The purpose of this study was to investigate the effect of sports surface on the magnitude of impact shock experienced during a lunge movement. Thirteen experienced, competitive fencers (age 32.4 ± 4.6 years; height 178.4 ± 7.2 cm; mass 74.4 ± 9.1 kg) performed 10 lunges on four different surfaces: concrete with an overlaid vinyl layer (COVL), wooden sprung court surface (WSCS), metallic carpet fencing piste overlaid on the WSCS, and aluminum fencing piste overlaid on the WSCS. An accelerometer measured accelerations along the longitudinal axis of the tibia at 1000 Hz. The results identified a significantly (P < .05) larger impact shock magnitude was experienced during a lunge on the COVL (14.88 ± 8.45 g) compared with the WSCS (11.61 ± 7.30 g), WSCS with metallic carpet piste (11.14 ± 6.38 g) and WSCS with aluminum piste (11.95 ± 7.21 g). Furthermore, the two types of piste used had no significant effect on the impact shock magnitude measured when overlaid on the WSCS compared with the WSCS on its own. The results of this investigation suggest that occurrences of injuries related to increased levels of impact shock may be reduced through the utilization of a WSCS as opposed to a COVL surface during fencing participation.

Keywords: biomechanics, sport, sports medicine, kinetics, fencing

Fencing is an Olympic sport involving two competitors whose aim is to strike their opponent’s body with their sword in various manners depending on the discipline (foil, epee, or sabre). The sport requires speed of body and thought, to avoid being struck while attempting to strike an opponent first to win the point. Success in fencing requires intensive repetitive practice to improve and maintain the speed of performance. Repetitive dynamic movements performed during fencing participation have been identified as exposing the musculoskeletal system to potential injury as a result of ground reaction forces. In particular, the lunge action which forms the basis of a number of offensive motions repeatedly exposes participants to potentially detrimental impact forces.

Recent research in fencing has reported that injuries and pain related to fencing participation were prevalent in 92.8% of the elite fencers. Further research identified that the majority of injuries occur in the lower extremities in competitive fencing. Injuries leading to suspension of participation may be considered more detrimental to the lives of fencers than pain or discomfort. Nevertheless, pain and discomfort are outcomes that may restrict both enjoyment and performance. Therefore, a reduction of all of these negative outcomes should enhance the enjoyment of fencing participation and may reduce drop-out within the sport.

The transient shockwave that is associated with footstrike propagates through the musculoskeletal system and carries with it the potential for injury. Epidemiological investigations propose that a positive relationship exists between the impact shock magnitude, rate of repetition, and the etiology of overuse injuries. Therefore given the influence of surfaces on the loading of the musculoskeletal system and the number of lunges typically performed by fencers, there is a clear need to investigate the impact attenuation properties of fencing surfaces. Due to the functional asymmetries present in fencing, the lunge in particular appears to expose the front foot side’s lower extremities to an increase in detrimental forces. This has been identified by research reporting large transient impact shocks experienced through the tibia of the front leg during a fencing lunge movement. Impact shock magnitudes have been found to be larger in groups of athletes with a history of suffering tibial stress fractures. Therefore, reducing the magnitude of the impact shock could result in a lower frequency of such injuries.

There is currently a paucity of research investigating the influence of different surfaces typically used during fencing training and competition. Fencing is typically performed on hard court floors or sprung sports surfaces. A metal or carpet piste (the piste is the fencing
area) is often laid down over these surfaces especially in competition as they are mandatory as it prevents a hit being detected if the sword makes contact with the ground accidentally. The material testing of surfaces has been criticized in terms of its reliability to predict its influence on the loading of the musculoskeletal system of an athlete performing a sports specific movement.\textsuperscript{12} This is due to the fact that the human is a multifaceted dynamic system in comparison with mechanical testing of sports surfaces.\textsuperscript{13,14} Therefore, mechanical testing may not be the most effective technique for relating surface stiffness properties to the incidence of injuries related to performance of the fencing lunge.

Compared with running, controlled landings appear to demonstrate more consistent results for impact shock magnitudes, between mechanical and human tests.\textsuperscript{18,19} Similar results may be apparent in a fencing lunge. Furthermore, the lunge movement has been shown to expose the participant to transient impact shocks that are consistently influenced by the design of the footwear used.\textsuperscript{4} Effects of surfaces on which the fencers participate may influence a population of fencers in a similar, consistent manner. By identifying the influence of different surfaces used during fencing participation on the magnitude of the impact shock during a fencing lunge, it may be possible to identify if a particular surface may assist in reducing the risk of injury. Therefore the aim of this study was to compare the influence of four different surfaces typically used during fencing participation on the magnitude of impact shock: a hard floor comprised of concrete with an overlaid vinyl layer (COVL), a wooden sprung court surface (WSCS), a metallic carpet fencing piste (Leon Paul, UK) overlaid on the WSCS, and an aluminum fencing piste (Leon Paul, UK) overlaid on the WSCS. It was hypothesized that a surface made to cushion impacts (WSCS) would consistently reduce the magnitude of tibial impact shock among a population of competitive fencers during a fencing lunge. It was further hypothesized that the different types of pistes used would also influence the magnitude of tibial impact shock.

**Method**

Thirteen participants (7 females and 6 males) volunteered to take part in this investigation (age 32.4 ± 4.6 years; height 178.4 ± 7.2 cm; mass 74.4 ± 9.1 kg). Participants were all actively involved in competition and had a minimum of three years’ experience. All were injury free at the time of data collection and completed an informed consent form. A statistical power analysis was conducted to reduce the likelihood of a type II error and to determine the minimum number participants needed for this investigation. It was found that the sample size was sufficient to provide more than 80% statistical power in the experimental measure. Ethical approval for this project was obtained from the School of Psychology ethics committee, University of Central Lancashire and each participant provided written consent.

Participants taking part in the study all wore full fencing attire as they would in practice and competition, this included their own fencing footwear. A triaxial accelerometer (Biometrics ACL 300, Gwent, UK) mounted to a lightweight carbon-fiber plate was attached to the distal antero-medial aspect of the tibia 8 cm from the center of the medial malleolus. This position was selected in accordance with recommendations from previous research\textsuperscript{20} and to allow comparisons between this study and previous similar research investigating impact shock during a fencing lunge.\textsuperscript{4} The carbon plate was attached to the participant’s shank by strong adhesive tape and as tightly as possible without causing major discomfort to the participant. The skin underlying the device was stretched to achieve a more rigid coupling of the accelerometer to the tibia and served to increase the resonance frequency of the mounted device to >70 Hz. The accelerometer was fixed in position to measure the acceleration along the longitudinal axis of the tibia. The accelerometer was set to record at 1000 Hz with a voltage sensitivity that recorded ± 100 g. The acceleration signal was recorded by a data logging system (Biometrics DL1001 Gwent, UK) attached to the participants by a tightly fitted backpack.

Four different surface conditions were set up ready for the participants: a hard floor comprised of concrete with an overlaid vinyl layer (COVL), a wooden sprung court surface (WSCS), a metallic carpet fencing piste (Leon Paul, UK) overlaid on the WSCS, and an aluminum fencing piste (Leon Paul, UK) overlaid on the WSCS. The surface areas used for testing were assumed to provide consistent cushioning characteristics. The aluminum section piste was made from sections of rolled aluminum which were bolted together and weighed approximately 300 kg and the carpet piste was made from woven metal with no backing and weighed approximately 70 kg.

The participants were instructed to complete a suitable warm-up as they would do before fencing participation. They were then allowed two minutes to practice lunging on one of the surfaces before acceleration data were recorded while they completed 10 lunges. During each lunge they were required to strike a dummy from a consistent distance which the participant defined themselves as most suitable to replicate training and competition situations (Figure 1). This procedure was repeated for all surfaces in a randomized order.

Descriptive statistics including means and standard deviations were calculated for each condition. The mean values of the footfalls per participant/condition for the axial component of the acceleration signal were quantified and used for statistical analysis. Differences in impact peak between surfaces were examined using a repeated measured ANOVA with significance accepted at the \( P \leq .05 \) level. Appropriate post hoc analyses were conducted using a Bonferroni correction to control for type I error. The Shapiro-Wilk statistic for each surface condition confirmed that the data were normally distributed and the sphericity assumption was met. Effect sizes were calculated using an eta square. Cohen’s suggestion regarding effects sizes was observed (small \( r < .3 \); medium \( r > .3 \).
and ≤ 0.5; large > 0.5. All statistical procedures were conducted using SPSS 19.0 (SPSS Inc., Chicago, IL, USA).

Results
The results indicate that the analysis of variance was significant $F_{(3, 36)} = 17.07, P \leq .001, \eta^2 = 0.59$, indicating a moderate effect size. Post hoc analysis revealed that peak axial impact shock was significantly higher in lunges performed on the COVL ($14.9 \pm 8.5$ g) in comparison with the WSCS overlaid with an aluminum fencing piste ($12.0 \pm 7.2$ g, $P = .007$), WSCS overlaid with a metallic carpet piste ($11.1 \pm 6.4$ g, $P = .002$) and WSCS ($11.6 \pm 7.3$ g, $P = .003$; Figure 2). The impact shock values measured on the WSCS, did not differ significantly from the values measured on the WSCS with the carpet ($P = .41$) or the metal ($P = .38$) piste overlaid. Furthermore, no significant difference ($P = .69$) was observed between the metallic carpet and the aluminum pistes overlaid on the WSCS (Figure 2).

Figure 1 — Fencer performing a lunge wearing the data logger with an accelerometer rigidly attached to the distal antero-medial aspect of the tibia.

Figure 2 — Peak tibial acceleration (g) (means, standard deviations) as a function of surface ($n = 13$). *Denotes significant difference from the COVL ($P < .05$).
Discussion

This study aimed to discover if different surfaces would influence the magnitude of tibial shock recorded during a fencing lunge. The results of this study appear to support the hypothesis that a surface made to cushion impacts (WSCS) would reduce the magnitude of tibial shock measured during a fencing lunge. However the results do not support the hypothesis that the two different types of piste used on top of the surfaces would influence the magnitude of tibial shock measured during a fencing lunge.

As an increase in tibial shock has been linked to various overuse injuries, reducing the magnitude in repetitive movements such as the fencing lunge may assist in reducing the occurrence of injury, pain and discomfort. Therefore, it appears based on the results of this investigation that a sprung or otherwise cushioned surface as opposed to a hard sports surface should be used during training and competition. Furthermore, it would appear that the critical factor in a suitable surface regarding attenuating impact shock is the underlying surface and not the piste.

The range of the mean magnitudes of impact shock recorded of all subjects on the different surfaces (11.14–14.88 g) are similar to those identified in previous research investigating footwear (8.75–15.93 g) on hard court sports surfaces. Furthermore, such an increase in impact shock magnitude between surfaces (33.6%) is comparable with the significant increase (32.5%, $P \leq 0.05$) in the same variable measured during running in a control group (5.81 g) compared with a group of athletes with a history of tibial stress fractures (7.70 g). Therefore, it would appear that increased cushioning in footwear and in surfaces may serve to assist in the reduction of impact shock magnitudes suggesting that by considering both these parameters, the magnitude of the impact shock could be reduced further. It should also be recognized that increased cushioning may have a detrimental effect on speed of performance, as well as increasing the risk of suffering an ankle inversion/eversion injury. Therefore further research investigating lower extremity kinematics and impact shock data together may provide further information that will allow suitable surfaces and footwear to be chosen.

The fact that the frictional properties of each surface were not considered may serve as a limitation for the current investigation as the coefficient of friction between foot and surface have been shown to have a significant influence on the loading and alignment of the lower extremities at foot contact. Therefore it is important for future investigations to consider also the grip characteristics of the surfaces used if the ideal surface conditions for participation in terms of performance and protection are to be found.

Skin mounted accelerometry is a complex technique and soft tissue artifact/skin resonance can negatively influence efficacy of the recording of underlying bone accelerations. The magnitude of the signal obtained from the accelerometer is highly dependent on the resonance frequency of the mounting making interstudy comparisons difficult (Sinclair et al., 2010). Furthermore, the axial acceleration signal is influenced by centripetal acceleration induced by sagittal plane tibial angular motion during the stance phase. Therefore, despite the distal mounting of the device some correction for angular motion of the tibial segment may still be necessary. Future, work is required to determine the necessary adjustment for angular motion during the fencing lunge.

The findings of this study conclude that magnitudes of impact shock implicated in the etiology of overuse injury may be reduced by training and competing on a sprung sports surface. However the types of pistes overlaid on the sprung sports surface do not appear to influence impact shock magnitudes. These results are of particular importance for fencers who are predisposed to overuse injuries in the lower extremities and may provide information to assist in reducing the incidence of injury in fencers through informed surface choice.

Acknowledgments

The authors would like to thank Kate Smith and the other organizers of the London International Open Epee Tournament. No funding was given for this study.

References

2. Viou E, Do M. In Fencing, Does Intensive Practice Equally Improve the Speed Performance of the Touche when it is Performed Alone and in Combination with the Lunge? Int J Sports Med. 2000;21(02):122,126.
10. Dixon SJ, Collop AC, Batt ME. Surface effects on ground reaction forces and lower extremity kinematics in running.
Impact Shock Experienced During a Fencing Lunge


