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Differentiation of the jump shot technique in handball players of various qualification levels based on kinematic indicators

This study aimed to identify the kinematic and biomechanical differences that occur during the execution of the jump-shot technique in elite and sub-elite male handball players. A total of ten right-handed athletes (five elite and five sub-elite) participated in the study; each player performed four jump shots. Movements were recorded and analyzed using high-speed 3D motion capture, electromechanical sensors, and laser radar technology. Based on the collected data, key kinematic variables such as center-of-mass oscillation and foot-movement distances were analyzed in detail. The findings revealed that vertical movement components and explosive-strength parameters play a critical role in increasing throwing force during the jump shot. The results indicate that greater vertical displacement and optimal coordination of lower-limb actions contribute significantly to throwing efficiency. Considering the biomechanical advantages of the jump-shot technique is essential for individualizing technical training programs and preventing sports injuries. This study highlights the importance of applying biomechanical diagnostics in handball to improve performance and maintain player health.

Keywords: throwing technique, jumping, biomechanics, center of mass, sports kinematics

Introduction

According to the International Handball Federation, more than 30 million athletes currently play team handball in 183 countries. Estimates indicate that handball players perform approximately 48,000 throwing actions during a single season, with an average throwing speed of about 130 kilometers per hour [1]. The overhead throwing technique in handball is considered one of the most important technical movements that directly influence competition outcomes. This movement requires players to direct the ball toward the goal with maximum speed and accuracy [2].

Previous research has reported that fatigue has no significant impact on the execution of throwing techniques in elite handball players throughout an entire match [3]. Kinematic analysis is now regarded as an essential method for gaining a deeper understanding of players' movements and techniques during goal-directed throws. Such analysis allows for a detailed study of the different phases of throwing, including the sequential motion of various body joints [4].

Biomechanical measurements make it possible to conduct an accurate and quantitative analysis of technical elements. This information can serve as a standard within the training process and is an important factor in developing effective training programs. Such an approach is especially valuable for determining an athlete's level of technical proficiency, monitoring individual progress, selecting appropriate kinesiological tools, and modeling methodological processes [5].

During gameplay, conditions are constantly changing. Usually, an opponent stands between the thrower and the goal, which forces the player to perform throws under different and often unstable conditions. As a result, there is considerable variability in both movement execution and throwing effectiveness.

Previous studies have shown that instability created by the opponent during the throwing process can significantly affect throwing kinematics [6]. The maximum velocity of the ball during the throw is generated through a combination of accelerations and decelerations of different body segments and joints [7].

Research by Herbert Wagner and colleagues indicates that as players gain more experience, their ball-throwing speed increases [8]. Recent studies have also shown that the use of various throwing techniques leads to significant differences in ball flight speed [9]. Studies conducted by Chelly and others have demonstrated that the main factors influencing throwing efficiency in handball players are the muscular strength and power of both the upper and lower limbs [10].

The application of innovative technologies to improve goal-shooting techniques is one of the key directions for achieving high performance. For example, analyzing the kinematic indicators of handball players' goal-shooting techniques makes it possible to identify common errors that occur during technical movements and provides opportunities to eliminate them.

Methods and materials

The study was carried out at the SPORTS 360° 3D MA Biomechanics Laboratory of the Uzbekistan State University of Physical Education and Sport. Player movements were recorded and analyzed using STT Technology software with a twelve-camera 3D motion capture system operating at 240 frames per second (Fig. 1).

The STT Full-Body Analysis (19 p) database (2019) was used as reference data. This database, commonly applied in gait analysis, contains seventy-three samples and provides comparative kinematic data such as joint angles, gait cycles, and body movement parameters during specific exercises including walking, running, and lunging.

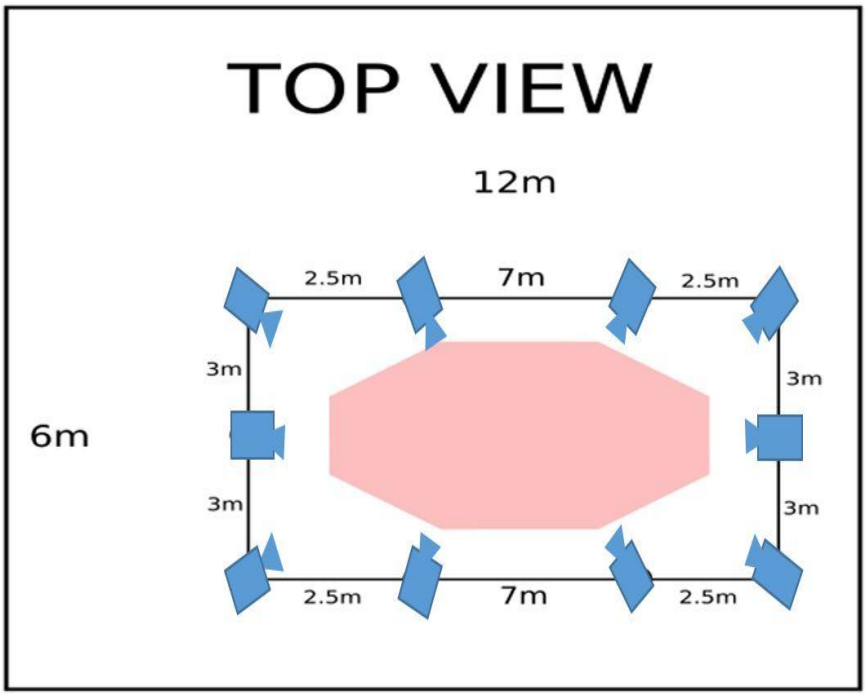

Figure 1. The positioning of 3D cameras in the laboratory setup

Ten right-handed male handball players (n = 10) from the handball team of the Uzbekistan State University of Physical Education and Sport, all participants in the Uzbekistan Higher League, took part in the study. The sample included five elite and five sub-elite athletes. Their mean age was 20.4 ± 4.1 years, mean body weight 74.6 ± 9.49 kg, and mean height 179 ± 8.3 cm. Each participant provided written informed consent before taking part in the research.

Nineteen reflective sensor markers were attached to specific anatomical points on the players' bodies for full-body motion capture (Fig. 2). The experiment was conducted using an IHF size 3 handball, in accordance with the official competition rules of the International Handball Federation. The ball had a circumference of 58–60 cm and a weight of 425–475 g.

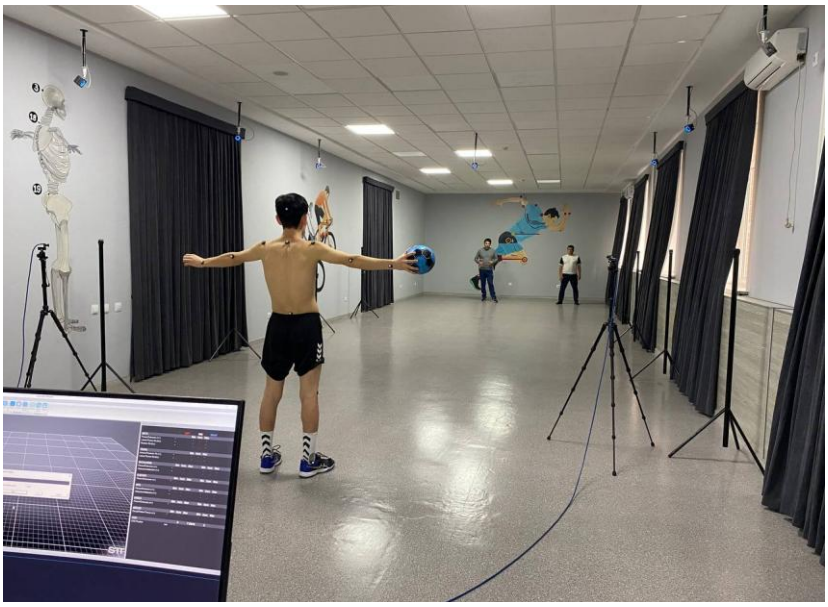

Figure 2. Placement of sensor markers on the body

Results and Discussion

After completing a 20-minute warm-up session, the handball players were instructed on the correct technique for performing the jump shot and were familiarized with the features of the 3D MA laboratory. Each player executed four jump shots from a distance of 8 meters toward the goal. The kinematic indicators associated with the highest ball velocity were selected using the 3D camera system. During the execution of the standing (grounded) shot technique, the full-body kinematic parameters of the players' movements were recorded and analyzed. The kinematic model developed by Katarina Ohnjec, Ljubomir Antekolović, and Igor Gruić served as the basis for analyzing the kinematic indicators obtained in this study.

The primary objective of biomechanical analysis of technical movements is to reveal the mechanisms of movement, explain their underlying causes, and scientifically substantiate the motor actions. This is achieved through the recording of kinematic and dynamic parameters.

T a b l e

Volume indicators of running performed during offensive technical actions by handball players with the title of Master of Sport (n=10)

Parameter	Movement performance indicators of elite handball players	V%	Movement performance indicators of sub-elite handball players	V%
	Value [mm]		Value [mm]	
Vertical COM oscillation	569,80±29,62	5,20	504,42±42,73	8,47
Right braking distance	204,08±21,90	10,70	159,50±19,59	12,28
Left braking distance	166,30±12,81	7,72	128,50±11,84	9,22
Right propulsion distance	340,92±34,86	10,2	275,08±21,98	7,99
Left propulsion distance	369,95±6,94	6,94	307,67±31,04	10,09
Support distance for right contacts	401,80±34,89	8,68	347,67±46,74	13,44
Support distance for left contacts	426,55±17,39	4,08	363,08±30,74	8,47
X coordinate of the right toe during contacts	675,30±44,17	6,54	631,42±44,62	7,07
X coordinate of the left toe during contacts	497.95±57,15	11,48	431,92±37,47	8,67
Speed of the ball m/s	29,10±4,14	14,23	24,75±2,56	10,79

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The parameters presented in the above table primarily encompass the vertical and horizontal components of movement. The analysis includes the calculation of the mean values and standard deviations for each parameter.

During the jump shot performed by elite handball players, the mean value of vertical displacement was 569.80 ± 29.62 mm, whereas for sub-elite players it was 504.42 ± 42.73 mm. In modern handball, greater vertical displacement is considered important for enhancing the effectiveness of goal shooting.

Elite players demonstrated a right-foot landing distance of 204.08 ± 21.90 mm, while sub-elite players showed 159.50 ± 19.59 mm. The landing distance provides insight into how athletes regenerate speed and force following a vertical jump. The left-foot landing distance was 166.30 ± 12.81 mm in elite players and 128.50 ± 11.84 mm in sub-elite players.

The average right-foot propulsion distance was 340.92 ± 34.86 mm for elite handball players and 275.08 ± 21.98 mm for sub-elite players. The left-foot propulsion distance measured 369.95 ± 6.94 mm in elite players and 307.67 ± 31.04 mm in sub-elite players. These indicators reflect the athletes' ability to coordinate force application and movement during the throwing action.

During the execution of the throwing technique, elite handball players achieved a ball velocity of 29.10 ± 4.14 m/s, while sub-elite players reached 24.75 ± 2.56 m/s. The throwing motion is biomechanically complex and influenced by the athlete's strength, speed, lower-limb movements, and ability to maintain correct posture during static phases. The synchronization of arm and leg movements during the throw is crucial for achieving maximal ball velocity.

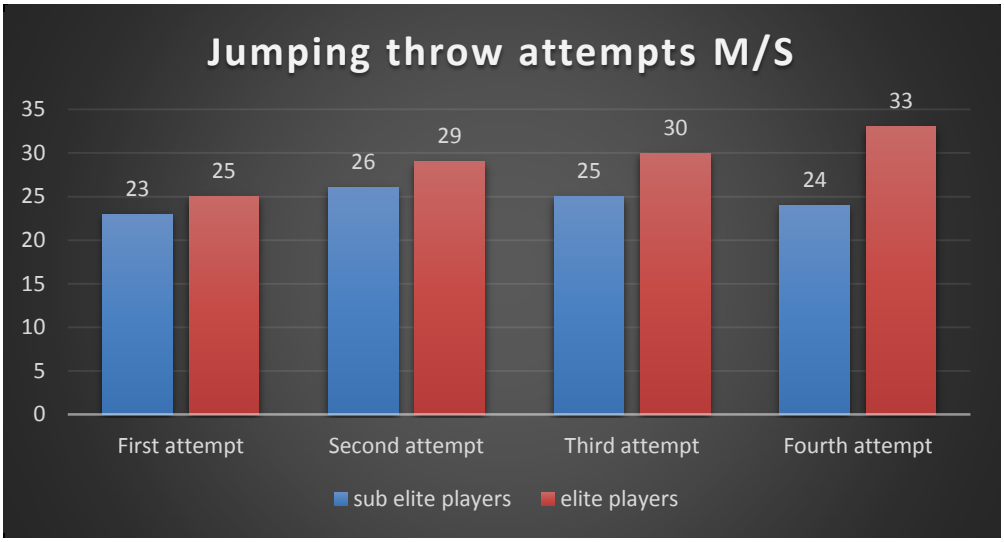

Figure 3. Attempt of a jump shot execution by handball players

In the first attempt, sub-elite handball players performed the throw at a velocity of 23 ± 2 m/s, while elite players achieved a throwing speed of 25 ± 3 m/s. In the second attempt, elite players reached a velocity of 29 ± 5 m/s, whereas sub-elite players recorded a speed of 26 ± 3 m/s (Fig. 3). Van den Tillaar and Ettema have shown that 67 % of ball velocity during a throw depends on the speed of arm extension and shoulder rotation [7]. In order to compare the obtained results, we identified the kinematic indicators of the jump shot technique performed by both elite and sub-elite handball players.

Conclusions

Improving the technical preparation of handball players remains one of the most important challenges in modern sports training. Numerous researchers have proposed different methods and tools to enhance the technical skills of athletes. The use of contemporary technologies plays a crucial role in preventing injuries and improving technical performance.

The present study demonstrates that during the execution of the jump shot, parameters such as foot movement distances, ground contact distances, vertical displacement, and ground contact coordinates have a significant impact on the force, effectiveness, and accuracy of the throw. The findings indicate that the coordination and precision of lower-limb movements, along with overall body stability, are essential for enhancing technical performance.

Therefore, designing training programs based on detailed kinematic indicators allows for a more individualized and scientifically grounded approach to athlete preparation. Such programs can help improve the efficiency of movement patterns, increase throwing power, and reduce the risk of injury. Conducting biomechanical analyses of this type is an important step toward optimizing performance and advancing technical mastery in handball players.

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