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Effects of Shadow Training and Leg Muscle Strength on Badminton Footwork Agility: A Factorial Experimental Design

Efectos del Entrenamiento de Sombras y la Fuerza Muscular de las Piernas en la Agilidad del Juego de Piernas de Bádminton: Un diseño experimental factorial

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Abstract. As badminton significantly emphasizes player footwork's agility and precision, performing shadow training and increasing leg muscle strength are believed to increase players' agility. However, despite recognizing the importance of both training methods in enhancing athletic performance, there is a lack of comprehensive understanding regarding their combined effects on a player's agility during gameplay. This study aimed to analyze group disparities in shadow training while considering varying levels of leg muscle strength and their impact on badminton players' footwork agility. The shadow training groups encompassed those using reaction lights and those under coach direction, while leg muscle strength was categorized as either high or low. Employing an experimental approach with a 2 x 2 factorial design, the study randomly selected 20 students aged 15.3±7.2. Shadow training was conducted in three sessions per week for approximately six weeks. This training focused on rapid/explosive movements. Data on muscle strength and agility were gathered using a leg dynamometer test and a foot exercise test. They were then statistically analyzed using two-way ANOVA at a significance level of 0.05. The results suggest that shadow training with reaction lights is more effective for individuals with high leg muscle strength. Meanwhile, shadow training with a coach's direction may yield better results for those with low leg muscle strength. However, both training modalities can be beneficial for individuals with low leg muscle strength. These findings provide valuable insights for coaches and badminton instructors in devising tailored training programs to enhance footwork agility.
Keywords: Shadow training, reaction lights, the coach's direction, foot work agility, leg muscle strength

Resumen. Como el bádminton enfatiza significativamente la agilidad y precisión del movimiento de los pies del jugador, se cree que realizar entrenamientos de sombra y aumentar la fuerza muscular de las piernas aumenta la agilidad de los jugadores. Sin embargo, a pesar de reconocer la importancia de ambos métodos de entrenamiento para mejorar el rendimiento atlético, falta una comprensión integral sobre sus efectos combinados en la agilidad de un jugador durante el juego. Este estudio tuvo como objetivo analizar las disparidades grupales en el entrenamiento de sombra teniendo en cuenta los diferentes niveles de fuerza muscular de las piernas y su impacto en la agilidad del movimiento de pies de los jugadores de bádminton. Los grupos de entrenamiento de sombra abarcaron a aquellos que utilizaban luces de reacción y aquellos bajo la dirección del entrenador, mientras que la fuerza muscular de las piernas se categorizó como alta o baja. Empleando un enfoque experimental con un diseño factorial 2 x 2, el estudio seleccionó aleatoriamente a 20 estudiantes con una edad de 15.3±7.2 años. El entrenamiento de sombra se llevó a cabo en tres sesiones por semana durante aproximadamente seis semanas. Este entrenamiento se centró en movimientos rápidos/explosivos. Los datos sobre la fuerza muscular y la agilidad se recopilaron utilizando una prueba de dinamómetro de piernas y una prueba de ejercicio de pies. Luego, se analizaron estadísticamente utilizando un ANOVA de dos vías con un nivel de significancia de 0.05. Los resultados sugieren que el entrenamiento de sombra con luces de reacción es más efectivo para individuos con una alta fuerza muscular en las piernas. Mientras tanto, el entrenamiento de sombra con la dirección de un entrenador puede dar mejores resultados para aquellos con una baja fuerza muscular en las piernas. Sin embargo, ambas modalidades de entrenamiento pueden ser beneficiosas para individuos con una baja fuerza muscular en las piernas. Estos hallazgos proporcionan información valiosa para entrenadores e instructores de bádminton al diseñar programas de entrenamiento adaptados para mejorar la agilidad del movimiento de pies.
Palabras clave: Entrenamiento de sombras, luces de reacción, dirección del entrenador, agilidad del trabajo de pies, fuerza muscular de las piernas.

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Introduction

The anatomical and physiological requirements of badminton are influenced by multiple factors, including gender, playing style, skill level, equipment, and playing surface. These factors also influence player performance since achieving excellence in badminton requires superior coordination, speed, mastery over movement, and agility. Agility is a vital component of physical fitness that requires the speed of changing the position of the body and its parts (Berhimpong et al., 2023; Bompa & Buzzichelli, 2015; Farley et al., 2020; Sridadi et al., 2021). It requires a high ability to adapt to changing situations during a match. Thus, it must be trained systematically based on the principles of agility training (Bompa & Buzzichelli, 2015; Gómez Rodríguez et al., 2021). (Nursamedy & Pramono, 2020) define agility as the ability to quickly change direction or body position, which is carried out with other movements. The training principles that should be optimally emphasized for training agility are overload, prepressure, and periodization (Atkinson et al., 2016; Mario et al., 2022; Marlina et al., 2023). In badminton, elite and sub-elite athletes require special agility, called footwork agility, as one of the physiological characteristics that badminton players must possess in addition to power, recovery ability, and anthropometrics (Chaeroni et al., 2023; Duncan et al., 2017; Ooi et al., 2009). For children, agility is a component of physical fitness (Giuriato et al., 2021; Sridadi et al., 2021; Sulistiyowati et al., 2022). It is an important quality in many sports played on the court or field, including badminton (Ayuningtyas et al., 2021; Park et al., 2017). In this sport, agility indicates the ability to move to the approaching shuttle with correct footwork. Previous research has been conducted not only on training programs to improve badminton fitness but also on the intake of caffeinated energy drinks to improve fitness during training or competition (Abian et al., 2015).

Besides agility, a badminton player is required to bear additional elements of physical condition, such as leg muscle power and cardiovascular endurance (Donie et al., 2023; Edmizal et al., 2023; Nugroho et al., 2021; Prajongjai et al., 2023). It is then assumed that by having strong leg muscle power, a badminton player can jump to smash, drop, and lob shots more quickly and accurately. Likewise, bearing good agility, a badminton player can control the field atmosphere so that he/she can reach and return the shuttlecock placed by the opponent without encountering significant difficulties. Overall, foot agility is very necessary not only for a badminton player but also for predicting the winner.

In badminton games, the legs function as a support for the body to move quickly in all directions (Chandrakumar & Ramesh, 2015; Nugroho et al., 2021). As a result, the body can be positioned in such a way as to make hitting movements effective. Footsteps in badminton games are often termed footwork. The basic principle of footwork in badminton is that the leg that matches the hand used to hold the racket when hitting always ends in the direction of that hand. Good footwork is determined by the rhythm and accuracy of steps (Arnando et al., 2023). Thus, to master the expected quality, a badminton player must practice as often as possible with movement simulations that resemble real badminton games. Since the importance of footwork for badminton players, Fatih and Aydos (2017) suggested several footwork training models, such as shadow badminton steps, stroke, leg strengthening, reaction, acceleration, agility, speed, and movement coordination. These forms of practice can be done by taking shuttlecocks placed on the edges of the field to be moved to the middle of the field or vice versa. Alternatively, it can be performed by moving to imitate the movement of the model (practice partner), coach's signal, light signals, and so on (Ahmad, 2022); (Mirantsoa Rasolofomanana et al., 2020).

Footwork exercises are also overarching for badminton players to ease the movement in different spots of the field. However, the agility factor is of great importance in the game to help players to do footwork correctly and quickly. This is related to the game of badminton in which explosive and fast movements are required. Therefore, footwork plays an important role in such a game. This step is needed in the wake of preparing the badminton players' hands and feet so they can move quickly and efficiently (Rahmat, 2021). By managing the legs properly, a player will be able to move as efficiently as possible to all parts of the court. There are six dotted areas where players have to move effectively.

Make a stroke/hit, and the player returns directly to the center of the field. Although the player must try to make a stroke, the more important thing is that the player must not move while the opponent is making a stroke. How to set the limbs is also very important. Players will not be able to hit the shuttle efficiently or control the opponent if the player cannot easily be in a position to hit (R. N. Miller, 2016). Footwork or leg movement is closely related to strength and agility, and some means are available to train such skills. The drill T-test, shuttle run, skipping, sprinting, and shadowing are deemed exercises that can improve the agility of footwork in badminton games. In this case, to train agility, the badminton player must adhere to various training principles, for example, volume, sequence, repetitions, sets, tempo of movements, rest between sets, and type of training (Gómez Rodríguez et al., 2021; Ilham & Dimyati, 2021; Medina Corrales et al., 2020; Ooi et al., 2009; Yendrizal et al., 2023). However, training volume and intensity are of great concern. Apart from this, the fitness components of speed and flexibility are very influential. This is why it is necessary to include speed and flexibility training when training to train agility.

The popularity of shadow training in badminton is very critical to train agility. Shadow is one of the exercises that is often used during badminton practice. To our best understanding, such badminton practice can be employed to increase the ability and fitness of a trainee at the same time by enabling him to move quickly, lightly, and frequently on the player's limbs with the main goal of being able to maintain balance at all times and regularly playing each stroke (Xu, 2015). Badminton players should have the agility to move at high speed in different directions on the court, like forward, sideward, and backwards, to execute many actions. Shadow training develops the muscles, bones, and joints (Giovanelli et al., 2017). After training is completed well, the muscles might become more elastic, and the range of motion for the joints will be better (Janssen et al., 2021; Ramos-Sepúlveda et al., 2016). Joints are very flexible, while the size of the muscles increases (Boguszewski et al., 2014; Bompa & Buzzichelli, 2015; Bouguezzi et al., 2023; Thiele et al., 2020). One of the models in this training is patterned shadow training. It is another form of badminton skill training in which the movements are almost the same as real playing (Donie et al., 2022; Ishak et al., 2020; Xin & Fitriana, 2020). This form of training does not use shuttlecocks. However, it is done repeatedly with several kinds of badminton training techniques (Ishak et al., 2020). Shadow is the movement of shadow steps to the corners of the badminton court (Fatih YÜKSEL & Aydos, 2017; Ishak et al., 2020; Muthiarani & Lismadiana, 2021). This training can be understood as a practice with proper movement without actually hitting an object or shuttlecock. Typically, the starting position is in the middle of the field, which requires the players to touch the eight corners of the field in succession. That is going and returning to the center position after doing the back forehand, front forehand, backhand back, front backhand, front forehand, side forehand, front backhand, and side forehand according to what you want, and only cross the legs on the backhand side.

Plenty of research has investigated how shadow training affects badminton players. For instance, research investigated that shadow training had a significant positive effect on achieving optimal agility and regular movement of the foot, the ability to change direction and position depending on the conditions encountered in a relatively short and rapid time for badminton players aged 12 to 15 years old (Rahman et al., 2020). Motor aspects resulting from shadow training exercises have also been studied previously (Yuksel & Aydos, 2017). Furthermore, to increase the footwork agility of badminton athletes, previous research has proven the use of shadow training using the application of badminton steps (Ihsan et al., 2023a). Sequential and crossover step shadow drills have also been studied to increase footwork agility (Muthiarani & Lismadiana, 2021).

In addition, shadow training methods can be carried out in several ways, for example, shadow training with audio direction, with instructions or guidelines from the coaches, and with reaction lights. A very commonly used exercise that has been shown to improve the agility of badminton players is the coach-led method. Meanwhile, training using reaction lights is still under-researched. Thus, this research tries to fill this gap by focusing not only on the coach-led method but also on the training with reaction lights. In addition, the research also takes into account another important element to increase agility, namely the strength of the leg muscles. Often, badminton players who want to increase agility need to look at the strength of their leg muscles.

Therefore, this study aims to analyze the differences in the influence of the shadow training intervention group by considering the level of leg muscle strength on footwork agility results. In this research, shadow training is divided into two groups: the group with reaction light and the group using coach direction. The results of this research are significant for coaches, physical education teachers, practitioners, and athletes to train in agility in badminton. Coaches can, therefore, take leg muscle strength into account to train agility.

Materials and Methods

Study design

The research employed an experimental method with a 2 x 2 factorial design where treatment was needed. The research method mainly aimed to look for the effect of certain treatments on others under controlled conditions involving different types of variables. Thus, shadow training (A) was used as an independent variable, while agility and leg muscle strength were treated as dependent and moderate variables. Shadow training (A) consisted of two forms of training, namely, the use of reaction lights (A1) and the use of coach direction (A2). Meanwhile, leg muscle strength (B) was divided into high (B1) and low (B2) leg muscle strength. The classification of these variables is illustrated in Table 1. In short, the research included four treatments: shadow training with reaction lights for high and low leg muscle strength (A1B1 and A1B2) and shadow training employing coach direction for high and low leg muscle strength (A2B1 and A2B2).

Table 1.
The two-way factorial ANOVA design.

Leg Muscle Strength (B)	Shadow training (A)	
	Reaction Light (A1)	Coach Direction (A2)
High (B1)	A1B1	A2B1
Low (B2)	A1B2	A2B2
Total	A1	A2

Participants

The study population consisted of extracurricular badminton students from middle schools, SMP Negeri 2 Banguntapan and SMP Negeri 1 Bantul. After applying randomly recruited, the total number of participants who took part in this research was 20 male badminton players. The written research volunteer's agreement was also signed as a condition of administering the research. The age of the participants is 15.3 ± 7.2 years. Meanwhile, body weight 47.5 ± 2.52 and body height 155.4 ± 2.42 cm. and BMI 21.65 ± 1.25.

Procedure

Distribution of treatment groups

For the initial step, we obtained all the permits and prepared the equipment and infrastructure necessary for this research. Participants would undergo a pre-test. However, before carrying out the pre-test, they were asked to sign a research consent form. The leg dynamometer test was performed to determine the groups using a two-way ANOVA design. This test was carried out before giving shadow training exercises using reaction lights and shadow training under the coach's direction.

The leg dynamometer test was carried out on 20 male badminton players, and the leg muscle strength was classified according to the maximum and minimum results. The test classified the participants into two groups. The higher group (27%, n = 10) was considered to have high leg muscle strength, while the lower group (27%, n = 10) was classified as having low leg muscle strength (P. W. Miller, 2008). The researchers classified the participants into upper and lower groups to make the participant's leg muscle strength significantly different (high and low).

Then, in the next step, the treatment groups were placed to shadow training with reaction lights and shadow training under the coach's direction. This placement was carried out by randomly drawing based on their groups, whether they had high or low levels of leg muscle strength. The detailed process can be seen in Figure 1 and Table 2. As shown in Figure 1 and Table 2, there are 4 treatment groups, with each group consisting of 5 participants.

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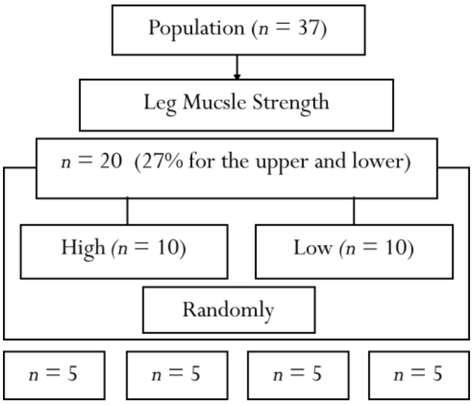

Figure 1. The flow of treatment group assignment in the research

Table 2.
The sample size for each treatment group.

Leg Muscle Strength (B)	Shadow Training (A)				Total (n)
	Reaction Light (A1)	n	Coach Direction(A2)	n	
High (B1)	A1B1	5	A2B1	5	10
Low (B2)	A1B2	5	A2B2	5	10
Total	A1	10	A2	10	20

Treatment for shadow training

This research used shadow training exercises with reaction lights and the coach's direction that took into account the strength of leg muscles. Shadow training was provided for ± 6 weeks, three times a week. The workout began with 10 minutes of warm-up (static and dynamic), followed by training in the shade (using a reaction light method and under the coach's direction). It ended with a time of recharge. Regular technical training by participants was always carried out as maintenance.

Agility training was scheduled over a period of ±6 weeks. The increase in training load was constant because it was worth remembering the principle of agility training, namely to do it explosively. The training dose was increased each week until the third consecutive week. In accordance with the training principles, overload, progressive, and individual principles were applied. In some weeks, for example, the fourth week, the training dose was equal to that of the second week, and the dose was the same as that of the fourth week. It means that there is a decrease in training load. This aims to prepare for or recover from efforts to increase the dose of exercise. The training dose escalation model was continued until week 6, before the post-test was conducted.

Shadow training with reaction lights for agility used a six-light reaction light board. In this procedure, students were requested to stand in the middle of the field, waiting for the lights to come on. Students moved towards the colored box depending on which light was on and then returned to the center. Then, they were treated to additional badminton game practice for 35 minutes. Each group played until number 7, and the team getting number 7 was declared the winner. The training ended with a recovery.

After that, shadow training under the coach's direction consisted of a series of footwork and fun games. The movement of the shadow was carried out according to the coach's direction by providing the same square in the reaction light training as 6 squares on the field and numbered from 1 to 6. Thus, when the coach gives a direction by mentioning a certain number, the player must enter the box with one foot. The intensity, volume, and recovery between sets were adapted to speed training, i.e. performed explosively. The set periodization was increased to develop the training load continuously. Each exercise took place on a badminton court. Before recovery, 1 fun badminton game session was offered, i.e., 35 minutes (whoever obtained the point 7 won the match).

These two forms of shadow training are fundamentally similar and aim to improve badminton players' agility, particularly footwork agility. The training was periodized over approximately 6 weeks. Besides, these drills used the same terrain and distance on the court while having the same range of motion. Therefore, they needed to be compared to see how effective they were. In addition, the exercise was performed almost the same way, i.e., starting with a warm-up, a basic workout with a similar progression of increasing doses, a badminton fun game, and then continuing with a cool-down. On the other hand, the fundamental difference between the two shadow training methods is in the response method, namely the use of reaction lights and the coach direction method. Once all rounds of programs had been completed, data analysis was carried out to present the research findings.

Instrument

This research employed varied instruments to collect data. For instance, leg muscle strength was measured by a Leg Dynamometer (validity: 0.745 and reliability: 0.960). Students were tested first for leg muscle strength 3x with a leg dynamometer. Then, they were required to perform 3x experiments, and the data were recorded. After that, the researchers took 1 experiment that was perceived as the best out of the 3 times. A stopwatch was employed to measure the 30-second leg exercise test, calibrated with the number 080A/LPPT-UGM/K/IV/2017, to measure the agility of the leg movement with the 30-second leg exercise test tool. Then, the validity level of this test instrument was found to be equal to 0.706, while the level of reliability was 0.808.

Statistical Analysis

Descriptive analysis was employed to characterize each data outcome for every treatment group using Microsoft Excel. Subsequently, the differential hypothesis test, or effect difference test, was conducted using SPSS version 25 and analyzed utilizing the two-way ANOVA option at a significance level of 0.05. Following this, the Tukey test was employed to compare the average pairs of treatments. Prior to conducting the hypothesis test, normality and homogeneity tests were performed on the acquired data. The normality test was assessed based on residual standard values, while the homogeneity test utilized the Levene test.

Results

This study found that the average scores and standard deviations of pre-test and post-test footwork agility increased as follows: A1B1 (11.80±3.352 to 14.20±1.483), A1B2 (10.60±1.924 to 13.40±0.894), A2B1 (11.20±1.304 to 12.20±1.924), and A2B2 (10.40±1.517 to 12.40±0.894). The highest percentage was observed in group A1B2, with a rate of 26.42% (2.8), ranking this group first. This was followed by group A1B1, with a 20.33% (2.4) increase and ranking second. After that, group A2B2 showed a third-highest percentage of 19.23% (2. Finally, group A2B1 exhibited an 8.92% (0.8) increase, ranking fourth. For more details, please refer to Table 3.

Table 3.
The mean differences, standard deviations, and percentage improvements in pretest and posttest scores of footwork agility for each treatment group

Shadow Training	Level of Muscle Leg Strength (Group) (n=5)	Pretest Mean±SD	Posttest Mean±SD	Differences	%
Light Reaction	High (A1B1)	11,80±3.352	14,20±1,483	2.4	20.33
	Low (A1B2)	10,60±1,924	13,40±0,894	2.8	26.41
Coach Direction	High (A2B1)	11,20±1,304	12,20±1,924	0.8	8.92
	Low (A2B2)	10,40±1,517	12,40±0,894	2	19.23

The results of this study also reported that the average score of agility footwork for groups A1 and A2 was 11.2±1.3 and 13.8±1.39. For groups B1 and B2, the means were 10.8±1.47 and 12.3±1.49. The average footwork agility scores for groups A1B1 and A2B1 were 14.2±1.30 and 12.2±1.92. Meanwhile, A1B2 and A2B2 were 13.4±1.51 and 12.4±1.14. Table 3 indicates that the A1B1 group had the highest average increase than other treatment groups. This data is presented in Table 4 and Figure 2. Meanwhile, Table 5 shows the results of data normality and homogeneity tests, which indicate that the data is normal and homogeneous (P>0.05).

Table 4.
The results of the footwork agility of each treatment group

Group	*n*	Min	Max	*M ± SD*
A1	10	9	14	11.2±1.3
A2	10	11	16	13.8±1,39
B1	10	8	13	10.8±1.47
B2	10	9	14	12.3±1.49
A1B1	5	11	16	14.20±1.48
A2B1	5	9	14	12.2±1.92
A1B2	5	11	15	13.4±1.51
A2B2	5	11	14	12.4±0.89

Legend: The dependent variable is footwork agility, the unit is score of footwork agility, "A1" is shadow training with reaction lamp, "A2" is shadow training with coach direction, "B1" is high leg muscle, "B2" is low leg muscle, "A1B1" is shadow training with reaction lamp and high leg muscle"A2B1" is shadow training with coach direction and high leg muscle, "A1B2" is shadow training with reaction lamp dan low leg muscle, "A2B2" is shadow training with coach direction and low leg muscle.

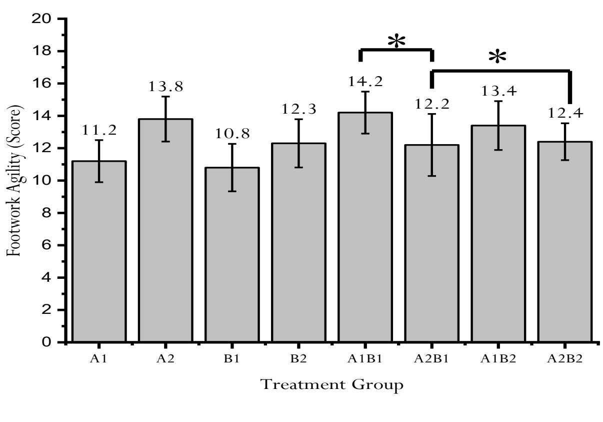

Figure 2. The average agility of foot work of each treatment group (*p<0.05) compared to each group. The data are presented with mean and standard deviation scores of foot work agility.

Table 6 below displays the results of the two-way ANOVA test. The table demonstrates a significant difference in footwork agility results between groups A1 and A2 (P < 0.05). Meanwhile, no significant disparities are observed between groups B1 and B2 (P > 0.05). Moreover, Table 5 confirms that there is no interaction between groups A and B (P > 0.05).

Consequently, further statistical analysis using the Tukey test was not conducted due to the lack of interaction between the groups.

Table 5.
Normality and homogeneity testing

Normality test						Homogeneity test		
Kolmogorov-Smirnov			Shapiro-Wilk			Levene's		
Statistic	*df*	*P*	Statistic	*df*	*P*	*df1*	*df2*	*P*
0.922	20	0.214	0.884	20	0.214	2	13	0.579

Legend: Data is normally distributed and homogeneous (P>0.05).

Table 6.
Two-way factorial ANOVA.

Source	Type III Sum of Squares	df	Mean Square	F	P
Shadow training (A)	11.25	1	11.25	5.00	0.040
Leg muscle strength (B)	0.450	1	0.450	0.20	0.661
Shadow training (A)*Leg muscle strength (B)	1.250	1	1.250	0.556	0.467

Legend: The dependent variable in this study is footwork agility. Significant differences were observed between groups A1 and A2 in terms of "shadow training" (P<0.05), indicating its impact on footwork agility. However, no significant difference was noted between groups B1 and B2 regarding "Leg muscle strength" (P>0.05). Furthermore, the interaction between "shadow training" and "leg muscle strength" groups (A and B) did not yield any significant effects on footwork agility (P>0.05)

Discussion

The findings of our study revealed a significant effect of shadow training on badminton footwork agility. Participants who engaged in shadow training sessions demonstrated a noticeable improvement in their footwork agility. However, it was found that the results of footwork agility from shadow training with light reaction were superior to coach direction for a high level of leg muscle strength. However, the results can be better if the low level of leg muscle strength is given shadow training with coach direction. Meanwhile, for low-leg muscle strength, both forms of training can be given. This confirms previous research findings that the implementation of shadow training enables players to rehearse and refine their movements without the pressure of live gameplay, ultimately resulting in enhanced agility during actual matches (Ghosh et al., 2022).

In addition, this result aligns with previous research emphasizing the value of shadow training in enhancing sports-specific skills (Ihsan et al., 2023a; Rahman et al., 2020; Yuksel & Aydos, 2017). This knowledge gap necessitates a rigorous investigation, as it not only impacts the performance of players but also informs evidence-based training strategies for badminton enthusiasts. Previous studies also explained that there was a significant improvement through shadow training (using badminton steps) in increasing footwork agility ($P<0.05$). They showed that the pre and post-test increased from 11.5 to 13 with an increase of 1.5 (Ihsan et al., 2023b). Thus, it is clear that the improvement of agility elements (footwork agility) is not easy to achieve, but it can be enhanced and observed through the percentage of improvement. Nevertheless, with the appropriate method and considering various factors in the field, the validity and reliability of shadow training might be demonstrated. Thus, further research is needed.

Other research that shares similar results is that Mukesh et al. (2021) reported. Although using different agility measurements, the six-week agility-specific exercise program effectively reduced the time required to complete the agility T-test. Agility exercise allows more muscles to be engaged in a shorter time by activating more motor units, enhancing the body's neural adaptation, and improving agility and intramuscular coordination. Agility training has been found to increase the activation of the medial hamstrings during sideways pivoting movements, and increased activation of the hamstrings helps to reduce the risk of ligament sprain injuries (Monajati et al., 2016).

Our study also demonstrated an increase but without significant effect between groups of leg muscle strength on badminton footwork agility. Participants with higher leg muscle strength demonstrated greater agility in their footwork. Strong leg muscles provide the power and stability needed for quick, precise movements on the badminton court. This seems very possible as the group's leg muscle strength is not significantly different, coupled with the research's limitations, which require a small number of participants. This connection between leg strength and agility underscores the importance of strength training in a badminton player's overall training regimen. It is imperative for athletes to focus on developing leg strength to bolster their agility, which is an essential component of success in badminton. It is true that leg muscle strength greatly influences agility factors. However, in this study, students with low leg muscle strength performed better, with a difference of 2.4, compared to students having high muscle strength, with a difference of 1.7. Thus, a too small gap indicates that the difference in influence between people with high and low levels of muscle strength in this study is not significant. This means that future research in terms of grouping leg muscle strength factors must use a large sample in order to obtain a wide variety of participant abilities.

Additionally, our factorial experimental design allowed us to examine the interaction effect between shadow training and leg muscle strength. Participants who combined regular shadow training with strong leg muscles demonstrated the most significant improvement in badminton footwork agility. However, no interaction was found in this study. This is possible because the athletes' abilities were almost the same. Furthermore, the interaction effect suggests that the benefits of shadow training and leg muscle strength are amplified when used in tandem. Coaches and athletes can use this information to design more effective training programs that prioritize both elements to optimize footwork agility.

In summary, research has shown that shadow training with reaction lights is better than shadow training with coach instructions for improving footwork agility. High and low leg muscle strength was also found to have no effect on increasing footwork agility. This finding also indicates no interaction between shadow training and leg muscle strength. However, our study highlights the significant contributions of shadow training and leg muscle strength to badminton footwork agility. Both factors play a crucial role in enhancing a player's performance on the court. Moreover, their combined effect is greater than the sum of their individual effects, emphasizing the importance of incorporating both shadow training and leg muscle strengthening into the training routines of badminton players. This combination is expected to excel in their sport. These findings provide valuable insights for coaches and athletes seeking to improve their badminton footwork agility and overall competitive performance. When taken together, the implications of the research results can be used as material for consideration for coaches, as well as badminton coaches, in making appropriate training programs to increase footwork agility.

Conclusions

This study concludes that training in the shadows with reaction lights has a significant positive effect in increasing the agility of badminton players' leg movements compared to training in the shadow involving the direction of the coach. However, this research also shows that high or low leg muscle strength does not have a significant influence on the agility of leg movements in badminton. Apart from that, no significant interaction was found between the type of shadow training and the level of leg muscle strength on the leg movement agility of badminton players. The results of this research can guide badminton coaches and players in designing more effective training programs to increase foot movement agility in badminton.

Conflicts of interest

The authors report that there is no potential conflict of interest.

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