

The Effect of Two-Handed Overhead Medicine Ball Throwing Exercises on Upper Extreme Muscle Strength and Kinematic Movement in Soccer Throw-ins

El efecto de los ejercicios de lanzamiento de balón medicinal por encima de la cabeza con dos manos sobre la fuerza muscular extrema superior y el movimiento cinemático en el saque de banda de fútbol

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Abstract. This study aims to analyze the effect of two-handed overhead medicine ball (THOMBT) training on upper extremity muscle strength and kinematic movement. This research utilized an experimental method with a pre-test and post-test design. Sample collection used a random sampling technique. The sampling results were then divided into a control group (CTRL) and an experimental group (THOMBT). The Shapiro-Wilk test and Levene's test were used as prerequisite tests. Paired t-tests and independent sample t-tests were used to compare improvements within and between groups. Statistical significance was set at $p < 0.05$. Cohen's effect size (ES) was used to measure group differences. A total of 15 players were in the experimental group with an average age of 16.20 ± 0.77 years, while 15 other players were in the control group with an average age of 16.13 ± 0.83 . Before and after the four-week trial period, upper extremity muscle strength testing was conducted using push-ups, sit-ups, and kinematic movement tests, which included throwing distance, arm angular speed, and release angle tests. The result is the THOMBT group showed significant improvements in push-ups ($p = .000$, $\Delta\% = 22.44$), sit-ups ($p = .000$, $\Delta\% = 9.33$), distance throws ($p = .000$, $\Delta\% = 8.20$), and arm angular velocity ($p = .000$, $\Delta\% = 14.98$). Meanwhile, the CTRL group did not have a significant increase. The conclusion is that THOMBT training for four weeks is effective in increasing upper extremity strength ability and movement kinematics, but not variable angle of release.

Keywords: throws, medicine ball, muscle strength, kinematics movement.

Resumen. Este estudio tiene como objetivo analizar el efecto del entrenamiento con balón medicinal de dos corazones (THOMBT) sobre la fuerza muscular extrema superior y la cinemática del movimiento. Esta investigación utiliza un método experimental con un diseño pre-test y posttest. El muestreo utilizó técnicas de muestreo aleatorio, luego los resultados del muestreo se dividieron en un grupo de control (CTRL) y un grupo experimental (THOMBT). Como pruebas de prerrequisito se utilizaron la prueba de Shapiro-Wilk y la prueba de Levene. Se utilizaron pruebas t pareadas y pruebas t de muestras independientes para comparar las mejoras grupales y entre grupos. La significación estadística se fijó en $p < 0,05$. Se utilizó el tamaño del efecto (ES) de Cohen para medir las diferencias grupales. Un total de 15 jugadores estaban en el grupo experimental con una edad de 16.20 ± 0.77 años, y otros 15 jugadores estaban en el grupo de control con una edad de 16.13 ± 0.83 . Antes y después del periodo de prueba de cuatro semanas, se evaluó la fuerza de los músculos extremos superiores mediante flexiones, abdominales y pruebas cinemáticas que incluyeron pruebas de distancia de lanzamiento, velocidad angular del brazo y ángulo de liberación. Los resultados fueron que el grupo THOMBT mostró mejoras significativas en flexiones ($p = 0.000$, $\Delta\% = 22.44$), abdominales ($p = 0.000$, $\Delta\% = 9.33$), distancia de lanzamiento ($p = 0.000$, $\Delta\% = 8.20$) y velocidad angular del brazo ($p = 0.000$, $\Delta\% = 14.98$). Mientras tanto, el grupo CTRL no experimentó un aumento significativo. La conclusión fue que el entrenamiento THOMBT durante cuatro semanas fue efectivo para aumentar las capacidades de fuerza de las extremidades superiores y la cinemática del movimiento, pero no las variables del ángulo de liberación.

Palabras clave: lanzamientos, balón medicinal, fuerza muscular, cinemática del movimiento.

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Introduction

In soccer, the ability to throw is considered a fundamental technique that every player should possess. Throw-ins have become a powerful tactic for creating goals against opponents over time. A direct throw towards the opponent's goal can create a better goal-scoring opportunity than a free kick or open play situation in soccer, depending on various factors such as the player's position, distance to the goal, team tactics, and the player's ability to execute certain strategies. Regrettably, the amount of research on soccer throw-in training is quite limited. It is worth noting that while there have been several studies conducted to improve throwing ability, they have primarily focused on other sports (Ignjatovic et al., 2012; Raeder et al., 2015). Previous research has indicated that resistance training may be an effective method for increasing the strength and power of young players (Barquilha et al., 2018; Assis et al., 2023;

Pecci et al., 2023; Sanchez-Sanchez et al., 2022; Vázquez & Rebollo, 2022). Furthermore, previous studies have reported positive results in improving throwing through the use of resistance training (Oranchuk et al., 2021). However, it is worth noting that according to research conducted by Ettema et al. (2008), training with a medicine ball is more effective than resistance training with resistance bands when it comes to soccer throwing training. This is due to the force-velocity relationship of muscles, which plays a crucial role in improving the ability to throw in soccer. Several studies have examined the benefits of medicine ball exercises in various sports (Ikeda et al., 2007; Singla & Hussain, 2020). However, there is limited research on the use of medicine balls in soccer training, particularly in relation to throw-ins, which differ significantly from other sports due to the use of both hands (Tillaar & Marques, 2009). Therefore, further investigation is needed to fully understand the potential benefits of medicine ball exercises

in soccer training. Training with a medicine ball can be beneficial for improving throw-ins due to its movement suitability. The shape of the medicine ball, which resembles a soccer ball, allows players to practice with the same movement as a throw-in. Additionally, the added weight of the medicine ball can have a positive impact on the development of the muscles involved in a throw-in (Hermassi et al., 2015). In line with research that has been conducted by DeRenne & Szymanski (2009), using tools that are heavier than the original has a positive increasing effect. With more weight, the overload principle can be achieved in this exercise (Tudor, 2019).

Beyond the benefits described above, it is necessary to scientifically study the effect of medicine ball training on throw-ins in soccer games in order to contribute new knowledge, especially in the field of soccer coaching.

Methods

The research utilized an experimental method with a two-group pre-test and post-test design. The study was conducted over a period of four weeks, with a frequency of three times per week. The data collection instruments for the pre-test and post-test included push-ups, sit-ups, throwing distance, arm angular speed, and release angle. This study proposes two hypotheses. The first hypothesis suggests that the two-handed overhead medicine ball throwing exercise may have a significant effect on upper extremity muscle strength. The second hypothesis suggests that the two-handed overhead medicine ball throwing exercise may have a significant effect on movement kinematics in soccer throwing.

Participant

The study population comprised of 52 male soccer players who met the criteria of having no history of shoulder injury, the ability to perform correct throw-ins, and at least three years of soccer practice. To ensure a representative sample, a purposeful random sampling technique was employed to select 30 participants for the study. These participants were then divided into two groups: the THOMBT group (n=15) and the CTRL group (n=15).

Study Protocol

All participants underwent a pre- and post-test to assess their ability to perform sit-ups, push-ups, throwing distance, arm angular velocity, and ball release angle. The THOMBT group received throwing training with a 3 kg medicine ball in weeks one and two, followed by a 4 kg medicine ball load in weeks three and four, while the CTRL group performed throwing exercises without any additional weight. Details are shown in Table 1 below.

According to Alcaraz et al. (2018); Chaalali et al. (2022); McMorrow et al. (2019), the study involved training three times a week for four weeks. Muscle strength was measured using sit-up and push-up tests, while movement kinematics were determined through video capture using

two Canon EOS 100D cameras and motion analysis software (Kinovea 0.9.5). The raw results of this research were obtained through these methods.

Table 1.

Procedure Treatment	
THOMBT	CTRL
Pre-test	
Week 1 and Week 2	
Throwing with 3 kg medicine ball 8 repetition 3 sets	Throwing with ball 8 repetition 3 sets
Week 3 and Week 4	
Throwing with 4 kg medicine ball 10 repetition 3 sets	Throwing with ball 10 repetition 3 sets
Post-test	

Statistical analysis

The data was analyzed using mean and standard deviation. Normality was assessed through the Shapiro-Wilk test, while homogeneity was assessed through the Levene test. To calculate the percentage change ($\Delta\%$) between pre-test and post-test results, the formula $\Delta\% = ((\text{Post-Pre})/\text{Pre}) * 100$ was utilized. Within-group effects were evaluated using the paired t-test, while improvements between the THOMBT and CTRL groups were compared using the independent sample t-test. Statistical significance was determined at a level of $p < 0.05$. Cohen's Effect Sizes (ES) were calculated to measure the differences between groups. Values above 0.8 were considered large, between 0.8 and 0.5 were considered medium, 0.5 and 0.2 were considered small, and less than 0.2 were considered insignificant (Cohen, 2013).

Kinematic

According to Huston (2013) on the kinematics of deep football throws suggests that several parameters are important, including ball speed, throw angle, distance, and direction. The velocity of the ball is particularly important, as higher speeds allow it to travel further, making it more difficult for opponents to intercept. This velocity is influenced by various factors, such as throwing strength, angle, and technique. Choosing the appropriate throwing angle is crucial in order to reach desired targets while reducing the possibility of interception. Typically, players evaluate the positions of their opponents and the targeted areas to determine the best angle. Analyzing the distance and direction assists in reaching the target effectively, enabling players to identify the most appropriate throwing position and direction for successful execution. These parameters collectively contribute to the precision and effectiveness of deep passes in soccer.

Result

The Shapiro-Wilk test was utilized to perform a normality test on all variables in the THOMBT and CTRL groups. The results indicated that all variables had a normal distribution with a significance value of $\text{Sig} > 0.05$.

Additionally, the Levene test was conducted to perform a homogeneity test, which yielded a significance result of > 0.05 for both groups.

Table 2.

Anthropometric characteristics of the study group

Group	Age (year)	Height (cm)	Body Mass (kg)	BMI
THOMBT	16.20±0.77	168.13±4.50	57.93±11.95	20.36±3.37
CTRL	16.13±0.83	167.93±5.20	57.82±12.36	20.35±3.41

Data are presented as mean±SD

Table 2 presents the characteristics of two groups: THOMBT and CTRL. The THOMBT group has an average age of 16.20 years, a height of 168.13 cm, a weight of 57.93 kg, and a BMI of 20.36. The CTRL group has an average age of 16.13 years, a height of 167.93 cm, a weight of 57.82 kg, and a BMI of 20.35.

Table 3.

Strength and kinematics results pre-test and post-test the training in both groups.

Variable	Group	Pre-test	Posttest	Δ%	P	ES
Push Up	THOMBT	23.47±5.25	28.73±5.51	22.44	.000*	3.54
Push Up	CTRL	23.27±4.56	23.47±4.78	0.86	.663	0.11
Sit Up	THOMBT	35.00±6.89	38.27±7.97	9.33	.000*	1.37
Sit Up	CTRL	33.93±7.36	34.20±7.05	0.78	.452	0.20
Throw distance	THOMBT	16.79±2.61	18.16±2.37	8.20	.000*	3.07
Throw distance	CTRL	16.63±2.78	16.69±2.54	0.38	.648	0.12
Arm Angular Velocity	THOMBT	1.87±.40	2.15±.47	14.98	.000*	2.76
Arm Angular Velocity	CTRL	1.82±.39	1.87±.40	2.71	.162	0.38
Angle of Release	THOMBT	40.20±7.50	40.80±6.45	1.49	.301	0.27
Angle of Release	CTRL	40.00±5.92	40.67±6.56	1.67	.230	0.32

Data are presented as mean±SD; Δ (%): percentage of change between pre and post-training performance; p: level of significance; ES: effect size; * Significant difference, $p < 0.05$.

Table 3 presents a comparison between the pre-test and post-test results of the THOMBT and CTRL groups. The THOMBT group showed significant differences in the ability to push-up ($p = .000$, $\Delta\% = 22.44$), sit-up ($p = .000$, $\Delta\% = 9.33$), distance throw ($p = .000$, $\Delta\% = 8.20$), and arm angular velocity ($p = .000$, $\Delta\% = 14.98$). However, the angle of release variable did not have a significant influence. In contrast, the CTRL group did not show significant differences in any of the variables.

Table 4.

Comparison of strength and kinematic variables in both groups

Variable	THOMBT	CTRL	Δ%	p	ES
Push Up	8.27±1.49	.20±1.74	96.20	.000*	4.99
Sit Up	7.20±2.43	.27±1.33	91.84	.000*	3.54
Distance Throw	1.38±.45	.06±.52	95.40	.000*	2.69
Arm Angular Velocity	.28±.10	.05±.13	82.38	.000*	1.99
Angle of Release	-.07±1.75	.53±2.10	11.11	.932	-0.03

Data are presented as mean±SD; Δ (%): percentage of change between group THOMBT and CTRL group; p: level of significance; ES: effect size; * Significant difference, $p < 0.05$.

According to Table 4, there appears to be a significant difference between the THOMBT and CTRL groups. Specifically, the push-up, sit-up, throw distance, and arm angular velocity variables in the THOMBT group showed a significant increase with a p-value of 0.000. However, it is worth noting that there was no significant difference in the angle of the release variable, with a p-value of 0.932.

Discussion

The data analysis results suggest a significant increase in THOMBT training on several variables, such as sit-up and push-up ability, throw distance, and arm angular velocity. However, there was no significant effect on the angle of release in either the research group or the control group. It is difficult to compare these results with similar sports because there are no studies available that use medicine balls in soccer throwing.

Specifically, an increase in push-up ability can be caused by an increase in the strength of the chest, triceps, and deltoid muscles. In contrast, an increase in sit-ups is characterized by an increase in the strength of the rectus abdominis and oblique muscles. In contrast, these muscles contract during movement during medicine ball training, which is in line with research Aandstad (2020), which found that medicine ball movements were correlated with sit-up and push-up movements. Significant improvements in sit-up and push-up abilities have a positive impact on ball-throwing results (Hanan et al., 2021; Saeterbakken et al., 2011).

In the THOMBT group, it was observed that the angular velocity of the arm during throwing increased significantly. This finding is consistent with the results of previous studies conducted by DeRenne & Szymanski (2009); Reinold et al. (2018), which suggest that the use of heavier balls during baseball throwing practice can have a positive impact on increasing ball speed. The observed increase in angular velocity in throwing movements can be attributed to improved coordination and strength of the muscles and joints involved, particularly in the rotator cuff (Escamilla et al., 2010, 2012; Kibler et al., 2023). According by Pisz et al. (2023), medicine ball throwing exercises can be used to specifically train the agonist and antagonist muscles responsible for rotational movements of the arm, which stimulate physiological adaptations that support increased angular velocity.

It has been observed that enhancing muscle strength and angular velocity of the arm can have a positive effect on throwing outcomes. This has been demonstrated by a significant increase in throwing distance during the throwing movement in a soccer game. The principle of conservation of momentum is applicable in this movement. By increasing the angular velocity of the arm, a large momentum is created and transferred to the thrown ball, which can increase the linear velocity of the ball (Schofield et al., 2022). Apart from that, the principle of segmental sequencing also has a positive impact on how far the ball is thrown. The transfer of energy from a larger part of the body, such as the shoulder or hip, to the arm can increase the kinetic energy of the system as a whole and is transferred to the ball when throwing, causing an increase in the ball's linear velocity (Fu et al., 2022).

Based on the given load, which was 3 kg in the first and second weeks and increased to 4 kg in the third and fourth weeks, it appears that there was a positive impact on adaptation. This finding is consistent with previous research by

Edoya et al. (2015); Hartmann et al. (2015), who concluded that gradual overloading through proper training periodization can effectively stimulate muscle growth by gradually increasing training intensity. Additionally Plotkin et al. (2022) have also expressed support for this idea.

One interesting finding of this study is that there was no significant difference in the angle of release between the experimental and control groups. In biomechanics, the angle of release refers to the angle at which the ball is released during the throwing motion (Huston, 2013). The study suggests that the absence of a training effect on the angle of release may be attributed to individual technique variability. It is possible that differences in release angles may result from individual technique preferences (Linthorne, 2001). It is worth considering that technical intervention may be necessary to achieve a change in the angle of release through training.

Additionally, it is important to acknowledge that the automatic movement patterns developed by each individual participant in this study may pose a challenge to modifying their technique. The study has a second limitation in that it did not include any intervention to correct throwing technique. Therefore, further research is needed to investigate the study's results, which indicated no significant influence on the release angle.

Conclusion

The study suggests that training with a medicine ball (THOMBT) can have a significant positive impact on several variables, such as sit-up and push-up ability, throwing distance, and arm angular velocity. However, it was observed that there was no significant change in the angle of release. The results indicate that training with a medicine ball can improve muscle strength and speed related to the throwing motion, but it is important to consider individual technique variations that may affect the angle of release.

Conflict of Interest

The author has no relevant financial or non-financial interest to disclose.

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