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Correlation between momentum and ball speed in shooting movements of female futsal players

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ABSTRACT

The purpose of this study was to find a correlation between momentum and ball speed in the shooting movements of female futsal players. This study used a correlational research design. Five female futsal players (aged 19) participating in this study performed shooting movements, which were recorded on video for analysis. The shooting movements of female futsal players were analyzed based on swing movements, foot contact with the ball, and body position. Pearson correlation test was used for data analysis. The results showed that the average magnitude of momentum (impact from foot contact with the ball) was 8.14±4.68 Ns and resulted in an average ball speed of 18.51±10.63 m/s. There is a relationship between the amount of momentum and the resulting ball speed (sig < 0.05). The correlation was positive, which shows the direction of a positive relationship so that the greater the momentum, the faster the ball speed. The greatest momentum is 16.49 Ns resulting in the highest ball speed of 37.48 m/s. To generate great momentum and the highest ball speed, the shooting movement is carried out with a backswing flexion angle of 106°, a kicking leg angle of 57°, and a hip and shoulder tilt angle of 14°.

KEYWORDS

Biomechanics; Shooting; Futsal; Female

1. INTRODUCTION

Futsal is a sport that resembles football. While in football, there are eleven athletes playing for each team, in futsal each team only consists of five athletes (Vieira et al., 2020). Kicking techniques in futsal consist of 3 types, namely dribble, passing, and shooting (Motta et al., 2020). Shooting is one of the futsal basic techniques that players must master. Shooting is the most common

way to score (Gioldasis, 2018). Kicking the ball at the goal and scoring goals are the determining keys for victory of each team. The shooting technique is an instep kicking technique, generally done to shoot the ball into the goal and to dispel and keep the ball away from its own area. Kicks with this technique will produce a shot that is so hard that it will be difficult to catch perfectly by the goalkeeper. Therefore, it is necessary to have the ability to master the kicking technique correctly and accurately.

Mastery of shooting techniques can be obtained through studies sport biomechanics which aims to evaluate movement so improving movement perform. Biomechanics uses principles mechanics and anatomy (Chakraborty & Mondal, 2020). This is because maximum ability is obtained through efficiency movement. The formation of movement skills in general has a lot to do with muscular coordination. Movement coordination is influenced by nerve function and is obtained from learning outcomes. Therefore, to obtain a high level of movement skills, one requires long-term practices, so that the function of the nervous system can be perfectly coordinated which leads to the automation of movement. In the study of biomechanics, the shooting movement needs to pay attention to several things, including the positioning of supporting foot right next to the ball, the positioning of the swinging leg, the positioning of the ball being kicked, the posture from the start of the kick to the follow-through attitude, and the eye focus to the ball and the target. In the preparation stage of shooting futsal balls, the right foot that will kick must be positioned as far back as possible or backswing. Similarly, when conducting front swing or swing forward, one must do it fast and strongly. Thereby the impact or foot impact on the ball is large enough, and the ball will be as far forward as possible. This is in accordance with third Newton law which states that a reaction caused by action (Martínez-Muñoz et al., 2019).

In shooting kicks, there are two interrelated movements, namely linear and rotational (angular) motion. Linear motion is the movement of an object as a whole from one place to another. In other words, it is the end result of the kick start process. At the time of execution, the ball can move straight or curved. When a futsal player kicks the ball, the foot movement will form a rotational or angular motion, which means that spinning occurs when an object moves in a circle around a fixed point. Thus, when shooting, there is an angular velocity that will push the ball forward. Angular velocity is the angular velocity of the leg when shooting can affect speed of the ball. The front swing movement that is carried out as fast as possible will result in a high foot speed, so that the impact of the foot is also greater, which in the end the ball that is kicked will move forward resulting in maximum ball speed and distance. The range of the kicking leg that starts from the back to the impact with the ball, if the axis angle at the hip joint is pulled, is about 45°. Then, the

angle span of the knee flexion axis reaches 90°. Therefore, when combined, the overall range reaches 135°. The contact of the foot with the ball is the most important thing in generating strength. There is an extension of the leg space starting from the hip joint followed by the knee joint. Of course, this space will increase the speed of foot movement and enable easier gain of the strength of muscular contraction.

Achievement of futsal sports needs to increase the effectiveness of movement in coordinating movements. Effective motion involves anatomical factors. The human body as a system consists of interconnected elements through the joints and existing muscular tissues. The biomechanics principles are used to describe the mechanics of the body and the forces required. Through the biomechanical analysis of the shooting motion, it can help athletes to develop training techniques and improve performance. Biomechanical analysis can also be a solution for coaches in correcting athletes' mistakes and improving athletes' performance by explaining movements that are efficient in performing training techniques. The aim of this study is to establish a correlation between momentum and ball speed during shooting movements among female futsal players.

1.1. Literature Review

Shooting in Futsal

Shooting is a shot at the goal to score a goal. Shooting is characterized by a very hard and fast ball speed that combines the power and accuracy of the shot. Shooting can be done with all parts of the foot, especially on the instep, inner side of the foot, and outer side of the foot. Shooting is a basic technique that must be mastered by every player since it is essential for winning the game. Shooting can be divided into two techniques, namely instep kick and side-foot kick (Hong & Asai, 2016).

Instep kicking technique

Instep kicking technique performed in the following manner: (1) Place the foot on the side of the ball with the toes straight facing the goal, not the kicking foot; and (2) Use the instep for shooting. Concentrate the gaze on the ball right in the middle of the ball as the instep touches the ball; (3) Lock or strengthen the heel so that the heel is stronger when it touches the ball.

Side-foot kick technique

Side-foot kick technique is performed in the following manner: (1) The body position is slightly inclined forward. If the body is not inclined, there is a high probability of hitting the lower ball and the ball will soar high; (2) The side-foot kick technique is the same as the instep kick. The

only difference is when shooting, the ball is positioned right on the inside of the foot; (3) Continue with the next movement, after touching the ball during the shooting, do not stop the swing.

Futsal Shooting Biomechanics

Biomechanics is defined as study of movement by using principles of mechanics (Priego-Quesada, 2021). In the early development, biomechanics was a combination of mechanics with anatomical and physiological cognition to describe the biological functions of the body. Biomechanics is a discipline that studies human motion in performing a technique. Biomechanics used the concepts of physics and techniques to explain the motion of various parts of the body and the forces acting on the parts of the body.

In biomechanical analysis, the human body is seen as a system consisting of links and joints, with each link representing certain body segments and each joint representing the existing joints. Humans can be likened to segments of objects, so the length of each link can be measured based on a certain percentage of height, while the weight is based on a percentage of body weight. Determination of the location of the center of mass of each link is based on the percentage of existing standards. The length of each link per segment rotates around the joint, and mechanics occurs according to Newton's laws. These principles are used to describe the mechanical forces on the body and the muscular forces needed to compensate for the movements that occur.

The biomechanical elements associated with kicking a ball are speed, force, momentum, energy, and hormonal systems. Momentum plays an important role in kick results. Momentum occurs when the foot hits the ball, called a collision. The more substantial momentum is produced when the foot touches the ball so hard that it generates higher ball speed. In general, the steps for kicking a ball can be described as follows: the supporting leg is placed slightly behind the ball, the kicking leg is then swung back and the knee is flexed, and the swing of the leg causes an action-reaction in the opposite arm in accordance with the third Newton law: if a certain part of the body produces a force on another part of the body, then two forces will arise, namely the one in the same direction and the opposite force, of the same magnitude. The leg swing is followed by rotation of the pelvis around the vertical axis (support leg) and the thigh of the kicking leg continues forward while the knee remains extended. When touching the ball, thigh movement slows down

2. METHODS

This study used a correlational research design to examine the relationship between momentum and ball speed in the shooting movements of female futsal players. The research subjects were 5 female Indonesian futsal players, aged 19, and had good futsal shooting techniques.

For the shooting phase analysis, we recorded the shooting test execution. The shooting test was carried out with the shooting test instructions of Ali (2011). Player stood facing the goal. The distance of goal and ball was 10 m. When a player was called by the researcher, the player took the starting position in the shooting zone and shot towards the goal. Players had two shooting opportunities in order to demonstrate their best shooting technical capabilities. We used three cameras placed on three places: the back side of the player to record the shooting motion from behind, the side of the player to record the shooting motion from the side, and the center to record the ball track.

In this study, the parameters of the shooting biomechanical analysis were swing motion, foot-to-ball contact, and body position when shooting. This study examined the correlation between the magnitude of the momentum (impact from hitting the foot with the ball) and the resulting speed of the ball.

We analyzed the results of the video with Kinovea software to extract photos and determine angles. Video recorder software used for data documentation is Kinovea software (Zimmerman et al., 2021). The extracted photos were shown as futsal shooting phases. The correlation analysis used the Pearson's correlation to determine the correlation between the momentum and the ball speed. Data analysis was performed by using SPSS 16 with the significance level of 0.05.

3. RESULTS

3.1. Data Description

Table 1 shows the data of ball speed and momentum. The minimum ball speed was 12.91 m/s, the maximum ball speed was 37.48 m/s, and the average ball speed was 18.51 ± 10.63. The minimum momentum was 5.68 Ns, the maximum was 16.49 Ns, and the average momentum was 8.14 ± 4.68.

Table 1. The data of ball speed and momentum

Sample	Ball speed	Momentum
1	13.60 m/s	5.98 Ns
2	12.91 m/s	5.68 Ns
3	37.48 m/s	16.49 Ns
4	14.95 m/s	6.58 Ns
5	13.60 m/s	5.98 Ns
Min	12.91	5.68
Max	37.48	16.49
Mean	18.51	8.14
SD	10.63	4.68

Table 2 shows the correlation between momentum and ball speed (sig < 0.05 and rvalue of 1.000 > rcrit 0.878). The calculated r value showed a positive value, meaning that the relationship between momentum and ball speed was considered positive. This means that the greater the momentum was, the faster the ball speed would be.

Table 2. The correlation of ball speed and momentum

Variable	N	Pearson Correlation	Sig (2-tailed)	Note
Ball Speed	5	1.000	0.000	Significant
Momentum	5			

3.2. Analysis of Shooting Movement

3.2.1. Swing stage

Sample 1

(a) (b)

Figure 1. Swing movement of Sample 1
(a) Backswing; (b) Frontswing

Sample 2

(a) (b)

Figure 2. Swing movement of Sample 2
(a) Backswing; (b) Frontswing

Sample 3

(a) (b)

Figure 3. Swing movement of Sample 3
(a) Backswing; (b) Frontswing

Sample 4

(a) (b)

Figure 4. Swing Movement of Sample 4
(a) Backswing; (b) Frontswing

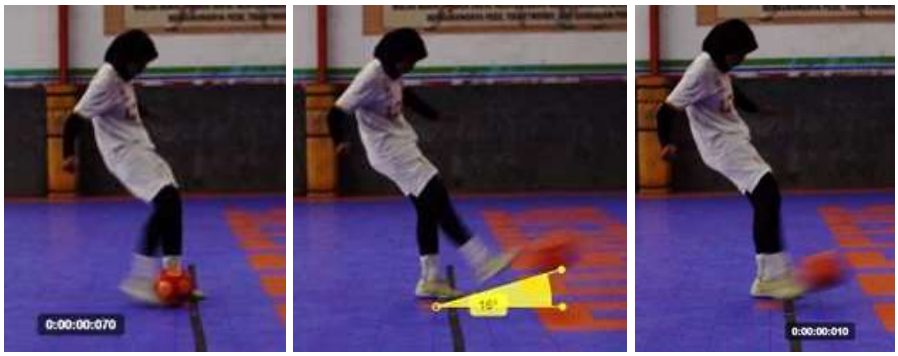
Sample 5

(a) (b)

Figure 5. Swing Movement of Sample 5
(a) Backswing; (b) Frontswing

3.2.2. Phase of Foot Contact with Ball

Sample 1



(a) (b) (c)

Figure 6. Movement of foot contact with ball of Sample 1
(a) Frontswing time; (b) Kict elevation angle; (c) Time of contact with ball

Sample 2

(a) (b) (c)

Figure 7. Movement of foot contact with ball of Sample 2
(a) Frontswing time; (b) Kict elevation angle; (c) Time of contact with ball

Sample 3

(a) (b) (c)

Figure 8. Movement of foot contact with ball of Sample 3
(a) Frontswing time; (b) Kict elevation angle; (c) Time of contact with ball

Sample 4

(a) (b) (c)

Figure 9. Movement of foot contact with ball of Sample 4
(a) Frontswing time; (b) Kict elevation angle; (c) Time of contact with ball

Sample 5

(a) (b) (c)

Figure 10. Movement of foot contact with ball of Sample 5
(a) Frontswing time; (b) Kict elevation angle; (c) Time of contact with ball

3.2.3. Body Position

Sample 1

(a) (b) (c)

Figure 11. Body position of Sample 1
(a) Kick foot angle; (b) Pelvic angle; (c) Shoulder Angle

Sample 2

(a) (b) (c)

Figure 12. Body position of Sample 2
(a) Kick foot angle; (b) Pelvic angle; (c) Shoulder Angle

Sample 3

(a) (b) (c)

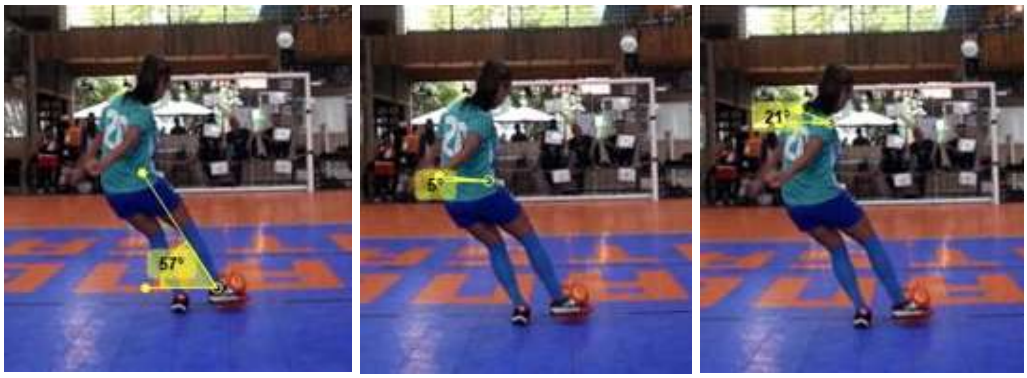
Figure 13. Body position of Sample 3
(a) Kick foot angle; (b) Pelvic angle; (c) Shoulder Angle

Sample 4

(a) (b) (c)

Figure 14. Body position of Sample 4
(a) Kick foot angle; (b) Pelvic angle; (c) Shoulder Angle

Sample 5



(a) (b) (c)

Figure 15. Body position of Sample 5

(a) Kick foot angle; (b) Pelvic angle; (c) Shoulder Angle

4. DISCUSSION

Futsal is an indoor team sport played by two teams, each consisting of four players and one goalkeeper, over two 20-minute periods on a 40 × 20 meter court (Sekulic et al., 2020). Futsal is a dynamic sport, where athletes are required to be always on the move, and good technical skills and determination are needed. Futsal requires athletes to have the ability to play which includes defense, skill/ability, power, balance and stamina/endurance. In essence, there are two futsal game characters, namely dynamic and balance. Dynamic game character includes the ability to improvise transition movements as a team from an attack-defense or defense-attack pattern. If a team only plays monotonously, then the opposing team will easily anticipate it. Dynamic character also includes individual skill/ability, and dynamic athlete movement when controlling the ball by shielding, keeping, zigzagging, and other tricks that will make it difficult for opponents to read the ball direction. The balanced game character in futsal includes the equally-good ability to attack and defend (offense-defense) by each player. Scoring a lot of goals is the main objective in futsal, and thus shooting accuracy is an important performance for players (Kam et al., 2021). The kicking technique produces a hard and fast kick that is difficult for the goalkeeper to catch.

In mechanics, the principle of changing the state of motion of an object is called force. The force is generated from the swing phases. The swing phases, namely backswing and front swing, affect the kick performance results. Performance in kicks lies in two main factors, namely the result of the kick and the speed of the ball. The backswing flexion angle and the hip angle exert different forces and will trigger the effect of the ball motion resulting from the kick. The leg, with the knee's support, is bent at 26° and remains bent up to 42° throughout the length of the kick when it comes

into contact with the ball. This stabilizes the movement before contact with the ball which allows the muscles to generate high force (Less, et.al., 2010). High force also produces high speed. In this study, the highest speed was performed with the backswing flexion angle of 106°. The range of the kicking leg that starts from the back to the impact with the ball, if the axis angle at the hip joint is pulled, is about 45°. Then, the angle span of the knee flexion axis reaches 90°. Therefore, when combined, the overall range reaches 135°. The back of the legs will be able to form a greater angle if the flexibility in the hip joint is large enough.

The contact of the foot with the ball is the most important thing in generating strength. Here, there is an extension of the leg space starting from the hip joint to the knee joint. Of course, this space will increase the speed of foot movement and will be able to more easily gain the strength of muscular contraction. In a stationary ball position, the athlete's footwork is an important part that influences the speed and trajectory of the ball. Foot velocity is identified to affect the outcome of the kick, namely ball speed. In this case, there is a law of momentum conservation which plays a role because there is an impact. There is a linear relationship between foot to the ball contact and the ball speed. The results show that there was a correlation between momentum and ball speed. The greater of momentum that results in the magnitude of the collision was, the greater the ball speed would be. The amount of momentum in the ball gives the maximum ball speed. The location of foot impact on the ball influences ball speed (Peacock & Ball, 2019).

Based on the analysis, body position was affected by the balance due to the center of gravity. The center of gravity is defined as the point where the force of gravity on the body acts. The point of gravity of the human body is not fixed, meaning that there is a shift to the heavier side which affects the swing of the kicking leg. Based on the gravity and other loads, and controlled by the nervous system, human movement is achieved through complex and highly coordinated mechanical interactions between bones, muscles, ligaments, and joints in the musculoskeletal system (Lu & Chang, 2012). The main factors that affect the swing of the kick leg are hip rotation, hip extension, and ankle flexion before contact with the ball (Aziz & Bylbyl, 2019). This is due to the angle of rotation which allows the leg to tilt the frontal plane towards the ball when the support leg slightly flexes. When the leg swings from the lateral plane to the medial plane, the pelvis will experience a transverse (vertical axis) and frontal (anterior-posterior) rotation, followed by bending of the body. In this study, high ball speed was performed with 57° kicking leg angle, and 14° hip and shoulder angle.

5. CONCLUSIONS

The momentum had a positive correlation with ball speed with a sig value of < 0.05, meaning that the greater the momentum was, the faster the ball speed would be. Based on the analysis of the shooting motion, the fastest ball speed was achieved through 106° backswing flexion angle, 57° kicking leg angle, and 14° hip and shoulder tilt angle.

6. REFERENCES

Ali, A. (2011). Measuring soccer skill performance: a review. *Scandinavian Journal of Medicine & Science in Sports, 21*(2), 170–183. https://doi.org/10.1111/j.1600-0838.2010.01256.x

Aziz, D., & Bylbyl, S. (2019). The Free Kick Kinematics of Elite Football Players. *International Journal of Sports Science and Physical Education, 4*(2), 18. https://doi.org/10.11648/j.ijsspe.20190402.11

Chakraborty, S., & Mondal, P. (2020). Importance of Biomechanics in Basketball Layup Shot. *International Journal of Physical Education, Sports and Health, 7*(5), 237-239.

Gioldasis, A. (2018). Changes of Technical Skills during an Official Futsal Game. *International Journal of Science Culture and Sport, 6*(28), 359–371. https://doi.org/10.14486/intjscs767

Hong, S., & Asai, T. (2016). Kinetic Analysis of Instep and Side-foot Kick in Female and Male Soccer Players. *Procedia Engineering, 147,* 214-219. https://doi.org/10.1016/j.proeng.2016.06.216

Lees, A., Asai, T., Andersen, T. B., Nunome, H., & Sterzing, T. (2010). The Biomechanics of Kicking in Soccer: A Review. *Journal of Sport Sciences, 28*(8), 805-817. https://doi.org/10.1080/02640414.2010.481305

Lu, T., & Chang, C. (2012). Biomechanics of Human Movement and its Clinical Applications. *Kaohsiung Journal of Medical Sciences, 28,* S13-S25. https://doi.org/10.1016/j.kjms.2011.08.004

Martínez-Muñoz, M., Muñoz-Jiménez, J., García-Gómez, M. J., Valiente-Blanco, I., & Díez-Jiménez, E. (2019). Making Physics Attractive to High-School Students Through Sports. *Gymnasium, 19*(1), 120–139. https://doi.org/10.29081/gsjesh.2018.19.1s.10

Motta, L. F. P. O., Vicentini, L. B., Rossi, R., De-Bortoli, A. L., & De-Bortoli, R. (2020). Futsal in Field with Variable Dimensions. *International Journal for Innovation Education and Research; 8*(08), 267-274. https://doi.org/10.31686/ijier.vol8.iss8.2514

Kam, K. K. W., Uiga, L., Lam, W., & Capio, C. M. (2021). The colour we wear: Impact on self-predicted and actual motor performance. *The Journal of Sport and Exercise Science, 5*(1), 16. https://doi.org/10.36905/jses.2021.01.05

Palucci Vieira, L. H., Arins, F. B., Guglielmo, L. G. A., de Lucas, R. D., Carminatti, L. J., & Santiago, P. R. P. (2021). Game Running Performance and Fitness in Women's Futsal. *International Journal of Sports Medicine, 42*(1), 74–81. https://doi.org/10.1055/a-1202-1496

Peacock, J. C. A., & Ball, K. (2019). Strategies to improve impact efficiency in football kicking. *Sports Biomechanics, 18*(6), 608–621. https://doi.org/10.1080/14763141.2018.1452970

Priego-Quesada, J. I. (2021). Exercise biomechanics and physiology. *Life, 11*(2), 1–3. https://doi.org/10.3390/life11020159

Sekulic, D., Gilic, B., Foretic, N., Spasic, M., Uljević, O., & Veršić, Š. (2020). Fitness profiles of professional futsal players: Identifying age-related differences. *Biomedical Human Kinetics, 12*(1), 212–220. https://doi.org/10.2478/bhk-2020-0027

Zimmerman, K. A., Kim, J., Karton, C., Lochhead, L., Sharp, D. J., Hoshizaki, T., & Ghajari, M. (2021). Player position in American football influences the magnitude of mechanical strains produced in the location of chronic traumatic encephalopathy pathology: A computational modelling study. *Journal of Biomechanics, 118*, 110256. https://doi.org/10.1016/j.jbiomech.2021.110256

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All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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