A Comparison of Landing Mechanics Between Dancers and Team-Sport Athletes

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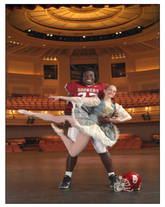
Abstract

Purpose: The incidence of anterior cruciate ligament [ACL] injuries among dancers is much lower than among team-sport athletes, and no clear gender disparity has been reported in dancers. Additionally, fatigue is strongly linked to increased risk of injury. The purpose of this study was to compare the effects of sex, group [dancer vs. team-sport athlete] and fatigue on single-leg drop-landing biomechanics. **Methods:** Kinematics and kinetics were recorded as 40 elite modern and ballet dancers [20 men and 20 women] and 40 athletes [20 men and 20 women] performed single-legged drop landings from a 30-cm platform, before and after a fatigue protocol [step-ups and vertical jumps]. Un-fatigued and fatigued joint kinematics and kinetics were compared between groups and genders using 3 separate MANOVAs according to three theories regarding ACL injury: ligament dominance, quadriceps dominance and trunk dominance. **Results:** Dancers of both genders and male athletes landed similarly in terms of frontal plane knee alignment, whereas female athletes landed with greater peak knee valgus [p=0.007]. Female dancers were found to have less hip adduction torque than the other three groups [p=0.003]. Dancers [males and females] exhibited less trunk side flexion [p=0.002] and less trunk flexion [p=0.032] than athletes. Dancers took longer [p=0.023] than athletes to reach a similar state of fatigue. Multiple parameters of landing changed with fatigue, such that fatigued subjects landed with mechanics that were more at-risk for ACL injury as compared to prior to fatigue. However, there was no differential effect of fatigue on dancers vs. athletes. **Conclusions:** In executing a 30-cm drop landing, female athletes displayed greater knee valgus than the other three groups. Dancers exhibited better trunk control than athletes. While dancers took longer to fatigue than athletes, fatigue changed landing mechanics similarly in both dancers and athletes, with all groups landing with worse alignment after fatigue. Female athletes had landing patterns associated with ACL injury risk when compared to the other three groups. These biomechanical findings may provide insight into the etiology of the epidemiological differences in ACL injury between dancers and athletes and the lack of a gender disparity within dancers.

Introduction



The sex disparity in the incidence of noncontact anterior cruciate ligament [ACL] injuries among team-sport athletes has been well documented, with adolescent and older female team-sport athletes are 4 to 6 times more likely to sustain an ACL injury compared with their equivalently-trained male counterparts.[1,5] By contrast, dance has been shown to have a much lower overall incidence of ACL injuries [0.009 ACL injuries per 1000 exposures] compared with team sports [0.07-0.31 ACL injuries per 1000 exposures], with no clear sex difference in the incidence of ACL injuries.[6]

Several neuromuscular deficit theories have been proposed to explain the sex disparity in ACL injury rates, including: ligament dominance [excessive reliance on ligaments to absorb landing forces]; quadriceps dominance [preferential use of quadriceps to stabilize the knee during landing]; trunk dominance [inability to control or stabilize the position of the trunk]; and leg dominance [side-side asymmetries].[4] Additionally, numerous studies have shown that ACL noncontact injuries occur more frequently during a game or performance than practice, as well as closer to the end of the day and season, suggesting an effect of fatigue over time.[3,6,7,9] Importantly, in laboratory studies examining the biomechanics of jump landings in athletes, fatigue results in landing mechanics that mimic the position of risk for ACL ruptures.[2,8]

Purpose: to compare dancers' and team athletes' resistance to fatigue and the biomechanics of a jump landing task before and after achieving fatigue relative to the risk variables associated with the ligament dominance, quadriceps dominance, and trunk dominance theories. We hypothesized that female dancers would perform a drop-landing task without demonstrating typical sex-related risk factors associated with an ACL injury exemplified by each and that dancers would be more resistant than team athletes to the onset of fatigue and/or would have different biomechanical responses than these athletes in landing tasks once fatigue has been achieved.

Materials and Methods

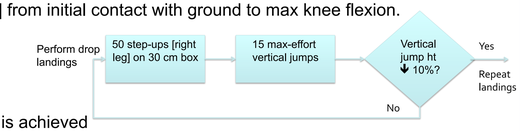
Subjects:
Twenty male and female professional female dancers and twenty male and female collegiate athletes performed single-leg landings from a 30 cm box before and after a lower extremity fatigue protocol.

	Height [cm]	Weight [kg]	Age [yrs]
Female dancers	170±7	56.9±6.0	25±5
Male dancers	184±7	73.5±9.4	27±6
Female athletes	176±8	67.6±7.5	20±2
Male athletes	185±7	78.8±13.6	22±2

Inclusion Criteria:
- Currently active in dance or jumping/cutting sports [basketball, volleyball, soccer]
- No history of surgery on the lower extremities
- No current lower extremity injuries
- No injuries to the lower extremities within the past year

Biomechanical Analysis:
- 22 reflective markers were placed on the lower extremity and motion data collected using eight infrared cameras [Motion Analysis Corp., 250 Hz]; force plate [AMTI, 2500 Hz].
- EMG data recorded from quadriceps [vastus lateralis] and hamstring [semitendonosus] muscles [Noraxon, 2500 Hz].
- Joint angles and inverse dynamics analysis calculated [Visual 3D] from initial contact with ground to max knee flexion.

Fatigue Protocol:
- 50 step-ups [up and down on the right leg] on 30 cm box
- 15 maximal-effort single-leg vertical jumps
- Repeated until a 10% decrease in maximum vertical jump height is achieved
- Number of sets recorded; subjective rating of fatigue at end using Borg CR-10 scale

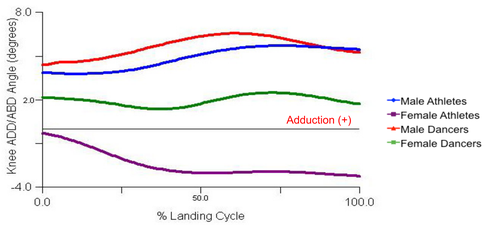


Statistics:
- MANOVA [group x sex x time] were used to test each theory:
  - *Ligament dominance:* knee abduction, hip adduction, and internal rotation angles [initial contact [IC], and peak] and knee abduction, hip adduction, and hip internal rotation moments [peak values]
  - *Trunk dominance:* trunk flexion and lateral trunk lean angles [peak]
  - *Quadriceps dominance:* knee flexion angle [initial contact and peak], knee flexion moment [peak value], and normalized [to 50% max vertical jump] EMG ratio of the vastus lateralis to the semitendinosus [averaged over 100 milliseconds before IC]
- ANOVA (group x sex) on subjective ratings of fatigue, number of sets to fatigue

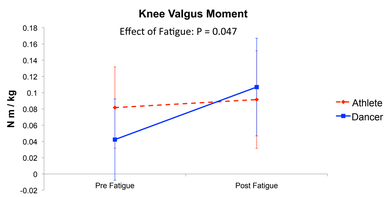
Results

Ligament Dominance

Group x sex interaction [P=0.039]
- Female team-sport athletes have a higher peak knee valgus angle than other 3 groups [P=0.007]
- Female dancers have lower peak hip adduction moment than those of the other 3 groups [P=0.003]



Main effect of fatigue [P<0.001]
- Increased the peak knee valgus moment [P=0.047]
- Decreased the peak hip adduction moment [P=0.044]
- Decreased the hip external rotation angle [at initial contact and peak; P<0.001 and P=0.002, respectively]

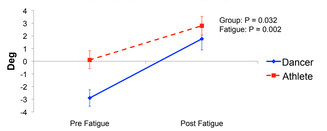


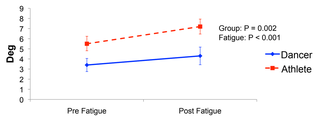
Results

Trunk Dominance:

Main effect of group [P<0.001]
Dancers landed with a lower peak trunk forward flexion, lower lateral trunk lean than did team-sport athletes

Main effect of fatigue [P<0.001]
Peak forward trunk flexion, lateral trunk lean increased





Quadriceps Dominance:

Main effect of group [P=0.018]
Athletes landed with slightly more knee flexion [< 2°] at IC than did dancers [P=0.017]

Main effect of fatigue [P<0.001]
Increased peak knee flexion angles [P<0.001] and decreased knee flexion moments [P=0.003]

Group x fatigue interaction [P=0.043]
Dancers slightly decrease [≈0.5°], athletes slightly increase [≈1.5°] knee flexion at IC with fatigue [P=0.001]

Fatigue:
Dancers took significantly longer to fatigue [approximately 40%] than did team athletes [P=0.023] with no effect of sex [P=0.208], nor sex x group interaction [P=0.782]. There were no significant main or interaction effects on Borg CR-10 scale subjective ratings of fatigue achieved for group [P = 0.755], sex [P = 0.157] or sex x group [P = 0.998].

Discussion and Conclusions

Female dancers do not exhibit several neuromuscular deficits that are evident in female team sport athletes and that would predispose them to ACL injuries. They exhibited similar biomechanical profiles to the male dancers **and landed with a significantly lower knee valgus angle, hip adduction moment, and trunk lateral flexion** than female team sport athletes. These findings may be related to the lower ACL injury rate that female dancers experience compared with female team sport athletes and the lack of sex disparity in ACL injury rates among dancers.

Fatigue had a significant effect on biomechanical variables across all 3 foci of analysis, although there were no significant differences in biomechanical responses to fatigue between team athletes and dancers. However**, dancers took significantly longer** to reach a similar [objective and subjective] state of fatigue than did team athletes, suggesting that future research examine fatigue resistance as a potential explanation for differences in ACL injury rates between team athletes and dancers.

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