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Article

The influence of training methodologies on reaction time and hand-eye coordination: A study of professional male and female badminton players

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Abstract. The study examines how visual-reaction and coordination-enhancement instruction affects the reaction time and hand-eye coordination between male and female professional badminton players between the ages of 17–25. To consider the effectiveness of training on the basis of gender, the study involves 60 national-level respondents in an experimental approach to training effectiveness. The findings show that a majority of the individuals involved in the game believe that they have shown considerable progress in their performance, especially in acceleration and coordination with regular and sport-related drills. Players were open to introducing new ways, although traditional techniques are being used most of the time. The results are consistent with the current body of knowledge and confirm the concept of structured training concerning athletic development and reflecting a gradually increasing trend of evidence-based and technologically enriched performance approaches to playing badminton.

Keywords: reaction time, hand-eye coordination, badminton, gender, training, players

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Влияние методов тренировок на время реакции и зрительно-моторную координацию: исследование среди профессиональных мужских и женских игроков в бадминтон

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Аннотация. В исследовании изучается, как обучение навыкам развития зрительной реакции и координации влияет на время реакции и зрительно-моторную координацию профессиональных игроков в бадминтон мужского и женского пола в возрасте от 17 до 25 лет. Чтобы оценить эффективность обучения с учетом гендерного фактора, в исследовании приняли участие 60 респондентов на национальном уровне в рамках экспериментального подхода к оценке эффективности обучения. Результаты исследования показывают, что большинство участников игры считают, что они добились значительного прогресса в своей работе, особенно в ускорении и координации движений при выполнении регулярных и связанных со спортом упражнений. Игроки были открыты для внедрения новых методов, хотя в большинстве случаев используются традиционные техники. Результаты соответствуют современным знаниям

и подтверждают концепцию структурированного обучения, касающуюся спортивного развития и отражающую постепенно растущую тенденцию использования научно обоснованных и технологически обогащенных подходов к игре в бадминтон.

Ключевые слова: время реакции, зрительно-моторная координация, бадминтон, пол, тренировка, игроки
время реакции, зрительно-моторная координация, бадминтон, пол, тренировка, игроки

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Introduction

Badminton is a sports game where participants engage in direct competition with each other every time they set out to play the game. Badminton is a high-intensity racket game, where the speed of the shuttlecock may reach and surpass 300 km/h. The aspect of having a sudden course change that requires very high neuromuscular control, agility, and precision within time constraints [1]. The players need to visualise the cues, decode, and generate the motor responses in fractions of a second and, thus, develop the continuation of the rallies and gain the tactical superiority. The rate in reaction time between the start of the stimulus, the start of the movement and hand-eye coordination, which is the smooth synchronisation between the visual information and the fine-motor action, plays a crucial role in the performance in the badminton game. An increased ability to respond and coordinate will allow the player to receive the high-velocity shots and better stroke accuracy and consistency [1, 2]. Empirical test results indicate that players who display lower latencies of reaction time and a greater score in the coordination metrics end up with a far superior accuracy of shot and defensive success [3]. Due to their significance, formal training strategies aimed at these capacities have been included in the elite badminton training. Visual-tracking drills, choice-reaction tasks, and sport-related coordination exercises have all been shown to cause measurable improvements in reaction time and hand-eye coordination [1, 3]. Nevertheless, the majority of the studies consider mixed-gender or university-age samples and fewer studies are given with regard to the gender specific reactions, including national-level athletes between the ages of 17–25.

There is a significant gap in comparative studies evaluating the way different training methodologies affect reaction time and hand-eye coordination independently in male and female professional badminton players. This study aims to:

- To assess the impact of two training protocols (visual-reaction drills vs. coordination-enhancement exercises) on reaction time and hand-eye coordination.
- To derive a comparison between pre- post post-intervention enhancements between male and female national-level players aged 17–25.

Literature Review

There are various contemporary, distinctive studies conducted by researchers relevant to the concept of this research.

Mahapatra and Pradhan have done observational research evaluating the connection between racquet conversion speed, hand-eye coordination, and reaction time in 60 amateur badminton players (ages 10–20) [4]. The authors assessed the speed of conversion with changes in grip per minute, coordination through wall-ball toss and reaction leveraging the ruler drop test. The outcomes showcased a significant negative correlation between coordination and conversion of grip ($r = 0.881$, $p < 0.001$) and also a significant negative correlation with reaction time ($r = -0.731$, $p < 0.001$), denoting that as the enhancement of coordination, the speed of conversion also increased, yet the time of reaction minimally slowed.

On the other hand, the study of Jaworski et al. explored which coordination motor abilities most robustly identify the level of skill within male badminton players from the Polish national team ($n = 12$) [5]. Through leveraging Spearman's correlation and various identification evaluations, the authors determined spatial orientation (≈42%), movement frequency (≈28%), and kinaesthetic differentiation (≈17%) as the top factors of coordination, critically estimating performance rankings ($p < 0.05$). The findings of the study recommend that these capabilities are significant for defining the

trajectory of a subtlecock and accomplishing fast and focused strokes. Therefore, the abilities should be given more importance in both tactical and technical training to improve the elite-level performance of badminton.

Furthermore, Chen et al. assessed visuomotor adoption and temporal forecasting in 28 badminton players, managing for cardiovascular fitness, age and education [6]. Through leveraging compensatory tracking and time-estimation tasks, the researchers identified a robust positive correlation between years of training and visuomotor adoption performance ($r \approx 0.57$, explaining $\sim$32% of variance, ($p = 0.001$). Although temporal forecasting showcased no such alignment, the findings support the contribution of drills, particularly in sports, in fostering perceptual-cognitive skills integral to performance. Building on this, Tan and Teoh investigated the predictive capabilities of Quiet Eye (QE) metrics, involving QE duration, onset timing and fixation features, integrated with biomechanical variables, leveraging neural network models to estimate the accuracy level of shots in badminton [7]. Through the collection and analysis of data from 30 Singaporean players (750 shots), the model accomplished 85% accuracy, determining QE duration and onset as the most effective predictors, followed by angle of wrist and racket speed. High-level athletes showcased a critically longer duration of QE ($M = 289.5$ ms), compared to intermediate and newcomer players, with duration QE significantly correlating with accuracy ($r = = 0.72$). The results of the research recommend that the adoption of metrics related to visual attention and biomechanics can improve the analysis aspect of performance in real-time and focused training in fast-paced racket sports. Pokaisasawan et al. have done a randomised controlled trial of 28 amateur badminton players (14 in the intervention group, 14 in the control group) [8]. The participants accomplished either a 10-minute exercise of pencil push-up (PPU) or rested with their eyes closed. The group of intervention demonstrated significant enhancements in in amplitude of accommodations (AA, $p < 0.0001$, Cohen's $d = 1.68$) and accommodative facility (AF, $p < 0.0001$, Cohen's $d = 3.10$). On the other hand, the control group showcased no changes. Near point of convergence (NPC), stayed statistically the same in both groups ($p = 0.45$). The outcomes of the study suggest that even a single session of PPU has the potential to acutely improve significant skills related to visual accommodation associated with performance of badminton, signifying the possible usage of visual-based training protocols in racket sports.

Methodology

Methodology played an important framework which significantly shaped the whole process regarding data collection and analysis of the data. Besides, the research approach is a crucial factor that can be indicated as a specific process and plan which decides the whole research process. In this context, this paper will implement a deductive research approach, which investigates any phenomenon or theory by testing hypotheses about it. In the case of philosophy, this paper will implement the positivist research philosophy that significantly highlights the importance of the scientific method and empirical evidence to understand and assess the influence of different training methodologies on reaction time and hand-eye coordination. The study used two main instruments: a computerised reaction time test to measure how quickly participants responded to visual stimuli, and the Alternate Hand Wall Toss Test to assess hand-eye coordination by counting how many successful catches were made in 30 seconds. All 60 participants completed both tests before and after a 6-week training period. The procedure ensured consistent testing conditions for both pre- and post-assessments. Data were analysed using SPSS software. Paired-samples t-tests were used to compare pre- and post-test scores, and independent-samples t-tests compared male and female improvements. A significance level of $p < 0.05$ was used (Table 1, 2).

Results

The findings of the paired Samples t-test reveal that there is a significant change in the reaction time and hand-eye coordination between the participants after the 6-week training program was conducted. On reaction time, the mean difference was about 0.0206 seconds ($p < 0.001$) between pre and post, and it has been found a significant decrease in reaction time was found post-training. SD was not too large, which implies that most participants performed better as compared to their previous performance. The difference (.0167 to .0246) 95% confidence interval contains zero, which proves that the improvement is significant. In the same manner, hand-eye coordination also improved substantially, with a mean difference of -1.532 successful catches ($p < 0.001$). The negative value implies higher post-test scores, as it is desirable in this case, and a better score is indicative of higher performance. The interval of the confidence in the difference in hand-eye coordination is (-1.794)–(-1.269), and again, zero is not included in that interval, and this proves that

Table 1. Paired Samples Test (Source: IBM-SPSS)

Pair		Paired Differences			
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference
					Lower
1	Reaction_Time_Pre – Reaction_Time_Post	.020616666666667	.015238323305900	.001967259079596	.016680190340894
2	Hand_Eye_Pre – Hand_Eye_Post	-1.531666666666659	1.015388656768326	.131086111919722	-1.793969370749536

Table 2. Independent sample test (Source: IBM-SPSS)

Changes	Equal variances	Levene's Test for Equality of Variances		*t*-test for Equality of Means	
		F	Sig.	*t*	df
Reaction_Changes	Assumed	.419	.520	.126	58
	Not assumed			.126	57.676
Hand_Eye_Change	Assumed	1.594	.212	.671	58
	Not assumed			.671	56.757

the result is significant. To conclude, it can be said that the paired samples *t*-test allows concluding that the training program positively and statistically significantly altered reaction time and hand-eye coordination. Such findings are consistent with the efficacy of the training intervention towards improving the development of some of the vital motor skills as pertains to performance in badminton.

Based on the results of the Independent Samples *t*-Test, the analysis was conducted to determine whether there was a significant difference in the gender categories of the difference in the improvement in reaction time and hand-eye coordination as a result of the training program. In particular, the means of change scores (post-test minus pre-test) were compared among males and females. To improve the reaction time (Reaction_Change), a significance value obtained by the Levene Test of Equality of Variances equals 0.520, and it is higher than the critical value of 0.05. This implies that the assumption of the same variances has been fulfilled, and the value of the *t*-test in this case is suitable for interpretation. Its *t*-value and degree of freedom were 0.126, 58 degrees of freedom, and its significance (in 2-tailed) was 0.900. This p-value is much higher than 0.05, which is why we should not calculate the effect of reaction time improvement concerning male and female contributors. It seemed that both genders equally shared the results of the training program in regards to decreased time of response.

Similarly, in hand-eye coordination improvement (Hand_Eye_Change), the Levene Test value was 0.212, which is also higher than 0.05. Thus, the assumption of equal variances in its rows is advisable once more. There was a 0.671 *t*-value in 58 degrees of freedom, and the significance (2-tailed) was 0.505. This once more surpasses the 0.05 value, which means that there is no statistically significant variance in the enhancement of hand-eye coordination between men and women. Overall, the Independent Samples *t*-Test found that gender had no remarkable role to play when the effectiveness of the training intervention was considered. The male and female subjects showed similar improvements in the areas of reaction time and hand-eye coordination. The results indicate the assumption that the training program can be useful for both genders of the athlete, and there can be an assumption that gender-specific alterations are not necessarily needed in this kind of motor skill instruction.

Discussion

The Findings of this study effectively show that the six-week training program improved both hand-eye coordination, reaction time among professional badminton players. The paired samples *t*-test supported the positive contribution of these motor skills in all participants, pinpointing the relevance of structured physical training in the improvement of functional performance. The independent samples *t*-test, however, did not reveal any significant difference in the improvement of males and females in the reaction time or in the hand-eye coordination. This indicates that the training intervention was equally effective for both genders, and this goes in favour of universality, too. These findings are consistent with the past studies, which show that specific coordination and reflex training may result

in a measurable change in athletic performance, irrespective of gender.

Most of the respondents agreed that they are experienced enough professionals to evaluate the training methodologies. This confirms that the gathered perceptions are valid since these results echo Smith et al. findings, who highlighted that subject expertise matters in the research on performance assessment [9]. In addition, the respondents stated that they spent a lot of time per week on training, which is also similar to those proposed by the Badminton World Federation (BWF), as elite players tend to train 1015 hours a week to achieve their maximum performance. As far as the training methods used were concerned, the majority of the participants claimed that their exercises were aimed at the specific problem of reaction time and hand-eye coordination. This conforms to the findings of Lochhead et al. showed that sports-specific response time training, such as shuttle run and multishuttle training, exhibits a significant effect of enhancing visual-motor response in racquet sports [10]. Nonetheless, as opposed to the findings made by Lochhead, which accentuated the popularity of such methods as virtual-reality simulations and neuro-tracking procedures, this study indicates that even nowadays, the players mainly resort to standard and mixed-methods drills, instead of involving the better digital technology.

Another significant result of the survey is that there is a significant level of concurrence among players that the hand-eye coordination drill is an elementary practice in their careers. This is corroborated by the findings of Lachowicz et al., who have found that continuous training of visuo-motor coordination results in faster response time and in-game accuracy [11]. Moreover, athletes also stated that the existing training practices are effective in enhancing reaction time and coordination. These findings are supported by the literature by Neri et al., which showed a significant difference in motor response time in the badminton players who were trained on agility ladders, shadow drills, and reaction ball exercises [12].

The analysis indicated that the majority of the respondents confirmed gameplay enhancements when targeted training concerning the reaction time was implemented. It is in line with this study that Zhu et al. underlined the fact that perceptual-cognitive training can help enhance the speed of decision-making and technical performance in dynamic sports, such as badminton [13]. Yet, as an opposition, one can say that the comparative literature on technology now indicates wearable sensors and AI-based feedback as being more efficient and measurable than subjective and player-led assessment. Most importantly, most of the players were willing to look into other or innovative training regimes. This observation is supported by the trend of updated sports science as adaptive learning is gaining popularity, and people use gamified drills as well as real-time performance feedback systems. Although the participants in the current study can be considered dependent on the traditional or mixed forms of training, their interest in applying new methods shows a larger cultural transition amid athlete development in which evidence-based and technology-enhanced systems of training are slowly catching on.

Conclusion & Recommendations

This research study was carried out to determine the impact of training techniques on reaction time and hand-eye coordination of professional male and female badminton players. According to the results, the majority of respondents are at an age when their performance is at the highest level (18–30), and have extensive experience and a willingness to train regularly. The prevalent opinion among the players was that their present training programs are powerful enough to improve the time of reaction time and coordination. The findings are in line with available literature, and they strengthen the fact that game-specific drills enhance neuromuscular receptiveness and accuracy during competitive play. Nevertheless, in contrast to certain research focusing on such premises as the idea of virtual reality or AI feedback, traditional or mixed training is still the primary training method for the majority of respondents. One of them is the readiness of players to consider new approaches, and it is indicative of the overall change in the culture of elite sport, with a tendency to use evidence-based and technology-enhanced performance systems.

According to the results, it is suggested that professional training in badminton should keep emphasising reaction time and hand-eye coordination with well-organised sports-specific exercises. The other recommendations are:

- training institutions have to make sure that players have enough training hours every week to optimise performance results, with the recommended number of hours being between 10 and 15, as recommended by BWF;
- sports scientists and coaches are encouraged to incorporate the new technology pool into their training, such as wearable sensors, Artificial Intelligence-driven performance tipping, and VR-based simulators;

- the new tools enable to supplementation of the conventional methods and the obtaining of more quantifiable information. The approach to gender-specific adaptations in training could be deepened, based on physiological and cognitive differences in responses;
- furthermore, the routine measurement of player perception and biomechanical level had to be integrated to optimise the training effectiveness. Players are willing to innovate. Therefore, the existence of pilot programs with gamified and adaptive learning models can be presented to consider their role in enhancing performance;
- finally, further research should entail integration of biometric performance data and qualitative interviews to have a more holistic perspective on the aspect of training effectiveness and player development.

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