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**Original Article**

# The relationship between trunk rotation strength and throwing ball velocity among female collegiate softball players

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**Abstract**
The throwing ball velocity is one of the most important skill required in numerous sports, such as softball. Throwing can be considered as an essential technique since softball players must implement this skill to prevent opponents from advancing and acquiring more points. The movement of throwing involves the power generated from lower extremities, mediated by trunk rotation, which moves onwards to the upper extremities. Trunk rotation is assumed to play a crucial role in increasing ball velocity through the throwing movement sequence. However, studies that highlight the relationship between trunk rotation and throwing ball velocity remain lacking. This research determines the relationship between trunk rotation strength and throwing ball velocity among female collegiate softball players. 72 female softball players from Universiti Teknologi MARA are selected to participate in this research. All participants are tested using the trunk rotation strength test and throwing ball velocity test. The recorded scores of both tests are analysed using Pearson's correlation coefficient to identify the relationship between the two variables. The result shows the relationship between these two variables is r=.53 indicates that there is strong relationship between the trunk rotation strength and throwing ball velocity (r<.50). Based on this outcome, trunk rotation strength should be included in softball training programs as well as many other sports that require similar throwing movements to successfully enhance the throwing velocity performance.
**Key Words***:* **- Softball, Strength, Throwing velocity, Trunk rotation, Sports**

## Introduction

Softball is among the most famous sports worldwide. It is a sport that requires less body contact and is more specific to female athletes, in contrast to baseball which is usually played by male athletes. Softball is a dynamic sport that consists of throwing, catching, batting, running and pitching. Throwing (overhead throw) is an essential technique that requires attention to effectively enhance softball performance. Softball players will use this skill regardless of their fielding positions (Rozella et al., 2018). Throwing is considered to be one of the most important technical skill in softball since it is a major determinant of all actions taken by the players. It is crucial to develop this skill for various reasons. To gain an advantage, one element to emphasise would be ball velocity when throwing the ball since it can stop the opposing team from acquiring more points. According to Zapartidis et al. (2009), sports that depend on ball throwing velocity to determine performance must examine the factors that influence the speed of the thrown ball, for instance, the physical characteristics (anthropometrical, gender and age) and the physical fitness (skill-related fitness and health-related fitness). Throwing velocity is related to muscle power and strength. Muscle power is seen as an important parameter that is responsible for the successful rapid movements made with maximum effort, such as the act of throwing (Bragazzi et al., 2020).

To establish high velocity while throwing, athletes must properly condition their muscle activity, such as the force generated during concentric contractions by specific muscles (Zawrotny, 2005). Developing proper conditioning for an overhead throw is extremely vital to fully comprehend the elements of a proper technique and the requirements needed to execute appropriate overhead throw (Kinoshita et al., 2017). Fleisig et al. (2013) stated that four phases of throwing are present during the overhead throw: wind-up, cocking, acceleration and follow-through. Each phase requires the development of different muscle groups. The individual must perform a certain series of actions to either accelerate or decelerate his/her body and provide the necessary energy and momentum to throw the ball (Evans, 2013; Zeppieri Jr et al., 2021). The core muscles aid in movement control, energy transfer, body weight shifting and stress distribution during weight-bearing (Wilk et al., 2016). Increasing the throwing velocity is a major challenge for effective strategy in the game of softball. Kimura et al. (2020)


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conducted a three-dimensional analysis on the action of throwing. It was found that the upper torso, upper arm, forearm, hand and the ball are where most mechanical energy is generated.

As mentioned by Cohen et al. (2019), athletes must execute a synchronised sequence of intricate, explosive motions (starting with the legs, moving through the pelvis, mediated by the trunk and ending with the throwing arm) to effectively throw with speed and precision. Aragon (2010) also emphasised that proper execution of the overhead throw requires significant strength and power of the lower extremity, trunk and upper extremity. The determinants of throwing speed seem to include the individual's ability to rotate multiple parts of the body with increasing velocity. The effect of trunk rotation is approximately 50 percent of the throwing speed, while the rest is the result of the movement of the upper limbs (Pedegana et al., 1982). Zawrotny (2005) explicitly indicated that 46.9% of throwing velocity can be attributed from stride and lower extremities, while 53.1% is due to trunk and arm action from upper extremities. This statement proves that trunk rotation does influence the throwing velocity through energy transfer from the trunk rotation strength to the throwing arm. Solomito et al. (2015) further mentioned that the player must focus on their trunk mechanics. Coaches usually teach throwers to adjust their throwing motion to maximise efficiency or avoid injury of the throwing arm. The trunk muscles are responsible for providing proximal stability which, in turn, enables distal motion (Özdal et al., 2019). These muscles facilitate the transfer of torque and angular momenta between the limbs. Due to its ability to carry, retain and redirect kinetic energy, the trunk has been dubbed “the powerhouse” (Gharote et al., 2017).

Several studies that examined different sports with the same throwing movement as softball, such as handball and tennis, indicated that the existence of throwing velocity is connected to the force generated by trunk rotation. Van den Tillaar and Ettema (2007) noted that there is a significant connection between the timing of the maximum pelvis angle and trunk with the speed of the ball. This indicates that skilled players begin rotating their pelvis and trunk to the front earlier when throwing during handball. Trunk rotation also occurs during the serve in tennis (overhand movement) which is an important part of power production and energy transfer from the lower to upper body via the kinetic chain (Ellenbecker & Roetert, 2004). Based on this statement, it is clear that the trunk rotation movement serves as a medium for transferring energy from lower extremities toward the throwing arm during the entire throwing sequence. Although several studies had explained that the kinetic chain of throwing does include trunk rotation strength and movement, there is still a lack of research on the exact relationship between trunk rotation strength and throwing ball velocity. This relationship must be determined to support the basis that trunk rotation movement can enhance the throwing speed and produce a greater ball release velocity, especially in the game of softball. Therefore, there is an urgent need to identify the relationship between trunk rotation strength and throwing ball velocity among softball players.

## Materials & Methods

*Subject*

The study was conducted on a sample of 72 healthy female softball players. All participants are right-handed collegiate females from Universiti Teknologi Mara Malaysia. The requirement is that participants must be involved in any softball tournament to ensure that they are familiar with the softball throwing skill. All participants also underwent 1 week of trunk rotation strength familiarisation sessions to gain the necessary experience for the trunk rotation strength test. Participants with current or prior injuries and illnesses that may place them at risk while conducting the necessary tests were excluded. Written informed consent was obtained from all subjects before participation.

*Instrumentation*

The current study consists of two variable tests: the throwing ball velocity test and trunk rotation strength test. In the throwing ball velocity test, a Mizuno ball M150 was used during the throwing trials since it is the official ball used in softball tournaments and is certified by the International Softball Federation (ISF). Throwing ball velocity was measured using a Doppler radar gun (Bushnell Speedster Speed Gun; Bushnell Inc, Lenexa, KS) with an accuracy of 1.61 km/h (1 mph) (Bowman et al., 2006). Tilaar and Marques (2013) reported that the intraclass correlation coefficient (ICC) of the Doppler radar gun is .97. Similarly, this study’s ICC result (ICC= .95) for the Bushnell Speedster Speed gun was highly consistent with the previous study mentioned earlier. The 3RM torso rotational strength test was used to measure the trunk rotation strength. A Cybex Torso Rotation Machine was employed to measure trunk rotational strength from the dominance side.

Based on the procedure accomplished in the study of Tilaar and Marques (2013), the radar gun was placed approximately 1 metre behind the target, perpendicular to the ball direction. A target was provided to control the projectile of the traveling ball. Participants were invited to perform three maximum throwing trials, and each trial was duly recorded. Approximately 30 seconds of rest was provided between all throwing trials to prevent the occurrence of muscular fatigue. The ball velocity was measured for a distance of 10 metres from the standing position of the subject to the throwing target. A 10-metre length was applied since the pre-investigation had identified that the ball projectile is within a minimum of 10 metre distance, as proven in the study of Escamilla et al. (2010). The middle distance between bases is the critical peak velocity for the overhead throw. The throwing ball velocity was assessed before and after the 6-week training program.

In the trunk rotation strength test, multiple repetition maximum protocols using the Cybex Torso Rotation Machine were employed to measure the torso rotational strength. This study used the three-repetition maximum (3RM) to calculate the estimated one-repetition maximum (1RM). The score was measured in kg and further calculated using the formula of Baechle and Earle (2008) to assess the estimation of 1RM. The following equation describes the estimation of the 1RM formula using multiple repetition maximum protocols.

1RM = *Weight x [1 + (0.033 x repetition)]* To measure the trunk rotation strength, participants were seated on the Cybex Torso Rotation Machine, placing both feet on the foot plates while squeezing their knees securely against the adductor pads. The seat height was adjusted to ensure that knees are at a 90-degree angle to the foot plates. Participants sat upright, grasped the handles with each hand and pulled their chest firmly to the chest pads. Next, each participant was asked to perform a specific torso rotation warm-up of five to ten repetitions with a light-to-moderate load. After one-minute rest, the load increased, and participants were asked to complete three to five repetitions. Next, a four-minute rest was permitted before the load further increased to the participant`s near maximal load. This allowed them to complete three repetitions. If participants were able to lift the load more than the targeted repetitions, a two-minute rest was provided, and the load increased. Participants again attempted the 3RM torso rotation. If they failed, a two-minute rest was given, and the load decreased by subtracting 5.9 kg. Since the weighted plate for the Cybex Torso Rotation Machine is 5.9 kg per plate, the load was either increased or decreased by that weight (5.9 kg). The process continued until participants completed the 3RM torso rotation with a proper exercise technique. During the torso rotation strength test, participants rotated their torso according to the range of motion in the torso rotation protocol (105°), as specified in a previous study (Szymanski et al., 2006). Participants were then tested on their dominant side. If they failed to achieve a specific full range of motion (105°) or did not perform the test properly, the test was considered invalid, and the process must be repeated.

*Data Analysis* - All data were analysed using the Statistical Package of Social Sciences (SPSS) program software version 20.0. Since the radar gun can only record the velocity score in miles per hour (mph), the score was converted to metre per second (m/s) by multiplying 0.447 (1 mph = 0.447 m/s). This conversion is important for adhering to the international system of units (SI). Prior to the analysis, the score of the trunk rotation strength test (kg) was divided by the participant’s body weight to measure the relative strength score. The absolute strength must be measured since body weight can influence an individual's muscular strength. Next, the Pearson’s correlation coefficient was used to obtain the correlation between the two variables (trunk rotation strength and throwing ball velocity) among female collegiate softball players.

**Results**

Table 1 presents the mean, standard deviation, minimum and maximum scores of throwing ball velocity and the relative trunk rotation strength variables. The mean for trunk rotation strength was .62. (SD=.14), with a minimum score of .41 and a maximum score of 1.07. The throwing ball velocity variable was 17.73 m/s for the mean score (SD=2.13), with a minimum score of 11.89 and a maximum score of 21.90 m/s for all 72 participants.

**Table 1:** Mean, standard deviation, minimum and maximum scores for relative trunk rotation strength and throwing ball velocity

| Variables | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Trunk rotation strength | .62 | .14 | .41 | 1.07 |
| Throwing ball velocity | 17.73 | 2.13 | 11.89 | 21.90 |

Table 2 displays the results of the correlation between trunk rotation strength and throwing ball velocity. The Pearson’s correlation coefficient was calculated to assess the relationship between trunk rotation strength and throwing ball velocity among female collegiate softball players. The correlation is (r=1) and the number of trunk rotation strength test is (n=72). The correlation of trunk rotation strength and throwing ball velocity (r=.534) is based on the pairwise values of n=72. There is a large correlation between trunk rotation strength and throwing ball velocity, r=.534, n=72, p=000.

**Table 2:** Correlation between trunk rotation strength and throwing ball velocity

| Variables | | Trunk rotation strength | Throwing ball velocity |
|---|---|---|---|
| Trunk rotation strength | Pearson’s correlation | | .534 |
| | Sig. (2-tailed) | | .000 |
| | N | 72 | 72 |
| Throwing ball velocity | Pearson’s correlation | .534** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 72 | 72 |

**Correlation is significant at the 0.01 level (2-tailed)

**Discussion**

Based on this current study, the results revealed that there is a strong relationship between trunk rotation strength and throwing ball velocity. The correlation coefficient value between the trunk rotation strength and throwing ball velocity is strongly related (r = 0.534). This indicates that trunk rotation strength does influence the throwing ball velocity. Stronger trunk rotation leads to greater force that enhances the throwing ball velocity. This statement is supported by Bullock et al. (2018) who found that trunk rotation strength can create a greater force that boosts the overhead throw and generates a greater throwing ball velocity. Toyoshima et al. (1974), as cited by Ishida and Hirano (2004), mentioned that the contribution of the throwing arm to the throwing velocity was proven to be 53.1%, indicating the energy value generated by the trunk's rotation.

The technical components that lead to this strong relationship may be due to the movement of the thrower's body during throwing, which has an impact on the speed of the thrown ball. It begins with the power obtained by the lower body and then the strength mediated by the trunk rotation, assisted by the hand swing, to influence the speed of the ball while throwing. Papas et al. (1985) noted that the overhead throw is a complete body movement through a sequence that moves from the left foot to the trunk, then to the right side with concurrent stimulation of body parts for a right-handed thrower. The combined acceleration of all body parts adds ballistic energy to the thrown ball, resulting in the highest velocity at the moment of release. Stodden et al. (2005) also emphasised that the upper torso begins to rotate towards the release of the ball, while the angle of the pelvis remains almost constant, and the rotation slows down. Rotation of the pelvis is the first to begin, followed by the upper body, allowing the trunk to curl. This twist of the trunk will create stretches in the trunk muscles, generating an increase in muscle strength from stored elastic energy.

Trunk rotation plays an important role in improving the throwing ball velocity. The result of this current study has proved that trunk rotation strength must be developed to maximise the potential of greater throwing ball velocity. This outcome is supported by Noakes et al. (2008) who noted that trunk muscles are activated prior to the throwing arm muscles, leading to an increase in throwing velocity. Their analysis also revealed that the angular velocities of the trunk and upper arm supply the velocity-dependent torque for the initial acceleration in elbow extension. Myrick et al. (2019) also stated that the trunk is necessary for the transmission of energy from the lower limbs to achieve the greatest angular momentum and torque during throwing and for controlling arm acceleration. Increased velocity of the ball and elbow pressure was associated with extreme contralateral trunk lean. The individual body segments of the thrower must act in a particular sequence during the throwing process to either accelerate or decelerate the body to produce the energy and momentum needed when throwing the ball. The core muscles help stabilise the motions, energy transfer, body weight change and weight-bearing stress distribution.

Previous research had connected the dynamics of ball pitching in baseball with other parts of the body such as the foot, pelvis, torso, shoulder and arm, which are the same movements as the overhead throw in softball. Rotation initially occurs in the pelvis then in the upper body, causing the trunk to twist (Ishida & Hirano, 2004). This twist of the trunk will create stretches in the trunk muscles, generating an increase in muscle strength from stored elastic energy. Papas et al. (1985) also explained that the pivot leg vigorously extends with ankle plantar flexion, knee and hip extension, moving the body forward into the movement as the striding leg continues around the body. The hips and pelvis begin to rotate forward together, followed by a segmental trunk movement that advances from the pelvis to the shoulders.

Several previous research supports the notion that training the trunk muscle will lead to better strength transfer to the arm during ball throwing. The increased power and strength of trunk rotation will increase the throwing ball velocity. During the arm cocking phase in softball throws, the athlete must be trained to aim for proper trunk rotation as well as strength and stability of the trunk to produce angular speed for optimum ball velocity (Stodden, 2002).

Future research can apply the relationship of trunk rotation strength and throwing ball velocity on other sports that have the same movement mechanics, for instance, handball, javelin throw, tennis, volleyball, badminton and other sports that require the same movement as the overhead throw. Future research on the relationship between trunk rotation strength and throwing ball velocity can compare between different genders or levels of participation. Potential research can also examine the aspect of injury that may result when the development of trunk rotation strength is neglected.

**Conclusion**

This study demonstrated how trunk rotation strength does influence the throwing ball velocity in the game of softball. As mentioned in previous research, the reason behind improved throwing velocity is due to the mechanism involved in the entire throwing process, through trunk rotation, which can also contribute in generating force. Trunk rotation strength allows the throwing arm to produce greater force while maximising the trunk rotation acceleration in the throwing movement. This indirectly increases throwing ball velocity. With this knowledge, coaches and athletes should consider including trunk rotation strength development in their training regimen to maximise the potential of throwing ball velocity. This study has proven that trunk rotation strength is one of the most important variables to be included in softball training. It is also recommended that future research should explore the relationship of this variable with additional features, such as other similar sports, various skill levels and gender differences to better understand this variable and its relationship with sports performance. To conclude, the inclusion of trunk rotation strength as an alternative training method for enhancing throwing velocity performance will be beneficial for softball as well as other sports that require similar throwing movement.

**Conflicts of interest -** There is no conflict of interest.

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