The Role of Footwear on Kinematics and Plantar Foot Pressure in Fencing

Mark D. Geil
Georgia Institute of Technology

The sport of fencing involves asymmetric motions, large forces, and rapid changes in momentum. Today’s fencing shoes are designed to facilitate footwork but they provide little plantar force dissipation. Plantar foot pressures and kinematics were measured in 13 fencers. The study compared fencing shoes to a standard court shoe. The court shoe resulted in a significant reduction in plantar pressures during the fencing lunge, advance-lunge, and fleche. However, most fencers preferred the fencing shoe for fencing. The court shoe tended to alter fencing kinematics, generally though not significantly decreasing the velocity of the front foot and the weapon hand, and increasing the range of motion and overall travel of the weapon hand. This effect on fencing mechanics may stem from the design of the court shoe, or from an accommodation effect.

Key Words: biomechanics, pedobarography, injury, shoes

Introduction

The sport of fencing presents unique physiological and biomechanical challenges to the athlete due to its asymmetry, the frequency of rapid motions involving large forces, and its reliance upon a combination of anaerobic and aerobic energy sources (Hoch, Werle, & Weicker, 1988; Nystrom, Lindwall, Ceci, et al., 1990; Todaro, 1983). Fencing is growing in popularity in the United States, with increased involvement at the youth level and increasing success in international competition (U.S. Fencing Association, 1997). This expanded participation coupled with the biomechanical demands of the sport has led to greater awareness of the prevalence of lower limb injuries associated with fencing.

Zemper and Harmer (1996) provide the only known review of the literature regarding the epidemiology of fencing injuries. Despite the scarcity of data as to fencing injury rates and patterns, Zemper and Harmer found that approximately half of all injuries to fencers occur in the lower extremities, especially the ankle.
and knee. Recently the USFA completed an injury survey deemed to be one of the most broadly based published reports of fencing injuries available to any nation (Carter, Heil, & Zemper, 1993). Respondents noted problems with fencing shoes including inadequate cushioning and heel support, as well as the lack of shoe designs that would protect against stresses specific to the sport, such as lunging. To reduce injury, Zemper and Harmer suggest changes to conditioning and technique and a redesign of fencing shoes.

The asymmetric nature of fencing results in large differences on the loading characteristics of the forward and backward limbs. The lead foot is maintained in an alignment generally parallel to the line of progression, while the back foot is kept generally perpendicular to the line of progression. Loading of the forward foot starts at the heel and progresses to the forefoot. Fencing shoes have an extended outsole at the heel, creating a curved surface from the height of the heel counter, to facilitate this motion. Loading of the backward foot is generally along the medial aspect, with the possibility of large shear forces along the line of progression, perpendicular to the back foot orientation.

Ankle range of motion involves dorsi/plantarflexion of both feet; in addition, the back foot undergoes a high degree of inversion. The orientation of the lower limbs appears to be unique to fencing: front hip flexed and externally rotated, both knees flexed, back hip flexed. Because these kinematic and kinetic demands are so different from those encountered with normal movements and even most sports, analysis of lower limb kinematics and distributed plantar foot pressures could shed some light as to causes of lower limb injury in fencers, and the role, if any, of the fencing shoe.

The purpose of this study was to compare fencing shoes with a standard off-the-shelf counterpart in terms of kinematics and plantar pressure. The study tested the hypothesis that court shoes will reduce peak plantar foot pressures during fencing movements in comparison to fencing shoes, with no significant influence on joint angles and temporal/spatial qualities of the movements.

**Methods**

Testing was conducted at the Center for Human Movement Studies at the Georgia Institute of Technology in Atlanta. Fencers with 3 to 27 years of experience were recruited from the Atlanta area. All tests were conducted in accordance with the standards of the Georgia Tech Institutional Review Board, and informed consent was obtained from each participant. Basic fencing attacks were measured including the lunge, advance-lunge, and fleche. The fencing lunge is the basic attack in which the weapon point is thrust forward while the rear knee extends and the front limb moves forward. The advance lunge is a lunge preceded by a single advance in which the front foot is brought forward and the back foot follows. The fleche is a rapid running attack in which the legs cross.

Thirteen fencers (9 M, 4 F) were recruited from fencing clubs throughout Georgia. Fencers had to be involved in active local competition. Each fencer was fitted with two sets of shoes for the study, a fencing shoe and a standard court shoe (Figure 1). The fencing shoe (Adidas Adistar Fence 86868) has a thin outsole with limited insole cushioning, an extended rounded heel counter, and a durable leather covering over the medial forefoot. The court shoe (Adidas Solo 35459) was chosen based on a curved heel counter and provided considerably more cushioning.
Each fencer was provided one pair of shoes to use in all fencing activities for one month prior to the first data collection session, after which he or she received the other pair of shoes. Following another month in which the second pair was used, a second data collection session was completed. The order of testing of fencing shoes versus court shoes was randomized.

At each data collection session, measurements were made of pedabarography and kinematics. Bilateral pedabarography was measured at 50 Hz using the Pedar insole pressure measurement system (Novel Electronics, Munich). Fencers were fitted with the appropriate size insole and the Pedar synch box was held in a backpack. Fencers wore their own shoes normally used in competition. Three-dimensional kinematics were measured at 60 Hz with a 6-camera Peak Performance real-time system. Spherical retroreflective markers were placed on the weapon wrist and on the ASIS, lateral femoral condyle, lateral malleolus, heel, and second metatarsal on each limb. To amplify segment rotation, additional markers were placed on 9.5-cm wands and attached to the thigh and shank in the frontal plane on both limbs.

The fencers were given time for warm-up prior to data collection. They were then asked to complete common fencing motions in continuous sets of three with recovery to the starting point following each attack. Similarly, sets of three advance lunges were assessed. Finally, individual fleches were measured. Four repetitions of each data set were completed. The same protocol was used with each fencer for each pair of shoes. At each data collection, fencers were asked if they encountered any problems or injuries when wearing that shoe while fencing. At
the end of the second data collection they indicated which shoe they preferred for fencing and why.

Motion data were filtered using a Butterworth filter and processed with Peak Motus 4.3. The second of each set of three motions was chosen for analysis to better approximate the continuous motions encountered in a fencing bout. Pedobarographic data were processed with the Novel-Win package from Novel electronics. Four trials for each type of motion and each type of shoe were averaged for each fencer and included in an ANOVA with independent variables of peak pressure, vertical weapon hand excursion, and time of motion.

**Results**

Significant \( p < 0.001 \) peak plantar pressure reduction was found with court shoes compared to fencing shoes (Table 1). Peak pressures occurred in both cases at the front heel (Figure 2) and back medial forefoot with pressures in the front foot’s first and second metatarsal regions at times exceeding those at the heel, particularly with the fleche motion.

| Table 1  Ensemble Avg Peak Pressures Normalized by Body Weight (N/kg – cm\(^2\)) |
|------------------------------------------|-----------------|-----------------|-----------------|
| Motion                                  | Fencing shoe    | Court shoe      | Pressure reduction |
| Lunge                                   | 0.0611          | 0.0517          | 15.37%           |
| Advance-lunge                           | 0.0805          | 0.0626          | 22.18%           |
| Fleche                                  | 0.0862          | 0.0634          | 26.38%           |

*Note:* Peak pressures averaged over participant included both feet for all trials of each fencing motion. Pressure reduction represents the percentage decrease in pressure when a court shoe was worn for the fencing motions instead of a fencing shoe.

Pressures were consistently higher at the front (leading) foot in each motion, with the most pronounced differences in the lunge and the smallest differences in the fleche (Figure 3). Court shoes reduced pressure compared to fencing shoes in both the front and rear feet, with similar side-specific differences for each motion.

While court shoes decreased plantar pressure, they also appeared to influence fencing mechanics, although not significantly. Some fencers demonstrated larger overall motion, even at the weapon hand (Figure 4), and less consistency in repeated movements. In addition, almost all fencers demonstrated increases in the overall time taken to complete a lunge or advance-lunge motion while wearing the court shoes. At both the front foot and the weapon hand, marker velocity dropped by as much as 1 m/s for most fencers. The exception was one fencer who demonstrated improved velocities with the court shoe and had worn a standard Reebok court shoe for fencing prior to participating in this study. He was the only person to
Figure 2 — Peak pressure reduction for right leading foot fencing shoe (A) vs. court shoe (B), representative advance-lunge trial. Grids show peak pressure in each sensor for the duration of the motion. Heel is at the bottom left of each figure and toe is at top right. Highest pressure encountered in this trial was 430 kPa for the court shoe and 730 kPa for the fencing shoe.
Figure 3 — Peak pressure normalized by body weight (N/kg \cdot cm^2) averaged over all trials and all fencers for each motion, comparing front and rear feet and shoe type. For all motions and shoe types, front foot pressures were greater than rear foot pressures, and pressures were consistently greater with fencing shoes vs. court shoes.

cite a preference for the court shoes for fencing, his stated reason being that it provided “more cushion.” Of the other 12 participants, 11 preferred the fencing shoe for fencing and one was undecided.

Discussion

The sport of fencing involves rapid transfers of momentum and consequent large accelerations and decelerations and forces. The interface of the fencer to the fencing strip is an essential component in his or her ability to achieve rapid transfers of momentum and dissipate the resulting large forces. While it is fairly clear that increased cushioning in footwear will facilitate the dissipation of forces, it was unclear whether the increased cushioning in standard court shoes could adequately dissipate the forces in fencing, and whether the difference in shoe would have an influence on fencing mechanics and performance. We hypothesized that there would be a significant reduction in plantar pressures with court shoes and a minimal influence on mechanics. While plantar pressures were reduced, the associated trends in fencing kinematics and their magnitude were unexpected.

From a biomechanical consideration of plantar pressure and subjective results alone, the court shoes were far superior to fencing shoes. The pressures were lower and covered a larger area, further reducing the need for soft tissue in a highly localized area to recover from this frequent loading. In subjective surveys recorded at each data collection session, the participants noted no injuries with the court
shoes, but several cited problems with blisters and abrasions with the fencing shoes. However, such problems may be unrelated to the increased peak pressures noted in the study.

Despite higher plantar pressures and concerns about soft-tissue injury, most participants preferred the fencing shoe for fencing. The reasons they gave centered on tactile and proprioceptive issues, generally termed as the “feel” of the fencing strip beneath the shoes. With more cushioning in the insole, that “feel” is diminished. Fencers also thought that the court shoes slowed their actions. While we had hypothesized that opinions concerning the effect of the shoe on mechanics would not be evidenced in the research, trends in the data corroborate these opinions (though statistical results reveal no significant effect of shoes on range or speed of motion).

There are many possible reasons for the small effect of court shoes on fencing mechanics. First, the increased damping properties in the shoe and the in-
creased travel of the foot during compression of the cushioned insole and midsole in the court shoe could contribute to slower overall motion at the feet. This reduced velocity could in turn contribute to the diminished velocity found in the weapon hand. The overall reduction in velocity, although not statistically significant, could alter practiced mechanics and produce the larger motions found in the data (Figure 4). In addition, the court shoes are heavier than the fencing shoes. On the other hand, reduced velocities and larger motions with court shoes could simply have resulted from the introduction of any significant equipment change. While a month-long accommodation period was included before testing with each pair of shoes, most of the fencers had already used some variety of fencing shoes for several years. The court shoes, even after a month of use, could represent a new equipment element in a relative sense, and one might suppose that after a significantly longer accommodation period, motion and speed would be identical.

While the reasons for the kinematic changes are unclear, the data demonstrate reduction in plantar pressures with standard court shoes versus fencing shoes. The fact that the majority of fencers preferred the fencing shoes suggests at least a perceived mechanical advantage for fencing shoes. Perhaps the best solution for fencing footwear lies in between: a shoe design with increased dampening material, particularly at the front heel and rear medial forefoot, but with adequate thinness and viscoelastic properties to enable sufficient tactile and proprioceptive feedback to satisfy the fencers.

References


Acknowledgments

This work was supported by a grant from the U.S. Olympic Committee and by the U.S. Fencing Association. The author acknowledges the contributions of Lance Rake.