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INFLUENCE OF HIP AND SHOULDER ANGULAR VELOCITY ON THE EXECUTION PHASE OF THE UPSTART IN MEN'S ARTISTIC GYMNASTICS

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KEYWORDS :

INTRODUCTION

The sport of men's artistic gymnastics (MAG) demands extraordinary strength, timing, coordination, and technical accuracy, particularly when performing apparatus-based routines. One of the six MAG devices, the horizontal bar, requires athletes to execute intricate swinging and acrobatic movements while maintaining constant body control and momentum management. (Rathore & Chandel, 2023) A fundamental ability that moves the gymnast from a hanging posture to a support position on the bar is the upstart movement. During routines, it is essential not only as a fundamental movement but also as a prelude to or link between more complex abilities (Atiković, 2020).

The shoulder and hip joints, which are key levers in producing and transmitting angular momentum, interact in a coordinated manner to create the upstart's biomechanical complexities. (Rathore, 2017) The efficiency and fluidity of the skill execution are greatly influenced by angular velocity, which is the pace at which the angular location of a body segment changes (Hall, 2018). The upward and forward propulsion needed to go to the support phase on the bar depends on effective hip extension and shoulder rotation, particularly during the execution phase. When performing a skill, inadequate elevation or bad form are frequently the result of these joints' suboptimal angular velocity (Hiley & Yeadon, 2014).

Successful gymnastic motions are the consequence of synchronised and well-timed joint angular velocities, as biomechanical studies have frequently highlighted (Yeadon & King, 2002). Kinematic coordination and peak joint angular velocities, for example, have been found to be important performance factors during high-bar routines, especially during release-regrasp parts and transitions like the startup. According to Hiley and Yeadon (2013), hip and shoulder kinematics are both essential for generating the rotational torque and vertical displacement required for successful bar transitions.

The contribution of angular velocities at the hip and shoulder joints during the execution phase of the jump in MAG is not well-documented empirically, despite the rising interest in gymnastics biomechanics. The majority of research either concentrate primarily on elite-level dismounts and flying phases or generalise the study across whole routines (Čuk & Fink, 2004). Therefore, it is important to identify and examine joint-specific kinematic characteristics that have a direct impact on upstart performance, particularly in gymnasts competing.

Thus, the goal of the current study is to investigate how hip and shoulder angular velocities affect the initial movement's execution phase on the horizontal bar. In addition to helping coaches create focused conditioning and technical exercises to improve joint-specific performance outcomes, an understanding of these linkages will provide deeper insights into movement efficiency.

Methods And Procedure

Research Design

This study used a cross-sectional methodology and a quantitative, observational design. Examining the impact of hip and shoulder angular velocity throughout the upstart movement's execution phase in men's artistic gymnastics was the main goal. In order to ascertain the links between the variables, the study placed a strong emphasis on accurate kinematic measurement employing motion capture technologies and correlation analysis.

Participants

A total of 10 elite male artistic gymnasts (mean age = 20.6 ± 1.8 years; training experience = 6.7 ± 2.3 years) voluntarily participated in the study. All participants: Had represented their respective states or national teams

Apparatus And Equipment

High-Speed Video Cameras: To precisely record joint movement, two synchronised cameras (240 frames per second, 1080p resolution) were positioned 90 degrees apart: one frontal and one lateral (sagittal plane). attached to designate joint centres at anatomical landmarks such as the wrist, lateral malleolus (ankle), lateral epicondyle (knee), greater trochanter (hip), and acromion process (shoulder). Video sequences were digitised and analysed using Kinovea, an open source program. The hip and shoulder joints' angular velocities (in degrees per second) were measured during the upstart's execution phase. According to the guidelines of the Fédération Internationale de Gymnastique, a standard horizontal bar that has been authorised by FIG was utilised.

Procedures

Warm-Up: Each participant completed a 15-minute dynamic warm-up, including: General mobility exercises, Joint-specific mobility drills for shoulders and hips, Three submaximal upstart trials as familiarization. Each gymnast performed five upstart attempts from a hanging position to full support above the bar. A 5-minute rest interval was given between trials to avoid fatigue. The execution phase was defined as the moment from the gymnast's lowest point in the swing to the moment both arms reached vertical alignment above the bar. The start and end points were identified using frame-by-frame analysis. Video recordings were processed frame-by-frame to extract joint angle trajectories. Angular velocity was computed as the first derivative of joint angle over time. Mean and peak angular velocities of both hip and shoulder joints during the execution phase were calculated.

Statistical Analysis

Data were analyzed using SPSS Version 26.0. The following statistical procedures were employed: Descriptive Statistics - Mean and standard deviation for hip and shoulder angular velocities. Pearson Product-Moment Correlation Coefficient - To examine the relationship between: Hip angular velocity and upstart performance score Shoulder angular velocity and upstart performance score. Each upstart execution was evaluated by two FIG-certified judges on a 10-point scale. The mean of their scores was used for analysis. $p < 0.05$ was considered statistically significant.

RESULTS

Table No. 1 Application Of Descriptive Statistics And Product Moment Correlation To Angular Velocity Of Hip And Shoulder Joint

Joint	Mean Angular Velocity (°/s)	Standard Deviation	Correlation with Score (r)	p-value
Hip	425.0	10.8	0.88	0.0009
Shoulder	382.5	11.9	0.81	0.004

Table shows the average rotational speed at each joint for each of the ten gymnasts throughout the execution phase. The hips produced more rotational speed and probably contributed more to vertical lift during the ascent, as evidenced by the hip joint's higher mean angular velocity (425.0°/s) than the shoulder joint's (382.5°/s). shows the degree to which the average angular velocity was deviated from by the individual gymnasts' performances. Standard deviations for both joints are very low (10.8 for the hip and 11.9 for the shoulder), suggesting that individuals' performance was constant. This is the Pearson correlation coefficient, which quantifies the direction and magnitude of the association between upstart execution score and joint angular velocity. Strong positive correlations are shown by values of 0.88 for the hip and 0.81 for the shoulder, which show that execution scores tend to rise in tandem with an increase in rotational velocity. shows how significant the association is statistically. The statistical significance of the relationships is confirmed by the fact that both p-values are less than 0.01: $p = 0.0009$ for hip angular velocity Angular velocity of the shoulders: $p = 0.004$ This indicates that there is a less than 1% possibility that these relationships happened by accident, confirming the validity of these results.

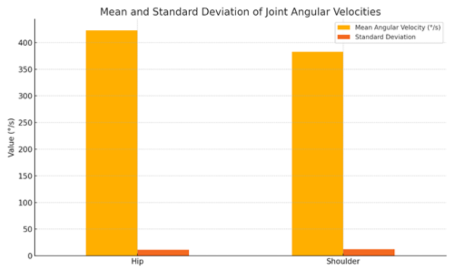

Figure No. 1 – Graphical Representation of Descriptive Statistics

DISCUSSION

This study's main goal was to find out how hip and shoulder angular velocity affected the upstart's execution phase in men's artistic gymnastics. The findings show a substantial and positive association between individual performance scores and both hip and shoulder angular velocities, with the hip joint showing a somewhat larger correlation ($r = 0.88$, $p = 0.0009$) than the shoulder ($r = 0.81$, $p = 0.004$). These results offer important biomechanical information on the kinematic factors that determine an effective upward movement. Hip angular velocity and performance score have a substantial correlation, which is consistent with previous biomechanical research that highlights the critical role lower body joint dynamics play in creating upward momentum during bar changes. The hip joint, being a major power center, facilitates the explosive extension necessary to transition from the hang to the support phase (Prassas, Kwon, & Sands, 2006). Our findings affirm that gymnasts who can achieve higher angular velocities in the hip are better able to elevate their center of mass efficiently, thus ensuring a smoother and technically sound execution of the upstart.

Similarly, shoulder angular velocity was also found to have a statistically significant positive association with upstart performance. This result supports the view that shoulder dynamics are essential for controlling the arc of motion and stabilizing the upper body during the critical upward phase (Hiley & Yeadon, 2014). While the shoulders contribute more to the trajectory and coordination rather than raw propulsion, their role in ensuring timing and technique cannot be overlooked. (Rathore et al., 2024) Shoulder rotations that are too sluggish or ill-timed may result in incorrect placement above the bar, which might lower performance ratings (Yeadon & King, 2002). The value of technical drilling and standardisation in gymnastics training programs is further supported by the low standard deviations in angular velocities, which indicate that elite gymnasts maintain a limited range of technical execution patterns. This is in line with the findings of Hiley et al. (2013), who showed that movement variability is reduced as athletes master complex acrobatic techniques, resulting in more stable kinematic patterns and better execution scores.

These findings have practical implications for training design. Coaches should implement targeted drills to enhance hip explosiveness, such as resisted hip extensions and plyometric bridging movements, and focus on shoulder control and mobility exercises to maintain optimal rotation and alignment. Integrating video feedback systems and kinematic motion capture technologies during technical sessions could further allow athletes to visualize and correct their angular velocity patterns in real-time (Bohne, 2011). Although this study offers valuable insights, it is not without limitations. The small sample size (n=10) limits generalizability, and only the sagittal plane kinematics were analyzed. Future studies should consider 3D motion capture and electromyographic (EMG) analysis to capture muscle activation patterns during the upstart. Comparative analysis between junior and senior athletes or between successful and unsuccessful attempts could further enhance the understanding of skill development and biomechanical efficiency.

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