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Lower Limb and Trunk Biomechanics After Fatigue in Competitive Female Irish Dancers

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Context: Because of the increasing popularity of participation in Irish dance, the incidence of lower limb injuries is high among this competitive population.

Objective: To investigate the effects of fatigue on the peak lower limb and trunk angles as well as the peak lower limb joint forces and moments of competitive female Irish dancers during the performance of a dance-specific single-limb landing.

Design: Cross-sectional study.

Setting: Laboratory.

Patients or Other Participants: Fourteen healthy, female, competitive Irish dancers (age = 19.4 ± 3.7 years, height = 165.3 ± 5.9 cm, mass = 57.9 ± 8.2 kg).

Intervention(s): Participants performed an Irish dance–specific leap before and after a dance-specific fatigue protocol. During each landing movement, 3-dimensional lower limb kinematics (250 Hz) and ground reaction forces (1000 Hz) were collected. Paired *t* tests were performed to determine the differences ($P \leq .05$) in lower limb and trunk biomechanics prefatigue and postfatigue.

Main Outcome Measure(s): Peak lower limb and trunk angles as well as peak lower limb joint reaction forces and external moments.

Results: Compared with the prefatigue trials, dancers landed with reduced ankle plantar flexion ($P = .003$) and hip external rotation ($P = .007$) and increased hip-adduction alignment ($P = .034$) postfatigue. Dancers displayed greater anterior shear ($P = .003$) and compressive ($P = .024$) forces at the ankle and greater external knee-flexion moments ($P = .024$) during the postfatigue compared with the prefatigue landing trials.

Conclusions: When fatigued, dancers displayed a decline in landing performance in terms of aesthetics as well as increased ankle- and knee-joint loading, potentially exposing them to a greater risk of injuries.

Key Words: jumping, landing, technique, kinematics, kinetics

Key Points

- Dancers displayed a reduction in the aesthetic component of the leap postfatigue compared with prefatigue.
- Fatigue resulted in greater loading at the ankle and knee joints, which may expose female Irish dancers to a greater injury risk.

Irish dance is a dynamic form of movement requiring flexibility, agility, poise, strength, endurance, and technical skill that originated in Ireland in the early 19th century.[1] As Irish dance has become increasingly popular on an international scale,[2] lower limb injuries have become frequent among competitive Irish dancers.[1,3,4] A descriptive epidemiologic study[3] of injuries among competitive Irish dancers (142 females and 17 males; aged 15–24 years) via questionnaire demonstrated that almost 80% of dancers sustained at least 1 musculoskeletal injury in the lead-up to a major championship; *injury* was defined as any incident that caused the dancer to be absent from dancing practice or competition for at least 2 weeks. Noon et al[1] conducted a retrospective review of 69 Irish dancers (aged 8–23 years) who presented with an injury to a sports physician over a 7-year period (from 2002–2009); more than 90% of all injuries occurred to the lower limbs, with the foot and ankle accounting for approximately 60% of all injuries.[1,3,4]

Overuse injuries are common among Irish dancers,[5] accounting for almost 80% of all injuries.[6] It has been suggested that overuse injuries may be the result of the numerous hours they devote to dance practice and improving technique.[1,5] Noon et al[1] reported that more skilled dancers (who qualify for international competition) dedicated 10 to 18 hours to dance per week and displayed higher injury rates (4.2 injuries per dancer) than less skilled dancers (2.2 injuries per dancer), who dedicated only 2 to 3 hours to dance per week. Ekegren et al[7] noted that preprofessional ballet dancers (aged 16–19 years old) spent an average of 30.3 hours on dance training each week, with an overall injury rate of 1.87 per 1000 dance exposures.[7] Sudden increases in training, rehearsal hours, and performances have also been suggested as extrinsic factors associated with overuse injuries in ballet dancers.[8] In an Irish dance routine (lasting 1–2.5 minutes), dancers perform a series of repetitive, high-intensity leaps, hops, and jumps (up to 50), requiring them to land on a single limb.[1] Similar to demipointe in ballet, for these single-limb landings, the dancer must be "on toe," demanding an extended limb (knee and hip) with ankle plantar flexion and toe extension, as well as an upright and rigid trunk, thereby requiring immense strength and core stability.[1] Given the repetitive nature of Irish dance and the association between time spent dancing and injury,[1,7] it is important to examine how fatigue may play a role in the performance of landing movements.

Performance declines have been demonstrated in ballet dancers as a result of fatigue.[9] *Fatigue* can be defined as a reduction in the maximal force-generating capacity of a muscle and may lead to disruptions in neuromuscular function after strenuous exercise.[10] A study[11] examining 13 elite vocational ballet dancers displayed an association between lower levels of aerobic fitness and increased injury incidence. Furthermore, Liederbach et al[9] compared the trunk and lower limb biomechanics of 40 ballet dancers and 40 team-sport athletes (males and females) during the performance of drop landings, both prefatigue and postfatigue. Fatigue had a negative influence on landing mechanics, contributing to greater knee-abduction loads ($P = .047$) and reduced peak hip external-rotation alignment ($P = .002$) as well as greater forward ($P = .002$) and lateral ($P < .001$) trunk flexion.[9] However, participants performed a drop-landing movement: this differs greatly from an Irish dance landing,[9] which has an aesthetic component. Therefore, despite the high injury risk in Irish dancers[1,4,6] and the association between fatigue and performance decline in ballet dancers[9] and other athletes,[9,12] research pertaining to the effects of fatigue on the lower limb biomechanics of Irish dance–specific leaps is lacking. Thus, the purpose of our study was to investigate the effects of fatigue on the peak lower limb and trunk angles as well as the peak lower limb joint forces and moments of female competitive Irish dancers during the performance of a dance-specific single-limb landing. We hypothesized that compared with prefatigue landing trials, dancers would display altered peak ankle, knee, hip, and trunk angles, as well as increased lower limb joint loading during the landing phase, when in a fatigued state.

METHODS

Participants

Fourteen healthy, female Irish dancers (age = 19.4 ± 3.7 years, height = 165.3 ± 5.9 cm, mass = 57.9 ± 8.2 kg) were recruited for this study by word of mouth at Perth-based Irish dancing classes as well as at the Australian National Championships. Dancers were included if they were competing at a national level; they were free from injury to the point where performance of Irish dance landings was unaffected; taping or bracing was not required for performance; and they had not undergone surgery in the previous 12 months. The university's Human Research Ethics Committee approved this study; all participants aged 18 years and over provided informed consent, and participants under the age of 18 years provided assent and their parents or guardians provided informed consent before testing.

Experimental Protocol

Upon arrival at the Motion Analysis Laboratory, we collected anthropometric measures of each participant's standing height to the nearest 0.1 cm on a calibrated stadiometer and body mass to the nearest 0.2 kg on a calibrated bathroom scale. A total of 46 retroreflective markers (12.7-mm diameter) were secured to each participant's right and left lower limbs and trunk for a static calibration trial based on a modified version of the University of Western Australia static lower limb marker set[13] (sternal notch, xiphoid process, C7 spinous process, T10 spinous process, anterior-superior iliac spine, posterior-superior iliac spine, lateral thigh rig [3 markers], medial and lateral femoral condyles, lateral tibia rig [3 markers]; posterior tibia [superior and inferior], anterior tibia, medial and lateral malleoli, calcaneus, superior and inferior calcaneus, first metatarsal head, fifth metatarsal head, and midway between the first and fifth metatarsal heads). Specific lower limb markers were then removed for the dynamic trials, based on a modified version of the University of Western Australia dynamic lower limb marker set[13] (26 remaining markers; sternal notch, xiphoid process, C7 spinous process, T10 spinous process, anterior-superior iliac spine, posterior-superior iliac spine, lateral thigh rig, lateral tibia rig, calcaneus, first metatarsal head, and fifth metatarsal head). This allowed the 3-dimensional motion of each participant's lower limbs and trunk to be captured.

Landing Movement

After a dance-specific warm-up and jump-task familiarization, participants performed an Irish dance–specific leap commonly referred to as a "leap over." During this movement, participants "skipped" up to the force platform from a standardized distance (6 m); lifted the right limb (defined as the *test limb*) into maximal ankle plantar flexion, knee extension, and hip flexion; and jumped off the left limb, ensuring maximal vertical jump height while still moving in a horizontal plane. Dancers then landed on the force platform with the right limb in an "on-toe" position, whereby the knee remained extended, with the ankle plantar flexed and the toes extended (Figure). The landing task was conducted while maintaining an erect posture through the trunk with the upper limbs extended by the dancer's side, as is standard practice for an Irish dancer. During all landing trials (prefatigue and postfatigue), participants were instructed to "jump as high as possible" to ensure that all jumps were performed maximally. Dancers performed 5 successful trials of this landing movement; a *successful trial* was defined as landing on the right limb in a plantar-flexed position within the confines of the force platform. The right limb was chosen as the test limb because right-sided injury is more prevalent among this population due to the strong leading pattern of the right lower limb.[6] Adequate rest (45 seconds, allowing for a work-to-rest ratio of 1 : 9)[14] was provided between trials to minimize the effect of fatigue during the prefatigue landing trials.

Fatigue Protocol

After the prefatigue landing trials, a dance-specific fatigue protocol was performed to music set at a pace typically used during Irish dance practice and competition (113 beats per minute). During the fatigue protocol, dancers performed consecutive maximal leap overs (Figure), and the rate of perceived exertion (RPE) score was recorded every 15 seconds.[15] Participants were classified as fatigued

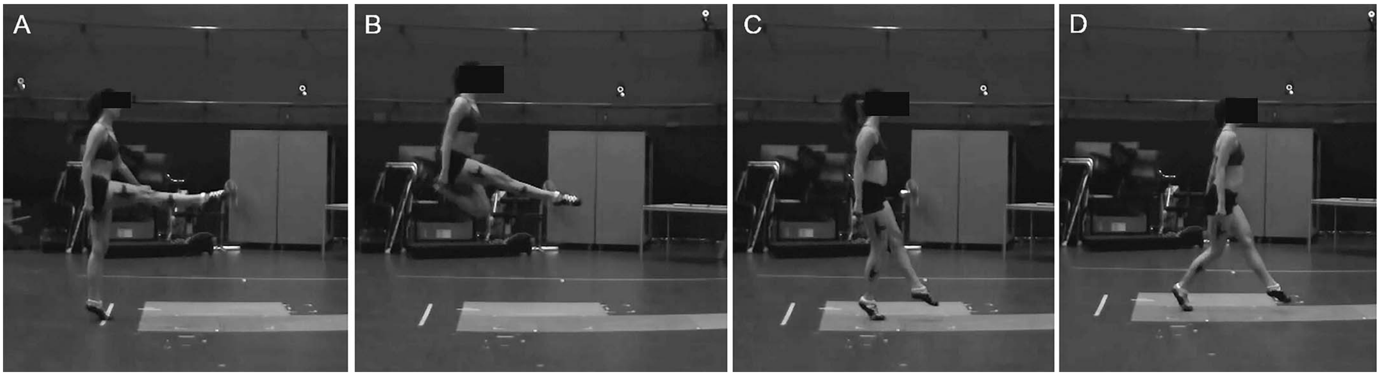

Figure. Jump execution of a leap over. A, On takeoff, the leading limb (right) is flexed at the hip with the knee extended and ankle plantar flexed. B, The trailing limb (left) moves into slight hip flexion, full knee flexion, and full plantar flexion at the ankle during the flight phase. C, Initial contact whereby dancers land on toe on their leading limb within the confines of the force platform. D, The time just before toe-off of the leading limb.

if they attained an RPE of 17 or higher (*very hard*) in accordance with Moran and Marshall,[16] and demonstrated a reduction in form as determined by the chief investigator (who has experience in Irish dance training). All dancers were deemed fatigued within 2 minutes of beginning the protocol (consistent with the typical length of a dance performance). Immediately after the fatigue protocol, dancers performed 5 successful trials of the leap over (Figure). To ensure that all dancers remained adequately fatigued during the postfatigue trials, they skipped back to the starting position (ie, no rest was provided), and RPE scores were recorded after each landing to ensure that a score of at least 17 was maintained. If a dancer reported a score lower than this (n = 3), the fatigue protocol was resumed until fatigue (RPE $\geq$ 17) was achieved.

Instrumentation

The 3-dimensional motion of each participant's test limb was recorded using an 18-camera, passive, 3-dimensional, 250-Hz motion-analysis system (Vicon; Oxford Metrics Inc, Oxford, United Kingdom). A calibrated multichannel 1000-Hz force platform embedded in the laboratory floor (Advanced Mechanical Technology Inc, Watertown, MA) was used to collect the 3 orthogonal components (vertical, anterior-posterior, and medial-lateral) of the ground reaction force generated by each participant during the leap over. The ground reaction force data were used in conjunction with the kinematic data in an inverse-dynamics approach to calculate peak ankle-, knee-, and hip-joint forces and external moments during the leap over.[17]

Data Processing and Analysis

A 3-dimensional model of each participant's right lower limb was created using a custom-written Labview program (LabVIEW version 2011 SP1; National Instruments, Austin, TX) based on each participant's static calibration trial and inertial properties.[18] The kinematics, ground reaction force, free moment, and center-of-pressure data were filtered using a fourth-order, zero-phase-shift, digital low-pass Butterworth filter. The cutoff frequency ($f_c = 10$ Hz) was determined using residual analysis[17] before calculating the magnitude of the peak ankle, knee, hip, and trunk angles as well as the ankle-, knee-, and hip-joint forces and external joint moments (mean of the 5 successful trials) from the time of initial contact to takeoff (landing phase) of the right limb. Furthermore, vertical-jump height was calculated by measuring the difference in the vertical displacement of the pelvic origin (the midpoint of the anterior-superior iliac spine markers) between the static and dynamic trials.

Statistical Analyses

Descriptive data (means and standard deviations) were calculated for demographic data (age, height, and mass) of the participants. The distribution of the data was examined using Q-Q plots as well as Kolmogorov-Smirnov and Shapiro-Wilk tests. Paired *t* tests were used to compare the differences ($P \leq .05$) in the mean lower limb and trunk biomechanics between the prefatigue and postfatigue conditions during the performance of a leap over, as well as the coefficient of variation (CV) for jump height prefatigue and postfatigue. Although multiple comparisons were made, we deemed adjustment to the α level unnecessary given the exploratory nature of the present study and because such adjustments may increase the likelihood of type II errors.[19] The Cohen d was also calculated to determine effect sizes.[20] All statistical procedures were conducted using SPSS software (version 21; IBM Corp, Armonk, NY), and the α level was set at .05.

RESULTS

Participants displayed similar peak vertical-jump height during the prefatigue compared with the postfatigue landing trials (0.29 $\pm$ 0.04 m and 0.28 $\pm$ 0.03 m, respectively; $P = .340$; d = 0.26). Although the difference was not significant, participants demonstrated a trend toward and moderate effect size for greater variability in their peak vertical-jump height during the postfatigue compared with the prefatigue trials (CV = 3.05% $\pm$ 1.66% and 2.06% $\pm$ 0.84%, respectively; $P = .083$; d = 0.5). Results for the peak joint angles at the ankle, knee, hip, and trunk are shown in Table 1. Overall, dancers exhibited a reduction in ankle plantar flexion postfatigue versus prefatigue, with a large effect size ($P = .003$; d = –0.97). Dancers also displayed an increase in hip adduction ($P = .034$; d = –0.63) and a decrease in hip external rotation ($P = .007$; d = –0.85) postfatigue compared with prefatigue. Although the difference was not significant, participants demonstrated a

Table 1. Peak Ankle, Knee, Hip, and Trunk Angles During the Leap Over for the Prefatigue and Postfatigue Conditions

Angle	°, Mean ± SD					
	Prefatigue	Postfatigue	*P* Value	*t* Statistic	95% Confidence Interval	Effect Size (Cohen d)
Ankle						
Plantar flexion	58.8 ± 5.2	55.9 ± 6.1	.003[a]	−3.648	−4.588, −1.175	−0.97
Eversion	14.8 ± 5.7	15.9 ± 6.5	.082	1.882	−0.156, 2.667	0.50
Knee						
Flexion	33.1 ± 7.8	33.2 ± 8.5	.934	−0.084	−2.959, 2.737	−0.02
Adduction	3.7 ± 2.2	3.6 ± 2.4	.820	0.232	−0.969, 1.203	0.06
External rotation	6.9 ± 4.6	7.2 ± 4.7	.691	0.407	−1.221, 1.787	0.11
Hip						
Flexion	16.0 ± 5.3	15.9 ± 5.0	.876	0.160	−1.314, 1.523	0.04
Adduction	15.4 ± 5.9	16.6 ± 5.7	.034[a]	−2.371	−2.161, −0.100	−0.63
External rotation	16.7 ± 8.5	13.7 ± 7.1	.007[a]	−3.175	−4.965, −0.944	−0.85
Trunk						
Forward flexion	11.7 ± 4.2	11.0 ± 4.9	.257	1.210	−0.581, 1.917	0.38
Lateral (right) flexion	5.8 ± 4.0	7.3 ± 4.0	.081	1.965	−0.230, 3.267	0.62

[a] Indicates a within-group difference at $P \leq .05$.

trend toward and moderate effect size for greater right-side lateral trunk flexion during the postfatigue compared with the prefatigue condition ($P = .081$; d = 0.62).

Peak ankle-, knee-, and hip-joint reaction forces exhibited by dancers during the prefatigue and postfatigue landing trials are shown in Table 2. Overall, dancers had increases in anterior ($P = .003$; d = –0.98) and compressive ($P = .024$; d = –0.68) ankle-joint forces postfatigue compared with the prefatigue landing trials, with large effect sizes (see Table 2). Although this difference was not significant, dancers also displayed a trend toward and moderate effect size for greater anterior shear forces at the knee during the postfatigue compared with prefatigue landing trials ($P = .084$; d = –0.50).

Peak ankle-, knee-, and hip-joint external moments of the dancers during the prefatigue and postfatigue landing trials are illustrated in Table 3. Overall, participants demonstrated similar joint external moments during the prefatigue and postfatigue landing trials ($P > .05$). However, participants did exhibit greater knee-flexion external moments postfatigue compared with prefatigue, with a large effect size ($P = .007$; d = –0.86).

DISCUSSION

Our study is the first to examine the effects of fatigue on the landing biomechanics of an Irish dance–specific jump. The purpose of this study was to investigate the effects of fatigue on the peak lower limb and trunk angles as well as the peak lower limb joint forces and moments of female competitive Irish dancers during the performance of a dance-specific single-limb landing. The results confirm that, as hypothesized, dancers displayed altered lower limb landing biomechanics in a fatigued state. We discuss the implications of these changes next.

The role of an Irish dancer requires not only a high degree of muscular power and endurance but also movement aesthetics.[6] It is interesting that even though dancers in the study were fatigued, the maximal vertical-jump height attained did not change from prefatigue to postfatigue. This result is contrary to previous findings that

Table 2. Peak Ankle-, Knee-, and Hip-Joint Forces During the Leap Over for the Prefatigue and Postfatigue Conditions

Joint Force	N, Mean ± SD					
	Prefatigue	Postfatigue	*P* Value	*t* Statistic	95% Confidence Interval	Effect Size (Cohen d)
Ankle						
Anterior	19.2 ± 11.0	24.5 ± 13.0	.003[a]	−3.656	−8.388, −2.157	−0.98
Posterior	−19.6 ± 10.2	−19.4 ± 7.2	.924	−0.098	−5.167, 4.720	−0.03
Compression	51.3 ± 10.6	55.4 ± 11.4	.024[a]	−2.550	−7.468, −0.618	−0.68
Lateral	16.2 ± 7.5	16.2 ± 8.5	.921	−0.101	−1.977, 1.780	−0.03
Medial	−18.0 ± 8.1	−18.2 ± 8.7	.845	0.200	−1.997, 2.405	0.05
Knee						
Anterior	121.4 ± 25.7	129.5 ± 28.1	.084	−1.870	−17.607, 1.271	−0.50
Posterior	−58.3 ± 17.1	−58.1 ± 26.3	.973	−0.035	−11.518, 11.156	−0.01
Compression	143.0 ± 30.8	146.6 ± 31.0	.598	−0.540	−18.054, 10.835	−0.14
Lateral	35.0 ± 19.1	38.7 ± 19.2	.379	−0.911	−12.453, 5.068	−0.24
Medial	−54.9 ± 21.3	−54.4 ± 21.3	.920	−0.103	−11.475, 10.435	−0.03
Hip						
Anterior	544.0 ± 369.1	581.3 ± 423.5	.319	−1.036	−114.988, 40.465	−0.28
Posterior	−76.6 ± 415.5	−100.2 ± 426.8	.177	1.428	−12.097, 59.295	0.38
Compression	417.7 ± 115.8	413.2 ± 100.5	.767	0.302	−27.633, 36.620	0.08
Lateral	92.7 ± 82.7	99.7 ± 76.2	.561	−0.596	−32.218, 18.278	−0.16
Medial	−159.5 ± 112.3	−137.8 ± 94.1	.142	−1.563	−51.529, 8.264	−0.42

[a] Indicates a within-group difference at $P \leq .05$.

Table 3. Peak Ankle, Knee, and Hip External Joint Moments During the Leap Over for the Prefatigue and Postfatigue Conditions

External Joint Moment	Nm, Mean ± SD		*P* Value	*t* Statistic	95% Confidence Interval	Effect Size (Cohen d)
	Prefatigue	Postfatigue				
Ankle						
Plantar flexion	2.3 ± 1.1	2.3 ± 1.1	.970	0.038	−0.237, 0.246	0.01
Eversion	1.2 ± 0.4	1.3 ± 0.5	.470	0.744	−0.118, 0.241	0.20
Knee						
Flexion	29.3 ± 6.2	32.4 ± 6.8	.007[a]	−3.219	−5.144, −1.012	−0.86
Abduction	16.3 ± 6.3	14.5 ± 6.1	.099	−1.775	−3.937, 0.386	−0.47
Internal rotation	4.7 ± 2.1	5.2 ± 2.0	.164	−1.475	−0.999, 0.188	−0.39
Hip						
Extension	114.0 ± 54.3	121.5 ± 55.5	.219	1.293	−5.041, 20.070	0.35
Adduction	61.0 ± 38.1	57.9 ± 29.6	.374	−0.920	−11.067, 4.455	−0.24
External rotation	21.1 ± 11.3	20.2 ± 9.0	.759	−0.314	−6.469, 4.828	−0.08

[a] Indicates a within-group difference at $P \leq .05$.

highlighted a reduction in vertical-jump height of team-sport athletes when fatigued,[21,22] potentially as a protective mechanism to reduce injury risk.[22] Although the aesthetic nature of Irish dance performance may explain the lack of change in jump height between conditions, we acknowledge that it may instead indicate that the fatigue protocol was insufficient to elicit changes that would provide greater insight into injury risk. However, Hopkins and Hewson[23] deemed a CV ratio that differed by a factor of 1.15 or more sufficient to indicate substantial differences in movement variability. The CV ratio of peak vertical-jump height (postfatigue/prefatigue CV) was 1.48 in the present study. Although fatigue did not affect jump height, the CV ratio indicated a substantial increase in movement variability postfatigue compared with prefatigue. Thus, we believe that the fatigue protocol was sufficient to evoke these changes in landing biomechanics.

We found it noteworthy that despite similar jump heights attained during the conditions, in agreement with previous literature,[9,21] the dancers displayed reduced ankle plantar flexion and hip external-rotation alignment as a result of fatigue. In Irish dance, the lower limb requires the hip to be externally rotated to allow for a "turned-out" foot position, with extended knee and maximal plantar flexion upon landing,[1] thereby demonstrating a decline in the overall aesthetics of the landing movement with fatigue. Furthermore, the dancers demonstrated increased hip adduction and a trend toward greater ipsilateral trunk-flexion alignment during the postfatigue landing trials. Liederbach et al[9] also reported an increase in lateral trunk lean as a result of fatigue; however, they suggested this was a postural-control strategy to reduce contralateral hip drop and lower limb loading. It is interesting that Hewett et al[24] observed greater ipsilateral trunk flexion in females with an anterior cruciate ligament injury compared with uninjured controls, indicating that dancers in our study may have been at an increased risk of such an injury during the postfatigue landings. Therefore, given the moderate effect size of this trend (Table 1), further investigation is warranted.

Irish dance landings are rigid and vary greatly from the force-distribution technique used in ballet, where dancers disperse and absorb forces through 3 phases: toe contact; toe extension, allowing the ball of the foot to lower; and finally, ankle dorsiflexion to allow heel contact moving into a plié.[25] We found greater (almost 30% higher) anterior shear and compressive forces at the ankle during the postfatigue compared with the prefatigue landing trials. Hreljac et al[26] reported greater (13% higher) vertical impact forces during running in a group of injured compared with uninjured runners. Although a different cohort from that of our study, these findings would suggest that the 30% increase in ankle loading displayed by dancers when fatigued, combined with the repetitive nature of Irish dance, may contribute to a decreased ability to absorb shock and may be linked with the high rate of overuse ankle injuries in this population.[1,5,6] This result therefore warrants further investigation into the effects of fatigue and lower limb loading on overuse injuries in Irish dancers.

Furthermore, the dancers in the current study landed with greater external knee-flexion moments during the postfatigue trials. Increased flexion external moments at the knee may require greater use of the knee extensors to counteract this torque and allow dancers to maintain an extended knee and overall rigid posture on landing, an aesthetic requirement.[1] Of note, reduced knee-extensor strength has been associated with overuse knee injuries, such as patellofemoral pain syndrome.[27] Recent researchers[28] have shown that high school cross-country runners with reduced isometric knee-extensor strength had a higher incidence of anterior knee pain. Furthermore, increasing knee-extensor strength has reduced knee pain and improved knee function in patients with patellofemoral pain syndrome.[29] Olsen et al[30] performed a randomized controlled trial examining the effect of a structured warm-up (including running, jumping, balance, and knee-strength drills) on injury rates in 15- to 17-year-old handball athletes ($n = 1837$). Participants in the intervention group had reduced rates of acute and overuse injuries at the ankle and knee compared with the control group.[30] The results of these studies suggest the need for further research into the effects of improving knee-extensor strength and decreasing injury rates in Irish dancers.

Despite the unique findings of our study, the limitations must be acknowledged. Although we suggest that a dance-specific fatigue protocol is more applicable to Irish dancers, the fatigue protocol we used has not been validated against an objective measure of fatigue. It was evident that dancers were "exhausted" after the fatigue protocol (based on a reduction in form as determined by the chief investigator), and we followed the procedures of Moran and Marshall[16] for determining fatigue ($RPE \geq 17$). However, further investigation is warranted to objectively measure the effects of fatigue in Irish dancers and their influence on injury risk.

CONCLUSIONS

Overall, we found that even though dancers attained similar jump heights in both conditions, the aesthetic component of the leap over was reduced during the postfatigue trials, whereby dancers landed with less ankle plantar flexion and hip external-rotation alignment, or turn out. Furthermore, dancers displayed greater loading on the ankle and knee joints, potentially exposing them to a higher risk of ankle- and knee-joint injuries during landing movements when fatigued. Further research prospectively examining the effects of fatigue and lower limb biomechanics on injury risk is therefore warranted.

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