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The Effect of Floor Stiffness on ACL and Meniscus Tear and Chondromalacia Susceptibility in Dancers

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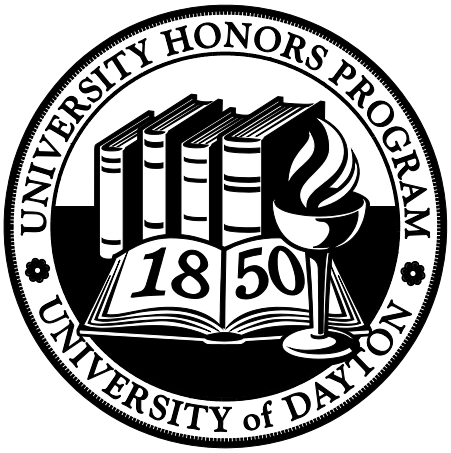

Honors Thesis

Kate Moreira

Theatre, Dance, and Performance Technology

Advisor: Jerome Yorke, MFA

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Abstract

Dance is a physically demanding art form, placing repeated strain on the joints and muscles of the body. Western dance technique emphasizes use of the lower extremity, resulting in a high volume of injury to the hip, knee, and ankle joints. Dance companies attempt to combat injury by installing low-stiffness floors in studios and performance spaces. These floors exert less pressure on dancers' joints during intense movement sequences. The purpose of this research is to determine the impact of floor stiffness on dancers' susceptibility to ACL and meniscus injuries and chondromalacia, specifically. Participants were asked about past and present dance training, floor type for all training, lower extremity injuries, and their path to recovery. The data were analyzed to find the frequency of dance-related injuries of each type, on both sprung (low stiffness) and non-sprung (high stiffness) floors. The results indicated that floor type does not have an effect on injury susceptibility in dancers. They also showed that of ankle, knee, and hip injuries, ankle injuries are the most common. A torn ACL and meniscus appeared in one participant, and no occurrences of chondromalacia were reported. Overall, the data show that ACL and meniscus tear are not common in low stiffness floors. Future research may investigate the effect of floor surface on lower extremity joint injury, as floors with high slickness may have a more immediate effect on dance injury.

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Introduction

Dance is a physically demanding art form. Dancers are consistently pushed to become more flexible, stronger, and asked to perform inhuman feats that, when executed improperly, increase the risk of injury. Even when using the correct technique, there can be negative consequences for the dancer caused by their environment. An important part of this environment is the floor. The floor is an essential tool used during rehearsal and performance and is integral for dancers' safety. Dance studios, programs, and companies commonly install sprung floors because they are a low-stiffness option that uses wood cross beams as the subfloor. In a study on grand jeté landings in ballet, researchers found that sprung floors help to reduce the frequency of musculotendinous injuries, as the softer floor absorbs the landing force rather than the leg (Hackney et al. 2011). A follow-up study produced similar findings in dancers landing a sauté (Hackney et al. 2011). Non-sprung floors typically contribute to joint injury, especially in the lumbar spine and ankle regions, because their foundation does not absorb impact and is made of concrete or rolled steel joists (Howse et al. 1988). Although these examples show that sprung floors reduce the frequency of injury and that non-sprung floors contribute to joint injuries in other areas, there is limited research on how the knee joint is affected explicitly by floor stiffness.

There are three major structures in the knee that are susceptible to injury: the anterior cruciate ligament, the posterior cruciate ligament, and the menisci. The cruciate ligaments connect the femur and tibia in a weight-bearing interaction (Drake et al. 2009). The anterior cruciate ligament attaches to the anterior side of the tibia and the posterior side of the femur in the intercondylar space of both bones (Drake et al. 2009). The posterior cruciate ligament does the opposite, connecting the posterior region of the tibia's intercondylar fossa to the anterior region of the femur's intercondylar fossa (Drake et al. 2009). The menisci are also essential to the knee's function. The two menisci provide a cushion between the femoral and tibial condyles so that the bones do not grind against one another during flexion and extension (Drake et al. 2009). Injury to any of these three structures can have detrimental effects on the joint's longevity. This type of damage could sometimes end a dancer's career.

Anterior cruciate ligament (ACL) injuries are most common during non-contact activities when cutting or pivoting movements occur (Drake et al. 2009). ACL tears may be acute or complete, characterized by rapid swelling or joint instability respectively (Drake et al. 2009). As highly active individuals, dancers who suffer a complete ACL tear usually undergo reconstructive surgery followed by physical therapy (Drake et al. 2009). In a study on ACL injury in professional dancers, six professional ballet dancers suffered complete ACL tears over eleven years (Meuffels and Verhaar, 2008). All dancers had an autograft, allograft, or hamstring graft reconstruction of the ACL (Meuffels and Verhaar, 2008).

Meniscal tears are injuries from the forceful rotation of the knee (Drake et al. 2009). Tears of the meniscus can be vertical, horizontal, or longitudinal and are usually diagnosed with MRI (Drake et al. 2009).

Chondromalacia is a degenerative disease in which the patellar cartilage softens, fissures, and eventually erodes (Bronitsky, 1947). It is relatively common in both young and old individuals, although its prevalence amongst dancers has not been widely investigated.

This study investigates floor stiffness and its effects on dancers' susceptibility to specific knee injuries. Through anonymous surveys, dancer experience will be analyzed to assess how floor type has affected knee injury across many styles and experiences. The hypothesis states that dancers with more experience on sprung floors will be less susceptible to specific knee injuries.

Methods

This study was conducted through anonymous surveys. Surveys were conducted on-site at a local dance company and online through Google Forms. Paper surveys were transcribed into Google Forms, and all data was gathered and analyzed in Microsoft Excel. Twenty-seven dancers were surveyed, and the results were filtered until eighteen

surveys remained. Injuries that did not occur while dancing were disqualified. Surveys disregarded from data analysis were incomplete, or the participant reported only non-dance-related injuries. Injuries were categorized based on the affected joint region: ankle, knee, or hip. The remaining injuries were sorted based on whether they occurred on sprung or non-sprung floors. A t-test was performed to calculate the statistical significance of floor type on injury susceptibility in the lower extremities of dancers.

Results

A total of twenty-seven dancers were surveyed. Seven participants failed to complete the survey. Of the remaining twenty dancers, two reported only non-dance-related injuries. One was an ankle injury when the participant fell from a balance beam,

and the other sustained a hip flexor injury during soccer practice. Data analysis will disqualify these injuries because they did not occur while dancing or pertain to the floor's influence on a dancer's ability to become injured. Results from the remaining eighteen dancers will be used in data analysis. Fifteen out of eighteen dancers suffered a dance-related injury during pre-professional (high-school level), collegiate, or professional dance experience. The injury and floor type for each dancer is shown in **Figure 1**. Of these fifteen dancers, three suffered two dance-related injuries, and eight were injured only once. In total, there were two hip injuries, twelve ankle injuries, and four knee injuries. Both hip injuries occurred on a sprung floor, as did three of the knee injuries and eight of the ankle injuries. 66.7% of injured dancers were injured on sprung floors, and of eighteen total injuries for those dancers, 72.2% occurred on sprung floors. As can be seen in **Figure 2**, 75% of knee injuries, 100% of hip injuries, and 66.7% of ankle injuries occurred on a sprung floor. There was one reported ACL full tear and one partial meniscus tear, both in the same patient and both in the left knee. No incidences of chondromalacia were reported. A t-test result of $p=0.294$ compared the mean of injuries on a sprung floor with injuries on a non-sprung floor.

Figure 1

Dancer	Injury Type	Floor Type
1	Ankle	Not sprung
2	Ankle	Not sprung
3	Ankle	Not sprung
4	Ankle	Sprung
5	Ankle, Knee	Sprung
6	Ankle	Sprung
7	Ankle	Not sprung
8	Knee	Not sprung
9	Knee	Sprung
10	Ankle, Knee	Sprung
11	Hip, Ankle	Sprung
12	Hip	Sprung
13	Ankle	Sprung
14	Ankle	Sprung
15	Ankle	Sprung

Figure 2

Affected Joint	Sprung (%)	Not sprung (%)
Ankle	66.7	33.3
Hip	100	0
Knee	75	25

Figure 3

	Sprung	Not sprung
SD	3.21	2.08
SEM	1.86	1.2
T-test	p=0.294 > 0.05	

Discussion

This study aims to investigate the effect of floor type on knee injury susceptibility in dancers. Injury to the lower extremity joints was investigated, and the results indicated that a sprung floor does not affect injury susceptibility. Out of the fifteen dancers reporting dance-related injuries, ten were injured while dancing on a sprung floor. A t-test was conducted to investigate the significance of floor type on lower extremity joint injury (**Figure 3**). The results indicate that neither sprung nor not sprung floor has a significant effect on injury susceptibility in dancers ($p=0.294$). This result exceeds the significance value of $p<0.05$. Based on these results, it cannot be assumed that sprung floors have an impact on any of the three injury types. There were high recorded percentages of dancers who sustained a hip injury (100%) or knee injury (75%). However, these results are skewed by the small sample size. Only two dancers suffered a dance-related hip injury, and although both happened on a sprung floor, the sample size is too small to conclude that the floor was a major factor. The same logic can be applied to dance-related knee injuries, of which there were four. Therefore, the t-test was necessary as a way to investigate the significance of floor type by comparing the mean number of injuries for sprung and unsprung floors.

This study could be improved by surveying only individuals who had dance-related knee injuries. This would have ensured a large sample size as well as insight into the frequency of ACL and meniscus tears, specifically. Of the four participants with dance-related knee injuries, one reported an ACL and a meniscus tear, both in the same knee. Others reported tendonitis in the right patella, interstitial tears in the left patellar tendon, an undiagnosed injury after landing a jump, and repeated kneecap dislocations. The kneecap dislocations reportedly happened thirteen times, eight during dance and five outside of dance. Due to the frequency of dislocations, this participant likely has an underlying issue with the knee joint, which increases their susceptibility to kneecap dislocation. The low number of recorded knee injuries suggests that knee injuries are not extremely common in dancers. A study on ACL injury in professional ballet and modern dancers found that, in a five-year period, twelve dancers (of sample size of 298) suffered ACL injuries (Liederbach et al., 2008). The authors also stated that the NCAA places

dancers in the lowest risk category for ACL injuries, in part due to their developed skills in jumping technique and the ability to control their landing (Liederbach et al., 2008).

Based on these results, injury cannot be allocated to the floor type alone and is more likely due to the floor surface than floor stiffness. Future studies may investigate floor surface slickness and friction and its effect on injury susceptibility. Floors with increased slickness can cause tightening of muscles in the hip and thigh as they compensate for the lack of stability (Howse, 1988). Additionally, floors with higher friction can increase sticking and twinging, making knee injury more likely (Howse, 1988). The purpose of this research is to study the effect of floor stiffness on acute injury. It is possible that floor stiffness, as described in this study, may contribute to long-lasting or chronic pain, whereas floor slickness is more prevalent in acute injury. It seems likely that floor type has more of an effect on chronic pain of the joints. This has been investigated in a study on low back pain and force absorption in the region of the upper body, which concludes that low back pain correlates with low attenuation capacity from the femoral condyle to the forehead (Voloshin, Wosk, 1982). This suggests that floors with low attenuation capacity (high stiffness) may contribute to low back pain because the back absorbs force from the ground.

Conclusion

This study aimed to investigate the effect of floor stiffness on specific knee injury susceptibility in dancers. The survey results and data analysis suggest that floor stiffness does not have a significant effect on acute injury susceptibility in the knee. It is clear that a sprung floor does not eradicate injuries, although it may be used as a tool in tandem with correct technique and care for the body to lower the likelihood of injury.

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