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Original research

Classification of lumbopelvic-hip complex instability on kinematics amongst female team handball athletes

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ABSTRACT

Objectives: The purpose of this study was to examine how lumbopelvic-hip complex (LPHC) stability, via knee valgus, affects throwing kinematics during a team handball jump shot.
Design: LPHC stability was classified using the value of knee valgus at the instant of landing from the jump shot. If a participant displayed knee valgus of 17° or greater, they were classified as LPHC unstable. Stable and unstable athletes' throwing mechanics were compared.
Methods: Twenty female team handball athletes (26.5 ± 4.7 years; 1.75 ± 0.04 m; 74.4 ± 6.4 kg; experience level: 4.8 ± 4.1 years) participated. An electromagnetic tracking system was used to collect kinematic data while participants performed three 9-m jump shots. The variables considered were kinematics of the pelvis, trunk, and shoulder; and segmental speeds of the pelvis, torso, humeral, forearm, and ball velocities. Data were analyzed across four events: foot contact, maximum shoulder external rotation, ball release, and maximum shoulder internal rotation.
Results: Statistically significant differences were found between groups in pelvis, trunk, humerus, and forearm velocities at all events ($p \leq 0.05$). Specifically, the unstable group displayed significantly slower speeds.
Conclusions: These findings suggest the difference in throwing mechanics are affected by LPHC instability for this select group of female team handball athletes. These differences infer an increased risk of injury in the upper and lower extremities when landing from a jump shot because of the energy losses throughout the kinetic chain and lack of utilization of the entire chain. It is recommended that further investigations also consider muscle activation throughout the throwing motion.

1. Introduction

Throwing is a kinetic chain activity requiring coordinated energy transfer from foot contact through the proximal segments of the pelvis and trunk to the most distal segments of the arm and hand.[1] The summation of speed principle states that the total energy in the kinetic chain is the sum of each segment's individual energy contribution.[1,2] This principle can be applied to throwing, and optimal energy transfer throughout the kinetic chain can be achieved when the proximal segment reaches its maximum speed then the next distal adjacent segment reaches its maximum speed.[1] Additionally, literature has shown inadequate strength and stability throughout the kinetic chain may contribute to inefficient force production and decrease energy transfer for throwing performance.[3,4]

The lumbopelvic-hip complex (LPHC) connects the lower extremity to the upper extremity and contributes approximately 50% of the energy and force during the dynamic motion of throwing.[4] LPHC stability is defined as the ability to control the location of the torso over the pelvis that allows for uninterrupted energy transfer.[4] In throwing, the LPHC stabilizes the upper extremity by increasing intra-abdominal pressure and thus creating an optimized energy flow; however, the lower extremity stabilizes the LPHC.[4] Previous research has shown that proper stabilization of the LPHC leads to higher rotational velocities of the upper extremity segments during dynamic overhead throwing.[5] It is known that LPHC instability has been associated with knee injury and is clinically recognized by an increase in hip varus, hip flexion, and ultimately dynamic knee valgus.[4]

It has also been shown that 49% of athletes with a posterior-superior labral tear in the shoulder have an unstable LPHC.[6] During rehabilitation from labral reconstructive surgery, lower extremity

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engagement has been found to activate the scapula and shoulder.[7] Additionally, a 20% decrease in energy generation from the hips leads to a 34% increase in demand on the shoulder and arm.[4] When specifically examining the effects of the kinetic chain in dynamic movement, Elliot et al.[8] found that tennis players who had a break down in the lower extremities increased the load on their shoulder and elbow by 23–27%. There has yet to be further investigation of the effects of lower extremity and LPHC instability on upper extremity motion in other sports, such as team handball.

The sport of team handball is unique in that it has side-to-side cutting, jumping, and overhead throwing. The ability to transfer energy and perform an accurate shot on goal is dependent on the synchronization, stabilization, and strength of both the upper and lower extremities. The objective of the game is to score more goals than the opponent by throwing the ball into the opposing team's goal. Athletes throw a variety of shots in order to score.[9–11] The two most frequent shots are the run-up throw to a jump shot and a run-up throw to a set shot.

In team handball, shoulder and knee injuries account for 44% and 26.7% of all injuries, respectively.[12] Even though the injury rates and the importance of energy transfer throughout the kinetic chain are known, there has yet to be a comparison examining the effects of LPHC stability on throwing mechanics in female team handball athletes. Therefore, the purpose of this study was to examine how LPHC stability, via knee valgus, affects throwing kinematics during a team handball jump shot. It was hypothesized that LPHC instability would affect kinematics of the pelvis, trunk, and shoulder; and segmental sequencing of the pelvis, torso, humeral, forearm, and ball velocities. Specifically, the authors expected the unstable athletes to display significantly slower segmental speeds and ball velocities and more pathomechanic kinematics.

2. Methods

Twenty female, team handball athletes (26.6 ± 4.7 years; 1.75 ± 0.04 m; 74.4 ± 6.4 kg; experience levels: 4.8 ± 4.1 years) were recruited to participate. All participants were active on the USA National Team residency program, in good physical condition, and had no injuries within the last six months. Training for the USA National Team includes 12 h per week of strength and conditioning and 16 h per week of practice. The University's Institutional Review Board approved all testing protocols. Informed written consent was obtained from each participant before testing.

Kinematic data were collected at 100 Hz using an electromagnetic tracking system (trakSTAR™, Ascension Technologies, Inc., Burlington, VT, USA) synced with The MotionMonitor™ (Innovative Sports Training, Chicago, IL, USA). The electromagnetic tracking system used has been previously validated for measuring humeral movements, and interclass correlation coefficients for axial humeral rotation in both loaded and non-loaded conditions have been reported greater than 0.96.[13,14] In addition, the current system was calibrated using previously established protocols prior to the collection of any data.[13,15,16] After calibration, the error in determining position and orientation of the electromagnetic sensors with the current calibrated world axis system was less than 0.01 m and 3°, respectively. A 40 cm × 60 cm Bertec force plate (Bertec Corp., Columbus OH) was built into the surface from which all jump shots were made such that the participant's stride foot would land on the force plate during the throwing motion. Force plate data were only used to event mark the instance of stride foot contact during the throwing motion and were sampled at a rate of 1000 Hz. If a participant did not land in the force plate, that trial was repeated.

Participants had a series of 11 electromagnetic sensors affixed to the skin using PowerFlex cohesive tape (Andover Healthcare, Inc., Salisbury, MA) to ensure the sensors remained secure throughout testing. Sensors were attached to the following locations: (1) posterior aspect of the trunk at the first thoracic vertebrae (T1) spinous process; (2) posterior aspect of the pelvis at the first sacral vertebrae (S1); (3) flat, broad portion of the acromion on the throwing scapula; (4) lateral aspect of the throwing upper arm at the deltoid tuberosity; (5) posterior aspect of the distal throwing forearm, centered between the radial and ulnar styloid processes; (6–7) lateral aspect of each thigh, centered between the greater trochanter and the lateral condyle of the knee; (8–9) lateral aspect of each shank, centered between the head of the fibula and lateral malleolus; (10–11) dorsal aspect of each foot on top of the shoe.[15] A twelfth, moveable sensor was attached to a plastic stylus used for the digitization of bony landmarks.[16–18] Joint centers were digitized using previously established and tested protocols.[19–21] Raw data regarding sensor position and orientation were transformed to locally based coordinate systems for each of the representative body segments using previously described methods.[17–19] All data were time stamped through The MotionMonitor™ and passively synchronized using a data acquisition board.

Even though dynamic knee valgus is known to indicate LPHC instability, no standard method has been described on how to measure LPHC instability within a throwing motion.[5] For the current study, knee valgus at landing was used for classification due to the large number of knee injuries that occur at this point in the throw.[12] In arthroscopy, knee valgus between 17° and 26° is considered grade II valgus deformation, and knee valgus greater than 26° is considered grade III valgus deformation.[26,22] Knee valgus around 7° is considered normal.[22] For the purpose of this study, LPHC instability was defined by a knee valgus of 17° or greater at landing because valgus deformation classification begins at this point and a large portion of knee injuries occur when landing from a throw.

Based on the aforementioned stability groups, the LPHC stable athletes (27.8 ± 3.2 years; 1.73 ± 0.05 m; 76.8 ± 5.5 kg; experience level: 5.6 ± 4.6 years; n = 9) had a knee valgus of 6 ± 5°, and the LPHC unstable athletes (24.9 ± 6.62 years; 1.74 ± 0.04 m; 73.66 ± 6.73 kg; experience level: 3.9 ± 3.5 years; n = 11) had a knee valgus of 19 ± 5°.

After sensor attachment and digitization, each participant was allotted an unlimited amount of time to warm-up (average warm-up time: 5 min) and become familiar with all testing procedures. The testing began only when the participant was self-declared ready to partake in the shots. For testing, each participant was instructed to throw the ball (International Handball Federation (IHF) Size 2) into a modified team handball goal at 9 m distance. The participants were required to accomplish three successful shots on goal of the run-up to a jump shot. A successful shot was defined as an athlete shooting the team handball goal.

Kinematic data (pelvis anterior/posterior and lateral tilt; trunk flexion/extension, lateral flexion, and rotation; shoulder plane of elevation, elevation, and rotation; and segmental sequencing of the pelvis, torso, humeral, forearm, and ball velocities) were collected across three trials of the jump shot for analysis. The throwing motion was defined by four events, as shown in Fig. 1: (1) foot contact (FC), (2) maximal shoulder external rotation (MER), (3) ball release (BR), and (4) maximal shoulder internal rotation (MIR). All data were processed using a customized MATLAB (MATLAB R2010a, MathWorks, Natick, MA, USA) script. Statistical analyses were performed using IBM SPSS Statistics 22 software (IBM Corp., Armonk, NY) for normally distributed data and a customized MATLAB script for non-normally distributed data with an alpha level set a priori at $\alpha = 0.05$. Prior to analysis, a Jarque–Bera test of Normality was run. Results showed normal distribution of the kinematic data and non-normal distribution for the segmental speeds. All kinematic variables were analyzed using repeated measure