



Association between strength and endurance of upper Trapezius and serratus anterior on performance in shot put players during delivery phase

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Abstract

Background: Shot put is a power-based throwing event where efficient force transfer through the shoulder girdle and scapular muscles is essential for optimal performance. The upper trapezius and serratus anterior muscles play a crucial role in scapular stabilization and movement during the delivery phase of shot put. Insufficient strength and endurance of these muscles may affect throwing performance and increase the risk of shoulder injuries. Therefore, evaluating the association between scapular muscle strength, endurance, and performance is important in throwing athletes.

Methodology: A cross-sectional study was conducted among 64 shot put players aged between 18–35 years in and around Latur using purposive sampling. Participants were assessed for scapular muscle endurance using the Scapular Muscle Endurance Test (SMET), muscle strength using Manual Muscle Testing (MMT), and performance using the Unilateral Seated Shot Put Test (USSPT). The collected data were analysed using descriptive statistical analysis.

Result: The study showed that players with longer training duration demonstrated higher endurance scores, improved muscle strength of upper trapezius and serratus anterior, and better shot put performance. Both endurance (SMET scores) and strength (MMT grades) increased progressively with training experience, and higher values were associated with greater USSPT distances.

Conclusion: The study concluded that increased training duration leads to improvements in muscle strength and endurance of the upper trapezius and serratus anterior muscles, which positively influence shot put performance. Strengthening and endurance training of scapular stabilizing muscles may enhance performance and help reduce the risk of shoulder injuries in shot put athletes.

Keywords: Shot Put, Upper Trapezius, Serratus Anterior, Muscle Strength, Muscle Endurance, Scapular Stability, Unilateral Seated Shot Put Test (USSPT)

Introduction

The shot put is one of the throwing events. It is regular track and field competition along with the discus throw, hammer throw and javelin. The two most widely used throwing techniques are the conventional glide and the rotational technique of the right-handed shot putter^[1]. Delivery phase is same in both the techniques^[7]. The force used in the shot-put throw begins from the ground transferred up from the lower extremity to the core and across the scapula, shoulder, and elbow and to the hand^[2]. 75% of the throwers presented one or more injuries of the throwing arm during their careers. The shoulder was the most injured body part^[1]. About 64.47% of individuals were diagnosed with multidirectional instability in the shot-put throwers. The repetitive overhead and pushing movements involved in shot put place significant stress on the scapulohumeral and thoracic musculature^[2].

The repetitive overhead motion can lead to injuries such as rotator cuff disease, labral tears, scapular dyskinesia and impingement syndrome, all of which are commonly seen in players who perform high intensity throwing motions^[3].

Muscle endurance is defined by the American College of Sports Medicine (ACSM) as the ability of muscle or muscle group to maintain a specific percentage of the maximum voluntary contraction for a prolonged period of time^[8].

Upper trapezius and serratus anterior endurance plays a pivotal role in enhancing upper body strength and stability,

which are crucial for players engaging in high-intensity, explosive sports like shot put. Sufficient endurance of these muscles is essential to maintain a consistent, proper scapulohumeral rhythm throughout prolonged overhead activity^[4].

Strength of the muscle or muscle group is defined as the maximal force generated at a specified or determined velocity^[9].

Methods

Ethical Statement

The study received approval from the Institutional Ethics Committee. It was conducted following the ethical guidelines of the Declaration of Helsinki (updated 2013) for medical research involving human subjects, as well as the 2017 National Ethical Guidelines for Biomedical and Health Research involving Human Participants from the Indian Council of Medical Research.

Design

A total of 64 samples were selected on the basis of inclusion criteria who were shot put players. Subject were assessed for scapular muscle endurance using the Scapular Muscle Endurance Test (SMET), muscle strength using Manual Muscle Testing (MMT), and performance using the Unilateral Seated Shot Put Test (USSPT). The result of tests were collected and analysed to find out association between

strength and endurance of upper trapezius and serratus anterior on performance in shot put players during delivery phase.

Participants

Total 64 participants were chosen on the basis of inclusion criteria of the study. The inclusion criteria for the study were shot put players aged between 18 and 35 years, including both males and females, who were willing to participate and had been undergoing training for at least 6 months. The analysis of study was done by using MS excel sheet.

Outcome Measure

1. Scapular Muscle Endurance Test (SMET)
2. Manual Muscle Testing (MMT)
3. Unilateral Seated Shot Put Test (USSPT)

Procedure

Ethical Committee approval was obtained from the institutional ethical committee. Total 64 subjects were screened as per inclusion and exclusion criteria. Subject was informed consent from in language understood by participants. Written Consent was obtained from the subject. Procedure was explained to the subject. At the starting of the study, demographic data was collected and Scapular Muscle Endurance Test, Manual muscle testing, Unilateral Seated Shot Put Test were performed. Data was collected. Statistical analysis was done by using descriptive analysis and result was obtained from after performing Scapular Muscle Endurance Test, Manual Muscle Testing, Unilateral Seated Shot Put Test.

Scapular Muscle Endurance Test (SMET) [3, 4, 8, 9]: It is used to evaluate the endurance of the serratus anterior and upper trapezius, the subjects were positioned with 90° shoulder flexion and 90° elbow flexion in standing position [3, 4, 8, 9]. The subjects held a digital isokinetic dynamometer in their hands and an adjustable wooden stick was placed between their elbows to maintain the test position. Subjects were instructed to stabilize their scapulae in neutral position. Subsequently, subjects were asked to perform shoulder external rotation to reach 1 Kg of load and maintain this load shown in dynamometer. When the subjects were no longer able to bear the load, dropped the stick or could not maintain the 90° shoulder flexion, the test was finished. The measurement was repeated twice, and the results were recorded as seconds. The highest value was recorded. The less is the scapular muscle endurance, the more chances of risk to the shoulder.



Fig 1: Assessment of SMET

Manual Muscle Testing (MMT) [15]: It is a clinical method used to assess muscle strength by applying resistance to a muscle's movement. To test the upper trapezius, the patient should be seated. The patient is instructed to elevate the acromial end of the clavicle and scapula while extending the neck posterolaterally. The examiner applies resistance by pressing downward on the shoulder in the direction of depression and against the head in the direction of anterolateral flexion.

To test the serratus anterior, the patient should be seated with the arm flexed to 120°–130°. The patient is instructed to perform scapular abduction and lateral rotation. The examiner applies resistance against the dorsal surface of the arm between the shoulder and elbow in a downward direction toward extension, while also applying slight pressure against the lateral border of the scapula in the direction that rotates the inferior angle medially.



Fig 2: Assessment of Upper Trapezius muscle strength



Fig 3: Assessment of Serratus Anterior Muscle strength

Unilateral Seated Shot Put Test (USSPT)

[11, 12, 13] This test is an easy to apply, inexpensive tool that is used to assess the upper extremity functional performance. This test requires pushing a weighted ball forward in a participant, motion, Participants were seated on the floor with their backs supported against the wall. The knees remained flexed and the feet flat on the floor. A measuring tape was placed on the floor and extended at distance of 10 meters. A 3 Kg medicine ball was then delivered to the participants, and they were instructed to hold it with the throwing hand at shoulder height and then push the ball as far as possible in relation to tape measure placed on the floor. Three attempts throwing with an interval of one minute between them. The average of three repetitions was considered for analyses.

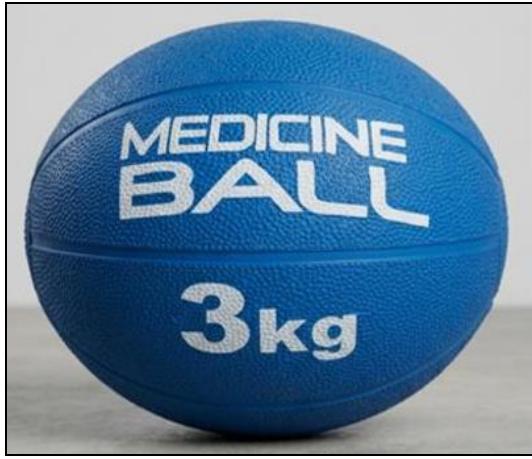


Fig 4: Medicine Ball



Fig 5: Assessment of Unilateral Seated Shot Put Test (USSPT)

Data Analysis

The data was collected and analysed using descriptive statistics using percentage in MS Excel sheet.

Result

A Total of 64 participants were assessed for scapular muscle endurance using the Scapular Muscle Endurance Test (SMET), muscle strength using Manual Muscle Testing (MMT), and performance using the Unilateral Seated Shot Put Test (USSPT).

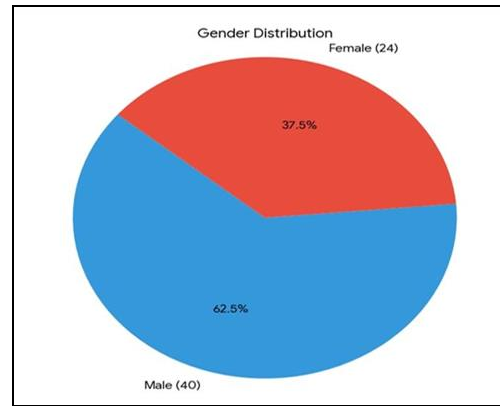


Chart 1: Gender wise distribution:

Interpretation: Chart 1 shows that this study consisted of 40 male players (62.5%) and 24 female players (37.5%), indicating that male participation was higher than female participation.

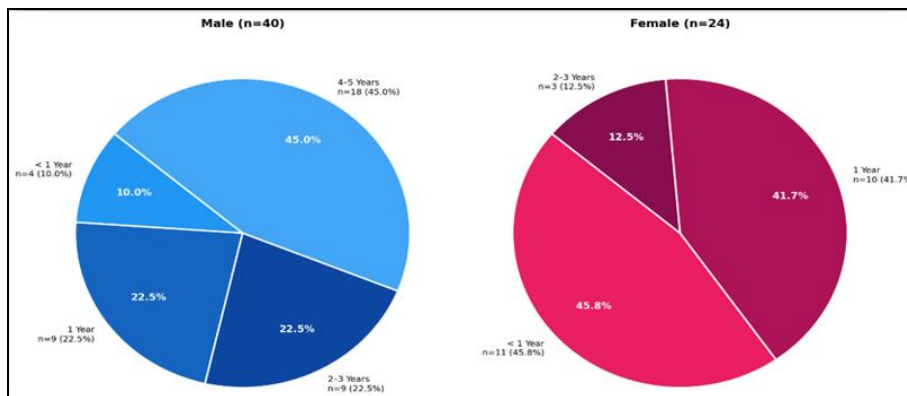


Chart 2: Training period distribution:

Interpretation: Chart 2 shows that, among male subjects (n = 40), the largest proportion (45.0%) had 4–5 years of training, while 22.5% had 1 year, 22.5% had 2–3 years, and 10.0% had less than 1 year. In contrast, female subjects (n = 24).

mostly had shorter training durations, with 45.8% having less than 1 year, 41.7% having 1 year, and 12.5% having 2–3 years, while none had 4–5 years of training. Overall, males had longer training experience, whereas females generally had shorter training histories.

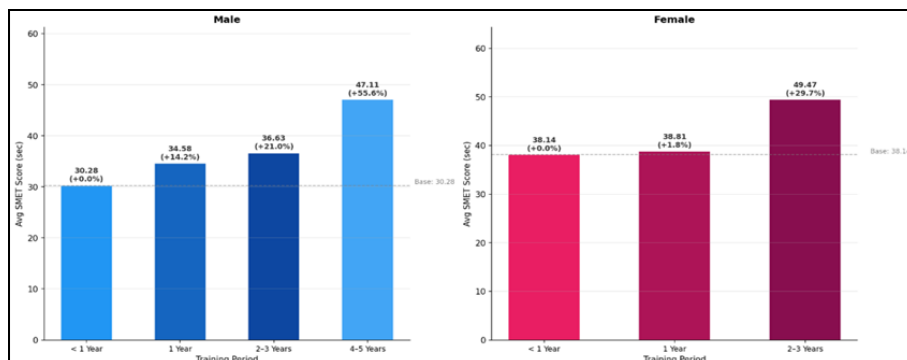


Chart 3: Endurance (Average SMET) Score by Training Period:

Interpretation: Chart 3 shows that SMET scores increase with training duration in both males and females. In males, the average SMET score rises from 30.28 seconds (<1 year) to 47.11 seconds (4–5 years).

Similarly, in females, it increases from 38.14 seconds (<1 year) to 49.47 seconds (2–3 years). Overall, the results indicate a positive relationship between training duration and endurance performance.

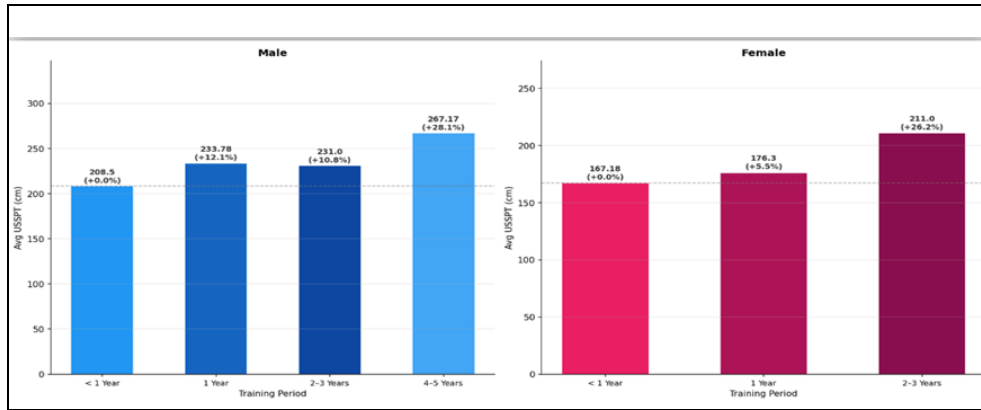


Chart 4: Shot Put Performance (Average USSPT) by Training Period:

Interpretation: Chart 4 shows that shot put performance (USSPT distance) improves with longer training duration in both males and females. In males, the average score increases from 208.5 cm (<1 year) to 267.17 cm (4–5 years), while in females it rises from 167.18 cm (<1 year) to 211.0 cm (2–3 years). Overall, longer training is associated with better performance, with males scoring higher than females.

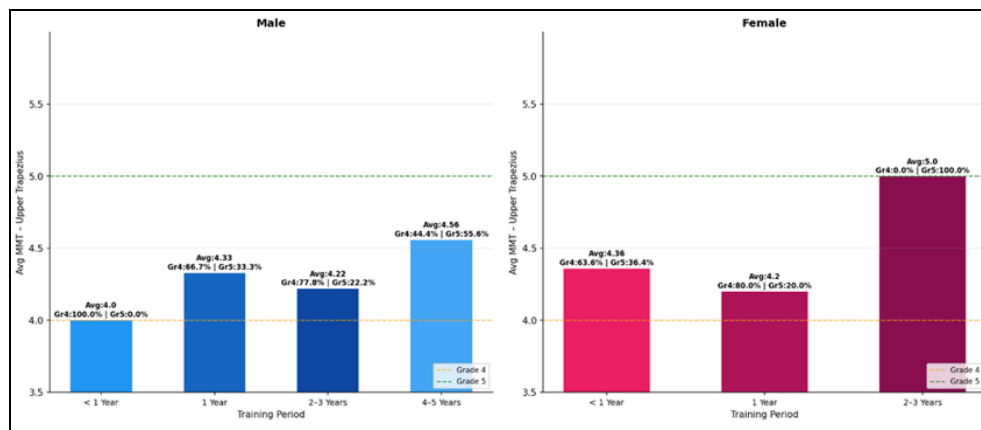


Chart 5: Strength – MMT Upper Trapezius by Training Period

Interpretation: Chart 5 indicates that upper trapezius muscle strength improves with increasing training duration in both males and females. In males, the average MMT score rises from 4.0 in <1 year to 4.56 in 4–5 years, with a greater proportion of participants achieving Grade 5 strength in longer training periods.

Similarly, females show improvement from an average of 4.36 in <1 year to 5.0 in 2–3 years, where all participants reached Grade 5 strength. Overall, the results suggest that longer training duration is associated with higher upper trapezius muscle strength in both genders.

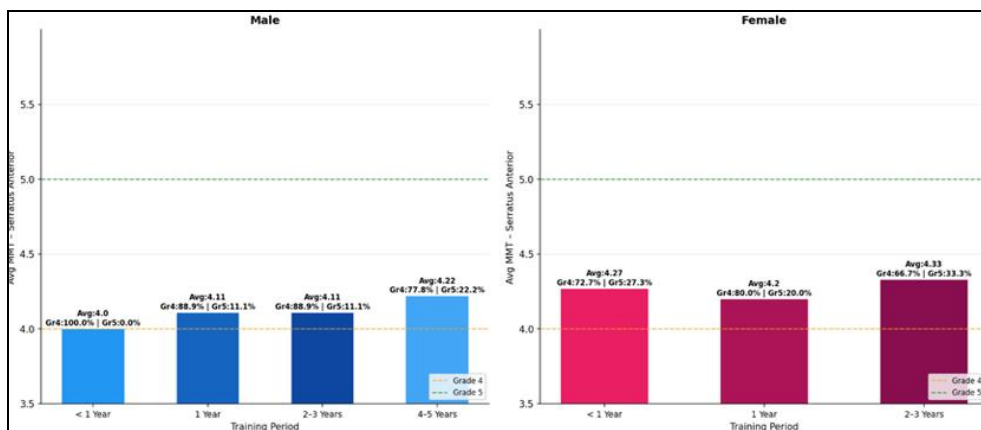


Chart 6: Strength – MMT Serratus Anterior by Training Period:

Interpretation: Chart 6 shows that serratus anterior muscle strength gradually improves with longer training duration in both males and females. In males, the average MMT score increases from 4.0 in <1 year to 4.22 in 4–5 years, with a gradual rise in the proportion of Grade 5 strength participants. Similarly, females demonstrate improvement from 4.27 in <1 year to 4.33 in 2–3 years. Overall, the results indicate that increased training duration is associated with better serratus anterior muscle strength, although improvements are relatively moderate compared to other muscle groups.

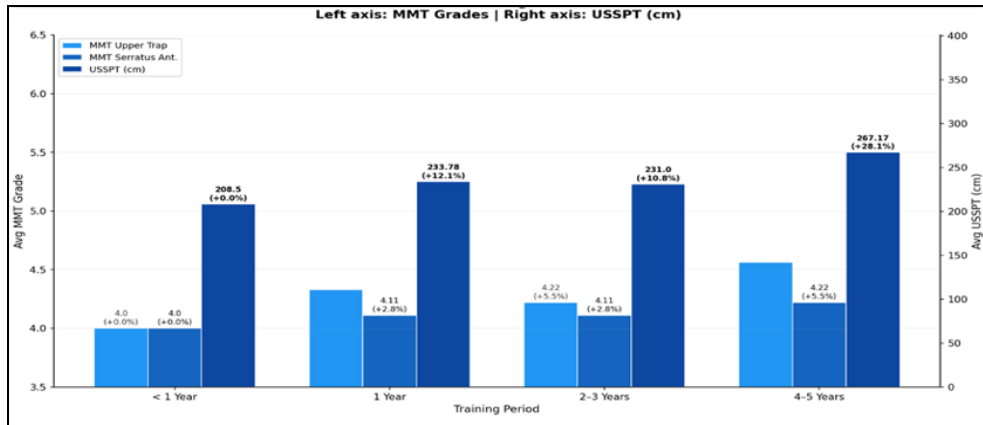


Chart 7: Association between Strength and Shot Put Performance in Male:

Interpretation: Chart 7 shows that as muscle strength (MMT grades of Upper Trapezius and Serratus Anterior) increases with longer training duration; shot put performance (USSPT distance) also improves in males.

From <1 year to 4–5 years of training, both MMT grades and USSPT scores gradually rise, indicating a positive association between muscle strength and throwing performance.

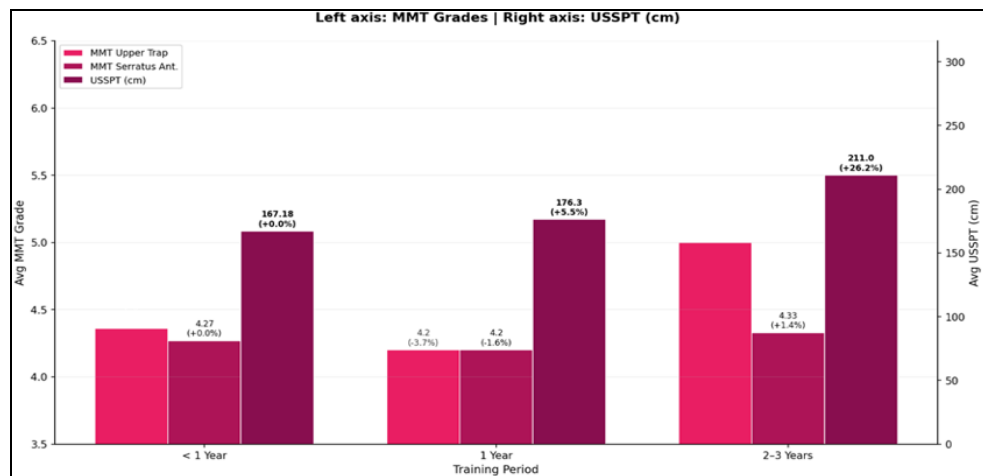


Chart 8: Association between Strength and Shot Put Performance in Female:

Interpretation: Chart 8 shows that in females, increases in muscle strength (MMT grades of Upper Trapezius and Serratus Anterior) are associated with improvements in performance (USSPT distance). As the training period

increases from <1 year to 2–3 years, both muscle strength and USSPT scores rise, indicating a positive association between strength and throwing performance in female participants.

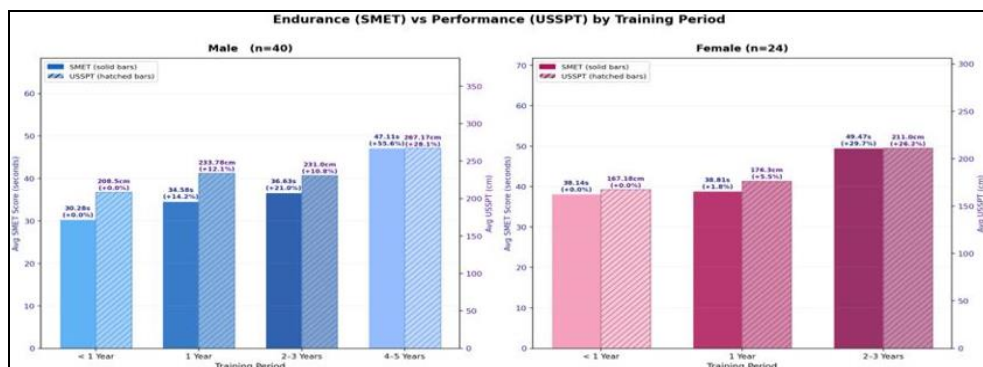


Chart 9: Association between Endurance and Performance in Male and Female:

Interpretation: The chart shows that both endurance (SMET) and performance (USSPT) increase with longer training duration in males and females. As training experience increases, SMET scores and USSPT distances rise simultaneously, indicating a positive association between endurance capacity and shot put performance.

Discussion

The present study examined the relationship between training duration, muscular strength, endurance capacity, and shot put performance among male and female players. The findings demonstrated that increased training duration was associated with improvements in endurance (SMET), upper limb muscle strength (MMT grades of Upper Trapezius and Serratus Anterior), and shot put performance (USSPT distance). These improvements can be explained through several physiological and cellular adaptations that occur with long-term training.

One of the major findings of this study was that endurance performance improved with increased training duration in both males and females. Regular physical training induces cellular adaptations within skeletal muscle, particularly in the mitochondria. Endurance training increases mitochondrial density, oxidative enzyme activity, and capillary supply within muscle fibres. These changes improve the muscle's ability to produce ATP through aerobic metabolism and delay the onset of fatigue. According to (Michael J. Joyner and Edward F. Coyle), endurance training enhances mitochondrial biogenesis and improves oxygen utilization within muscle cells, resulting in improved endurance performance. Increased capillary density also enhances oxygen and nutrient delivery to working muscles, thereby supporting sustained physical activity.

Another important finding of this study was the increase in muscle strength of the Upper Trapezius and Serratus Anterior with longer training duration. Strength training stimulates muscle hypertrophy, which occurs due to an increase in the cross-sectional area of muscle fibres. At the cellular level, resistance training activates satellite cells and increases the synthesis of contractile proteins such as actin and myosin. These adaptations increase the number and size of myofibrils within muscle fibres, leading to greater force production. As described by Brad J.

Schoenfeld, mechanical tension and metabolic stress during resistance training stimulate protein synthesis through signalling pathways such as the mTOR pathway, ultimately resulting in muscle hypertrophy and strength gains.

The serratus anterior and upper trapezius muscles play an essential role in scapular stabilization and shoulder movement during throwing activities such as shot put. Improved strength in these muscles enhances scapular control and allows more efficient transfer of force from the trunk to the upper limb during the throwing motion. According to Vladimir M. Zatsiorsky, optimal coordination of shoulder girdle muscles is critical for generating maximum force during overhead or throwing movements. Strong scapular stabilizers contribute to improved biomechanics and increased throwing distance.

The study also demonstrated that shot put performance (USSPT distance) improved with longer training duration. This improvement can be attributed to neuromuscular adaptations that occur with training. Resistance and skill-specific training enhance motor unit recruitment, firing

frequency, and synchronization of muscle fibers. These neural adaptations enable athletes to produce greater muscular force in a shorter time period. As explained by William J. Kraemer, early strength gains during training are largely due to neural adaptations, while long-term improvements involve both neural and muscular changes. Additionally, the results showed a positive association between muscle strength and throwing performance. Increased strength of the upper trapezius and serratus anterior contributes to greater shoulder stability and improved force transmission during the throwing motion. At the cellular level, muscle fibers undergo hypertrophy and increased myofibrillar density, allowing greater contractile force generation. These structural changes enable athletes to generate higher velocity and power during the shot put throw.

Another key observation from the study was the simultaneous improvement in endurance (SMET) and performance (USSPT) with increased training duration. Improved endurance allows athletes to maintain higher training volumes and recover more efficiently between efforts. Enhanced mitochondrial function, improved energy metabolism, and increased buffering capacity within muscle cells help delay fatigue and support repeated high-intensity movements during training and competition.

Overall, the findings of this study support the concept that long-term training induces both physiological and cellular adaptations that improve athletic performance. Increased mitochondrial density, enhanced capillarization, muscle fibre hypertrophy, and improved neuromuscular coordination collectively contribute to improved endurance capacity, muscular strength, and shot put performance.

During the delivery phase of the shot put, scapular muscles must maintain stable positioning while large forces are generated through the upper limb. If these muscles fatigue prematurely, scapular dyskinesis may occur, reducing the efficiency of the kinetic chain and negatively affecting performance. Kibler and Sciascia (2010) emphasized that endurance of scapular stabilizers is essential for maintaining proper shoulder mechanics in throwing athletes [21]. Therefore, athletes with greater endurance capacity of the upper trapezius and serratus anterior may be able to sustain optimal scapular control, resulting in improved shot put performance.

Conclusion

The present study investigated the relationship between training duration, muscle strength, endurance, and shot put performance among male and female players. The results showed that athletes with longer training duration had better muscle endurance (SMET), greater upper trapezius and serratus anterior strength, and improved shot put performance (USSPT distance). A positive association was also observed between muscle strength and throwing performance. Overall, the study concludes that increased training duration significantly improves muscular strength, endurance, and athletic performance in shot put players.

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