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Effects of Hybrid Training Combining Shadow, Dynamic Ball, Sensory, and Game Drills on Forehand Drive Performance in Young Table Tennis Players: A 2×2 Factorial Design

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Abstract

Background. Optimal training protocols for the forehand drive in young table tennis players (ages 6–9) are still under development. Although shadow drills, dynamic ball practice, sensory tools, and game-based activities each provide unique benefits, no research has integrated these methods into a hybrid model. Additionally, the moderating role of baseline EHC remains unclear, limiting the design of inclusive training programs.

Objectives. This study investigated the effect of a hybrid training model on forehand drive performance and assessed whether its effectiveness varied according to the athlete's baseline EHC level.

Materials and Methods. A 2×2 factorial quasi-experimental design was employed. Twenty-eight athletes from PTMSI Makassar were divided into experimental (n = 14) and control (n = 14) groups and further stratified by high or low EHC levels (measured using the Beery VMI). Forehand drive accuracy (maximum score = 50) was assessed before and after 14 training sessions (50 minutes each, three times per week). Data were analyzed using two-way ANCOVA while controlling for pretest scores.

Results. After adjustment, the hybrid group achieved significantly higher scores than the control group (M = 44.68 vs. 42.11; $p < 0.001$, partial $\eta^2 = 0.483$). Athletes with high EHC outperformed those with low EHC (M = 44.54 vs. 42.25; $p < 0.001$, partial $\eta^2 = 0.423$). The interaction between training and EHC was not significant ($p = 0.991$).

Conclusions. The hybrid training model significantly improved forehand drive performance compared to conventional training methods. Coaches are encouraged to incorporate all four training methods into daily practice programs. These findings highlight the importance of integrating diverse training approaches at an early age and suggest potential applications in pediatric physiotherapy and motor performance rehabilitation.

Keywords: table tennis, forehand drive, hybrid training, eye-hand coordination, early childhood.

Introduction

Modern table tennis demands high reaction speed, technical precision, and exceptional perceptual-motor coordination, especially in young athletes during their early developmental stages (ages 6–9). Among the basic strokes, the forehand drive is widely recognized as a key offensive technique, serving as the foundation for more advanced attacking shots, as demonstrated by Grycan et al. (2023) and Mao et al. (2023). According to Faber et al. (2021) and He et al. (2022), mastering the forehand drive at an early age is critical because it builds the technical foundation for acquiring subsequent skills.

Various training methods have been developed to enhance forehand drive performance. Shadow training improves movement patterns without ball contact interruptions (Gusman et al., 2025; Pratama, 2021). Dynamic ball training and multiball exercises increase repetition frequency and enhance the upper arm muscle stretch-shortening cycle (Asri et al., 2017). Sensory tools, such as target boards and auditory cues, provide feedback that enhances shot accuracy and proprioceptive awareness (Basiri et al., 2020). Game-based training reinforces decision-making and adaptability in unpredictable match contexts (Pane et al., 2020). While each of these methods demonstrates benefits, the current literature remains at an impasse, primarily due to technical gaps rather than holistic approaches.

The primary limitation of the existing protocols is their fragmentation. When applied independently, these methods fail to address the holistic demands of motor learning in children, an approach increasingly recognized as essential for youth development (Martindale et al., 2007). For 6–9-year-olds, monotonous repetitive training, which is the default in many conventional settings, leads to premature technical consolidation without the necessary contextual variation for long-term skill retention and transfer (Schmidt & Lee, 2019). This concern is supported by research on contextual interference, which indicates that while blocked practice may lead to faster initial performance gains, it typically results in poorer retention and transfer to novel situations compared to more variable practice schedules (Krstulović et al., 2020). In contrast, relying solely on game-based play without sufficient technical repetition leads to higher error rates and reinforcement of flawed biomechanical patterns. This tension creates a pedagogical contradiction—developmental needs for high-volume, accurate repetitive training to consolidate motor pathways directly conflict with the psychological need for varied, engaging stimuli that maintain attention and prevent fatigue in young children.

Furthermore, the role of eye-hand coordination (EHC) as a potential moderator of intervention effects remains a critical unanswered question. EHC is not merely a correlate of performance; it is a fundamental perceptual-motor barrier that training stimuli must overcome (Hülsdünker et al., 2019; Utama et al., 2023). It is plausible that complex multimodal interventions may inadvertently benefit children with superior basic visuomotor integration, thus widening the performance gap (Matthew effect). The Matthew effect in this context would manifest as the "rich become richer" phenomenon, where small initial advantages in ability could accumulate and be amplified by a training program that is not sensitive to individual baseline differences (Bakermans-Kranenburg et al., 2005). Conversely, if the hybrid model provides adequate external scaffolding (e.g., enhanced feedback from sensory tools), it may narrow the gap, acting as a compensatory mechanism for children with low baseline EHC. The absence of empirical evidence regarding this interaction renders current coaching practices speculative. Coaches cannot ascertain whether the integrated training protocol is an inclusive tool for all athletes or a selective accelerator for those already well-coordinated and transform a potentially polarizing training tool into a universally effective and equity-promoting intervention (Plak et al., 2016).

This study is designed to resolve the specific pedagogical contradiction identified in the research question: the inherent tension between high-volume, accurate repetition required to consolidate motor pathways and the limited attentional capacity typical of children aged 6–9. Therefore, the objective is not merely to analyze the broad effects but to determine whether the sequential multimodal hybrid training protocol can reconcile this contradiction more effectively than conventional constant training. Furthermore, this study aims to clarify whether basic eye-hand coordination (EHC) moderates intervention effectiveness, for example, whether the hybrid model serves as an inclusive developmental tool or as a selective accelerator that differentially benefits those with higher early visuomotor capacity.

Three initial hypotheses were formulated: (1) The hybrid model will result in a significantly greater improvement in forehand drive accuracy compared to conventional training, based on contextual interference and part-to-whole transfer; (2) athletes with high EHC will outperform athletes with low EHC, regardless of training condition, reflecting the fundamental performance constraints imposed by visuomotor integration; and (3) a significant Training × EHC interaction will emerge, with competing predictions between compensatory mechanisms (narrowing the gap) versus Matthew effects (widening the gap) to be empirically tested. Based on the needs analysis, preliminary observations of PTMSI Makassar coaching, and the identification of forehand drive training methods and models previously applied by coaches, the researchers plan to further develop this training model by integrating several methods, including shadow training, dynamic ball exercises, sensory tools, and game-based play. The combination of these various training methods has been summarized into a structured training program.

Materials and Methods

Study Design

A 2×2 factorial, parallel group, quasi-experimental design was used to examine the main and interaction effects of the training model (hybrid vs. conventional) and eye-hand coordination level (high vs. low) on forehand drive performance. The study was conducted at the Table Tennis Training Center of PTMSI Makassar, Indonesia.

Table 1. The 2x2 Factorial Design

Training Model	High EHC	Low EHC
Experimental (Hybrid)	EH_H (n = 7)	EH_L (n = 7)
Control (Conventional)	CH_H (n = 7)	CH_L (n = 7)

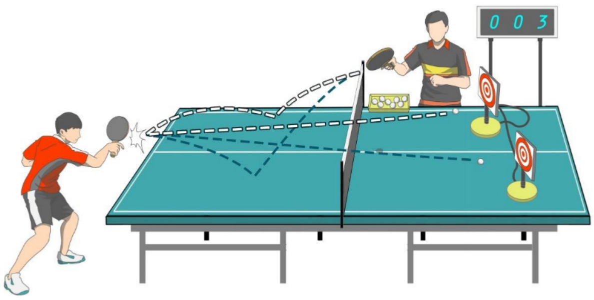
Note: EH_H = Experimental group, High EHC; EH_L = Experimental group, Low EHC; CH_H = Control group, High EHC; CH_L = Control group, Low EHC. All four cells contain 7 participants, yielding a total sample of 28.

Sample and Allocation

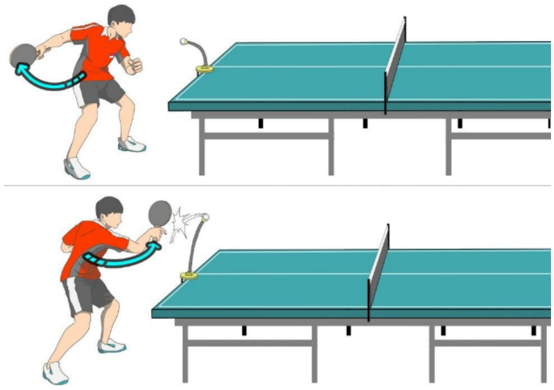
A total of twenty-eight young table tennis athletes (ages 6–9) registered with PTMSI Makassar were recruited through purposive sampling. A priori power analysis conducted using GPower 3.1 (Faul et al., 2007) for a two-way ANOVA ($\alpha = 0.05$, power = 0.80, large effect size $f = 0.40$) indicated that a minimum total sample of 24 participants was necessary; thus, 28 participants were enrolled to account for potential attrition. The inclusion criteria included: (a) active PTMSI membership for at least one year; (b) the ability to perform a basic forehand drive; (c) no history of upper or lower extremity injury within the preceding six months; and (d) willingness to attend all 14 training sessions. The exclusion criteria were: (a) absence from more than two consecutive sessions and (b) any acute illness or injury occurring during the intervention.

Allocation procedure

Due to the need for coordinated access to specific training equipment and coaching schedules, participants were nonrandomly assigned to either the experimental group (hybrid training, n = 14) or the control group (conventional training, n = 14). The allocation was based on the convenience of training slots while ensuring that the groups were balanced in terms of age and initial performance level; subsequent pre-test analysis confirmed baseline equivalence (see Results). Within each group, the 14 athletes were further stratified into high (n = 7) and low (n = 7) eye-hand coordination subgroups based on their age-adjusted Beery VMI standard scores (high: ≥100, low: <100).



(i)



(ii)

Fig. 1. Forehand Training using Dynamic Ball (i) and Sensory Tool (ii)

Procedure

Eye–Hand Coordination Assessment

Eye-hand coordination was assessed before the intervention using the Beery-Buktenica Developmental Test of Visual Motor Integration (Lim et al., 2015). The test requires children to copy 24 geometric forms of increasing complexity within 10–15 minutes. Raw scores were converted to age-adjusted standard scores (M = 100, SD = 15), and participants were classified as high (≥100) or low (<100) EHC.

Training Protocols

Both groups engaged in 14 training sessions (three sessions weekly, each lasting 50 minutes), overseen by certified table tennis coaches. The experimental group adhered to a structured hybrid model comprising: (1) ten minutes of shadow drills without a ball to enhance movement patterns and footwork; (2) fifteen minutes of dynamic ball training utilizing a suspended ball apparatus to promote high-volume repetitive strikes with intrinsic feedback; (3) ten minutes of sensory tools, including visual and auditory targets, designed to improve shot accuracy and proprioceptive feedback; and (4) fifteen minutes of game-based drills, such as modified small-sided matches, to facilitate the transfer of skills into representative contexts. Conversely, the control group underwent traditional training, characterized by repetitive forehand drive exercises devoid of any systematic advancement or integrated elements.

Evaluator and Concealment

All pre-test and post-test evaluations of forehand drive performance were administered by a sole certified table tennis coach possessing 10 years of coaching experience, who remained independent of the training intervention. The assessor was unaware of the participants' group assignments and did not know if any athlete belonged to the experimental or control group during both assessment sessions. Due to the nature of the physical intervention, it was impractical to blind either the coaches administering the training or the participants involved. Nonetheless, data analysts were unaware of group assignments during the statistical analysis phase.

Regulation of External Training Loads

To minimize extraneous variation, all participants and their guardians were instructed to abstain from any supplementary organized table tennis practice outside the designated study sessions throughout the 5-week intervention period. Compliance was assessed via a weekly self-report log; no participant indicated significant external training throughout the study.

Performance Indicator

The performance of the forehand drive was assessed utilizing the validated test established by Rihtiana and Tomoliyus (2014). Each athlete performed 10 forehand drives aimed at three concentric target zones (30×30 cm, 60×60 cm, and 60×60 cm), receiving scores of 5, 3, and 1, respectively, resulting in a maximum attainable score of 50. The instrument exhibits substantial test-retest reliability (ICC = 0.89) and content validity.

Statistical Analysis

Descriptive statistics were computed for each factorial cell. Baseline equivalence was assessed via one-way ANOVA on pre-test scores. To evaluate the intervention effect while controlling for initial differences, a two-way analysis of covariance (ANCOVA) was performed on post-test scores with pre-test scores as the covariate, training model and EHC level as fixed factors, and the two-way interaction term included. Effect sizes were reported as partial eta squared (η^2), interpreted according to Cohen's benchmarks (.01 small, .06 medium, .14 large). Assumptions of normality, homogeneity of variance, and homogeneity of regression slopes were checked and satisfied. All analyses were conducted in SPSS (version 26.0) with $\alpha = 0.05$.

Results

Descriptive analysis presents the mean scores and standard deviations of forehand drive skills in table tennis for athletes in both the experimental and control groups. The two groups were distinguished by their high and low eye-hand coordination abilities. Table 1 displays the average forehand drive scores and standard deviations for each of the four factorial cells. The forehand drive assessment has a maximum score of 50 points. No participant attained this maximum; nonetheless, the highest recorded score was 49 points. Consequently, this measure is sufficiently sensitive to detect changes without range limitations.

Table 2. Pretest and Posttest Forehand Drive Scores

Group	n	Pretest Mean (SD)	Posttest Mean (SD)	Mean Change
Experimental High (EH_H)	7	42.14 (3.67)	45.86 (2.41)	+3.71
Experimental Low (EH_L)	7	41.86 (2.48)	43.43 (1.13)	+1.57
Control High (CH_H)	7	42.71 (1.70)	43.57 (1.51)	+0.86
Control Low (CH_L)	7	41.57 (3.16)	40.71 (2.69)	−0.86

Note: Maximum score = 50 points. SD = standard deviation.

The descriptive analysis in Table 2 indicates that all groups commenced with similar baseline levels, with mean scores between 41.57 and 41.86 for the low category and between 42.14 and 42.71 for the high category. Post-intervention, the experimental groups exhibited more substantial positive changes (+3.71 for EH_H, +1.57 for EH_L) relative to the control groups (+0.86 for CH_H, −0.86 for CH_L). The raw change scores offer preliminary evidence of varying improvement, which was later examined through inferential analysis that considers baseline variance.

Baseline Equivalence

A one-way analysis of variance (ANOVA) was performed on the pre-test forehand drive scores to assess the comparability of the four groups prior to the intervention. The analysis indicated no statistically significant differences between the groups, $F_{(3, 24)} = 0.21$, $p = 0.892$, partial $\eta^2 = 0.026$. The minimal and inconsequential effect size suggests that any pre-existing disparities in forehand drive performance were trivial. Consequently, the assumption of baseline equivalence is fulfilled, thereby enhancing the internal validity of subsequent causal inferences concerning the effects of the intervention. To ensure thoroughness and facilitate comparison with studies presenting basic post-test analyses, a two-way factorial ANOVA was performed on post-test forehand drive scores, utilizing Training Model (Experimental vs. Control) and Eye–Hand Coordination (High vs. Low) as between-subjects variables. The assumptions of normality (Shapiro–Wilk, $p > 0.05$) and homogeneity of variance (Levene's test, $F_{(3,24)} = 0.52$, $p = .672$) were satisfied.

There was a significant difference between the group receiving the hybrid training model and the group receiving conventional training, regardless of eye-hand coordination level ($F_{(1, 24)} = 10.53$, $p = 0.003$, partial $\eta^2 = 0.305$). Additionally, a significant effect of eye-hand coordination level on forehand drive performance was observed: athletes with high EHC consistently scored higher than athletes with low EHC, regardless of the training group ($F_{(1, 24)} = 11.77$, $p = 0.002$, partial $\eta^2 = 0.329$). However, the interaction was not significant. This means that the difference in scores between the hybrid and conventional training groups was not dependent on the child's eye-hand coordination level ($F_{(1, 24)} = 0.08$, $p = 0.783$, partial $\eta^2 = 0.003$), with the hybrid model showing benefits for both high and low EHC children.

In this study, the correlation between pre-test and post-test scores was moderate and positive, $r_{(26)} = 0.52$, $p = 0.005$, which meets the key condition for the effective use of ANCOVA. Therefore, a two-way ANCOVA was performed on post-test forehand drive scores, with pre-test scores as the covariate, training model (Experimental vs. Control), and eye-hand coordination level (EHC High vs. Low) as between-subjects factors, including the two-way interaction term.

Before interpreting the ANCOVA results, the underlying assumptions were tested. The assumption of normality was assessed using the Shapiro-Wilk test for the residuals of each factorial cell; all p values exceeded 0.05, indicating no significant departure from normality. Levene's test confirmed the homogeneity of variances across the four groups, $F_{(3, 24} = 0.52$, $p = 0.672$. The assumption of homogeneity of regression slopes was satisfied, as the interactions between the covariate and each independent variable were not significant: Pre-test × Training Model, $F_{(1, 22)} = 0.06$, $p = 0.814$; Pre-test × EHC, $F_{(1, 22)} = 0.30$, $p = 0.592$. Thus, all assumptions underlying ANCOVA were satisfied.

A significant main effect of eye-hand coordination (EHC) was also observed, $F_{(1, 23)} = 16.90$, $p < 0.001$, partial $\eta^2 = 0.423$, with high EHC athletes (M = 44.54, SE = 0.39) outperforming low EHC athletes (M = 42.25, SE = 0.39). The interaction between the training model and EHC was not significant, $F_{(1, 23)} = 0.001$, $p = 0.991$, partial $\eta^2 < 0.001$, indicating that the magnitude of the hybrid training model's advantage over conventional training did not differ significantly between high and low coordination participants within the constraints of the current sample. To further explore the differences between individual factorial cells, Tukey's Honestly Significant Difference (HSD) post-hoc tests were conducted (Table 5).

The only statistically significant pairwise difference was identified between the Experimental High EHC group

Table 3 (Alternative). TwoWay ANOVA Results for Posttest Forehand Drive Scores

Source	Type III SS	df	MS	F	p	partial η²
Training Model (T)	43.75	1	43.75	10.53	.003	.305
Eye–Hand Coordination (EHC)	48.89	1	48.89	11.77	.002	.329
T × EHC Interaction	0.33	1	0.33	0.08	.783	.003
Error	99.72	24	4.16			

Note. $R^2 = .48$ (Adjusted $R^2 = .42$).

Table 4. TwoWay ANCOVA Results Forehand Drive Scores

Source	Type III SS	df	MS	F	p	partial η^2
Corrected Model	102.96	4	25.74	11.95	<.001	0.675
Intercept	24.25	1	24.25	11.26	0.003	0.329
Pretest	38.24	1	38.24	5.89	0.023	0.204
Training	46.32	1	46.32	21.50	<.001	0.483
EHC	36.40	1	36.40	16.90	<.001	0.423
Training × EHC	0.0003	1	0.0003	0.001	0.991	0.000
Error	49.53	23	2.15			
Total	53107.00	28				
Corrected Total	152.49	27				

Note. R^2 = .66 (Adjusted R^2 = .60). Partial η^2 benchmarks: small ≈ .01, medium ≈ .06, large ≈ .14 (Cohen, 1988).

Table 5. Tukey's HSD PostHoc Comparisons Between Factorial Cells

(I) Group	(J) Group	Mean Difference (I–J)	SE	p	95% CI Lower	95% CI Upper
EH_H	EH_L	2.43	1.09	0.145	−0.62	5.48
EH_H	CH_H	2.29	1.09	0.186	−0.76	5.34
EH_H	CH_L	5.14	1.09	<0.001	2.09	8.19
EH_L	CH_H	−0.14	1.09	0.999	−3.19	2.91
EH_L	CH_L	2.71	1.09	0.081	−0.34	5.76
CH_H	CH_L	2.86	1.09	0.060	−0.19	5.91

Note. SE = 1.09 (pooled from oneway ANOVA MS_within = 4.155, df = 24). Bold text indicates a significant pairwise difference (p-value < .05). All pvalues are adjusted for multiple comparisons.

(EH_H, M = 45.86) and the Control Low EHC group (CH_L, M = 40.71), resulting in a difference of 5.14 points. No further comparisons reached statistical significance. This pattern corresponds with the principal effects observed in the ANCOVA and highlights the synergistic benefit of hybrid training and enhanced baseline coordination in the most favorable condition compared to the least favorable one. However, owing to the absence of substantial interaction in the comprehensive factorial model, these cell-wise comparisons should not be overinterpreted.

Illustration of the Insignificant Interaction

An interaction plot was created to demonstrate the absence of a significant interaction (Figure 2). The graph depicts the mean forehand drive scores for the experimental and control groups at two tiers of eye-hand coordination. The lines representing the two training models are nearly parallel, suggesting that the influence of the hybrid training model was unaffected by the athletes' initial eye-hand coordination. Figure 2 depicts parallel lines, signifying a non-significant interaction.

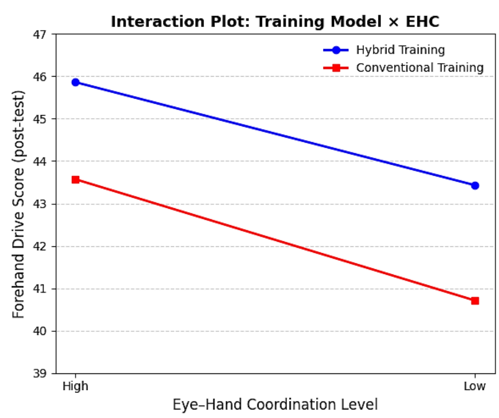


Fig. 2. Interaction Plot of Training Model × EyeHand Coordination on Forehand Drive

Discussion

This study investigated the impact of a sequentially integrated hybrid training model comprising shadow drills, dynamic ball exercises, sensory apparatus, and game-based activities. The influence on forehand drive performance was evaluated in young table tennis players aged 6 to 9 years, considering the significance of eye-hand coordination (EHC). This study's findings can be encapsulated in three principal results: (1) the hybrid training model yielded a statistically and practically significant enhancement in forehand drive accuracy relative to traditional training, after adjusting for pre-test scores; (2) elevated EHC was independently correlated with improved post-test performance; and (3) no significant interaction was observed between the training model and EHC level.

The substantial primary effect of the training model, indicated by a large effect size partial η^2 = .483, aligns with research highlighting the advantages of diverse and organized training. All elements of this hybrid protocol conform to established principles of motor learning. Shadow training deconstructs movement patterns and diminishes the cognitive burden associated with ball tracking (Gusman et al., 2025; Robin & Dominique, 2025; Pratama, 2021). Dynamic ball exercises offer the necessary repetition volume to improve motor pathways while incorporating intrinsic feedback (North et al., 2019; Asri et al., 2017). The sensory apparatus offers supplementary feedback aimed at enhancing spatial precision (Basiri et al., 2020), which is crucial for athletes to accurately track and respond to moving objects during dynamic ball exercises. Game-based training exposes participants to progressively distracting contextual conditions, which has been demonstrated to improve skill retention and transfer (Vaghetti et al., 2023; Pane et al., 2020; Galatti et al., 2019; Schmidt & Lee, 2019). By amalgamating these elements into a unified session, the hybrid model may have fulfilled the requirement for engaging, repetitive practice for youth while maintaining balance. The Beery VMI test employed in this study assesses visual perception, motor planning, and fine motor control, all pertinent to the demands of striking small, rapidly moving targets. The recent discovery that EHC can autonomously predict the precision of the forehand drive aligns with prior research and indicates that EHC assessment may serve as an effective instrument for identifying young athletes (Susetyorini et al., 2019) who might gain from enhanced motor-perceptual training.

Research by Basiri et al. (2020) demonstrates that visual training, when combined with forehand practice, improves reaction time, anticipation-coincidence timing, and eye-hand coordination, as well as the acquisition and retention of the forehand drive in novice players. This corresponds with the study's findings, indicating that enhancing EHC capabilities through visual training can aid in the acquisition of technical skills, such as the forehand drive in table tennis. This study illustrates that integrating varied visual and motor exercises into a hybrid training model validates the importance of visual-based training, especially eye-hand coordination, in the enhancement of complex motor skills. Extensive research by Johor & Rahmadiky (2020) and Kurniawan & Rangkuti (2020) demonstrated that eye-hand coordination and arm strength significantly correlate with forehand drive proficiency, each accounting for over fifty percent of the variance in this skill within their respective samples. These findings correspond with the study's results, indicating that EHC functions as an independent predictor of forehand drive accuracy. This study found no significant interaction between training models and EHC levels; however, the results substantiate the claim that EHC significantly affects technical performance. The positive correlation between eye-hand coordination and arm strength with stroke proficiency suggests that these elements are crucial for the development of motor skills in table tennis (Sharma et al, 2024).

Mongsidi et al. (2023) illustrate that focused eye-hand coordination training significantly improves forehand drive skills in children. The findings endorse the training methodology utilized in the hybrid model, indicating that exercises focused on repetition and reinforcement of motor coordination with a dynamic ball can improve the precision of the forehand drive movement. The results correspond with current literature, indicating that enhancing fine motor coordination and visual perception in a sports context can accelerate the acquisition of intricate technical skills. Shinkai et al. (2024) demonstrated that during a forehand rally with a moving ball, the coordination of the eyes, head, and arm is markedly temporally synchronized, revealing correlations between the head and arm, as well as between the eyes and arm. Research indicates that hand-eye coordination, a component of perceptuo-motor skills, can predict future competitive performance and reduce dropout risk in youth table tennis, highlighting its importance in long-term athlete development (Faber et al., 2023). This indicates a strong correlation between integrated visual and motor movements in the forehand technique of table tennis. This study suggests that improved visuomotor coordination, marked by better synchronization of eye, head, and arm movements, may substantially enhance forehand skills. These findings provide a framework for enhancing motor coordination training in forehand instruction, as head and eye movements, in conjunction with arm movements, are crucial for refining the accuracy and timing required for this technical skill (Warzuqni et al, 2025).

This study offers initial evidence on the efficacy of the hybrid training model and the independent function of EHC; however, the lack of a significant interaction between the training model and low-level EHC indicates the necessity for additional research with a larger sample size. The interaction effect between training model and eye-hand coordination (EHC) level on forehand drive performance was non-significant with a negligible effect size. Any alternative interpretation of this interaction is erroneous. Future research should examine moderating variables or non-linear relationships that could elucidate the connection between eye-hand coordination and technical skills within the framework of table tennis training. Moreover, research incorporating biomechanical or neurophysiological assessments, such as those performed by Shinkai et al. (2022), will yield enhanced understanding of the mechanisms driving skill enhancement.

Limitation

Multiple facets of the study design must be contemplated when analyzing the results. The sample size (n = 28; 7 per cell) was established through a priori power analysis and was adequate for detecting large main effects with high precision; however, the statistical power to discern small or moderate interactions was constrained. The study lacked kinematic or physiological measures that could clarify the mechanisms behind any training effects, and the sample was sourced from a single training center, potentially limiting external validity.

Conclusions

The hybrid training model, integrating shadow drills, dynamic ball equipment, sensory devices, and game-based activities, significantly improves forehand drive performance in children aged 6–9 years compared to conventional repetitive training, with a substantial effect size (partial $\eta^2 = 0.483$). Higher baseline eye-hand coordination is associated with better forehand drive accuracy. The interaction between training model and EHC level was non-significant with a negligible effect size.

Ethics Approval and Consent to Participate

Ethical approval for the research protocol was obtained from the Research Ethics Committee of Universitas Negeri

Jakarta (Approval No: 2716/UN39.6.Ps/LT/2023. Informed consent was obtained from all individual participants included in the study prior to their involvement.

Data Availability Statement

Data are available from the corresponding author upon reasonable requestю

AI Transparency Statement

The authors used AI-assisted tools for language editing and for generating the code used in Figure 2. The authors take full responsibility for the content of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Вплив гібридного тренування, що поєднує імітаційні вправи, динамічні вправи з м'ячем, сенсорні вправи та ігрові завдання, на результативність удару справа у юних гравців у настільний теніс: факторний дизайн 2×2

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 5 табл., 2 рис., 32 джерела.

Передумови. Оптимальні протоколи тренування удару справа у юних гравців у настільний теніс (6–9 років) усе ще перебувають на стадії розроблення. Хоча імітаційні вправи без м'яча, динамічні вправи з м'ячем, сенсорні засоби та ігрові вправи мають окремі переваги, жодне дослідження не інтегрувало ці методи в єдину гібридну модель. Крім того, модифікувальна роль вихідного рівня координації «око–рука» (EHC) залишається нез'ясованою, що обмежує можливості розроблення інклюзивних тренувальних програм.

Мета. Дослідження мало на меті вивчити вплив гібридної моделі тренування на результативність виконання удару справа та оцінити, чи залежить її ефективність від вихідного рівня координації «око–рука» спортсмена.

Матеріали та методи. Було застосовано квазіекспериментальний дизайн 2×2. Двадцять вісім спортсменів із PTMSI Makassar були розподілені на експериментальну (n = 14) та контрольну (n = 14) групи, а також стратифіковані за високим або низьким рівнем координації «око–рука» (визначеним за допомогою тесту Beery VMI). Точність виконання удару справа (максимальний бал — 50) оцінювали до та після 14 тренувальних занять (по 50 хвилин, тричі на тиждень). Аналіз даних проводили за допомогою двофакторного ANCOVA з контролем показників попереднього тестування.

Результати. Після коригування результатів гібридна група продемонструвала достовірно вищі показники порівняно з контрольною групою ($M = 44.68$ проти 42.11; $p < 0.001$, partial $\eta^2 = 0.483$). Спортсмени з високим рівнем координації «око–рука» показали кращі результати, ніж спортсмени з низьким рівнем координації «око–рука» ($M = 44.54$ проти 42.25; $p < 0.001$, partial $\eta^2 = 0.423$). Взаємодія між типом тренування та рівнем координації «око–рука» не була статистично значущою ($p = 0.991$).

Висновки. Гібридна модель тренування достовірно покращила результативність виконання удару справа порівняно з традиційними методами тренування. Тренерам рекомендується інтегрувати всі чотири методи тренування у щоденні програми підготовки. Отримані результати підкреслюють важливість інтеграції різноманітних тренувальних підходів у ранньому віці та свідчать про потенційні можливості їх застосування у дитячій фізіотерапії та реабілітації рухових функцій.

Ключові слова: настільний теніс, удар справа, гібридне тренування, координація «око–рука», ранній дитячий вік.

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