Influence of surface on impact shock experienced during a fencing lunge.

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Abstract

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 ten 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: aluminium fencing piste overlaid on the WSCS. An accelerometer measured accelerations along the longitudinal axis of the tibia at 1000Hz. The results identified a significantly ($P < 0.05$) larger impact shock magnitude was experienced during a lunge on the COVL (14.88 ± 8.45g) compared to the WSCS (11.61 ± 7.30g), WSCS with metallic carpet piste (11.14 ± 6.38g) and WSCS with aluminium piste (11.95 ± 7.21g). Furthermore, the two types of piste used had no significant effect the impact shock magnitude measured when overlaid on the WSCS compared to 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.

Introduction

Fencing is an Olympic sport involving two competitors whose aim it 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 in order to win the point. Success in fencing requires intensive repetitive practice to improve and maintain the speed of performance.[1-2] 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.[3] In particular, the lunge action which forms the basis of a number of offensive motions repeatedly exposes participants to potentially detrimental impact forces.[4]

Recent research in fencing has reported that injuries and pain related to fencing participation were prevalent in 92.8% of the elite fencers.[5] Further research identified that the majority of injuries occur in the lower extremities in competitive fencing.[6] 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[7]. Epidemiological investigations propose that a positive relationship exists between the impact shock magnitude, rate of repetition, and the aetiology of overuse injuries.[8-9] Therefore given the influence of surfaces on the loading of the musculosketal system[10] 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.[4] Impact shock magnitudes have been found to be larger in groups of athletes with a history of suffering tibial stress fractures.[9, 11] 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 (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 criticised in terms of its reliability to predict its influence on the loading of the musculoskeletal system of an athlete performing a sports specific movement.[12] This is due to the fact that the human is a multifaceted dynamic system in comparison to mechanical testing of sports surfaces.[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 to running, controlled landings appear to demonstrate more consistent results for impact shock magnitudes, between mechanical and human tests[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.[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 (a hard floor comprised of concrete with an overlaid vinyl layer (COVL); a wooden sprung court surface (WSCS); a metallic carpet fencing piste (made from woven metal) overlaid on the WSCS and: a aluminium fencing piste (made from sections of solid aluminium bolted together) overlaid on the WSCS) on the magnitude of impact shock. It was hypothesised that a surface made to cushion impacts (WSCS) would consistently reduce the magnitude of tibial impact shock amongst a population of competitive fencers during a fencing lunge. It was further hypothesised 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 in order 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 tri-axial accelerometer (Biometrics ACL 300, Gwent, UK) mounted to a lightweight carbon-fibre plate was attached to the distal anterio-medial aspect of the tibia 8cm from the centre of the medial maleolus. This position was selected in accordance with recommendations from previous research[20] and to allow comparisons between this study and previous similar research investigating impact shock during a fencing lunge.[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 in order to achieve a more rigid coupling of the accelerometer to the tibia and served to increase the resonance frequency of the mounted device to >70Hz. The accelerometer was fixed in position to measure the acceleration along the longitudinal axis of the tibia. The accelerometer was set to record at 1000Hz 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 aluminium fencing piste (Leon Paul, UK) overlaid on the WSCS. The surface areas used for testing were assumed to provide consistent cushioning characteristics. The aluminium section piste was made from sections of rolled aluminium 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 prior to fencing participation. They were then allowed two minutes to practice lunging on one of the surfaces before acceleration data was 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 randomised 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 $p \leq 0.05$ 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 was normally distributed and the sphericity assumption was met. Effect sizes were calculated using an Eta^2. Cohen's suggestion regarding effects sizes was observed (small $r < 0.3$; medium $r > 0.3$ 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 $F_{(3, 36)} = 17.07$, $p \leq 0.001$, $\eta^2 = 0.59$, 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 ± 8.5 g) in comparison to the WSCS overlaid with an aluminium fencing piste (12.0 ± 7.2 g, p=0.007), WSCS overlaid with a metallic carpet piste (11.1 ± 6.4 g, p=0.002) and WSCS (11.6 ± 7.3 g, p=0.003; 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=0.41) or the metal (p=0.38) piste overlaid. Furthermore, no significant difference (p=0.69) was observed between the metallic carpet and the aluminium pistes overlaid on the WSCS (figure 2).

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,[7, 9, 11] 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 – 14.88g) are similar to those identified in previous research investigating footwear on a variety of indoor sports surfaces.[4] 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 (5.81g) compared to a group of athletes with a history of tibial stress fractures (7.70g)[11]. 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 be recognised that whilst impact shock magnitudes may be reduced during the fencing lunge movement, the levels of shock magnitude are still relatively high compared to other sports movements and therefore overuse injury risk may still be a concern. Furthermore, increased cushioning may have a detrimental effect on speed of performance.[3] as well as increasing the risk of suffering an ankle inversion/eversion injury.[21] 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.[22-23] 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 artefact/skin resonance can negatively influence efficacy of the recording of underlying bone accelerations.[24] The magnitude of the signal obtained from the accelerometer is highly dependent on the resonance frequency of the mounting making inter-study 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.[25] 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 aetiology 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.

Conflict of interest statement

No conflict of interest will arise from any author as a result of the publication of this work.

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References

1.Stewart SL, Kopetka B. The kinematic determinants of speed in the fencing lunge. Journal of Sports Sciences. *J Sports Sci.* 2005;2:S105.***[Journal Article]***

2.Yiou 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.***[Journal Article]***

3.Geil MD. The Role of Footwear on Kinematics and Plantar Foot Pressure in Fencing. *J of App Biomech.* 2002;18(2):155-162.***[Journal Article]***

4.Sinclair J, Bottoms L, Taylor K, Greenhalgh A. Tibial shock measured during the fencing lunge: the influence of footwear. *Sports Biomech.* 2010;9(2):65-71.***[Journal Article]***

5.Trautmann C, Rosenbaum D. Fencing injuries and stress injuries in modern fencing sport- a questionnaire evaluation. *Sportverletz Sportschaden.* 2008;22(4):225-230.***[Journal Article]***

6.Harmer PA. Getting to the point: injury patterns and medical care in competitive fencing. *Curr Sports Med Rep.* 2008;7(5):303-307.***[Journal Article]***

7.Whittle MW. Generation and attenuation of transient impulsive forces beneath the foot: a review. *Gait Posture.* 1999;10(3):264-275.***[Journal Article]***

8.Nigg BM, Segesser B. Biomechanical and orthopedic concepts in sport shoe construction. *Med Sci Sports Exerc.* 1992;24(5):595-602.***[Journal Article]***

9.Pohl MB, Mullineaux DR, Milner CE, Hamill J, Davis IS. Biomechanical predictors of retrospective tibial stress fractures in runners. *J Biomech.* 2008;41(6):1160-1165.***[Journal Article]***

10. Dixon SJ, Collop AC, Batt ME. Surface effects on ground reaction forces and lower extremity kinematics in running. *Med Sci Sports Exerc.* 2000;32(11):1919-1926.***[Journal Article]***

11. Milner CE, Ferber R, Pollard CD, Hamill J, Davis IS. Biomechanical factors associated with tibial stress fracture in female runners. *Med Sci Sports Exerc.* 2006;38(2):323-328.***[Journal Article]***

12. Nigg BM. The validity and relevance of tests used for assessment of sports surfaces. *Med Sci Sports Exerc.* 1990;22(1):131-139.***[Journal Article]***

13. Saunders N, Twomey D, Otago L. Clegg Hammer Measures and Human External Landing Forces: Is There A Relationship? *Int J of Sports Sci and Eng.* 2011;5(4):231-236.***[Journal Article]***

14. Boyer KA, Nigg BM. Muscle activity in the leg is tuned in response to impact force characteristics. *J Biomech.* 2004;37(10):1583-1588.***[Journal Article]***

15. Elvin NG, Elvin AA, Arnoczky SP. Correlation Between Ground Reaction Force and Tibial Acceleration in Vertical Jumping. *J of App Biomech.* 2007;23:180-189.***[Journal Article]***

16. Hennig EM, Lafortune MA. Relationships Between Ground Reaction Force and Tibial Bone Acceleration Parameters. *Int J of Sport Biomech.* 1991;9:303-309.***[Journal Article]***

17. Laughton C, McClay Davis I, Hamill J. Effect of Strike Pattern and Orthotic Intervention on Tibial Shock During Running. *J of App Biomech.* 2003;19:153-168.***[Journal Article]***

18. Zhang S, Derrick TR, Evans W, Yu Y-J. Shock and impact reduction in moderate and strenuous landing activities *Sports Biomech.* 2008;7(2):296-309.***[Journal Article]***

19. Shorten MR, Himmelsbach JA. Impact shock during controlled landings on natural and artificial turf. Paper presented at: XVII Congress ISB1999; Calgary.***[Conference Proceedings]***

20. Nokes L, Fairclough JA, Mintowt-Czyz WJ, Mackie I, Williams J. Vibration analysis of human tibia: the effect of soft tissue on the output from skin-mounted accelerometers. *J Biomed Eng.* 1984;6(3):223-226.***[Journal Article]***

21. Stussi E, Stacoff A, Lucchinetti E. Cushioning versus stability. *Sportverletz Sportschaden.* 1993;7(4):167-170.***[Journal Article]***

22. Menck H, Jorgensen U. Frictional forces and ankle fractures in sport. *Br J Sports Med.* 1983;17(4):135-136.***[Journal Article]***

23. Dowling AV, Fisher DS, Andriacchi TP. Gait modification via verbal instruction and an active feedback system to reduce peak knee adduction moment. *J Biomech Eng.* 2010;132(7):071007.***[Journal Article]***

24. Light LH, McLellan GE, Klenerman L. Skeletal transients on heel strike in normal walking with different footwear. *J Biomech* 1980;13(6):477-480.***[Journal Article]***

25. Lafortune MA, Hennig EM. Contribution of angular motion and gravity to tibial acceleration. *Med Sci Sports Exerc.* 1991;23(3):360-363.***[Journal Article]***

Figure Captions

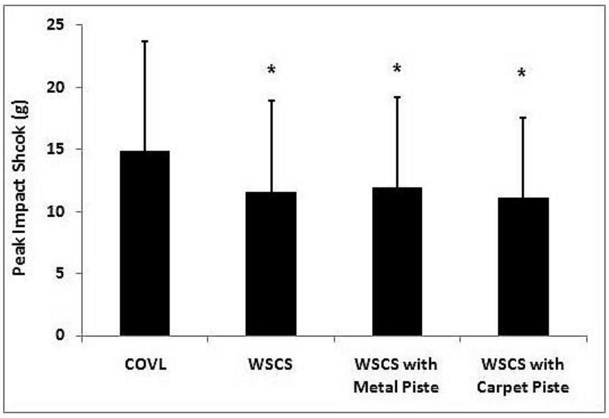
Figure 1. Fencer performing a lunge wearing the data logger with an accelerometer rigidly attached to the distal anterio-medial aspect of the tibia.

Figure 2: Peak tibial acceleration (g) (means, standard deviations) as a function of surface (n=13). * denotes significant difference from the COVL ($P < 0.05$).

Figures

Figure 1

Figure 2


Peak Impact Shcok (g)
25
20
15
10
5
0
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*
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COVL
WSCS
WSCS with Metal Piste
WSCS with Carpet Piste