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Original research

Dance floor mechanical properties and dancer injuries in a touring professional ballet company

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ABSTRACT

Objectives: The mechanical properties of the floors used by dancers have often been suggested to be associated with injury, yet limited etiological evidence is available to support this hypothesis. The dance floors at three theatres regularly used by a touring professional ballet company were mechanically quantified with the aim of comparing floor properties with injury incidence in dancers.
Design: Cross sectional.
Methods: Test points on the floors were quantified in accordance with European Sports Surface Standard protocols for force reduction. Injuries and associated variables occurring within the ballet company dancers during activity on the three floors were recorded by the company's medical staff. An injury was recorded if a dancer experienced an incident that restricted the dancer from performing all normal training or performance activities for a 24 h period. Injuries were delimited to those occurring in the lower limbs or lumbar region during non-lifting tasks.
Results: Floor construction varied between venues and a range of floor mechanical properties were observed. None of the floors complied with the range of force reduction values required by the European Sport Surface Standards. The highest injury rate was observed on the floor with the greatest variability of force reduction magnitudes. No difference in injury frequency was observed between the venues with the highest and lowest mean force reduction magnitudes.
Conclusions: Professional dancers can be required to perform on floors that may be inadequate for safe dance practice. Intra-floor force reduction variability may have a stronger association with injury risk than mean floor force reduction magnitude.

1. Introduction

Dancers employed in touring companies are regularly required to rehearse and perform at different venues with little consideration for the mechanical properties of the stage floor and the potential influences on injury risk. 'Hard', 'stiff' or 'unsprung' dance floors are anecdotally suggested to influence dance injury risk exposure.[1–3] In a retrospective survey of 1056 dancers, between 20% and 28% of professional dancers from multiple disciplines suggested that the floor surface was etiologically associated with development of a prior injury.[2] It is well established that humans alter leg mechanics during locomotion across floors with changing mechanical properties,[4–6] however, it is unclear if these biomechanical adaptations are related to the perceived injury risk associated with floor mechanical properties.[1–3] Due to the unique nature of the movements involved in dance training,[7] bespoke standards have been recommended for dance floors,[8,9] such as that developed in North America for what has been termed 'live performance venues',[10] as opposed to the generic standards applied to indoor multi-purpose sports halls.[11] If particular dance floor mechanical properties are identified as increasing injury risk predisposition to the dancer, changes could be made to floor properties that would promote safer dance practice and performance.

Scant evidence is available examining the relationship between floor properties and athletic injury. The injury incidence within a dance population has the potential to provide valuable insight concerning the injury risks associated with quantified dance floor mechanical properties. Etiological investigation of floor types and

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injury have typically used descriptive, as opposed to quantitative methods, when assessing the mechanical properties of the investigated floors.[12,13] Furthermore, many studies investigating the relationship between floors and injury have not controlled for confounding environmental variables, such as varied shoe/floor interactions.[12,13] Dancers wear minimal footwear during dance training[14] and perform in a well rehearsed and controlled environment where the floors may be quantified. In a related example, the performance floors used by professional circus artists have been suggested to be inadequate for elite physical performance and have been associated with injury incidence.[15] Nigg[15] hypothesized that variability of the intra-floor mechanical properties may pose a greater injury risk to the performer than overall floor hardness, however the floor properties and injury incidences discussed were not explicitly quantified.

Epidemiological studies of selected dance populations have reported a high incidence of injury (see Ref. 16 for review) and injury occurrence to a dancer places multiple burdens on the individual and respective dance company. The majority of dancer injuries are overuse in nature and occur in the lower limbs and trunk.[17,18] Dancers regularly spend more than 40 h per week training on dance floors,[17] while training for more than 5 h per day has been associated with an increased risk of stress fracture in the lower limbs or vertebrae.[14] The psychological impact of injury produces similar emotional responses in dancers to those demonstrated by athletes.[19,20] Worker's compensation claims as a result of dance injury pose a significant financial burden for professional dance companies.[18,21] Reducing dancer injuries using dedicated injury management protocols can alleviate many of the issues facing the dancing industry,[18,21,22] however specific injury risk factors in dance have not been well established.[3,23]

The aim of this study was to investigate potential injury risk factors related to the mechanical properties of floors used for dance training and performance. The mechanical properties of stage floors used by a touring professional ballet company were quantified in accordance with the applicable sports surface standard protocols, and these data were compared with the prospectively recorded injuries during dance activities on each floor. The hypotheses were tested that the floors at the touring venues with the (A) lowest force reduction mean magnitude and (B) highest force reduction variability would be associated with larger injury rates than the other test venues.

2. Methods

The mechanical properties of the stages at three theatre venues used by a touring professional ballet company were quantified with reference to the force reduction (FR) variable, measured using standard sports surface testing equipment, the Advanced Artificial Athlete (Metaalmaatwerk, NL). The costs associated with the data collection for this study were partially funded by British Harlequin Dance Floors PLC, however British Harlequin had no influence on the interpretation of the results. FR is a relative measure of the peak force recorded during impact with a surface by a 20 kg mass, attached to a spring of 2000 kN/m stiffness dropped from a height of 0.055 m. FR is expressed as a percentage value of the peak impact force recorded on a test floor relative to that recorded on a rigid concrete floor. Therefore, a rigid floor similar to concrete is referred to as having a low FR. More specific details of the floor quantification protocols for FR have been previously reported.[8,24] These protocols allowed comparison of the results with the European Sports Surface Standards BSEN 14904.[11]

Venue floors consisted of plywood boards that were approximately 30 mm thick covered by a thin layer of vinyl (Harlequin cascade, London, UK) that enhances the friction characteristics of the surface. Primary support structures for the venue floors were steel girders, which supported the floors above storage areas. Wooden, metal and/or foam secondary support structures lay in between the plywood and the primary support structures. The orientation and spacing of the primary and secondary support structures differed between floors. None of the stages were raked (floor surface is laid at an acute angle to the horizontal). Test points were selected at each venue to ensure that FR values on and between floor supports were quantified in order to provide a full representation of the FR variability across the floor surface. Data were always recorded on at least two mechanically analogous test points across the floors. As substructure differed between venues, the number of test points varied between venues (Table 1). Support locations could only be identified from below the theatre floors and therefore, could not be visually identified by the dancers during activity on the floors. FR testing sessions were conducted in an ambient temperature of 18–21 °C.

Injury data were collected over three annual performance seasons. During this time the company comprised between 52 and 58 dancers (males $n = 25$–29; females $n = 27$–29; principals $n = 6$–8; soloists $n = 11$–14; artists $n = 33$–38) with a mean age 23.5 years ±5.7, height 1.7 m ±0.1 and weight 60.7 kg ±12.0. All company dance activities (warm up class, rehearsal and performance) were performed on the test floors during the injury data collection period. The company spent 6 weeks training and performing on location at each venue during the data collection period. One week at a venue conservatively represented approximately 1485 dancer hours of exposure to the floors, based on 55 dancers, rehearsing or performing 6 days per week for 4.5 h per day. Theatre venues were within one day's road travel from the company's home venue. The touring schedule of the ballet company differed over the three year period, that is, the test venues were visited at different times across the performance seasons. This provided a degree of random exposure of the cohort to the venues. The repertoire performed at the touring venues did not differ between venues and included

Table 1

Descriptive statistics of the force reduction and construction characteristics observed at venues one, two and three.

Venue	Test points	Mean (%)	Standard deviation	Range (%)	Maximum (%)	Minimum (%)	Mean variability (%)	Standard deviation variability	Support spacing (m)	% Stage surface area
	Primary support values									
1	6	48.21	±6.61	19.92	56.34	36.42	4.17	±4.78	3.30	9.80
2	7	15.76[a]	±2.84	8.12	18.93	10.81	2.11	±1.70	3.25	6.30
3	10	24.12[a,b]	±2.43	6.24	27.51	21.27	1.91	±1.36	2.40	14.70
	Secondary support values									
1	16	45.55	±6.84	19.49	55.83	36.35	6.25	±2.28	0.38	90.20
2	25	37.58[a,c]	±3.44	12.03	43.80	31.77	2.76[a]	±1.98	0.23	93.70
3	27	41.93[c]	±8.35	28.14	58.73	30.58	7.53[b,c]	±3.29	0.60	85.30

[a] Significantly different ($p < 0.05$) to venue one.

[b] Significantly different ($p < 0.05$) to venue two.

[c] Secondary support values significantly different ($p < 0.05$) to primary support values of same venue.