Kinematic Sequencing Differences Between Dancers and Team-Sport Athletes During Jumping and Landing

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Abstract
The propulsive phase of a countermovement jump is characterized by a proximal-to-distal transfer of joint velocities, with peak hip extension velocity preceding peak ankle dorsiflexion velocity. During this phase, dancers are considered experts in these tasks and would be expected to demonstrate optimal kinematic sequences. Purpose: To compare lower extremity kinematic sequence during single-leg countermovement jumps and drop-landings between male and female dancers and team-sport athletes. Methods: Forty dancers (20M, 20F) and forty collegiate athletes (20M, 20F) performed single-leg countermovement jumps to 50% of their maximum jump height. Results: Distinct proximal-to-distal and distal-to-proximal kinematic sequences were evident for takeoff and landing in 85% of the dancers (34 of 40), but only 50% of athletes (20 of 40) (P = 0.0016). During takeoff, the time from peak hip velocity to peak knee velocity was longer in female dancers compared to female athletes (17±10 msec vs. 11±7 msec, P = 0.04). During landing, the time from peak ankle velocity to peak knee velocity was longer in female athletes compared to female dancers (26±6 msec vs. 21±6 msec, P = 0.002). There were no differences for males. Conclusions: Dancers were more likely than athletes to demonstrate correct kinematic sequence, likely because of their intense training in jumping aesthetics. During takeoff, female dancers appear to utilize their hips more effectively than female athletes to generate initial propulsion. Female dancers also appear to utilize their ankles more effectively to absorb the initial impact of landing. The more rapid transfer of joint velocities, from the hip to the knee in takeoff, and from the ankle to the knee in landing, for female athletes versus dancers indicates a knee-dominant strategy.

Introduction
The propulsive phase of a stretch-shortening cycle movement, such as a countermovement jump, is characterized by a proximal-to-distal transfer of joint velocities. Peak hip extension velocity precedes peak knee extension velocity, which in turn precedes peak plantarflexion velocity. This sequence of joint and segmental rotations contributes to the optimal acceleration of the center of mass to reach the desired jump height. [1,2] Similarly, during landing, energy is absorbed through the kinetic chain in a distal-to-proximal pattern with the ankle reaching peak dorsiflexion velocity first, followed by peak knee flexion velocity, followed by peak hip flexion velocity. From a very early age (about 6-8 years of age), dancers receive rigorous training specifically targeting jumping, landing and balance ability. Throughout the course of their daily training and practice, dancers perform numerous (>200) jumping and landing activities. [3] Due to their extensive training in jumping activities, dancers are considered experts in these tasks. Previous research has shown an association between the timing of maximal joint velocities and skill level in team handball players. [4] Therefore, kinematic sequence analysis of jumping may distinguish expert jumpers from less-skilled participants.

Purpose: To compare lower extremity kinematic sequence during single-leg countermovement jumps and drop-landings between male and female dancers and team-sport athletes.

Materials and Methods
Forty dancers (20M, 20F) and forty collegiate athletes (20M, 20F) performed single-leg countermovement jumps to 50% of their maximum jump height (takeoff analysis) and drop-landings from a 30 cm platform (landing analysis).

Biomechanical Analysis:
• 22 reflective markers were placed on the lower extremity and motion data collected using eight infrared cameras (Motion Analysis Corp.; 250 Hz).
• For takeoff: ankle plantarflexion, knee extension and hip extension velocities were calculated and defined as positive values (Visual 3D).
• For landing: ankle dorsiflexion, knee flexion and hip flexion velocities were calculated and defined as positive values (Visual 3D).

Results
Takeoff
• A significantly longer interval between peak hip velocity and peak knee velocity was found in the dancers compared to the athletes (16 ± 6 ms vs. 12 ± 6 ms, Main Effect of Activity, P = 0.024).
• This interval was significantly longer in female dancers compared to female athletes (17±10 msec vs. 11±7 msec, P = 0.04), but no difference was found between male dancers and male athletes (P = 0.297).

Landing
• The time from peak ankle velocity to peak knee velocity was longer in dancers compared to athletes (26±6 msec vs. 21±6 msec, P = 0.002), but no difference was found between male dancers and male athletes (P = 0.061).

Discussion and Conclusions
Dancers were more likely than athletes to demonstrate correct kinematic sequence, likely because of their intense training in jumping aesthetics. During takeoff, female dancers appear to utilize their hips more effectively than female athletes to generate initial propulsion. Female dancers also appear to utilize their ankles more effectively to absorb the initial impact of landing. The more rapid transfer of joint velocities, from the hip to the knee in takeoff, and from the ankle to the knee in landing, for female athletes versus dancers indicates a knee-dominant strategy.

References
5. Harkness Center for Dance Injuries, NYU Langone Medical Center Hospital for Joint Diseases, New York, NY

Figure 1: Correct (A and C) and incorrect (B and D) examples of kinematic sequences for takeoff and landing

Figure 2: Occurrences of incorrect kinematic sequences during takeoff and landing

Figure 3: During takeoff, time intervals between peak hip and knee maximum velocity, as denoted by the red area, is longer in female dancers compared to female athletes.

Figure 4: During landing time intervals between peak ankle and knee maximum velocity, as denoted by the red area, is longer in female dancers compared to female athletes.