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Effects of Futsal Sports-Specific Training on Neuromuscular Coordination in Youth Male Futsal Players

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ABSTRACT

Introduction: The studying neuromuscular coordination is integral to futsal training as it provides valuable insights into performance enhancement, injury prevention, optimized training strategies, and talent identification and development. By integrating knowledge of neuromuscular coordination into coaching and training practices, futsal teams can strive for higher levels of success on the court while minimizing the risk of injuries and maximizing the potential of their athletes. This pre-experimental research aimed to evaluate the effect of futsal sports-specific training on neuromuscular coordination in youth male futsal athletes, both before and after 4 and 8 weeks of training.

Methods: The sample was obtained by calculating the sample size to estimate the average population size as the population size was known, totaling 26 youth male futsal athletes, by using a systematic random sampling method. The experiment instrument was a futsal sports-specific one that combined specific futsal training and plyometrics three days a week for eight weeks, finding the Index of item objective congruence (IOC = 1.0). The instruments used to collect data were the FAF's slalom test to assess the change of direction and the eye-body movement test to assess the reaction time. Descriptive statistics include percentages, means, standard deviations, and inferential statistics, including one-way analysis of variance with repeated measures and the Bonferroni test, with statistical significance set at the 0.05 level.

Results: The results found that the futsal athletes had a mean resting heart rate of 75.54 bpm, their heart rate during exercise was 150.16 bpm, and their RPE during exercise was 13.36. When conducting a one-way ANOVA with repeated measures, it was found that only reaction time was significantly different before, the 4th week and after the 8th week of training. Comparing the mean pair, it was found that reaction time decreased significantly both before and after the 4th week, before and after the 8th week, and after the 4th week and after the 8th week.

Conclusion: Futsal sports-specific training is a complex program that influences futsal players' performance, specifically depending on neuromuscular characteristics such as reaction time, agility, and change of direction.

Keywords: Futsal sports-specific training, neuromuscular coordination, futsal player

Introduction

Futsal is officially licensed by the Fédération Internationale de Football Association (FIFA) and is becoming more popular around the world; according to Barbero-Alvarez et al [1], futsal is a team sport that uses running with maximum speed and intensity over a shorter distance than other sports such as football [2], basketball [3], and handball [4]. It is clear from the above that this is futsal exercise at its most intense level. For futsal athletes, the running-to-rest ratio is roughly 1:1; running is defined as covering a distance at a moderate, fast, or quickest speed; resting is the player strolling or running slowly. Barbero-Alvarez et al. [1] stated that futsal players use low intensity in playing (50-60% of HRmax) every 14 seconds, moderate intensity (60-70% of HRmax) every 37 seconds, and high intensity (70-80% of HRmax) every 43 seconds, and the highest level of intensity in playing (which will be 80-90% of HRmax) every 56 seconds. While playing, players will change direction every 3.3 seconds. From this evidence, it can be concluded that futsal is constantly evolving and is a type of sport that uses anaerobic running at maximum speed, more than football and other types of speed sports [5].

In addition, Chaddock et al [6] stated that futsal is unique in that it is a sport that involves exercising at the highest level of intensity (80-90% of HRmax). It is noteworthy that in recent years, the number of futsal-related studies has increased significantly, and it has been described that the performance characteristics of futsal athletes while competing for maximum efficiency must include [7], physiological factors [8], neuromuscular coordination [9], or biochemical responses [7]. In addition, many sports scientists have suggested that what is especially interesting about futsal athletes is their anatomy and physiology [2]. In particular, neuromuscular properties play an important role in futsal, such as running speed, agility, and changing directions [9]. If athletes have better neuromuscular coordination than other athletes, they will tend to use speed and change direction faster than other athletes. [10]. In addition, there are studies by Milanez et al [9] and Ribeiro et al [4] that investigated the relationship between neuromuscular coordination. It was found that there were important changes in muscle function after futsal matches [10, 4], especially the decrease in force and muscle work. This may be due to the fatigue that occurs after the competition.

Moreover, it has a reduced running speed that is statistically significant [11]. For this reason, the nervous system, muscle speed, and agility of athletes are important things that should be developed and promoted [12]. Agility performance is a complex test that combines reactive agility, change of direction speed (CODs), and straight running [13]. It can be seen that futsal is a complex sport to practice for body movement. Futsal sports-specific training is a high-intensity workout that combines muscle strengthening exercises followed by plyometric exercises to increase the activity of the central nervous system (CNS) and increase the strength of type IIb muscle fibers, resulting in maximal explosive force [13]. Barbero-Álvarez, et al [15] found that combined training that will affect the maximum physical performance of athletes, especially running speed, must consist of two main factors: the number of steps and the length of the stride. The maximum force occurs during the stride length; therefore, the main factor in increasing running speed is that athletes should train to increase lower limb strength regularly, three days a week. A study by Jason et al [16] also studied the long-term effects of complex training and found that complex training affects the explosive power of muscles, such as jumping and speed. Freeman's study [17] found that combined exercise is the interaction of the neuromuscular system, specifically the relationship between the contraction of type 2a and type 2b muscle fibers, and develops to maximum strength, also known as explosive power. In summary, it was found that complex training has been used with many different types of athletes with great success.

From the above studies, it has been shown that futsal is considered a sport that combines strength, speed, change of direction, and the coordination of the neuromuscular systems. Most literature reviews discussed game analysis or players' physiological needs during playing and training [1]. Despite the popularity of futsal, there may be a lack of scientific research, especially focusing on the effects of sports-specific training on neuromuscular coordination in youth male players. Addressing this gap in the literature can advance our understanding of futsal's unique physiological and biomechanical demands and inform evidence-based coaching practices. However, few studies have examined the effectiveness of futsal sports-specific training on neuromuscular coordination in futsal athletes.

For this reason, futsal players with higher neuromuscular coordination might be more likely than players with lower neuromuscular coordination to play in accordance with the coach's playing style [18], thoroughly covering the relationship between strength, speed, change of direction, and the neuromuscular system. Therefore, the researcher was interested in studying the effects of futsal sports-specific training on neuromuscular coordination before and after the 4th and 8th weeks in youth male futsal athletes. The hypothesis that futsal sports-specific training results in the neuromuscular coordination of youth male futsal athletes in Sakon Nakhon Province before, after the 4th week and after the 8th week was different. Despite the importance of developing knowledge, there is still a need for personnel who need to study and understand every aspect of knowledge continuously and thoroughly. So that sports personnel, especially futsal, can apply it appropriately.

Methodology

Participants

This study was approved by the Institutional Review Board of Thailand National Sports University No. 081/2565 in Thailand and was conducted in accordance with the Declaration of Helsinki.

Twenty-six youth futsal players aged between 15 and 17 were registered as athletes of the Sakon Nakhon Province Sports Association. In summary, selecting youth futsal players aged 15 to 17 as the target population allows researchers to investigate the intersection of neuromuscular coordination. By focusing on this age group, the study can provide valuable insights for improving training strategies, reducing injury risks, and maximizing the athletic potential of young futsal players. Systematic random sampling from this formula $k = \frac{240}{16}$ = 15; therefore, athletes with numbers 1, 16 (1+15), 31 (16+15), 46 (31+15), and 61 (46+16) will be the sample and the samples will be randomly drawn systematically until the number is reached, derived from the calculation formula, is used to estimate the mean population size in cases where the population size is known [19]. $NZ^2_{\alpha/2}$ is the specified confidence (1.96) [19], σ^2 is the variance (0.60) [20], ***d*** is the effect size value (2.54) [20], with an estimated influence size value (0.5) [21], and *n* is the population (313). The calculation formula is as follows:

$d = \frac{\overline{x_1} - \overline{x_2}}{s}$; $\overline{x_1}$ = mean of pre-test, $\overline{x_2}$ = mean of post-test, s = standard deviation of pre-test [20]

$$n = \frac{NZ^2{}_{\partial/2}\sigma^2}{d^2(N-1) + Z_{\partial/2}\sigma^2}$$

$$n = \frac{313(1.96^2)6^2}{2.54^2(313-1) + 1.96^2(6^2)}$$

To prevent dropout, the researcher increased the sample size by 30 percent (n = 26).

Intervention

The futsal sports-specific program training was performed thrice weekly for eight weeks (Monday, Wednesday, and Friday). Initially, players were warmed up at 50–60% of HRmax and 6–8 of rating of perceived exertion (RPE) for 10 minutes, then week 1–2 they performed futsal sports-specific program training at 60–70% of HRmax and 9–11 of RPE, and week 3–8 they performed futsal sports-specific training at 70–80% of HRmax and 12–16 of RPE for 40 minutes and cooled down for 10 minutes. The RPE scale presented of the perceived exertion scale (Borg RPE 15 points, 6–20) [20]. The minimum effort should elicit a rating of 6 (absence of any effort), while the RPE rating of 19 should elicit the maximum effort required to perform maximum repetitions (extremely hard).

On Monday of each week, players performed program 1 (20 minutes), followed by program 2 (20 minutes), divided into four groups (6-7 players each). Stand at designated points X1, X2, X3, and X4.

Program 1: Firstly, starting with Y1, the first player passes the ball to player 1 of group 2 (Y2) with his inside foot and moves it to the left following the arrow, then maximum speed to X5, performs explosive step-ups three times (A1), then maximum speed to position X3, and lines up to wait for the next round of training. Finally, player 1 of the next group (X2, X3, and X4) in each group does the same as player 1 of group 1 (Y1) until everyone is complete and within the specified time (Figure 1a), resting for 5 minutes.

Program 2: First, starting with player 1 of group 1 (Y1) passing the ball inside his foot to the left to player 1 of group 2 (Y2) following the arrow. Maximum speed to A1, performing drop jumps three times, then maximum speed to X4, and line up to wait for the next round of training. Finally, player 1 of the next group (X2, X3, and X4) in each group does the same as player 1 of group 1 (Y1) until everyone is complete and within the specified time (Figure 1b).

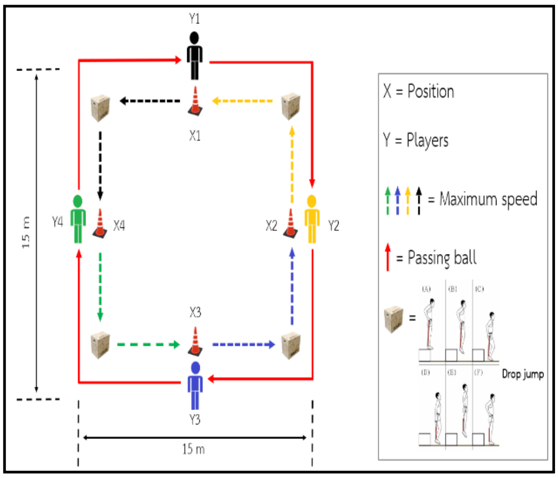

Figure 1a

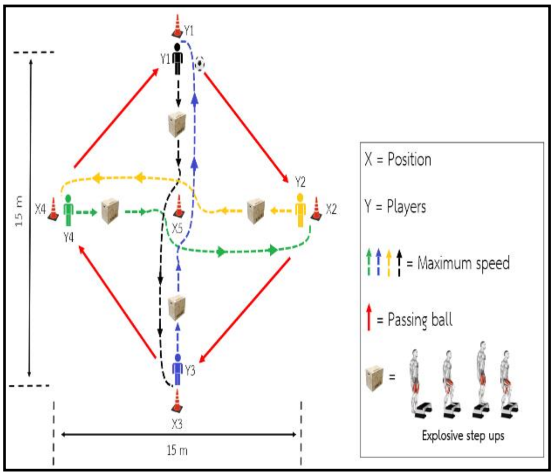

Figure 1b

On Wednesday and Friday of each week, players perform programming 1 (20 minutes), followed by program 2 (20 minutes), divided into two groups of 13 players each to train thoroughly and reduce the rest period of the athletes (both groups performed the same). Each group is represented by the symbols Y1–Y13 and lines up at position X1.

Wednesday, program 1: First, start with player 1 of each group (Y1) dribbling the ball with maximum speed around the cones at positions X1, X2, and X3, then stop the ball at position X4 and pass the ball back to the next player (Y2) at position X1, then speed to position X5, performing skater hops. After that, maximum speed to position X6, performing high knee raises, then maximum speed to position X7, and returning to the end of the line to wait for the next round of training. Finally, the next players (Y2-Y13) perform the same as player Y1 until everyone is complete and within the specified time (Figure 2a).

Program 2: Program 2: First, start with player 1 of each group (Y1) dribbling the ball with maximum speed around the cones at positions X1, X2, and X3, then stop the ball at position X4 and pass the ball back to the next player (Y2) at position X1, then speed to position X5, performing burpee. After that, maximum speed to position X6, performing high knee raises, then maximum speed to position X7, and return to the end of the line to wait for the next round of training. Finally, the next players (Y2-Y13) perform the same as player Y1 until everyone is complete and within the specified time (Figure 2b).

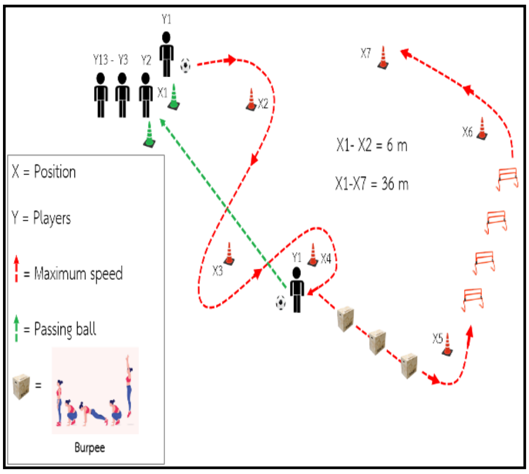

Figure 2a

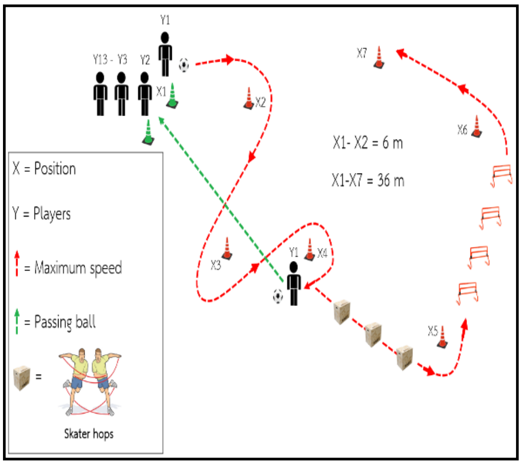

Figure 2b

On Friday, program 1: First, start with player 1 of each group (Y1) performing skater hops, then use maximum speed to pick up the ball from player Y13 to score a goal. After scoring a goal, player Y1 moves to replace player Y13, and player Y13 moves to the end of the line to wait for the next round of training (X1). Finally, the next players (Y2-Y13) perform the same as player Y1 until everyone is complete and within the specified time (Figure 3a).

Program 2: Each group is represented by the symbols Y1–Y13 for group 1 and lines up at position X1, and Y14–Y26 for group 2 and lines up at position X3. Firstly, starting with all players moving together (Y1 and Y14), player Y1 has maximum speed to position X2, performs a burpee, then speeds to position X5, while player Y14 dribbles ball to X6 and dribbles ball back to X5, then dribbles ball to X7 and dribbles ball back to X5, then dribbles ball to X8 and dribbles ball back to X5 and dribbles ball to X4. When both players complete the action together, player Y14 passes the ball to player Y1 to score a goal. Finally, player Y1 moves to the line of group 2 to wait for the next round of training, and player Y14 moves to the line of group 1 to wait for the next round of training. The next players of each group perform the same as the first player of the group (Y1 and Y14) until all are complete and within the specified time (Figure 3b).

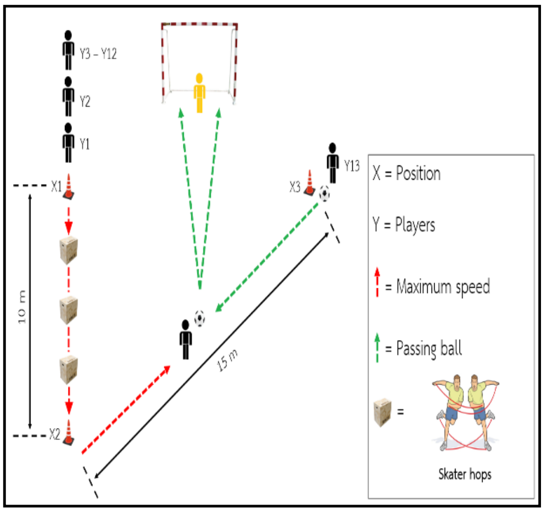

Figure 3a

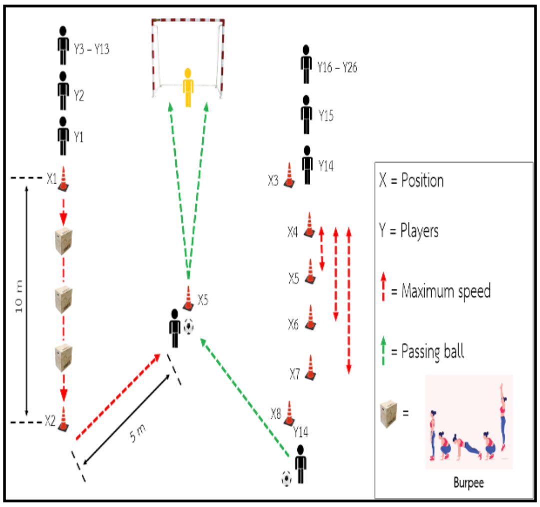

Figure 3b

Outcome measurement

Initially, the participants were evaluated for change of direction and reaction time at before experiment. Across all variables, the participants took measurements using standardized protocols (pre-test) and re-evaluated all variables at 4th weeks and 8th weeks.

(i) Change of direction (COD) was assessed using the standard FAF's slalom test. The simple correlation of Pearson's correlation coefficient (r) with FAF's slalom test is 0.912. Each player performed maximum effort in two trials interspersed with a 5-minute passive rest, and the fastest time (second) was used for statistical analysis (Figure 4).

(ii) Reaction time was assessed using the standard eye-body movement test. The simple correlation of Pearson's correlation coefficient (r) with the eye-body movement test is 0.892. The player standing at the starting point when the lights come on will sprint into the light position for 4.5 meters and return to the starting position in no more than 5 seconds, repeated 15 times. Cut out the fastest value three times and the slowest value three times, and find the average (second) (Figure 5).

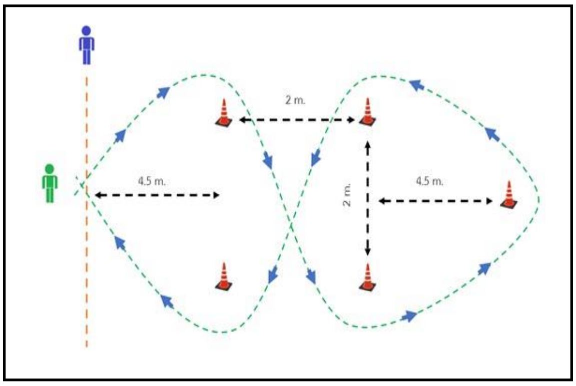

Figure 4 Change of direction test

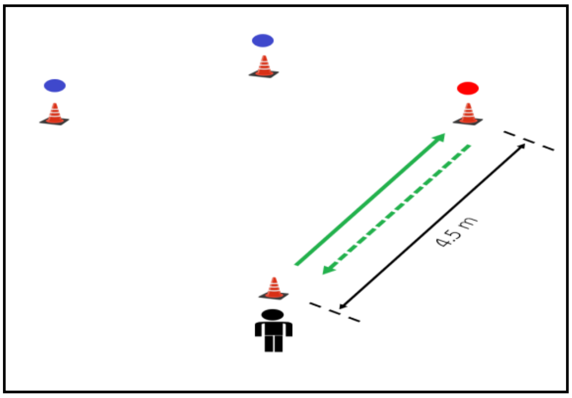

Figure 5 Reaction time test

Statistical analysis

Statistical analysis used STATA 13 (Texas, USA, 2007). The S-Wilk test was used to test the normal distribution of values. Descriptive statistics included frequency, percentage, mean, and standard deviation to express age, body mass index (BMI), and futsal experience. The inferential statistic was a one-way ANOVA with repeated measures and a Bonferroni test to compare change of direction and reaction time between before, after the 4th week, and after the 8th week of training (post-test) at a 95% confidence interval. We used $\alpha = 0.05$ as the cut-off point for statistical significance.

Results

The results of the assumption test found that both the change of direction and reaction time data have a normal distribution (p-value= 0.74 and 0.14, respectively), which is in accordance with the assumption on the use of parametric statistics (Table 1).

Table 1 Shapiro-wilk test (n=26)

Variables	n	Shapiro-wilk test		
		statistic	df	p-value
Change of direction	26	0.97	26	0.74
Reaction time	26	0.94	26	0.14

Characteristics

The players had an average age of 16.81 (SD=0.40), an average weight of 60.66 kilograms (SD=4.76), an average height of 169.92 centimeters (SD=5.61), an average body mass index of 20.99 (SD=0.98), and 3.46 years of experience playing futsal (SD=0.51) (Table 2).

Table 2 Characteristics (n=26)

Measure	Mean (SD)	Min-Max
Weight (kg)	60.66 (4.76)	(51.75 - 75.96)
Height (kg)	169.92 (5061)	(161.00 - 182.00)
Age (year)	16.81 (0.40)	(16 - 17)
BMI	20.99 (0.98)	(19.97 - 22.93)
Futsal experience	3.46 (0.51)	(3.00 - 4.00)

Heart rate and rating of perceived exertion

During exercise, players had their heart rate increase accordingly, from 149 to 163 beat per minute (bpm) (63.90 - 64.1% of HRmax) in weeks 1-2 and in weeks 3–8, the average heart rate while exercising was 163–176 times per minute (75.18 - 76.69% of HRmax) (Figure 6). They had a rating of perceived exertion of

9.80 - 10.07 in weeks 1 - 2, and in weeks 3 - 8, the average rating of perceived exertion while exercising was 12.88 -15.11 (Figure 7).

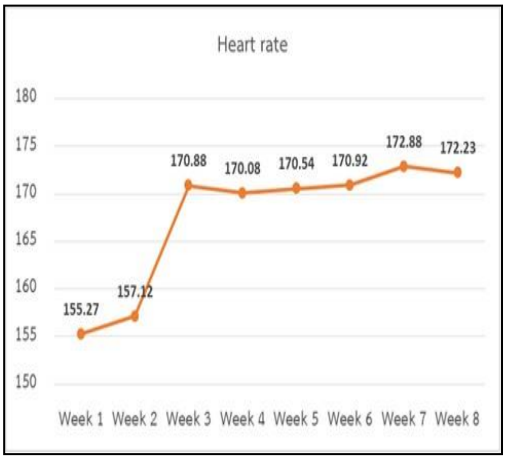

Figure 6 Heart rate

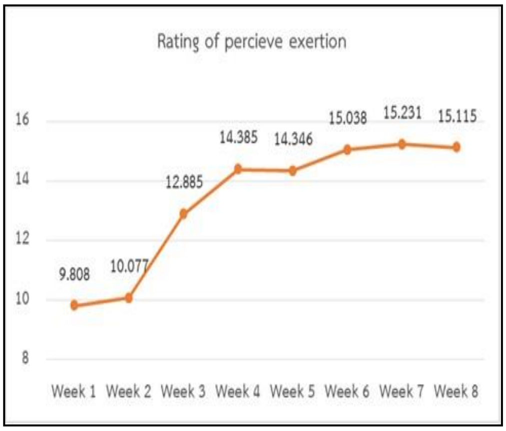

Figure 7 rating of perceived exertion

Change of direction and reaction time

The average change of directions before training was 8.26 s, after the 4th week was 8.21 s, and after the 8th week was 8.15 s (Figure 8), and the average reaction time before training was 3.5 s, after the 4th week was 3.22 s, and after the 8th week was 3.03 s (Figure 9).

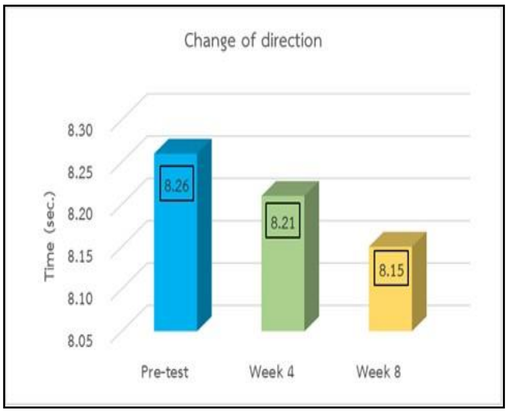

Figure 8 Change of direction

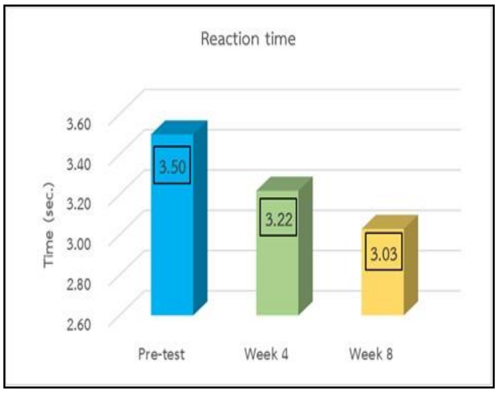

Figure 9 reaction time

Comparison of one-way ANOVA with repeated measures change of direction and reaction time

A one-way repeated-measures comparison of variance found that only the reaction times between before training, after training week 4, and after training week 8 were significantly different (Table 3). Therefore, the means had to be compared for each pair using the Bonferroni test.

Table 3 Change of direction and reaction time

Source	SS	df	MS	F	p-value
change of directions					
Within group	0.18	2	0.09	0.17	0.84
Error	38.49	75	0.51		
Total	38.66	77			
Reaction time					
Within group	2.91	2	1.46	23.53	0.000
Error	4.64	75	.062		
Total	7.55	77			

The Bonferroni test of reactime

Comparing the mean pair by the Bonferroni test found that, both pre-test and after week 4, pre-test and after week 8, and after week 4 and after week 8, reaction time decreased significantly (3.50, 3.22, and 3.03 seconds, respectively) (Figure 10).

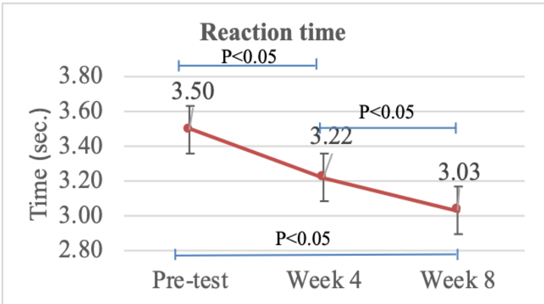

Figure 10 The Bonferroni test of reaction time

Discussion

The results of a one-way ANOVA with repeated measures on the change of direction before, after the 4th week, and after the 8th week of training showed no statistically significant difference. This may be because the training program is not a competitive situation and there may be some disparity among the athletes, so there are moments when they lose control, including muscle fatigue because change of direction mostly requires the work of muscle groups. Therefore, this muscle group becomes fatigued from working hard, which has a direct effect on the muscle command system, also called the neuromuscular system. This will result in a change of direction for the athlete as well. Considering these factors can help researchers interpret the results of the study and identify areas for improvement in future research or training interventions aimed at enhancing change of direction performance in athletes.

The results of the one-way ANOVA with repeated measures on reaction time before, after the 4th week, and after the 8th week of training were significantly different. Therefore, the average values must be pair-compared using Bonferroni's method. It was found that reaction time between before and after week 4, before and after week 8, after week 4, and after week 8 decreased statistically significantly. This is because the study involved a total of six futsal sport-specific training programs, with each program emphasizing athletes' ability to make quick decisions when passing the ball and their quick-fire ability to score goals. Reaction to evade an opponent's movement, including the fast reaction time, allows athletes to predict their opponent's moves and make split-second decisions. This quick reaction time allows athletes to quickly respond to situations, giving an advantage to the opponent. It also helps increase the accuracy of athletes' movements, all of which are said to develop the relationship between movement skills (Coordination motor skills; CMS) [22]. This is an important factor that influences athletes' performance during competition [23].

According to Ljach and Witkowski [24], increasing the level of training to develop movement skills is one of the important factors that result in athletes being successful. Additionally, Dane et al. [25] also explained that an important factor in sports is the assessment of each athlete's ability level, one of which is the assessment of movement skills, which can be divided into two types: application ability or application of movement. It refers to the ability to quickly develop a style of movement or change movements when encountering constantly changing situations [24]. This ability occurs in approximately 26.07 percent of male futsal players: ability to all parts of the body: 16.7%; ability to move towards the ball: 13.9%; and ability to balance: 9.3%. Another one is a wide range of reaction times, meaning the ability to quickly respond to stimuli or the response to movement in a short period of time in various parts of the body, both knowing and not knowing the stimulus before [25]. According to Colzato et al. [26], athletes have better simple reaction times than non-athletes. Additionally, training efficiency has a positive effect on both reaction time [26] and speed, especially futsal, which is a combination of speed and lower limb strength [27].

Overall, improvements in reaction time can translate into tangible benefits for futsal players, enhancing their efficiency, effectiveness, and competitive advantage during gameplay. By honing their reactive abilities through targeted training interventions, athletes can elevate their performance levels and contribute to their team's success on the futsal court. Additionally, some studies have reported that reaction time during competition depends on the fine motor skills of the lower limbs, especially in futsal [28]. While many studies have studied reaction times across both dominant and non-dominant sides, it has been found that non-athletes have poorer reaction times than athletes [29]. There is also a study by Welford [30] that studies the mechanisms of the human motor nervous system, including perception, decision-making, planning, and control. The process of perception is receiving information from outside; the decision-making process depends on the basis of exposure to stimuli; and planning is the act or decision to do something. All of this is a result of the operation of the command mechanism of the perception process through sensory input, decision-making, action mechanisms, and administrative mechanisms.

In addition, the study by Land [31] found that the response mechanism through visual perception depends on three nervous systems, as follows: The visual response perception system, the command system of the motor skills of the limbs for that type of work, and the visual perception system will respond to the information received. Recent studies have found that visual movement skills that can benefit specific sports are a result of the athlete's motor nervous system. Proprioceptive neuromuscular is the interrelationship between all body processes that play an important role in movement planning; for example, mechanisms work quickly to achieve effective change during planning [32]. The Pacific Sports Visual Performance Profile (PSVPP) consists of 23 tests that assess visual perception performance related to sporting events. It is also a basic assessment of refractive perception and eye health, as well as a test of cognitive performance in relation to many sports [33].

One of the tests was to test the athletes' reaction times to evaluate the athletes' rapid reflexes generated by visual perception through the perceptual system before motor skills begin [34]. This is measured in milliseconds [35]. The reaction time for touch is approximately 110 milliseconds. This is due to hearing at 150 milliseconds and vision at 200 milliseconds. Reaction time is caused by the work of the brain areas called the primary somatosensory cortex and the posterior parietal cortex. The integration of the motor nervous system sends information to the motor cortex in all six parts of the brain. This is the area where movement is planned-the so-called pre-order reaction times. During a command, information from part 6 of the brain is sent to part 4 of the motor cortex to initiate movement. The cerebellum then plays an important role in the movement of various parts of the body, depending on the quality of the cortical excitability, which determines whether the reaction time is fast or slow [36].

Reaction time is a movement skill that can be difficult to master depending on the athlete's genetics. However, reaction time can be increased by 10–20 percent through visual perception training [36]. Professional athletes have faster reaction times than trained or untrained athletes [37], and when athletes are very focused on the activity, their reaction time will be faster [38]. Factors affecting reaction time and response speed include age between 20 and 30 years and type of training, physical fitness of athletes, fatigue level, and intelligence level of athletes [34]. Reaction time is important for some sports, especially futsal. The study by Nascimento et al. [38] confirmed that after futsal athletes received visual perception training, they had better reaction times than the control group, thus resulting in athletes being more efficient while competing.

Improvements in reaction time are mediated by complex neuromuscular mechanisms involving various brain areas responsible for perception, movement planning, and proprioceptive neuromuscular feedback. Here's an overview of the key processes involved: Perception and Sensory Processing: Reaction time begins with the perception of a stimulus, such as a visual cue or auditory signal [35]. Sensory information from the environment is transmitted to the brain through specialized sensory receptors (e.g., photoreceptors in the eyes for visual stimuli, and hair cells in the inner ear for auditory stimuli). The primary sensory cortices in the brain, such as the visual cortex for visual stimuli and the auditory cortex for auditory stimuli, process this sensory information. Integration and Decision Making: Once sensory information reaches the brain, it undergoes integration and interpretation [38]. Higher-order brain areas, including the prefrontal cortex, parietal cortex, and supplementary motor area, are involved in integrating sensory inputs, assessing their significance, and making decisions about the appropriate motor response. These areas are crucial for movement planning and initiating the appropriate motor commands based on the perceived stimulus.

Motor Planning and Execution: After the decision-making process, motor commands are generated and transmitted from the motor areas of the cerebral cortex (such as the primary motor cortex and premotor cortex) to the spinal cord. These motor commands initiate muscle contractions and coordinate movement sequences required to execute the desired response [34]. The corticospinal tract is the primary pathway through which motor commands travel from the cortex to the spinal cord. Proprioceptive Neuromuscular Feedback: Proprioception refers to the sense of the body's position and movement in space. Proprioceptive feedback plays a crucial role in rapid reflex generation and fine-tuning motor responses [35]. Proprioceptive receptors located in muscles, tendons, and joints provide continuous feedback about the body's position, muscle length, and tension. This feedback is integrated with motor commands in the spinal cord through reflex circuits, such as the monosynaptic stretch reflex and the reciprocal inhibition reflex, to modulate muscle activity and ensure smooth and coordinated movements.

Conclusion

Futsal-specific training combined with plyometrics results in an increase in neuromuscular reaction-time coordination. In summary, the observed improvements in reaction time among futsal players are likely driven by a combination of neural adaptations, skill acquisition processes, and enhanced proprioceptive feedback mechanisms. Through targeted training interventions and practice regimes, athletes can systematically enhance their reactive abilities, ultimately translating into improved performance and competitive success in the sport of futsal.

Limitations

The limitation of this research is that there was no control group to compare the effects of futsal sports-specific training on neuromuscular coordination. By addressing these considerations and implementing a rigorous study design with appropriate control measures, future research can provide more robust evidence regarding the effects of futsal sports-specific training on neuromuscular coordination in youth male futsal players.

References

[1] Barbero-Alvarez J, Soto V, Barbero-Alvarez V. Match analysis and heart rate of futsal players during competition. J Sports Sci. 2021; 26(1): 63-73.

[2] López-Fernández J, García-Unanue J, Sánchez-Sánchez J, Colino E, Hernando E, Gallardo L. Bilateral asymmetries assessment in elite and sub-elite male futsal players. Int J Environ Res Public Health. 2020; 17(3169): 1-11.

[3] Walton SR, Broshek DK, Freeman JR, Hertel J, Meyer JP, Erdman NK, et al. Institutionally based impact test® normative values may differ from manufacturer-provided normative values. Archives of Clinical Neuropsychology. 2020; 35(3): 275-82.

[4] Ribeiro JN, Gonçalves B, Coutinho D, Brito J, Sampaio J, Travassos B. Activity profile and physical performance of match play in elite futsal players. Front Psychol. 2020; 11(1709): 1-9.

[5] Barbero-Álvarez JC, Castagna C. Activity pat-terns in professional futsal players using global position tracking system. Journal of Sports Science and Medicin. 2020; 6(10): 208–9.

[6] Chaddock-Heyman L, Erickson KI, Voss MW, Knecht AM, Pontifex MB, Castelli DM, et al. The effects of physical activity on functional MRI activation associated with cognitive control in children: a randomized controlled intervention. J International Neuropsychological Society. 2018; 7(72), 1-13.

[7] Bekris E, Gioldasis A, Gissis I, Katis A, Mitrousis I, Mylonis E. Effects of a futsal game on metabolic, hormonal, and muscle damage indicators of male futsal players. J Strength Cond Res. 2020; 34(1): 1-11.

[8] Yiannaki C, Barron DJ, Collins D, and Carling C. Match performance in a reference futsal team during an international tournament - implications for talent development in soccer. Biol Sport. 2020; 37(7): 147–56.

[9] Milanez VF, Bueno MJDO, Caetano FG, Chierotti P, De Moraes, SMF, Moura, FA. Relationship between number of substitutions, running performance and passing during under-17 and adult official futsal matches. Int J Perform Anal Sport. 2020; 20(12): 470–82.

[10] Freitas TT, Pereira LA, Alcaraz PE, Arruda AFS, Guerriero A, Azevedo PHSM, Loturco I. Influence of strength and power capacity on change of direction speed and deficit in elite team-sport athletes. J Hum Kinet. 2019; 68(113): 167–76.

[11] Milioni F, Vieira LH, Barbieri RA, Zagatto AM, Nordsborg NB, et al. Futsal match-related fatigue affects running performance and neuromuscular parameters but not finishing kick speed or accuracy. Front. Physiol. 2016; 7(518): 1-10.

[12] Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci. 2018; 3(21): 519-28.

[13] Rodrigues VM, Ramos GP, Mendes TT, Cabido CE, Melo ES, Condessa LA, Coelho DB, Garcia ES. Intensity of official futsal matches. J Strength Cond Res. 2018; 25(9): 2482-87.

[14] Ebben WP. Complex training: a brief review. J Sports Sci Med.2021; 1(2): 42–6.

[15] Barbero-Álvarez JC, Soto V, Granda J. (Effort profiling during indoor soccer competition. Journal of Sports Science. 2017; 22(231): 500-1.

[16] Bennie JA, Shakespear-Druery J, De Cocker K. Muscle-strengthening Exercise Epidemiology: a New Frontier in Chronic Disease Prevention. Sports Medicine. 2020; 6(40): 1-8.

[17] Freeman D. Teacher learning in language teaching. Cambridge University Press. 2021.

[18] Ward P, Williams AM. Perceptual and cognitive skill development in soccer: The multidimensional nature of expert performance. J Sport and Exercise Psychology. 2020; 25(1): 93-111.

[19] Jirawatkul A. Biostatistics for health sciences, 3th ed. Klangnana press: Khon Kean, Thailand. 2017.

[20] Cohen J. Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers. 1988.

[21] Borg DN, Bach AJE, O'Brien JL, Sainani KL. Calculating sample size for reliability studies. PM&R; 14(8): 1018-25.

[22] Nascimento H, Alvarez-Peregrina C, Martinez-Perez C, Sánchez-Tena MÁ. Vision in futsal players: coordination and reaction time. Int J Environ Res Public Health. 2021; 18(3): 9069.

[23] Atmojo MB. Test and measurement in physical education and sport; UNS Press: Surakarta, Indonesia. 2010.

[24] Jaakkola J, Watt A, Kalaja S. Differences in the motor coordination abilities among adolescent gymnasts, swimmers and ice hockey players. Hum Mo.2017; 1(9): 44-50.

[25] Malhotra V, Goel N, Ushadhar, Tripathi Y, Garg R. Exercise and reaction times. Journal of Evolution of Medical and Dental Sciences. 2015; 4(25): 4277-4281.

[26] Dane S, Hazar F, Tan Ü. Correlations between eye-hand reaction time and power of various muscles in badminton players. Int J Neurosci. 2015; 118(5): 349-54.

[27] Colzato LS, Nitsche MA, and Kibele A. Noninvasive brain stimulation and neural entrainment enhance athletic performance—a review. J Cogn Enhanc.2017; 1(3): 73-9.

[28] Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. J Strength Cond Res.2005; 19(4): 77-8.

[27] Davranche K, Burle B, Audiffren M, and Hasbroucq T. Physical exercise facilitates motor processes in simple reaction time performance: an electromyographic analysis. Neurosci Lett. 2006; 396(9): 54-5.

[29] Laby DM, Kirschen DG, Govindarajulu U, DeL P. The hand-eye coordination of professional baseball players: the relationship to batting. Optom Vis Sci. 2018; 95(6): 557–67.

[30] Welford AT. Skilled Performance: Perceptual and Motor Skills, 1st ed.; Scott & Foresman: Northbrook, IL, USA. 1976.

[31] Land MF. Vision, eye movements, and natural behavior. Vis. Neurosci. 2007; 26(5): 51–62.

[32] Riemann BL, Lephart SM. The Sensorimotor System, Part II: The role of proprioception in motor control and functional joint stability. J Athl Train. 2002; 37(6) 80–84.

[33] Zago M, Piovan AG, Annoni I, Ciprandi D, Iaia FM, Sforza C. Dribbling determinants in sub-elite youth soccer players. J Sport Sci. 2016; 34(3): 411–419.

[34] Iteya M, Gabbard C. Laterality patterns and visual-motor coordination of children. Percept Mot Ski. 1996; 83(3): 31–34.

[35] Schmidt R, Bancroft I. Genetics and genomics of the brassicaceae, 1st ed.; Springer: New York, NY, USA. 2006.

[36] Byrne JH. Concise learning and memory, 6th ed.; Academic Press: San Diego, CA, USA. 2002.

[37] Knudson DV. Qualitative diagnosis of human movement: improving performance in sport and exercise, 3rd ed.; Human Kinetics: Champaign, IL, USA. 1997

[38] Nascimento H, Alvarez-Peregrina C, Martinez-Perez C, Sánchez-Tena MÁ. Vision in futsal players: coordination and reaction time. Int J Environ Res Public Health. 2021; 18(17): 9069.