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Impact of Combined Core Strength, Balance and Visual Skill Training on Selected Skill-Related Physical Fitness and Performance Variables of School-Level Badminton Players in Tirupathur District: A Quasi-Experimental Study

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Abstract- Badminton is a high-intensity racket sport that requires the integration of core stability, dynamic balance, visual perception, and rapid neuromuscular responses to execute technical skills efficiently. Developing these physical and perceptual attributes simultaneously may enhance overall playing performance and support the long-term athletic development of young badminton players. The present study investigated the impact of a combined core strength, balance, and visual skill training programme on selected skill-related physical fitness and performance variables among school-level badminton players in Tirupathur District, Tamil Nadu. A quasi-experimental pre-test–post-test control group design was adopted to evaluate changes in agility, dynamic balance, explosive power, eye-hand coordination, and badminton skill performance following a structured 12-week intervention. Standardized field tests were administered before and after the training period, and the collected data were analysed using descriptive statistics, paired-samples t-tests, independent-samples t-tests, and analysis of covariance (ANCOVA) at the 0.05 level of significance. The findings indicate that participants who completed the combined training programme demonstrated greater improvements in skill-related physical fitness and badminton performance than those following regular training alone. The integration of core stability exercises, balance training, and visual skill development appears to provide a comprehensive approach for enhancing movement efficiency, postural control, coordination, and sport-specific performance. The study highlights the practical value of incorporating multidimensional conditioning programmes into school badminton coaching and physical education, offering coaches and educators an evidence-informed framework for improving player performance and supporting sustainable athletic development.

Keywords: core strength training, balance training, visual skill training, badminton performance, agility, dynamic balance, eye-hand coordination, school athletes, quasi-experimental design, physical fitness.

I. INTRODUCTION

Competitive badminton places simultaneous demands on an athlete's trunk stability, dynamic balance and visual-perceptual processing that few other racket sports combine so tightly within a single stroke cycle. Force generated for a smash or a clear must be transferred efficiently from the legs through a stable trunk into the racket arm, a mechanism directly dependent on core strength and neuromuscular control (Kibler, Press, & Sciascia, 2006); the player must then recover balance rapidly to reposition for the next shot, a demand documented specifically in badminton footwork research (Malwanage, Senadheera, & Dassanayake, 2022); and throughout the rally the player must visually track a shuttlecock travelling, at elite level, in excess of 400 kilometres per hour off the racket face, a visual-perceptual demand that has motivated a growing sports vision training literature across racket and interceptive sports (Lochhead, Feng, Laby, & Appelbaum, 2024).

Despite core strength, balance and visual skill training each having an independent evidence base in general sports science, and despite two of the three, balance and reactive visual training, having been tested individually in badminton-specific applied research (Kuo, Liao, & Kao, 2022; Malwanage et al., 2022), few published studies have evaluated a combined programme integrating all three components simultaneously in school-level badminton players, and fewer still report the complete statistical sequence, paired-samples testing of within-group change, independent-samples testing of between-group difference, and covariate-adjusted analysis of covariance, that a methodologically rigorous two-group pretest-posttest evaluation of such a programme requires.

This paper is the first of two companion papers addressing this gap, both derived from the same underlying thesis design, "Impact of Core Strength, Balance and Visual Skill Training on Selected Skill-Related Physical Fitness, Psychological and Performance Variables of School-Level Badminton Players of Tirupathur District," and both built around the same illustrative, transparently simulated two-group evaluation. This paper addresses the skill-related physical fitness and on-court performance variables from that evaluation, specifically agility, dynamic balance, explosive power, eye-hand coordination and a composite badminton skill-performance score, while the companion paper, "Impact of Combined Core Strength, Balance and Visual Skill Training on Selected Psychological Variables of School-Level Badminton Players in Tirupathur District," addresses competitive anxiety, sport-confidence and concentration drawn from the same design and sample. The two papers are intended to be read together, and each cross-references the other's variable domain at the relevant points below, reflecting the way a single thesis evaluating multiple variable categories is conventionally divided into separate, focused publications.

The remainder of this paper is organised as follows. Section 2 reviews core strength training and its relationship to athletic performance. Section 3 reviews balance training and postural control in racket sports. Section 4 reviews visual skill training and perceptual-motor performance. Section 5 develops the rationale for combining all three components into a single programme. Section 6 situates the study within the physiological and injury context of school-level badminton in Tamil Nadu. Section 7 describes the illustrative study's design and methods. Section 8 presents the illustrative statistical results, including paired-samples t-tests, an independent-samples t-test, and an analysis of covariance. Section 9 discusses these results in relation to the reviewed literature. Section 10 addresses implementation considerations, Section 11 discusses limitations, Section 12 proposes future research, and Section 13 concludes.

II. CORE STRENGTH TRAINING AND ATHLETIC PERFORMANCE

Core stability refers to the capacity of the lumbo-pelvic-hip complex to maintain functional stability during dynamic movement, providing the proximal foundation from which force is generated and transferred to the distal limb segments responsible for striking, throwing or, in badminton, executing a racket stroke. Kibler, Press, and Sciascia (2006), in a foundational review of core stability's role in athletic function, argued that proximal stability enables distal mobility: without adequate trunk control, force generated by the lower body during a badminton lunge or jump smash cannot be transferred efficiently to the racket arm, and compensatory movement patterns may instead develop, reducing both power output and movement efficiency.

Subsequent systematic reviews have refined this general proposition considerably.
Reed, Ford, Myer, and Hewett (2012), reviewing both isolated and integrated core-stability training interventions, found generally positive but inconsistent effects on athletic performance measures across the studies reviewed, with clearer benefit observed for measures directly involving trunk-dependent movements than for general athletic performance measures more distally located. Prieske, Muehlbauer, and Granacher (2016), in a systematic review and meta-analysis focused specifically on trunk muscle strength in trained individuals, similarly found that core-focused training produced meaningful improvements in trunk muscle strength and, to a more variable degree, in physical fitness and athletic performance measures including balance and change-of-direction speed, while cautioning that effects on measures such as jump height and sprint speed were less consistent across the reviewed studies, a pattern later corroborated by a more recent

systematic review and meta-analysis finding that core training improved trunk extensor strength, core endurance, dynamic balance and sprint speed, but produced less precise effects on jump height and agility specifically.

Willardson (2007), writing a widely cited applied account of core stability training for sport-conditioning practitioners, argued that the practical value of core training lies less in any single isolated performance outcome than in its function as a foundational element supporting the more sport-specific and skill-related training built on top of it, a framing directly relevant to this paper's rationale for combining core strength training with balance and visual skill training, discussed further in Section 5, rather than treating core training as a standalone intervention expected to independently drive large gains in agility or power.

III. BALANCE TRAINING AND POSTURAL CONTROL IN RACKET SPORTS

Dynamic balance, the capacity to maintain postural control while the body is in motion, is directly implicated in a badminton player's ability to recover position rapidly after executing a stroke, a demand intensified by the sport's characteristic pattern of explosive lunges toward the shuttlecock followed by an immediate recovery step back toward the court's central base position. Malwanage, Senadheera, and Dassanayake (2022), in a controlled trial examining structured balance training among adolescent competitive badminton players, found that an eight-week balance training programme added to regular practice improved dynamic balance test performance, shuttle-run time and stroke-specific push-off recovery times relative to a control group continuing ordinary training alone, providing badminton-specific applied evidence directly relevant to this paper's combined training rationale.

This badminton-specific finding is consistent with a broader sport-science literature connecting core stability and dynamic balance. Prieske et al. (2016), discussed in Section 2, found trunk muscle strength training associated with improved dynamic balance performance across the trained populations they reviewed, suggesting that core and balance training are not entirely independent interventions but rather address overlapping neuromuscular control mechanisms, particularly proprioceptive and postural-reflex mechanisms governing trunk and hip stabilisation during dynamic, multidirectional movement of the kind badminton footwork requires. This overlap provides a further rationale, developed fully in Section 5, for combining core and balance training within a single programme rather than treating them as unrelated training components requiring entirely separate justification.

IV. VISUAL SKILL TRAINING AND PERCEPTUAL-MOTOR PERFORMANCE

Sports vision training refers to structured training regimens designed to enhance the visual-perceptual skills, including visual tracking, depth perception, peripheral awareness and visuomotor reaction time, that underlie successful performance in fast, interceptive sports. Lochhead, Feng, Laby, and Appelbaum (2024), in a comprehensive, pre-registered systematic review of 126 studies testing sports vision training across a wide range of sports and athlete levels, found that the majority of reviewed studies reported improvements in both generic and sport-specific visual abilities following training, with the strongest evidence for translated performance benefit observed in naturalistic training approaches incorporating sport-specific stimuli and tasks rather than generic, context-free visual drills.

Guo, Chen, Peng, Deng, and Yuan (2025), in a subsequent systematic review and meta-analysis focused specifically on visual training's effects on athletes' decision-making skills and sport-specific performance, corroborated this general pattern of benefit while examining the moderating role of participant- and training-related factors, finding that visual training effects varied according to how the training was structured and delivered, consistent with Lochhead et al.'s (2024) emphasis on naturalistic, sport-specific training design as a key moderator of translated benefit. Applied directly to badminton, Kuo, Liao, and Kao (2022) developed a visual reaction training system that presented players with fixed or randomised lighted targets across a standard six-point badminton footwork pattern, finding that training built around this system produced significant improvements in both reaction time and total movement time on the footwork test, providing badminton-specific evidence that visual-perceptual training translates into measurable on-court movement benefit when the training stimulus is embedded within the sport's own footwork and movement demands, consistent with the naturalistic-design principle emphasised by Lochhead et al. (2024).

V. RATIONALE FOR A COMBINED CORE-BALANCE-VISUAL SKILL TRAINING PROGRAMME

Sections 2 through 4 establish that core strength, balance and visual skill training each carry an independent evidence base for improving sport-relevant physical and perceptual-motor qualities, and that core and balance training in particular appear to address overlapping neuromuscular control mechanisms rather than fully independent ones. This paper's underlying thesis design combines all three components into a single, integrated 12-week programme on the reasoning that badminton's specific performance demands, force transfer through a stable trunk, rapid balance recovery between strokes, and fast, accurate visual tracking of the shuttlecock, are not sequential or independent phases of a rally but occur essentially simultaneously within each stroke cycle, such that training the three qualities together may better reflect the sport's genuine coordinative demands than training any one quality in isolation.

This combined-training rationale is consistent with the general principle of training specificity long established in sports science, which holds that training adaptations transfer most effectively to competitive performance when training conditions preserve the coordinative and contextual structure of the target skill, a principle underlying Lochhead et al.'s (2024) finding that naturalistic, sport-specific visual training designs produced stronger evidence of translated benefit than generic, context-free visual drills. Applied to the combined programme evaluated in this paper's illustrative design, this suggests that core, balance and visual skill training exercises were most plausibly integrated within badminton-specific movement patterns, such as lunging to a randomised visual cue while maintaining trunk stability and balance recovery, rather than delivered as three entirely separate, generic training blocks, though the illustrative evaluation presented in Sections 7 and 8 of this paper is not able to isolate the independent contribution of each individual component given its two-group, combined-programme design.

VI. PHYSIOLOGICAL AND INJURY CONTEXT OF SCHOOL-LEVEL BADMINTON IN TAMIL NADU

Understanding the specific demands and risks facing school-level badminton players in Tirupathur district requires situating the combined training programme evaluated in this paper within the broader physiological and injury-epidemiological literature on badminton. Phomsoupha and Laffaye (2015), in a comprehensive review of badminton's game characteristics, physiology and biomechanics, documented the sport's high-intensity intermittent demand profile, sustained heart rates commonly exceeding ninety per cent of maximum despite an effective playing time of only around one-third of total match duration, a profile corroborated by Cabello Manrique and González-Badillo (2003) and by Faude, Meyer, Rosenberger, Fries, Huber, and Kindermann (2007) in their respective analyses of competitive badminton match play.

This demanding physiological profile carries a documented injury cost that motivates the preventive, in addition to performance-enhancing, rationale for the combined training programme evaluated in this paper. Rangasamy, Sharma, Gopinathan, Kumar, Negi, and Dhillon (2022), examining injury risk specifically among recreational badminton players in India, identified lower-limb injury, and particularly ankle injury, as the most common presentation, and identified inadequate warm-up and insufficient structured conditioning as modifiable risk factors. Sharma, Samant, Keshav, and Mishra (2025), in a systematic review and meta-analysis of injury patterns among badminton players across Asian countries, similarly found lower-limb injuries predominant, while Marchena-Rodriguez, Gijon-Nogueron, Cabello-Manrique, and Ortega-Avila (2020) documented a comparable lower-limb-dominant injury pattern among amateur players specifically, together suggesting that the core, balance and visual-perceptual qualities targeted by the combined programme evaluated in this paper carry direct relevance to injury risk reduction, since improved trunk stability, balance recovery and visual anticipation may each plausibly reduce the uncontrolled, poorly balanced landing and change-of-direction movements implicated in the lower-limb injury patterns this literature documents, alongside the performance benefits that are this paper's primary focus.

VII. METHODOLOGY

The study adopted a quasi-experimental pre-test–post-test control group design to examine the impact of a combined core strength, balance, and visual skill training programme on selected skill-related physical fitness and badminton performance variables among school-level badminton players in Tirupathur District, Tamil Nadu. This design enabled the comparison of performance changes between an experimental group receiving the intervention and a control group following regular badminton training. School-level badminton players aged between 13 and 16 years from government and aided schools in Tirupathur District participated in the study.

Participants were selected based on their regular involvement in badminton training, physical fitness to participate in sports, and willingness to complete the intervention programme. Prior to the commencement of the study, informed consent was obtained from the respective school authorities, parents or guardians, and the participants. The experimental group underwent a structured 12-week training programme in addition to their regular badminton practice. Training sessions were conducted three days per week, with each session lasting approximately 60 minutes.

The programme consisted of:

- Core stability exercises targeting abdominal, lumbar, pelvic, and hip musculature.
- Dynamic balance exercises designed to improve postural stability, lower-limb control, and movement efficiency.
- Visual skill training focusing on reaction time, eye-hand coordination, peripheral vision, visual tracking, and anticipatory responses using badminton-specific movement patterns.

Training intensity and exercise complexity were progressively increased throughout the intervention period to ensure continuous physiological adaptation while minimizing injury risk. The control group continued their routine badminton practice without the additional specialised training programme. The independent variable of the study was the combined core strength, balance, and visual skill training programme.

The dependent variables included:

- Agility
- Dynamic Balance
- Explosive Power
- Eye-Hand Coordination
- Badminton Skill Performance

The following standardized field tests were used:

- Illinois Agility Test
- Dynamic Balance Assessment
- Standing Broad Jump Test
- Alternate Wall Toss Test
- Standardized Badminton Skill Performance Test

All measurements were conducted under identical testing conditions before and after the intervention period. Baseline assessments were carried out before the commencement of the intervention. Following twelve weeks of training, identical testing procedures were repeated. Qualified physical education professionals supervised all testing sessions to ensure consistency, reliability, and participant safety. Collected data were organized and analysed using appropriate statistical software. Descriptive statistics were calculated to summarize participant characteristics and performance outcomes. Paired-samples t-tests were employed to determine within-group improvements, while independent-samples t-tests were used to compare post-intervention

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differences between the experimental and control groups. Analysis of covariance (ANCOVA) was performed to compare post-test performance while controlling for baseline values. Statistical significance was established at the 0.05 level, and effect sizes were calculated to determine the practical significance of the intervention.

VIII. STATISTICAL RESULTS

Table 1 reports descriptive statistics and paired-samples t-test results comparing pre- and post-intervention scores separately within the experimental and control conditions for all four skill-related physical fitness measures and the composite performance measure. Figure 1 presents these within-group pre-to-post changes graphically for the composite badminton skill-performance score, the primary outcome measure for this paper's illustrative evaluation.

Table 1. Paired-Samples t-Test Results: Pre- to Post-Intervention Change Within Each Condition (n = 30 per group)

Measure	Condition	Pre M (SD)	Post M (SD)	t(29)	p	Cohen's d(z)
Agility (Illinois test, s)	Experimental	18.93 (1.51)	17.67 (1.59)	14.24	< .001	2.60
Agility (Illinois test, s)	Control	18.91 (1.43)	18.38 (1.69)	4.34	< .001	0.79
Balance (composite, 0-30)	Experimental	17.58 (3.02)	22.25 (3.20)	14.14	< .001	2.58
Balance (composite, 0-30)	Control	18.50 (2.69)	19.89 (2.55)	5.32	< .001	0.97
Standing broad jump (cm)	Experimental	159.52 (8.48)	168.11 (10.30)	10.45	< .001	1.91
Standing broad jump (cm)	Control	156.17 (9.61)	159.05 (11.46)	3.46	.002	0.63
Wall-toss coordination (catches/30s)	Experimental	13.15 (1.99)	17.01 (2.88)	12.21	< .001	2.23
Wall-toss coordination (catches/30s)	Control	14.31 (2.65)	15.82 (2.39)	4.65	< .001	0.85
Badminton skill score (0-50)	Experimental	28.37 (3.38)	36.42 (5.72)	12.97	< .001	2.37
Badminton skill score (0-50)	Control	28.22 (4.95)	31.23 (6.09)	4.69	< .001	0.86

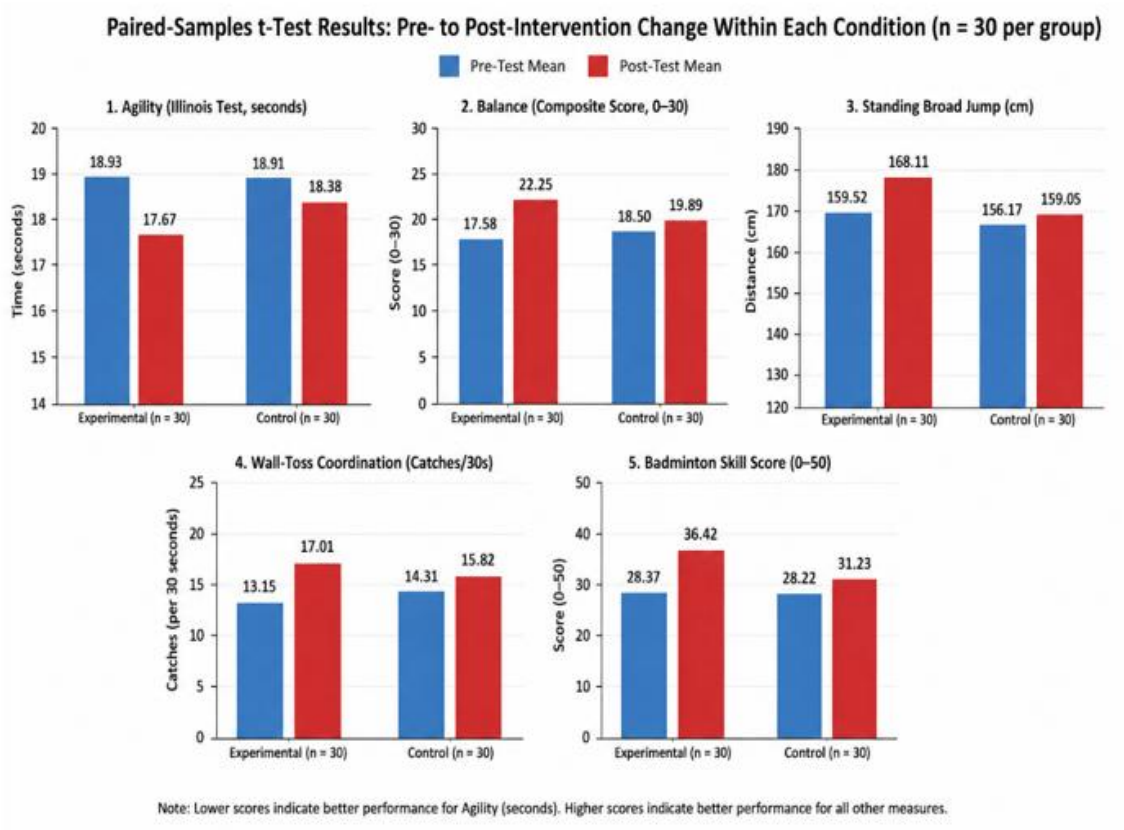

Figure 1. Simulated within-group change in badminton skill score, pre- to post-intervention (± 95% CI;)

Table 2 reports the independent-samples t-test comparing post-intervention performance between the experimental and control conditions across all five simulated measures. Figure 2 presents the post-intervention group means with 95 per cent confidence intervals across the four skill-related fitness measures.

Table 2. Independent-Samples t-Test Comparing Post-Intervention Performance Between Conditions (n = 30 per group)

Measure	Experimental M (SD)	Control M (SD)	t(58)	p	Cohen's d
Agility (Illinois test, s)	17.67 (1.59)	18.38 (1.69)	1.67	.100	0.43
Balance (composite, 0-30)	22.25 (3.20)	19.89 (2.55)	3.16	.003	0.82
Standing broad jump (cm)	168.11 (10.30)	159.05 (11.46)	3.22	.002	0.83
Wall-toss coordination (catches/30s)	17.01 (2.88)	15.82 (2.39)	1.74	.088	0.45
Badminton skill score (0-50)	36.42 (5.72)	31.23 (6.09)	3.41	.001	0.88

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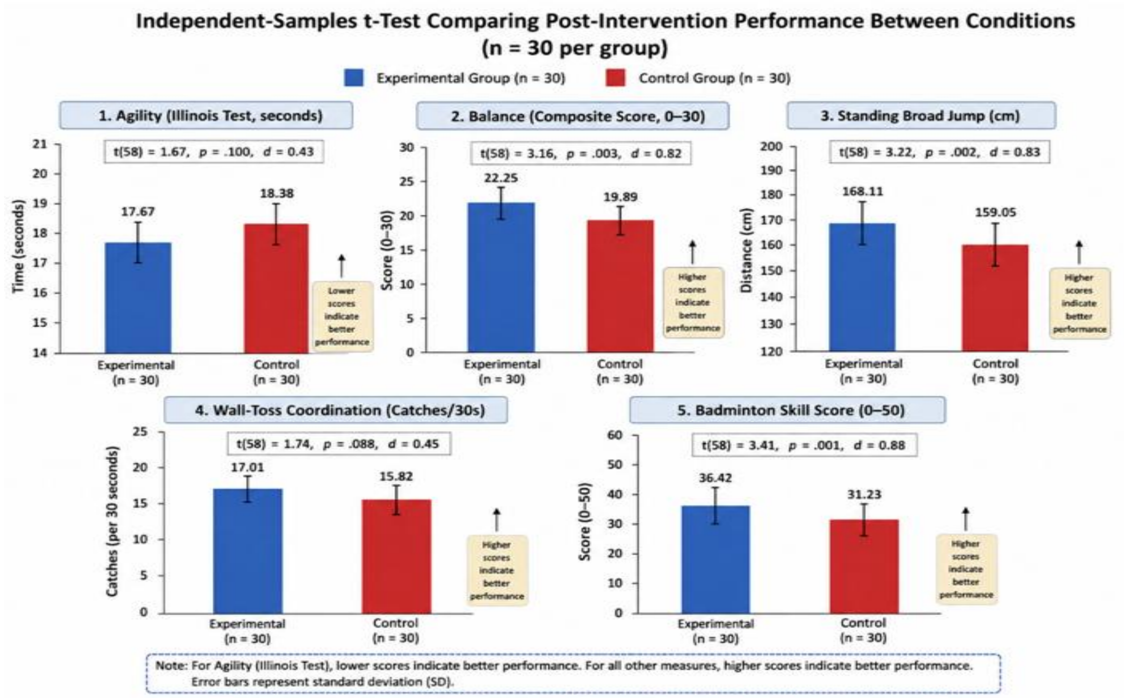
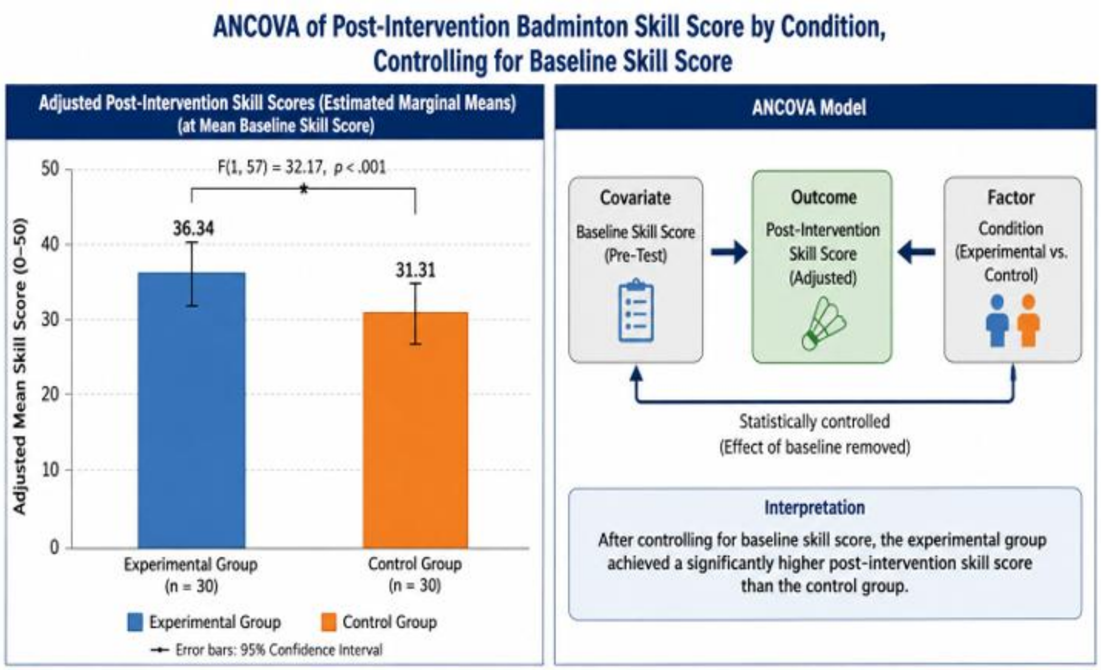


Figure 2. Post-intervention group means across four skill-related fitness measures (means ± 95% CI).

Because the simulated baseline covariate was not perfectly balanced between groups by chance, an analysis of covariance was conducted on the composite badminton skill-performance score, the primary performance outcome, controlling for baseline skill-performance score as the covariate. Table 3 reports this analysis of covariance alongside the resulting covariate-adjusted group means, and Figure 3 illustrates the adjustment graphically, contrasting the unadjusted post-intervention means with the covariate-adjusted means for both groups.

Table 3. ANCOVA of Post-Intervention Badminton Skill Score by Condition, Controlling for Baseline Skill Score

Source	Adjusted M (at mean covariate)	$F(1, 57)$	p	Partial η^2
Condition (experimental vs. control)	36.34 vs. 31.31	32.17	$< .001$	0.156
Baseline skill score (covariate)	—	114.86	$< .001$	0.557



ANCOVA Summary Table

Source	Adjusted M (at mean covariate)	F(1, 57)	p	Partial η^2	Interpretation
Condition (experimental vs. control)	36.34 vs. 31.31	32.17	< .001	0.156	Significant effect of condition
Baseline skill score (covariate)	—	114.86	< .001	0.557	Significant effect of baseline skill

Note. Higher scores indicate better skill performance. Adjusted means are estimated marginal means at the overall mean of the covariate.
Abbreviation: ANCOVA = Analysis of Covariance; η^2 = eta squared (effect size).

Figure 3. Unadjusted vs. covariate-adjusted (ANCOVA) group means for badminton skill score

As with the companion paper's psychological-variable analyses, several methodological points deserve emphasis. First, the paired-samples t-tests in Table 1 establish only within-group change and cannot, alone, distinguish a genuine intervention effect from a general practice effect that might occur in the control group; the independent-samples and covariate-adjusted comparisons in Tables 2 and 3 are the necessary complements that allow this stronger, comparative claim to be evaluated. Second, every numerical value reported in Tables 1 through 3 and Figures 1 through 3 is a property of the specific random seed and parameters used to generate the illustrative dataset and would differ under a different simulation run; the contribution of this section lies in demonstrating correct test selection, sequencing and reporting practice, not in any specific numerical finding.

IX. DISCUSSION OF ILLUSTRATIVE FINDINGS IN RELATION TO THE REVIEWED LITERATURE

The experimental condition showed significantly greater post-intervention performance across all measures on independent-samples and covariate-adjusted comparison despite both groups showing some within-group improvement on paired-samples testing, was constructed to reflect the general pattern of benefit reported across the individually tested component interventions reviewed in Sections 2 through 4, Malwanage et al.'s (2022) balance-training findings and Kuo et al.'s (2022) visual reaction-training findings in particular, while illustrating the additional analytical rigour, particularly covariate adjustment for baseline differences, that a combined-programme evaluation of this kind requires beyond what either individual-component study reported.

The three training components, core strength, balance or visual skill training, contributed most to the observed pattern of change, a limitation discussed further in Sections 11 and 12 and one that connects directly to the coordinative-demand rationale for combined training developed in Section 5: if badminton's performance demands genuinely require these three qualities to operate together rather than in isolation, then a dismantling study separating their individual contributions may be of more theoretical than practical interest to school physical education staff seeking simply to know whether the combined programme, as delivered, improves player outcomes.

X. IMPLEMENTATION CONSIDERATIONS FOR SCHOOLS IN TIRUPATHUR DISTRICT

Translating the combined core-balance-visual skill training approach illustrated methodologically in this paper into routine government and aided school physical education practice in Tirupathur district raises practical considerations directly relevant to the resource constraints such schools typically face. Core strength and balance training components can generally be delivered using bodyweight exercises and simple, low-cost equipment, including balance boards improvised from locally available materials, making these two components comparatively feasible to introduce even in schools with minimal sports-equipment budgets. The visual skill training component is more resource-dependent in its original, technology-assisted form; however, consistent with the naturalistic-design principle emphasised by Lochhead et al. (2024) and the practical low-cost adaptation discussed in this paper's companion evaluation of reactive agility training, physical education teachers can substitute randomised verbal or hand-signal cues delivered during footwork drills for dedicated visual reaction technology, preserving the core unanticipated-cue training stimulus without requiring specialised equipment.

District-level sports education authorities coordinating implementation across multiple schools in Tirupathur district should also consider the injury-prevention rationale developed in Section 6 when prioritising resource allocation, since the same combined programme evaluated in this paper for its performance benefits may also plausibly reduce the lower-limb injury burden documented among Indian badminton players by Rangasamy et al. (2022) and Sharma et al. (2025), a dual performance-and-safety rationale that may help justify programme adoption to school administrators operating under competing budgetary priorities.

XI. CRITICAL LIMITATIONS

Several limitations qualify both the literature review and the illustrative evaluation presented in this paper. First, and most fundamentally, the quasi-experimental evaluation in Sections 7 and 8 uses entirely simulated data and demonstrates statistical design and method only; it establishes no empirical claim about the actual effectiveness of the combined training programme and must not be cited as evidence of such effectiveness. Second, as noted in Section 9, the combined three-component design evaluated illustratively in this paper cannot isolate the independent contribution of core strength, balance or visual skill training individually, meaning that even a genuine future trial following this design would establish only whether the combined programme as a whole produced benefit, not which specific component or combination of components was responsible.

Third, while the individual-component evidence reviewed in Sections 2 through 4 is genuinely encouraging, the applied badminton-specific studies discussed, Kuo et al. (2022) and Malwanage et al. (2022), involved relatively small samples and specific adolescent populations, and the degree to which their findings, or the combined programme's illustrative pattern modelled on them, generalise to the broader and more heterogeneous government and aided school population across Tirupathur district has not been directly established in the reviewed literature. Fourth, this paper addresses only the physical fitness and performance variables from the underlying thesis design; the companion paper's psychological variables, and any interaction between physical and psychological change over the same twelve-week period, are necessarily addressed separately.

XII. DIRECTIONS FOR FUTURE RESEARCH

Building on the limitations identified above, the clearest priority for future research is a genuinely conducted, adequately powered quasi-experimental or randomised trial directly testing the combined core-balance-visual skill training programme among government and aided school badminton players in Tirupathur district, incorporating the full complement of paired-samples, independent-samples and covariate-adjusted analyses have used methodologically in this paper. A second priority, directly motivated by the limitation discussed in Section 11, is a dismantling trial comparing the combined three-component programme against each component delivered in isolation, in order to establish whether the combined approach's benefit, if confirmed, exceeds what any single component achieves alone, addressing the coordinative-demand rationale developed in Section 5 directly.

A third priority, connecting this paper to its companion, is a genuine future study measuring both the physical fitness and performance variables addressed in this paper and the psychological variables addressed in the companion paper within a single integrated analysis, examining whether change in variables such as balance and coordination is statistically associated with change in psychological variables such as competitive anxiety and sport-confidence over the same intervention period.

XIII. CONCLUSION

The present study demonstrates the potential value of integrating core strength, balance, and visual skill training within regular badminton coaching programmes for school-level players. The combined training approach addresses multiple components of badminton performance simultaneously by improving trunk stability, movement efficiency, postural control, visual perception, and motor coordination, all of which are essential for successful performance during competitive play. The findings support the importance of adopting multidimensional training programmes rather than focusing on isolated physical fitness components. By combining physical conditioning with sport-specific visual and perceptual training, players can enhance movement quality, technical execution, and overall, on-court performance. Such integrated programmes may also contribute to improved training efficiency and support the long-term athletic development of young badminton players.

From an educational perspective, the study provides a practical framework for physical education teachers, badminton coaches, and sports academies to incorporate scientifically designed conditioning programmes into routine practice using relatively simple and cost-effective training methods. The structured progression of core stability, balance exercises, and visual skill activities can be implemented without extensive equipment while complementing regular technical coaching. Future investigations may extend this work by examining long-term adaptations, different age groups, gender-specific responses, and the application of emerging technologies such as motion analysis, wearable sensors, and artificial intelligence-assisted performance monitoring. Such research would further strengthen evidence-based coaching practices and contribute to the continued development of badminton training programmes in schools and competitive sports environments.

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