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Kinematics and Accuracy of The Upward Jumping Throw in Handball

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Purpose: To investigate the effect of using a proposed training program on selected kinematic variables of accuracy of shooting by an upward jumping throw at different backcourts for a school's team of beginners at Handball. **Methods:** Ten players were selected from a schools' team of the Directorate of Education in the Bethlehem Governorate, and they were divided into two groups, 5 experimental and 5 controlled. Two Sony HDR-CX220E cameras (50 images/sec) were used to capture the upward jumping throw in two styles of shooting with a defense wall and without a defense wall. A proposed training program was applied to the experimental group while the controlled group went in to traditional training routine. Pre- & post-analyses were administered using Kinovea software. **Results:** the proposed training program had a positive effect on the height of the jump and the vertical velocity of the shooter for the experimental group. Accuracy of shooting also improved in the experimental group. A decrease in the values of the kinematic variables of shooting by an upward jumping throw was also found when aiming from the left side in the case of the existence of a defense wall. **Conclusion:** It is suggested to use the kinematics' approach when designing the training program.

Key words: *training program, kinematic variables, jumping throw, handball.*

Introduction

Team Handball requires enormous power from the lower and upper extremities; it is a stressful sport that focuses on running, jumping, aiming, throwing and pushing. It is characterised by strong, and continuous violent man-to-man competition with the opponent throughout the game. The main determinants of the player's speed and accuracy are: performance, the technical

aspects of performance, the kinematic chain of body segments, and the strength of the upper and lower extremities (Gorostiaga, Granados, Ibañez, González & Izquierdo, 2005). Wagner, Buchecker, Duvillard and Mulller (2010) stated that the upward jumping throw is the most common type used in a handball match, at a rate of 73 -75%of the percentage of throwing, throwing and piercing at a rate of 14-18%, followed by the 7-meter throw at 6 -9% then the rest of the throwing types. Van den Tillaar & Ettema, (2004) also indicate that 67% of the ball's speed in aiming is a result of the effect of the extension velocity of the arm and the shoulder medial rotation of the aiming arm. Yotov & Arkchiysk, (2011) and Ohnjec, Vuleta, Milanović, and Gruić (2008) agree that coaches can benefit from knowing the details of the kinematics that influence the accuracy during the upward jumping throw. Players can take advantage of all the forces and mechanical factors that influence its success. In our country Palestine, the problem of shooting by an upward jumping throw became apparent during the national and international tournaments. The low number of goals scored by the Palestinian national team for handball during the West Asian Junior Championship led to their loss in all of the matches. On the other hand, the recorded rate for the players from the right side reached 5 goals out of 16 with an upward jumping throw from outside the 9-meter line and from the left side 7 goals out of 19 shots from outside 9 meters, which called on us to investigate the effect of using a proposed training program on selected kinematic variables of the accuracy of shooting by an upward jumping throw using different backcourts for handball beginners.

Theoretical background

The relationship between the production of muscle strength and the speed of contractility is inverse, as indicated by the results of laboratory research on the sarcomere of the frog muscle. (Hill, 1967; Lin & Nichols, 2003). It seems that there is a contradiction reported by scientific research when applying this to humans, as Abu-Ata, Abdelhaq, & Kilani, (2006) referred to some linear and non-linear relationships. Also, some tasks require analysing different relationships, especially when accuracy is important. If the task requires fine motor movement or gross motor movements, that relationship also changes.

When we talk about the relationship between speed and accuracy, the complex relationship between an individual's desire to respond quickly and make relatively more errors compared to his desire to respond slowly and make relatively fewer mistakes is the trade-off between speed and accuracy. This trade-off is also affected by the type of tasks and the kinetic performance, according to the goal to be achieved. (van den Tillaar & Aune, 2019)

Ideally, the individual would try to optimise performance in both velocity and accuracy. However, in some tasks, the individual may reduce their response time at the expense of increasing the accuracy, while in other situations the individual may find it necessary to increase their response time in order to reduce their overall accuracy level (Proctor & Vu, 2003). The problem increases when it is related to the force production, the velocity of muscle contraction and the use of the mechanical energy stored in the tendons and muscles during the stretch-

shortening cycle while increasing the level of accuracy. (Kilani, & Finch, 2001; Kilani, Palmer, Adrian, Gapsis, 1989)

Most individual games use the stretch-shortening cycle, with the exception of swimming, as well as in team games with the use of shooting at a goal. (Eslim, AlKilani, & Kilani, 2010) Throwing and scoring from jumping higher in handball is one of the important factors in the success of the team, especially since the team moves within certain limits in exchange for various defensive movements and with commitment to the implementation of the law of the game. However, what areas can be controlled and used to make handball movement more efficient? Thus, considering a jump shot in team handball at its various stages is analysed to find out where efficiency lays.

One of the goals of playing handball is that the ball's velocity and shot accuracy are powerful with running and jumping. In collegiate handball, shooting to score goals is one of the most important aspects of the game; for a shot to be successful, it must have the maximum speed of the ball and accuracy to surprise the goalkeeper (Wagner & Muller, 2008). Wagner, et al, (2010) stated that 67% of the ball velocity upon release of the ball was explained by a kinematic sequence influenced by the elbow extension velocity and the internal rotation of the shoulder. Thus, the movement can be segmented into approach, jump, throw and landing .In scientific terms, if the ball is quickly thrown at the goal, the goalkeeper's response is slow to protect the goal. Therefore, the requirements of the language impose on players to throw as fast as possible with the highest level of accuracy, and thus the player must keep up with the optimum competency of these two factors (Zapartidis, Gouvali, Bayios, and Boudolos, 2007).

Accuracy of correction can be defined as an important variable for the study. Therefore, the players lay squares on the goal in order to throw at the goal. Thus, in the performance analysis stage, there is a table to judge the subject matter of throwing effectiveness into the performance of the skill. Zapartides, Toganides, Varlitzes, Christodoulides, Kororos and Skovas (2009) reported that players during a match are significantly affected by time as the shooting accuracy or ball velocity gradually decreases. Furthermore, Akl, Hassan, Hassan, Bishop, (2019), investigated the ball's velocity and the key kinematic variables of jump throwing during different throwing phases in three strides. They found that the velocity of the throwing hand was the most important variable during jump throwing with the initial flight.

Most coaches apply eight biomechanical principles when analysing their players in most sports (Bartlett, 2007). These principles are essential to use in training and are divided into two categories; the three basic universal principles: Using the stretching shortening cycle, reducing energy use, and controlling the degrees of freedom. As for the other five general principles, they are: the sequential action of muscles, reducing inertia, generating impulses, maximising the acceleration path, and stabilisation. These apply to the kinematic tasks and are usually used to generate speed.

Nevertheless, Knudson (2020) points out that it is difficult to apply all of these principles in every sport. For example, stability is one of the biomechanical principles that apply to wrestling and martial arts such as judo. While it does not apply to handball, there is less emphasis on having a broad base of support for stability when preparing to shoot at a target.

Biomechanical principles that can be applied in handball are: reducing the energy used, the sequential action of the muscles, reducing inertia, generating momentum and kinetic quantities, using the stretching shortening cycle, controlling the degrees of freedom, and increasing the acceleration path. (Kilani & Alsulaimi, 2016)

Recalling every part of the body is important so that the maximum speed of these parts is developed as this is done from the close parts and then from the distant parts of the body. The larger proximal joint begins to work with acceleration, and thus momentum transfers results in high velocity to the smaller distal joints. Each part of the kinematic chain correlates with stopping the proximal segment resulting in an increase in angular velocity (Pori, Bon, & Sibila, 2005).

When scoring at a goal, some physiological characteristics are taken into account. Therefore, at least for some muscle groups, there should be the shortest possible time between the stretching and shortening cycle for the muscles involved in this phase (Yousef, Kilani, & Ermeley, 2020; Alzeer & Kilani, 2020). Puri et al (2005) concluded that better players use wrist extensors better than worse players.

Biomechanics branches:

Biomechanics is the science that studies the application of internal and external forces to human movement from a biological point of view. Therefore, this word is divided into physics and life science. Sports biomechanics is a quantitative and qualitative study and analysis of athletes in various classifications and sports activities of teams in general. (Baumann,1989) It can be described as the physics of sports. In this subfield of biomechanics, the laws of mechanics are applied to mathematical performance in order to gain a greater understanding through modern sciences such as modelling, simulation, and optimisation. Biomechanics is the study of the structure and function of biological systems by means of the methods of mechanics (the branch of physics that includes the analysis of the behaviour of forces). Within mechanics there are two sub-fields of study: static, which is the study of systems that are in constant motion either at rest (without motion) or moving at a constant speed; and dynamics, which is the study of moving systems in which acceleration is present, which may involve kinematics (the study of the motion of objects in relation to time, displacement, velocity, and velocity of motion either in a straight line or in the direction of rotation) and kinetics (the study of forces associated with motion, including causative forces of motion and forces resulting from motion). (Tommy, 2011) Sports bio-mechanists help people get the best performance of muscle recruitment. The

biomechanics specialist also uses his knowledge to apply appropriate contraceptive techniques to preserve the body. (BASES, 2017)

Significance:

1- There are no previous studies - to the best of the researchers' knowledge - related to the subject of kinematic variables of jump shot on high school students in team handball in the Bethlehem governorate.
2- The scarcity of interest in the game of team handball in Palestinian schools and universities, and the absence of sports championships leagues that schools hold in this field.
3- The shortage of specialists in the field of team handball and training its skills.
4- Previous studies confirmed that the topic of kinematic variables in general occupies great importance that improved jump-up shooting skill.
5- There is diversity in the previous studies in terms of the population, the sample size, and some of them were conducted on professional, amateur and junior players.

Therefore, it is imperative to conduct this study for the specific benefits of schools' teachers and coaches in general.

Purpose:

To investigate the effect of using a proposed training program on selected kinematic variables of accuracy of shooting by an upward jumping throw at different backcourts for school Team Handball beginners.

Methods:

The study sample consisted of 10 handball players for the school team of the Directorate of Education in the Bethlehem Governorate; they were distributed in a simple random way into two students' groups; a control group and an experimental group. Each of these groups consisted of 5 players, the experimental group applied the training program, and the control group has been subjected to the traditional program. All players use the right arm to score from all backcourt positions. Table 1 displays the characteristics of 10 players from the Palestinian junior handball team (Mean age 17.9 years, SD 2.45). Two Sony HDR-CX220E cameras (50 images/sec) were used to capture the upward jumping throw in two styles of shooting with a defence wall and without a defence wall. The cameras were mounted on a fixed tripod, on a level ground and aiming at the subject. The cameras were positioned as far away from the action in order to reduce perspective error. The field of view (FOV) was adjusted to match with the performance of the subjects as was recorded, as this took advantage of the performer being on the projected image and increased the accuracy of digitising the stick figure. Once the FOV was in place ; it was kept constant at all time. The cameras were placed perpendicular to capture the

movement of the subjects from two planes, the sagittal and the frontal planes; the horizontal scale of 7m and vertical reference from the goal post had been referenced. Figure 1.

A pre- & post- analysis were administered using "Kinovea" software for the selected kinematics variables. The kinematic variables were calculated and confirmed according to the following equations:

Resultant velocity = √ ((vertical velocity) ^ 2 + (horizontal velocity) ^ 2)
Vertical velocity = velocity * sin angular velocity
Horizontal velocity = velocity * cosine angle
Maximum height the ball can reach = (Tan angle * resultant velocity) ^ 2 / (9.81 * 2)
Ball release angle (inverse tangent) t-1 = (vertical velocity) / (horizontal velocity)

As for the jump shot, it was measured by using the kinaesthetic test, which measures the ability to estimate the position of the body and measure the accuracy of the aiming by the jump up. Appendix 1.

Paired Sample T test and Independent T-test were used to compare between the pre- and post-measurement of the control group and the experimental aiming accuracy. Table 3.

Table 1: Means, standard deviations of handball player's characteristics (N = 10)

Variables	Unit of Measurement	Group	Total	Mean	SD	Total	Mean	SD
Age	Year	Control	5	17.40	0.54	10	17.9	2.45
		Experimental	5	17.70	0.43			
Height	Cm	Control	5	177.8	1.00	10	178.6	2.66
		Experimental	5	178.3	1.77			
Weight	Kg	Control	5	70.40	1.14	10	70	1.86
		Experimental	5	70.00	1.58			

5 squares were designed and placed on the corners and middle of the target (Figure 1) to detect the accuracy of the shooting by upward leap on the goal. A wall is present on both the left- and right-back positions, and without a defensive wall on center-back position (Midfield). Data were analysed and showed statistically significant differences between pre- and post-analyses. Table 2 shows time distribution of the training program.

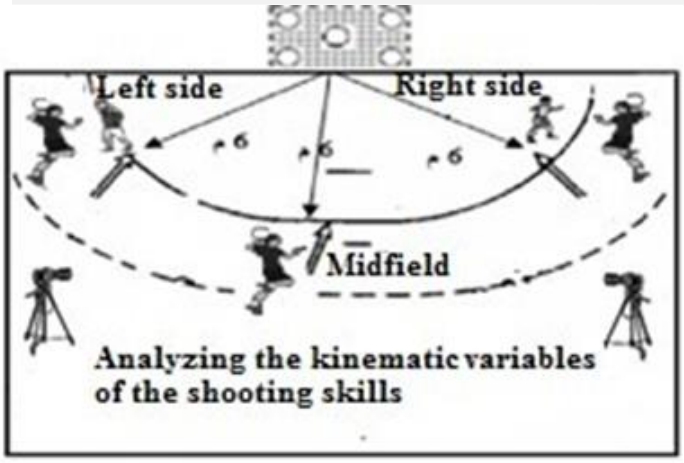

Figure 1: displays the protocol of shooting and cameras setting.

The values of the kinematic variables under study were obtained through the Kinovea. (**Kinovea** is a video player for sport analysis)

Figure 2: Real time capturing from the Kinovea video player.

Results: Table 3 shows an improvement in the values of the kinematic variables among the members of the experimental group compared to the members of the control group. The results also show an increase in the values of the kinematic variables when aiming at the goal, and when aiming from the right side without a defensive wall, while the values of the kinematic variables decreased when aiming from the left side which has a defensive wall. Table 4.

Table 2: Time value distributions of training modules for experimental group on court.

Part of the training module	First month				Second month			
	First week	Second week	Third week	Fourth week	First week	Second week	Third week	Fourth week
Warm up	30min	30min	30min	30min	30min	30min	30min	30min
Reaction speed	21min	25min	25min	14min	14min	21min	14min	25min
Arm velocity strength characteristic	35min	20min	20min	20min	20min	35min	20min	20min
Foot velocity strength characteristic	20min	25min	25min	35min	35min	20min	35min	25min
Velocity of transition	14min	20min	20min	21min	21min	14min	21min	20min
Jump shot on the move	20min	30min	40min	15min	40min	40min	40min	45min
Passing + jump shot	40min	30min	30min	45min	15min	30min	15min	20min
Dribbling + jump shot	40min	40min	30min	45min	25min	20min	25min	20min
Perimeter jump shot	20min	20min	20min	15min	40min	30min	40min	35min
Cool down	30min	30min	30min	30min	30min	30min	30min	30min

Table 3. Significant pre- and post-t tests for jump shots and accuracy between the two groups.

Jump shots	measurement	Control					Experimental				
		Mean	SD	T	Sig	Percentage of change	Mean	SD	T	Sig	Percentage of change
Aiming from different positions	Pre-test Post-test	3.70 4.30	0.95 0.48	1.78-	0.09	%16.2	3.30 4.90	0.82 0.56	5.06-	*0.00	%48.5

Table 4. T test for two independent groups, to indicate the differences in the jump shots of the experimental and control groups. N10

Jump shots	Measurement number	Mean	SD	T value	Significance level	Change rate(%)
Aiming from different positions	Control Experiment	4.30 4.90	0.48 0.57	2.55-	*0.02	%32.3

There was a statistically significant difference in the post-tests between the two groups and in favour of the experimental group.

Discussion:

Team handball is played between two teams of 7 players each trying to throw the ball into the other team's goal. The team with the most goals wins after two periods of 30 minutes. A player must possess a variety of skills and fitness components (throwing accuracy, running speed, jumping ability, etc.) to perform at the highest level (Buchheit, Mendez-Villanueva, Quod, Quesnel, Ahmaidi, 2010), and the sport is distinguished by periods of intermittent high-speed and explosive activities, interspersed with less intense activities (Ingebrigtsen, Jeffreys, & Rodahl, 2013). Thus, components of physical fitness and motor abilities are widely seen as the most important factors behind the performance of a handball team (Granados, Izquierdo, Ibanez, Bonnabau, Gorostiaga, 200). Although previous research indicates that the abilities in speed, strength, and jumping can play important roles in handball, very few studies have analysed the kinematics of motor abilities and a training program has been built on the results of that analysis such as the speed, strength, and jumping abilities of junior team handball players. It is well known that speed, repeated sprinting, strength, and jumping abilities are prerequisites for senior elite handball. (Ingebrigtsen, et al, 2013)

Table 5: Arithmetic means, Percentage of change for study variables in the sample group's pre- and post-measurements

Variables	Group	shooting skills without a defensive wall on the midfield			shooting skills \ negative wall on the right side			shooting skills \ positive wall on the left side		
		Pre-test	Post-test	Percentage of change	Pre-test	Post-test	Percentage of change	Pre-test	Post-test	Percentage of change
Ball Release velocity (m/s)	control	17.01	17.15	%0.82-	17.68	17.74	%0.34-	16.27	16.34	%0.43-
	experimental	17.05	18.10	%6.16-	17.65	18.72	%6.06-	16.38	18.61	%13.61-
Ball Vertical Velocity (m/s)	control	6.42	6.53	%1.71-	6.16	6.30	%2.27-	6.54	6.70	%2.45-
	experimental	6.46	6.95	%7.59-	6.23	6.80	%9.15-	6.63	7.39	%11.46-
Ball Horizontal velocity (m/s)	control	15.75	15.85	%0.63-	16.57	16.58	%0.06-	14.89	14.90	%0.07-
	experimental	15.84	16.71	%5.49-	16.51	17.44	%5.63-	14.97	17.08	%14.09-
Ball Release angle (°)	control	° 22.2	° 22.4	%0.90-	° 20.4	° 20.8	%1.96-	° 23.7	° 24.2	%2.11-
	experimental	° 22.3	° 22.6	%1.35-	° 20.7	° 21.3	%2.90-	° 23.9	° 23.4	%2.09-
Ball Release Height (m)	control	2.10	2.17	%3.33-	1.93	2.02	%4.66-	2.18	2.28	%4.59-
	experimental	2.13	2.46	%15.49-	1.98	2.35	%18.69-	2.24	2.78	%24.11-

Our results showed similar features in the sample age group between 14 – 18 years old in consistent with the previous Ingebrigtsen, et al, (2013) results. This also indicates that maturation, and development via a training program can improve such skills in team handballs players. The improvement in the values of the kinematic variables among the members of the

experimental group compared to the control group is due to the components of the proposed program that focused on recent physical and motor abilities.

Exercises such as coordination exercises targeting the working muscles of the lower extremities of the handball players, could help in increasing the jumping abilities of the experimental group in the post-measurement. The velocity of the ball release, maximal ball acceleration, maximal velocity of the end points of the five segments and maximal angles, angles at ball release and maximal angular velocities of the 11 joint movements and their timing during the throw, were analysed by van den Tillaar, Zondag, & Cabri, (2013),who found that the timing and the amount of maximal angular pelvis rotation were the main contributors to the difference in the maximal ball release velocity between the selected skills. In this study sequential and simultaneous coordination of the segments were absent, so no contribution of kinetic chain could be matched.

There was a decrease in the values of the kinematic variables of the experimental group from the left side throw in the presence of a defense wall. The lack of experience among the players and the inability to act well made them inaccurate to be successful in scoring a large number of goals.. This was reflected in the decrease in the velocity of the launch of the ball and is consistent with what was indicated by a study of van den Tillaar & Ettema, (2006) - when the accuracy of shooting is more important, the velocity of the ball decreases. The relationship between kinematic variables of the jump throwing, and ball velocity in elite handball players was also determined by Akl, et al, (2019), and it was found that the velocity of the throwing hand was the most important variable during jump throwing, which was correlated with ball velocity during the performance.

Kilani & Alsulaimi, (2016), indicated a decrease in the velocity of the launch of the ball in the event of a defensive wall. Rivilla, Martínez, Navarro, and Sampedro, (2011), Garcia, Grande, Sampedro, and van den Tillaar, (2011), also showed the negative impact of defense on the ball's launch velocity.

Ghosh, & Mondal, (2017), analysed the kinematics parameters (release height, release angle and ball release velocity) and compared them between national and inter-varsity level players; kinematics parameters of jump shot in handball were variable depending on the level of players. The researchers attribute the shooting accuracy to the presence of a defensive wall that changes the player's kinetic style and technique and this is reflected in the velocity of the ball's launch; however, Gorostiaga, et al. (2005) indicated that there is no difference in the velocity of the ball's launch with and without the presence of a defensive wall in professional players. Since our data showed that there were statistically significant differences in the post-tests between the two groups and in favour of the experimental group, these results were consistent with Kilani & Alsulaimi's findings, (2016). Meanwhile, this indicates that the development of the motor abilities for junior athletes could be improved by means of coordination, and strength conditioning.

In addition, coaches need to understand the value of kinematics analyses for a targeted and sequenced physical development program to ensure the appropriate development of key physical performance parameters. This clearly needs to be an integral part of the overall performance development pathway for juniors and elite handball players. Furthermore, to enhance the coach's ability to construct and deliver tailormade moves are based on kinematic measure programs, which are needed to meet the specific junior game demands of their sport in general, and playing position specifically, such as shooting against various wall defences with jumping accuracy on the goal.

Conclusion:

This emphasis on developing the skill of vertical jumping for handball players during the training process through the use of different forms of a defense wall, would put the player in a positioning similar to the conditions of the match and also help to execute accurate target shooting by an upward jumping throw to improve the velocity of the ball launch. It may be advisable to use the kinematics' approach when designing the training program, for developing the power, and other motor abilities for athletes in various team handballs, and even in basketballs.

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Appendix 1.

Test name: - Shooting from different positions
Objective: - To measure the ability to assess body position.

- Measuring accuracy of aiming by jumping up

Tools: (stopwatch, whistle, registration form, cones, hand balls, camera).

Test description:

A- Cones from (1-7) are randomly numbered as shown in Figure (3).
B - The player stands at the starting point on the (9 m) line and when he hears the coach's whistle, he shoots by jumping from No. 1 to No. 7 respectively (according to the order of numbers).

C- All the balls are above the cones.
D) The distance between all cones = 2 m, and the distance of all cones from the center of the goal line = 6 m. The diameter of the circles that the player is aiming at inside the goal is 45 cm. Figure No. (3) illustrates that:

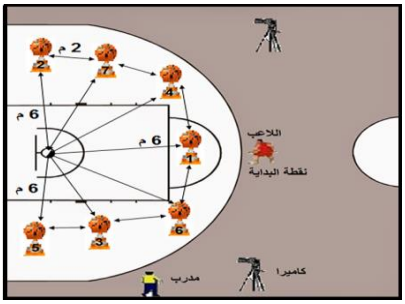

Figure No. (3)

Recording method:

-1 The player is allowed to take the test twice.

-2 The best attempt is counted from the two attempts.

3- A player's total of successful corrections is calculated. (Upgrade accuracy indicator)
4- He records for the player the time it took to shoot by jumping up from the sound of the whistle until the end of the correction on funnel No. (7). (Indicator of harmonic ability)