Study of impact shocks in fencing

Abstract

Fencing is a high intensity sport involving dynamic movements which expose the musculoskeletal system to high impact forces that may lead to overuse injuries. One of the most frequently used high impact movements is the lunge. With many different types of sports footwear available providing different levels of midsole cushioning, selecting the most suitable for a sport may be a factor in preventing the onset of injury. The aim of this study was to investigate the magnitudes of the transient axial impact shock experienced at the tibia between traditional fencing shoes and standard athletic footwear during the impact phase of the fencing lunge. Peak tibial shock was measured in 19 male fencers in 4 different footwear conditions using an accelerometer placed on the distal aspect of the tibia. The standard footwear resulted in significant reductions in peak impact shock in comparison to the traditional fencing shoes. Thus the reduction in impact shock found suggests that running or squash specific footwear may reduce overuse injury occurrence. However, despite this, the majority of participants indicated that they preferred fencing specific footwear for fencing. The results of this study suggest that there is justification for a re-design of fencing shoes.

Introduction

Competitive fencing (foil, sabre and epee) has experienced a rapid increase in participation rates during the past decade (Harmer, 2008). The sport places unique demands on the athlete and is characterised by asymmetry and the incidence of rapid motions which have the potential to generate large forces (Geil, 2002). In particular, the frequently used lunge which is the basis of most attacking motions is a high impact movement (Kopetka & Stewart, 2005).

The expansion in participation combined with the biomechanical demands of the sport has led to enhanced awareness of the incidence of injuries associated with fencing. Nonetheless, prospective, epidemiological studies of the incidence of repetitive strain and overuse injuries in fencing are scarce. As a result, it is difficult to draw dependable conclusions regarding the etiology of fencing injuries and their prevention based on impartial information (Roi & Bianchedi, 2008). However existing studies indicate that overuse injuries account for approximately 30% of injuries that interfere with training (Carter et al., 1993). The majority of injuries are confined to the lower extremities (e. g., stress fractures, impingement enthesopathies of the patellar tendon and tibia and plantar fascia) associated with fencing (Harmer, 2008, Wild et al., 2001; Zemper & Harmer, 1996) characteristic of dynamic activities involving high velocity change in momentum actions (Harmer, 2008).

No apparent data has been published providing information regarding the total number of lunges executed during a competitive bout. However, Roi and Bianchedi (2008) suggest that there are anywhere between 66 and 210 attacks (depending on the weapon) during a competition, which given the lunge’s function as the most common attacking mechanism, it appears that fencers will be regularly subjected to the impact forces imposed by the lunge.

One of the characteristics of the foot impacting the surface during a lunge is a rapid change in velocity of the foot and this velocity reaches zero upon foot placement in a short period of time (Whittle, 1999). This impact leads to the transmission of an axial transient shock wave through the body and carries with it the potential for injury. It is important to recognise that loading is necessary for maintenance of cartilage, bone, and muscle health (Stone, 1988). An optimal loading window for tissue strength can be characterized by frequent impacts of certain magnitude, duration, and frequency. Movements beyond the optimal loading window can lead to the breakdown of body tissue and overuse injuries (Hardin et al., 2003).

The magnitude of the impact shock is commonly measured using accelerometers. Accelerometers are traditionally placed onto the skin overlying the tibia to quantify the transient impact shockwave during motion. Despite the consensus that soft tissue interferes with the acceleration recording of underlying bone, the utilization of skin mounted devices is considered appropriate provided they are lightweight and rigidly attached to the overlying skin (Shorten and Windslow, 1992). This method has been used to examine the cushioning properties of athletic footwear (Lake & Greenhalgh, 2005) and better differentiates between impact conditions compared to data acquired using a force platform (Lafortune & Hennig, 1992). The high impact nature of the lunge implies that the lower extremities may be at risk from overuse injuries.

To date there is no information available regarding the potentially detrimental effect of the impact accelerations experienced during this movement. However, epidemiological studies suggest that a relationship exists between the magnitude of the transient shockwave and the etiology of a number of lower extremity overuse injuries (Nigg & Segesser, 1992). Therefore with a significant number of lunges being undertaken by a fencer and the potential connection between the magnitude of the impact shockwave and the incidence of overuse injuries makes it important to investigate the shock attenuation properties of fencing footwear.

The 1992 U. S Fencing Association review of the factors that may contribute to fencing injuries indicates that of the three primary areas for prevention, deficient equipment and facilities may be responsible for as many as 28% of the injuries associated with fencing, with ineffective footwear forming a significant component (Carter et al., 1993). The review noted problems with fencing shoes citing inadequate cushioning as well as the lack of footwear designs that could shield against the high impact nature of the sport, particularly lunging. To reduce injury, Zemper and Harmer (1996) have suggested a redesign of fencing shoes.

The primary function of athletic footwear as described by Stacoff et al., (1988) is to provide shock attenuation. The properties of athletic footwear have been linked to the prevention of overuse injuries. With many different types of sports footwear available providing different levels of midsole cushioning, selecting the most suitable for a sport can be vital in preventing the onset of injury. Fencing equipment retailers in the UK offer very few options for specific footwear, with only 2 major brands on offer (Adidas and Hi Tec). It also appears that the fencing shoe has been more specifically designed for the function of the trail foot to enable good grip on the piste as well as maximising the life span of the shoe if dragging the back foot, which is common in fencing.

The limited availability of specific shock attenuating footwear to the fencer may predispose fencers to overuse injuries. The majority of studies analyzing the influence of different footwear conditions on impact kinetics have focused on running.

Therefore, the aim of the present study was twofold. First, to assess the magnitude of the peak axial tibial transient accelerations associated with the lunge in fencing to provide practitioners with information regarding the potential causes of injury. Secondly, to compare two specific fencing shoes with two standard sports shoes (running and squash) with regards to their shock attenuating properties during the lunge movement.

In particular, it was predicted that peak axial transient accelerations were lower in shoes which have been particularly developed for shock absorbing qualities (running and squash shoes) in comparison to fencing shoes during the stance phase of the fencing lunge.

Methods

Participants

Nineteen male (17 right handed and 2 left handed) competitive fencers with a minimum of 2 years experience (Age 25. 6 + 8. 3 years; Height 1. 78 + 0. 5 m; Weight 76. 8 + 9. 0 kg) comprising a mixture of the foil (n= 2), epee (n= 15) and sabre (n= 1) disciplines, volunteered to take part in this study. All were injury free at the time of data collection and completed an informed consent form. The procedure was approved by a university ethical board.

Materials

Each participant was fitted with four pairs of shoes for the study. The shoes were the same for each participant; they differed in size only (sizes 9 and 10 men’s UK sizes) and consisted of a conventional running shoe (Saucony Grid forum), squash shoe (Hi-Tec squash indoor) and fencing shoes (Hi-Tec blade) and (Adidas en guard). A tri-axial (Biometircs ACL 300) accelerometer sampling at 1000Hz was utilized to measure axial accelerations at the tibia. The device was mounted on a piece of lightweight carbon-fibre material. The combined weight of the accelerometer and mounting instrument was 9g. The voltage sensitivity of the signal was set to 100mV/g, allowing adequate sensitivity with a measurement range of ± 100 g.

The device was attached securely to leading leg on the distal anterio-medial aspect of the shank 8 cm above the medial maleolus in alignment with its longitudinal axis.

This location was selected as the boniest prominence of the distal tibia in accordance with the Nokes et al., (1984) conclusions to improve the mechanical coupling of the accelerometer mounting to the tibia and reduce artefact due to interposing soft-tissue. The accelerometer was positioned so that acceleration was measured in the direction up the tibia (Figure 1). Strong adhesive tape was placed over the device and the lower leg to avoid overestimating the peak positive acceleration due to tissue artefact. The device was attached as close to the tibia as possible, the skin on overlying the bone itself was stretched thus ensuring a more rigid coupling between accelerometer and tibia. Furthermore, adhesive tape was positioned over the device itself to ensure it was maintained in a fixed position along the longitudinal axis of the tibia. The acceleration signal was sent to a Biometrics data logger with a 2 GB memory card. The data logger was fastened securely to a lightweight backpack to reduce movement of the device during trials.

Procedure

The fencers completed a suitable warm-up and were allowed two minutes to familiarize themselves with the experimental protocol and footwear condition prior to the commencement of data collection. They were then required to complete ten lunges hitting a dummy with their weapon in each footwear condition whilst returning to a starting point (pre-determined by each participant prior to the commencement of data capture) following each trial to control lunge distance. Each trial was comprised of a lunge where contact between the sword and dummy defined a successful outcome. The starting point for the movement was adjusted and maintained. The order in which the different footwear conditions were worn was randomized. Upon conclusion of the data collection participants were asked to subjectively indicate which shoe they preferred for fencing.

Kinetic data was quantified/processed using Biometrics data-log software. The stance phase of each trial was acquired from each accelerometer signal for analysis. Peak positive axial tibial acceleration was defined as the highest positive acceleration peak measured during the stance phase after a 60Hz 1st order low pass filter had been implemented in accordance with the Lake and Greenhalgh (2005) recommendations.

The mean values of the footfalls per participant/condition for the axial component of the acceleration signal was quantified and used for statistical analysis. Descriptive statistics were calculated for each variable including means and standard deviations. Differences between footwear conditions were examined via a within subjects repeated measures analysis of variance with significance accepted at the p

Results

A statistical power analysis of pilot data was conducted in order to reduce the likelihood of a type II error and determine the minimum number of participants needed for this investigation. It was found that the sample size was sufficient to provide more than 80% of statistical power in the experimental measure. Figure 2 provides the mean and standard deviations for the peak tibial accelerations for the four different shoe types. The Mauchly’s sphericity assumption was violated and as such the degrees of freedom of the F statistic was adjusted via the Greenhouse Geisser correction. The Shapiro-Wilk statistic for each footwear condition confirmed that the data was normally distributed. The analysis of variance was significant (F (1. 97, 35. 52) = 16. 31; P < . 001; ? 2 = . 48). Post-hoc comparisons showed that the peak axial tibial shock was significantly lower in the squash and running shoes in comparison to the fencing shoes (p <. 01). The fencing shoes did not differ from each other in terms of peak axial acceleration (P = . 48) nor did the running and squash shoes (P = 0. 087).

Discussion

The aim of this study was to determine the differences in the magnitude of the transient acceleration between traditional fencing shoes and standard athletic footwear during the impact phase of the fencing lunge. The results of this study support our hypothesis, in that the magnitudes of the axial impact shockwaves were significantly lower in both the running and squash shoes compared to the traditional fencing footwear.

The transient shockwave is linked to the development of a variety of overuse injuries (Whittle, 1999). It is essential to acknowledge the link between the magnitude of these forces and overuse injuries, as the frequency of these conditions can be reduced by attenuating the impact magnitude (Whittle, 1999). Therefore the significant reduction in impact shock found would suggest that running/squash footwear may assist in the reduction of overuse injury occurrence.

Interestingly, despite the higher impact magnitude and concerns regarding the potential development of overuse injuries, the majority of participants indicated that they preferred fencing specific footwear for fencing. This finding agrees with those of Geil (2002) who hypothesized that this finding centred on plantar sensory proprioceptive mechanisms, whereby the feel of the fencing piste underneath the foot is reduced in shoes that offer a high degree of midsole cushioning. Geil (2002) suggested that footwear may influence fencing performance. They noted that increased midsole cushioning and travel of the foot during compression may lead to slower motion of the feet, which in turn could contribute to diminished velocity of the weapon hand, reducing the overall execution quality of the movement itself.

Based on these findings it appears that midsole cushioning properties should play only a partial role in the design characteristics of an effective fencing shoe. Fencing involves a number of movement strategies in addition to the lunge, and as such shoe designs must cater to this. Fencers like most athletes require sure footing during competition; as such footwear designs must deliver adequate traction to provide stability during lunging, attacking and retreating motions. Furthermore, the medial forefoot of the trail shoe is an area traditionally subjected to high abrasion forces and thus heavy wear. Manufacturers should therefore focus attention on developing more resistant materials for this purpose to prolong the lifespan of the shoe. Whilst shock attenuation is the primary function of midsole cushioning, the elastic energy stored and recovered by cushioning systems has been proposed as a mechanism by which the oxygen cost of movement can be reduced. Given the aerobic demands the sport of fencing places on the athlete (Roi & Bianchedi, 2008) additional research should focus on this factor as it may serve to slow the onset of fatigue and improve performance.

The results of this study however, suggest that there is some justification for the Zemper and Harmer (1996) recommendations regarding the re-design of fencing shoes due to the demonstrated high transient impact forces on the front foot during the lunge. The primary design dilemma facing footwear manufacturers is to include features that would serve to attenuate the large impact forces and help reduce overuse injuries. At the same time, the design characteristics should also provide the fencer with an adequate feel for the fencing piste beneath the foot.

The severe angle between foot-segment and ground on initial contact is also significant when designing the shoe. The shoe cushioning system must therefore provide protection in the extreme rear of the heel, an area not normally associated with consistent high impact forces in other sports. The obvious asymmetry of the sport presents a challenge to footwear manufacturers and arguments can be made for the development of asymmetrical footwear designs.

Several different surfaces in fencing are used. Surface stiffness can have a significant influence on the magnitude of the impact shock during landing (Kim et al., 1994). This study was conducted during training sessions on a training surface as opposed to a traditional piste used during competition thus the results obtained may not adequately represent actual competition. During competition a hard floor can be used, as well as a metallic piste (either a cloth placed over the hard floor or a hard metallic piste). Future research should therefore concentrate on the magnitude of the impact shock during competition on a true fencing piste.

Limitations

Accelerometry is a complicated approach and methodological problems can affect the efficacy of collected data (Lake and Greenhalgh 2005). The magnitude of the signal obtained from the accelerometer is dependent on the mounting interaction, making cross study comparisons difficult. Soft tissue artefact can also influence the acceleration recording of underlying bone (Light et al., 1980). Attaching the device directly to bone represents the most accurate method of measuring impact shock and further work is necessary to determine the efficacy of the less traumatic skin mounting technique.

The device signal is also reliant on the centripetal acceleration due to angular motion of the shank in the sagittal plane during ground contact

(Lafortune and Hennig 1991). Lake and Greenhalgh (2005) noted that despite the application of a distally mounted device, correction for angular motion may still be necessary. Further research should be conducted to investigate the necessary signal corrections for angular motion.

Another potential limitation/restriction of this study is that the results obtained are entirely specific to the footwear and ground surface conditions, any variation in these parameters would most likely cause changes to the participant’s fencing kinetics/kinematics. In addition this study analyzed the lunge motion only. The lunge represents a high impact motion; however there are other movements of lower intensity which may still be important in terms of the development of overuse injuries. Therefore, additional research is necessary regarding the influence of footwear on the magnitude of the transient shockwave during different fencing movements before appropriate prescriptions of fencing footwear can be made.

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