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RESEARCH ARTICLE

Biomechanical Features of the Double Back Tuck on the Floor Exercises in Gymnastics in Male Artistic Gymnastics

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Abstract
This study aims to identify the characteristics of the takeoff and landing in the round off performance followed by followed by a double back tuck. One gymnast participated in this study, and the data was captured using an camera at a speed of 240 fps and perpendicular to the plane of movement. Data were extracted using the analytical software SkillSpector and Kinovea. The data revealed that the vertical velocity, which was when takeoff (5.9 m/s). This was evident at the maximum height of the center of mass, which was measured (2.3 m). The higher values for the maximum height of the center of mass were the result of a combination of several performance factors, such as the contact angle and the takeoff on the floor with horizontal and faster leg extension. The horizontal velocity at contact was (5.7 m/s) and decreased to (-2.5 m/s) at takeoff. The results of the study indicate that the double back tuck movement involves a reduction in horizontal velocity and an increase in vertical velocity. This is because the horizontal velocity is converted into vertical velocity to raise the body to a great height so that the gymnast can get the time required to execute the skill while flying in the air. The leg muscles also played the dominant role in takeoff and landing through contact angles and takeoff and landing.

Keywords
Artistic Gymnastics, Kinematic, Skillspector, Vertical Velocity, Center Of Mass

INTRODUCTION

The back takeoff is one of the most important and widely used components in gymnastics and can occur at any point in the performance. It is recognized that the gymnast, while flying in the air as a projectile, is subject to the law of ballistics and cannot change the linear or angular momentum during that stage, and the only determinant of the angular velocity around his center of gravity is the value of the moment of inertia of the body around the horizontal axis passing through it only. The success of the gymnast in performing the motor task of the skill depends on his good use of this technique during the takeoff phase (Radhi & Obaid, 2020a).

During the takeoff phase, the gymnast accumulates the linear and angular momentum necessary to perform any somersault and obtains the appropriate takeoff by performing the round off followed by the takeoff movements. The amount of propulsion generated in both the vertical and horizontal directions during the takeoff phase depends on the extent of the athlete's success in developing linear and angular movement during his performance of the round off.

The athlete exploits the outcome of the final linear and angular movement in performing aerobic flips during his flight in the air, which confirms the necessity of both the athlete and the coach understanding the sensitivity of the balance between linear and angular movement when takeoff in order to successfully perform aerobic skills (Payne and Barker, 1976).

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The researcher noticed a scarcity of studies that were concerned with quantitative data on the mechanics of takeoff in aerobic cycles, including the study (Simaliyasky et al., 1976) of the dynamics of the round off skills with the twist and the back handspring and the pike backflip, which was the most important. The results reached by the researcher are that the times of propulsion with the legs and propulsion with the hands allow for an increase in the speed of the body during its flight in the pike backflip.

In addition, a study by (Payne, Barker, 1976), which aimed to compare the forces of takeoff in the back handspring and the back tuck in gymnastics. The study sample included four top-level gymnasts. The most important results of this study resulted in differences between the contact angle in both skills, as the contact angle in the back tuck was (70 degrees), while its counterpart in the back handspring was (48 degrees) with the horizontal plane. A difference was also found between the angular movement About the horizontal axis at the surface of the force platform in each of the two skills, where the angular momentum during the takeoff in the back tuck was greater than the angular momentum when rising in the back handspring.

Bruggemann (1983, 1987), One of the goals of Brueggemann's investigations was to determine the contributions of the arms, trunk, and legs to the total angular and linear momentum of the body. Also use force pads to record ground reaction forces (GRF) during the support phase (touch down to takeoff). The legs and trunk were responsible for the majority of the propulsion exerted on the ground during takeoff. The contribution of the legs was almost double that of the trunk due to their greater mass. Therefore, accurately positioning the legs when touching was of great importance in order to control the angular velocity of the body.

Radhi & Obaid (2020b), reported results from selected gymnastics sequences performed by male and female gymnasts during the 1989 Stuttgart World Gymnastics Championships. They concluded that the most important factors in takeoff for a successful flip were high center of mass and angular momentum. In all cases, the legs played the dominant role in contributing to the total angular momentum during the rise.

Newton et al, (1993) reported on selected biomechanical data for triple back tuck on one gymnast collected as part of an ongoing study in 3D robotic analysis. Their findings showed a 29% increase in vertical velocity when takeoff from double back tuck, which gave a 57% increase in the height reached by the center of gravity, were used in order to verify their performance characteristics.

The landings performed by elite gymnasts during major competitions represent one of the most extreme conditions under which the body must provide adequate force absorption. As a result, landings after advanced skills occur at high speeds and subsequently result in high impact forces. Gymnasts must also meet specific tumbling performance requirements imposed by the rules of the sport. The current FIG code of points (Zschocke, 1993) is the official judge's guide to evaluating the performance of gymnasts and defines landing errors in each event. Situations such as environment (surface) and skill (performance) are related to landing ability (Brueggemann, 1990). The relative contributions of body parts, soft tissue, and bone depending on local fatigue, task constraints, or muscle fitness are responsible for the action of the eccentric muscles that control joint flexion (McNitt-Gray et al., 1993).

Saleh, Radi & Hashem (2020), pointed out that when an object falls, its vertical force, kinetic energy, and momentum are directly related to the distance over which it falls, due to the exponential effect of gravity (Alp and Brueggemann, 1993) measured the pressure distribution and acceleration Foot and leg during landing in gymnastics. Maximum peak foot and leg acceleration was recorded at approximately 49 g.

With regard to landing after jumps from different heights, the force ranges from 3.9 to 11 times the body weight. Significant differences in peak vertical force, time to peak vertical force, landing phase time, and lower extremity kinematics across different drop heights have been reported (McNitt-Gray et al., 1993). There were no statistically significant differences in the peak vertical impact between the soft and hard extensors (McNitt-Gray et al., 1993). On the other hand, the kinematics of the lower extremity showed a significant difference between the extensors of different composition. These results indicate Changes in fall height and mat structure may lead to changes in landing strategies for female gymnasts. In short, there is a wealth of information and a good understanding of the somersaults requirements.

However, there is much less information regarding the biomechanics of somersaults techniques at all possible skill stages. Therefore, the current study here makes an effort to expand the horizon of knowledge by presenting new facts and ideas. For the above reason, this study was conducted to analyze the takeoff and landing of the back double tuck according to selected biomechanical variables.

Data in the biomechanics literature on landing in gymnasts during competition is limited. During competition, gymnasts must adhere to specific performance guidelines that require them to reduce their body speed to zero with a single foot stance (Brueggemann, 1994, McNitt-Gray et al., 1993). The researchers noticed that Iraqi gymnasts do not perform back double tuck on the floor, due to the lack of sufficient information about their structural composition, which prompted the researcher to conduct this study as in Figure (1). This study aims to identify the characteristics of the takeoff and landing in the round off performance followed by back double tuck.

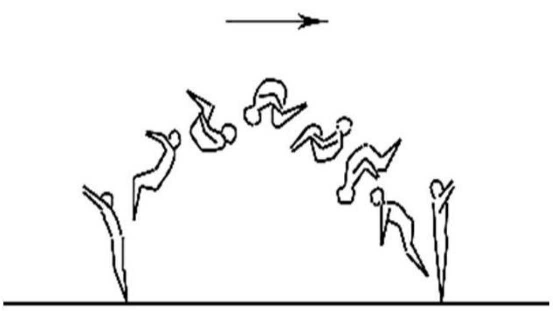

Figure 1. The research skill under study

MATERIALS AND METHODS

Participants

Gymnast participated in this study from the city of Mashhad - Iran and trained in the training center of Khorasan Razavi. The physical characteristics of the player were age 17 years, height 173 cm, mass 60 kg, and training age 13 years. He participated voluntarily and was informed about the course of the study in advance. Signed informed consent before participating in

The left human body model was defined as a rigid body system connected to 8 pieces of the body with 10 articulation points.

the study (consent was signed by legal guardians of participants under 18 years of age).

The study was approved by the Ethical Committee of the University of Basra/Student Activities Department and is in accordance with the Declaration of Helsinki. This article's necessary ethics committee permissions were obtained with University of Baghdad College of Physical Education and Sports Sciences for Woman Ethics Committee Commission Date: 12.02.2024 Issue/Decision No: 2024/12. Regarding vulnerable groups, the authors took into account the needs and priorities of the groups/individuals in which the study was conducted, in accordance by Articles 19 and 20 of the WMA Declaration of Helsinki , and the situation that the study could not be carried out outside these groups and individuals was taken into account. "In this study, additional precautions were taken by the researcher(s) to protect the volunteers."

Data Collection Tool

The gymnast was photographed using an (iPhone 11pro) camera, with a camera speed of 240fps and a resolution of (1080*1920) pixels. The researcher took care that the camera was vertical to the sagittal plane, 5 meters away and 1.50 meters high from the ground. Figure 2.

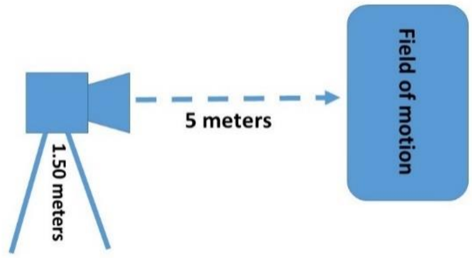

Figure 2. Camera position

In order to conduct biomechanical analysis of the video. Biomechanical analysis was performed by SkillSpector software. The researcher also used Kinovea software to measure the relative angular characteristics at each major position of the body structure. Spatial coordinates were calculated using a 4-point calibration frame at a scale of 2 × 2 m. It was placed in the place where the movement occurred and photographed for transferring it to the motion analysis program.

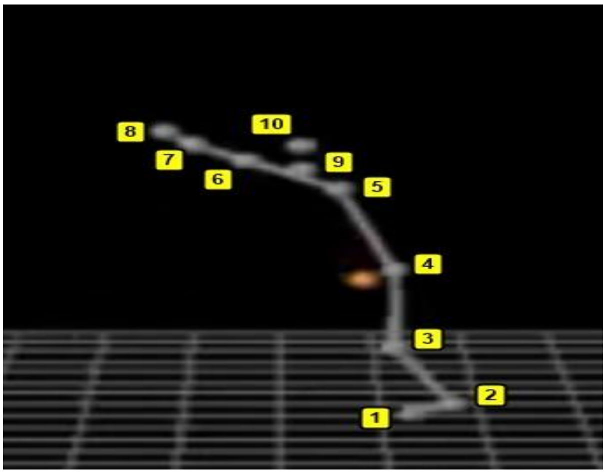

Figure 3. Definition of joints points

Toes (1), Ankle (2), Knee (3), Hip (4),The Shoulder (5) ,Attached (6), Wrist (7), Fingers (8), Palate (9), Top Of Head (10)

Statistical Analysis

SPSS package program was used in the statistical analysis of our research. It was determined by the normality distribution and skewness coefficients of the data. Significance level was determined as P 0.05 and all data were presented as mean standard deviation (SD) unless stated otherwise.

RESULTS

Table 1. Extracted variables for contact moment, takeoff, and landing

Variables	Measurement	value
contact time	second	0.15
Time takeoff	second	0.14
Height center of mass in contact	meter	0.86
Height center of mass in takeoff	meter	1.1
Maximum height of the center of mass	meter	2.3
Knee angle at contact	degree	149.2
Knee angle in takeoff	degree	174.9
The angle of the torso with the horizontal in the takeoff	degree	81.2
The angle of the thigh with the horizontal in the takeoff	degree	91.6
Contact angle with the horizontal	degree	68.6
Angle of takeoff with the horizontal	degree	92.2
Shoulder angle at contact	degree	93.1
Shoulder angle in takeoff	degree	155.8
Vertical speed of contact	m/s	2.3
Vertical speed of takeoff	m/s	5.9
Horizontal speed of contact	m/s	5.7
Horizontal speed of takeoff	m/s	2.5-
Angular velocity of the shoulder	degrees/s	265-
Angular velocity of the hip	degrees/s	307
Angular velocity of the knee	degrees/s	248-
Angular velocity of the ankle	degrees/s	354
Height center of mass in landing	meter	0.85
Vertical speed of landing	m/s	4.96-
Horizontal speed of landing	m/s	2.9
Time from maximum takeoff to landing	second	0.43
Angle of landing from horizontal	degree	85.8
Knee angle in landing	degree	182.8
The angle of the trunk with the horizontal in landing	degree	21.2
Angle the thigh with the horizontal in the landing	degree	80.9

Table 1 shows the results of the linear and angular variables for the study sample and for one gymnast, who was the ideal performer in this study. Figures (2, 3, 4, 5, and 6) show the angles of contact, takeoff and landing, the horizontal vertical velocity of contact, takeoff, and the maximum height of the center of mass, respectively

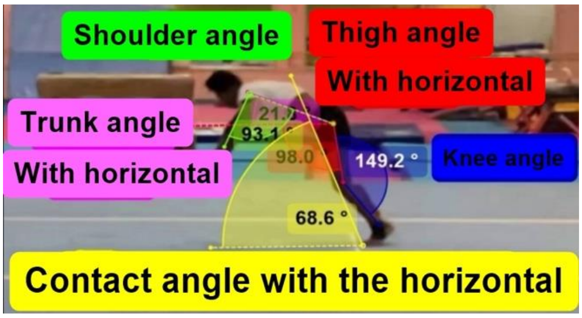

Figure 3. Angles in the contact phase

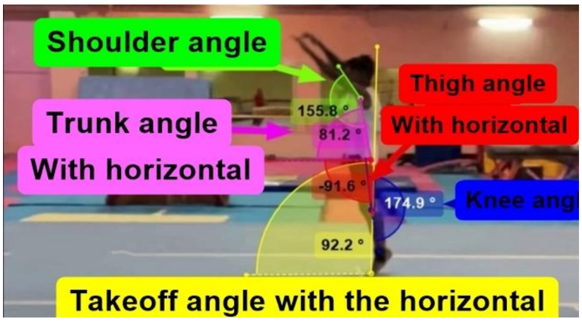

Figure 4. Angles in the takeoff phase

Figure 5. Angles in the landing phase

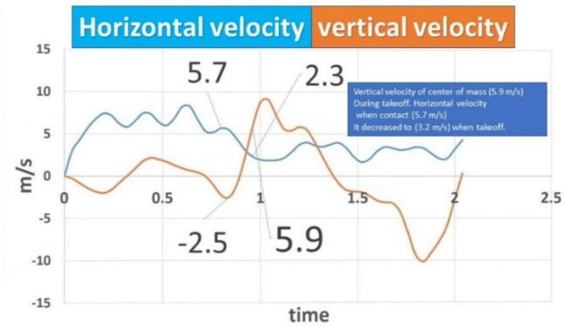

Figure 6. a graph of the horizontal center and takeoff and vertical velocity of the of mass in contact

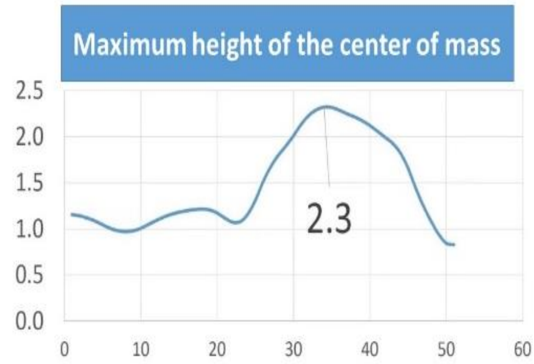

Figure 7. a graph of the maximum height of the center of mass

DISCUSSION

Data analysis showed that the most important performance factor in determining the height of the double back tuck was the vertical velocity, which was at the takeoff (5.9 m/s) as in the figure (6)(7). This was evident at the maximum height of the center of mass and was measured (3.2m). The highest values were for the maximum height of the center of mass. Resulting from a combination of several performance factors such as contact angle, takeoff to the horizontal and faster leg extension. The value of the vertical velocity was higher, compared to the studies previously referred to by (Bruggemann 1983, 1987) of 4.57 m/s, (Shaker, Tuama, & Radhi, 2022) 4.45 m/s, (Newton et al.1993; Shaker, Tuama, & Radhi, 2022) 5.8 m/s. that the leg muscles played the dominant role in takeoff.

The horizontal velocity at contact was (5.7 m/s) and decreased to (-2.5 m/s) at takeoff. The duration of the takeoff phase was (0.15 seconds), and the contact angle was (68.6˚) and in the takeoff (2.92˚). Data analysis revealed that the maximum height of the center of mass before landing was (2.3m) and the height upon landing was (0.85m). The vertical speed at landing was (-4.96 m/s) and the horizontal speed was (2.9 m/s). Knee angles at landing were (182.8˚). The performance showed reasonable extension of the body or kick before landing, and the landing was effectively predicted by appropriate foot placement. The torso-to-horizontal and thigh-to-horizontal angles at landing were (21.2˚) and (80.9˚), respectively as in the figure (3), (4), (5). The time from maximum height to landing was (0.43 seconds).

Double back tuck, which have both linear and angular momentum before takeoff, and during landing, are very difficult to control. The flexible landing surface also increases the challenge and thus makes it difficult to stick to the landing. Therefore, in order to minimize the stress on the musculoskeletal system during the landing, the gymnast must effectively dissipate the large forces he experiences during the landing phase.

The increase in landing phase time due to the maximum height of the center of mass before landing is consistent with the trend observed by (McNitt-Gray, 1991). For technically well-executed double back tuck, the extended position of the joints upon landing with the option to use a large range of joint motion during the landing phase. This may create a large margin of safety, especially if gymnasts need to adjust their strategy during the landing. For example, if the hip joint is flexed before landing, as in a double back tuck landing that lacks to adequate rotation, less movement will be available to the hip joint during the landing phase. If there is not enough movement available in the hip range, the knee joint would be expected to play a greater role.

Conclusion

The results of the study indicate that the double back tuck movement involves a reduction in horizontal velocity and an increase in vertical velocity. This is because the horizontal velocity is converted into vertical velocity to takeoff the body to a great height so that the gymnast can get the time required to execute the skill while flying in the air. The leg muscles also played the dominant role in contact and takeoff. Contact angles, takeoff, and landing played the dominant role during performance double back tuck. The angular velocity of the joints leads to acceleration performance double back tuck.

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Ethics Committee

This study was performed by adhering to the Helsinki Declaration. ethics committee permissions were obtained with University of Baghdad College of Physical Education and Sports Sciences for Woman Ethics Committee Commission Date: 12.02.2024 Issue/Decision No: 2024/12

Author Contributions

Planned by the authors: Study Design, MMA, QMS and SQN; Data Collection, QMS, MMA and SQN; Statistical Analysis, MMA, QMS and SQN; Data Interpretation, MMA, QMS and SQN; Manuscript Preparation, MMA, QMS and SQN; Literature Search. All authors have read and agreed to the published version of the manuscript.

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