengthening Exercises with Instructional Videos group and the Proprioceptive Training Exercises group, participants moved from a Good level during the pretest to a

Very Good level during the posttest. The significant pretest–posttest improvements indicate that structured training activities can enhance serve control, precision, and consistency. Thus, the null hypothesis on no significant pretest–posttest difference was rejected.

The study further concludes that the two interventions were comparably effective: after controlling for pretest scores, their adjusted posttest means did not differ significantly. Therefore, the null hypothesis stating that neither intervention is more effective than the other was not rejected. Both interventions nonetheless produced large, significant within-group gains, so each is an effective option on its own. These findings suggest that badminton low-serve accuracy is improved through training approaches that combine physical skill development with either visual instructional support or proprioceptive–neuromuscular regulation.

Based on the findings, Physical Education teachers, badminton coaches, and school sports trainers are encouraged to integrate either Fine Motor Strengthening Exercises with Instructional Videos or Proprioceptive Training Exercises into badminton training programs to improve low-serve accuracy. Schools with access to digital resources may maximize video-assisted instruction to enhance technical modeling, while resource-limited settings may prioritize proprioceptive drills as an equally effective alternative. Future researchers are encouraged to replicate the study using larger and more diverse participant groups, longer intervention durations, and additional badminton performance variables such as high serve accuracy, footwork, reaction time, or game performance to further validate and expand the applicability of these interventions across broader badminton development contexts.

REFERENCES

- Beckmann, J., Fimpel, L., & Wergin, V. (2021). Preventing a loss of accuracy of the tennis serve under pressure. *PLOS ONE*, 16(7), e0255060. <https://doi.org/10.1371/journal.pone.0255060>
- Biao, Z., & Lu, X. (2023). Influence of strength training on physical fitness of badminton players. *Revista Brasileira de Medicina do Esporte*, 29. https://doi.org/10.1590/1517-8692202329012023_0062
- Caballero, C., Barbado, D., Hernández-Davó, H., Hernández-Davó, J., & Hernández, F. (2021). Balance dynamics are related to age and levels of expertise: Application in young and adult tennis players. *PLOS ONE*, 16(4), e0249941. <https://doi.org/10.1371/journal.pone.0249941>
- Chen, T., Tongdecharoen, W., & Tasnaina, N. (2024). Construction of an intensive training program for badminton reserve players before team selection match. *International Journal of Sociologies and Anthropologies Science Reviews*, 4(4), 175–186. <https://doi.org/10.60027/ijrsar.2024.4371>
- Costa, C., Valentini, N., Nascimento, E., & Ugrinowitsch, H. (2024). Validity and reliability of the volleyball serve accuracy test. *Journal of Human Sport and Exercise*, 19(2), 570–578. <https://doi.org/10.55860/jj2b1p83>
- Gómez, M., Cid, A., Rivas, F., & Pérez, L. (2020). Serving patterns of women's badminton medalists in the Rio 2016 Olympic Games. *Frontiers in Psychology*, 11, 136. <https://doi.org/10.3389/fpsyg.2020.00136>
- Indarto, A., Nugroho, S., & Rakhmawati, S. (2023). Analysis of backhand service badminton doubles athletes in the championship in Banyumas. *International Journal of Physical Education, Sports and Health*, 10(1), 99–103. <https://doi.org/10.22271/kheljournal.2023.v10.i1b.2760>
- Irawan, F., Ma'dum, M., Indardi, N., Trans, M., & Fatmasari, A. (2022). Potential and limitations of short backhand serve in badminton: Kinematics analysis. *Jurnal Sportif: Jurnal Penelitian Pembelajaran*, 8(4), 342–354. https://doi.org/10.29407/js_unpgri.v8i4.18383

- Labott, B., & Donath, L. (2023). Agility performance in healthy older adults is associated with handgrip strength and force development: Results from a 1-year randomized controlled trial. *European Geriatric Medicine*, 14(3), 547–555. <https://doi.org/10.1007/s41999-023-00789-8>
- Li, W., Zhao, Y., & Wang, C. (2024). Structural design and dynamic characteristic analysis of adjustable badminton serving machine. *Vibroengineering Procedia*, 56, 189–195. <https://doi.org/10.21595/vp.2024.24271>
- Pan, Z., Liu, L., Li, X., & Ma, Y. (2024). A study of racket weight adaptation in advanced and beginner badminton players. *Applied Bionics and Biomechanics*, 2024, 1–10. <https://doi.org/10.1155/2024/8908294>
- Parimi, F., Abdoli, B., Ramezanzade, H., & Aghdaei, M. (2024). The effect of internal and external imagery on learning badminton long serve skill: The role of visual and audiovisual imagery. *PLOS ONE*, 19(9), e0309473. <https://doi.org/10.1371/journal.pone.0309473>
- Shafiq, N., Shabbir, S., Alam, M., Akhtar, W., Burhan, M., & Masora, A. (2024). Intra-rater reliability of star excursion balance test. *Journal of Health and Rehabilitation Research*, 4(2), 1692–1696. <https://doi.org/10.61919/jhrr.v4i2.1126>
- Vial, S., Croft, J., Schroeder, R., Blazeovich, A., & Cochrane, J. (2020). Does the presence of an opponent affect object projection accuracy in elite athletes? A study of the landing location of the short serve in elite badminton players. *International Journal of Sports Science & Coaching*, 15(3), 412–417. <https://doi.org/10.1177/1747954120915670>
- Williyanto, S., Wiyanto, A., Santoso, N., & Masri, M. (2021). Backhand serve test model for junior badminton athletes. *International Journal of Human Movement and Sports Sciences*, 9(4A), 112–118. <https://doi.org/10.13189/saj.2021.091319>
- Winter, L., Huang, Q., Sertic, J., & Konczak, J. (2022). The effectiveness of proprioceptive training for improving motor performance and motor dysfunction: A systematic review. *Frontiers in Rehabilitation Sciences*, 3. <https://doi.org/10.3389/fresc.2022.830166>
- Yilmaz, O., Soylyu, Y., Erkmen, N., Kaplan, T., & Bařalıık, L. (2024). Effects of proprioceptive training on sports performance: A systematic review. *BMC Sports Science, Medicine and Rehabilitation*, 16(1). <https://doi.org/10.1186/s13102-024-00936-z>

Conflict of Interest: The author declares that there is no conflict of interest regarding the publication of this article.

Acknowledgements: The researcher extends his sincere gratitude to Almighty God for His wisdom and grace, to his thesis mentor, professors, and panellists for their invaluable guidance and support, and to his family and loved ones for their unwavering love and encouragement, to whom all glory is humbly offered.

Funding: This research received no external funding and was supported solely by the personal resources of the primary author.

Ethical Approval: The study was reviewed and approved by the Lourdes College Research Ethics Committee, and ethical approval was secured prior to data collection, in accordance with the Belmont Report. As the participants were minors (Grade 7 students), written assent was obtained from the students together with written consent from their parents or guardians, and data privacy was protected in compliance with Republic Act No. 10173 (Data Privacy Act of 2012).

AI Declaration: This study utilized artificial intelligence tools to assist in preparing this article. Specifically, an AI assistant was used to help condense the full thesis manuscript into a reduced journal-article format and to enhance language quality, clarity, and tone, with human supervision and editing throughout. The author carefully reviewed and edited all outputs to ensure academic rigor and integrity.

Data Availability Statement: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. Requests for access will be evaluated in accordance with ethical guidelines and data privacy policies.