INTRODUCTION

Research on the overuse injury phenomena is dominated by running studies that have been undertaken either retrospectively or biomechanically, attempting to gain insight into possible associations between selected variables of the lower extremity and specific injury types (Nigg, 1983; Subotnick, 1985; Messier and Pittala, 1988 & James, Dufek & Bates, 2000). Presently however, the lack of a direct link between biomechanically assessed variables and the relative risk of developing specific overuse injuries means that the relationship between injury mechanisms and injury types remains associative.

Research has suggested that the increased use of artificial surfaces in sport has led to an unanticipated higher prevalence of overuse injury (Nigg & Yeardon, 1987). Artificial surfaces in sport were born out of a necessity to reduce the maintenance costs of sports play areas and reduce the influence of adverse weather conditions on surface playing ability (Kolitzus, 1984 and Nigg & Yeardon, 1987). According to Nigg and Yeardon (1987), although artificial surfaces helped to extend the boundaries in some sporting domains such as gymnastics and athletic sprinting events, force magnitudes and the direction of forces acting on the human body also altered.

Suggested overuse injury causes as a result of an increase in the frequency of sports play on artificial surfaces include increased levels of impact (James, Bates & Osternig, 1978; Cavanagh & Lafortune, 1980; Nigg, Frederick, Hawes & Luethi, 1986 and Miller, 1990) and altered joint movement patterns (Hamill, Bates & Holt, 1992 and Stergiou & Bates, 1997). Previous assessments of changes in biomechanical variables during running with changes in either shoes, surfaces or both, have generally revealed maintenance of impact peak magnitudes (Clarke, Frederick & Cooper, 1982; Nigg and Yeardon, 1987; Bobbert, Yeardon and Nigg, 1992; Dixon et al. 2000; Dixon & Stiles, 2003), some of which have been explained by kinematic adjustment such as increased initial knee flexion, reduced heel impact velocity or reduced initial foot angle relative to horizontal on stiffer surfaces (Bobbert, et al. 1992). Some research also concludes that there are a variety of regulatory mechanisms available to the individual during running (Hamill, Emmerik and Heiderscheit, 1999) that could therefore explain maintenance of impact peaks on an individual basis (Dixon et al. 2000).

In relation to sports surfaces, Dixon, Batt and Collop (1999) concluded that interaction between the athlete and interface was not well understood. The majority of research to date that considers the interaction between performer and surface has predominantly focused on the movement modality of running. In tennis however, a variety of movements are performed that include explosive elements (Lafortune, 1997) and thus more dynamic movements in addition to running. It was suggested that employment of a tennis-specific movement may yield trends in force variables and human kinematics to changes in surface that have not been observed during running.

The purpose of the present study was to biomechanically assess the relative levels of surface impact absorption while subjects performed a tennis specific movement in the laboratory. It was hypothesised that a surface with increased mechanical cushioning would result in a reduction in peak impact force measured during the performance of a tennis-specific movement.

METHODS

Video observation of tennis matches revealed an array of movements for selection. Initial analysis of peak magnitudes of vertical force for two selected movements revealed that one movement was more energetic than the other. The movement that yielded markedly higher forces underwent further group analysis. The movement selected was termed the ‘running forehand foot plant’ (Figure 1.). Angular conventions used to detect levels of kinematic adjustment are present in Figure 2.

Figure 1: Running forehand left foot plant

Figure 2: Angular conventions for the foot relative to the horizontal plane, ankle (dorsi-flexion – plantar-flexion: DF-PF) and knee flexion-extension.

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the School of Sport and Health Sciences Ethics Committee, University of Exeter). Subjects became accustomed with the desired movement; self-selected sub-maximal run followed by a left-footed plant for right-handed players or a right-footed plant for left-handed players and then recovery steps. Self-selected entry speeds into the testing area were monitored using photocells over a 1.8m distance. Movement familiarisation trials were performed by each subject and with each change in surface condition, then a further 5 trials were performed before data collection commenced.

Three different surfaces were assessed; sand-filled artificial turf (Turf), carpet and cushioned acrylic hardcourt (Acrylic) together with a ‘baseline’ condition incorporating a concrete runway and an uncovered force plate. The additional three surfaces were laid over the baseline surface during testing. The start and end corners of the carpet surface were anchored to prevent surface slippage. A consistent model of tennis shoe was worn by each subject (adidas Big Court II).

An initial study prior to group analysis revealed that the collection of 8 trials from each subject for each surface condition would satisfy trial stability. Methods of assessing trial stability were employed using protocols described by Bates, Osternig, Sawhill and James (1983) and Bates, Dufek and Davies (1992).

Simultaneous collection of force plate data (AMTI, 960Hz) and three-dimensional kinematic data (Peak Motus, 120Hz) for the foot plant terminating a 9m sub-maximal run was undertaken. Where subjects failed to make contact with the force plate or failed to perform a typical movement trial, data were discarded and the trial repeated. Three co-linear markers positioned on each segment enabled three-dimensional angles to be determined for the joints of the lower extremity. Peak impact force, peak rate of loading, initial foot angle and knee flexion angles and heel impact velocity (resultant) were analysed. Group mean results were inserted into a repeated measures ANOVA to detect differences in test variables (p<0.05).

RESULTS AND DISCUSSION

Group mean bodyweight-normalised (BW) vertical force data revealed that the baseline surface yielded the lowest peak impact magnitude (Table 1). Statistical analysis revealed that the increases in peak impact force for the three tennis surfaces compared with the baseline condition were significant (p<0.05). In support of the group finding, the baseline condition also yielded the lowest peak impact value for each individual subject (Figure 2). This factor alone could indicate that the baseline interface has a high level of cushioning, however mechanical impact testing suggests otherwise (Dixon and Stiles, 2003). Figure 2 also contains a line representing the group mean value for peak impact force and thus shows the relatively steady maintenance of peak impact force between the three other tennis surfaces. Group peak rate of loading did not reveal significant differences between surfaces, although individual rates of loading show a trend between surfaces to mimic individual peak impact trends. Entry speeds were not significantly different between surfaces.

Figure 2: Subject and group mean peak impact force values for each surface

Explanation of the group peak impact finding for the baseline condition cannot be provided from changes in the measured kinematic variables (Table 1), since no significant differences in kinematic variables were detected (p>0.05). Individual assessment regarding the use of initial and impact kinematic variables to explain the consistently lower impact peak forces for the baseline surface are mixed. For Subjects 1 and 6, no kinematic distinctions were detectable for the baseline surface in comparison to the other three test surfaces. Subject 2 yielded a slight increase in initial knee flexion angle for the baseline surface. Subject 3 although also showing a small increase in initial knee flexion angle, showed a distinctly lower initial foot angle for the baseline surface. Subjects 4 and 5 yielded the lowest heel impact velocities for the baseline surface, with subject 5 also showing a lower initial foot angle relative to the horizontal for the baseline surface compared to carpet, acrylic and turf.

Interpretation of the increases or decreases in respective kinematic variables described for each subject for the baseline surface in comparison to the other test surfaces may suggest that instinctive levels of adjustment are being made prior to ground contact to reduce the higher impact forces that the baseline surface is expected to yield and thus be experienced by the human body. It remains uncertain however whether such possible instinctive adjustments could be considered to be of a significantly high magnitude to cause an over-compensatory response observed by the production of significantly lower peak impact forces for the baseline condition.

Table 1. Group mean results (*p<0.05)

<table>
<thead>
<tr>
<th>Mean peak impact force (BW)</th>
<th>Baseline</th>
<th>Carpet</th>
<th>Acrylic</th>
<th>Artificial Turf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean peak loading rate (BW s⁻¹)</td>
<td>360.89 (±209.04)</td>
<td>477.81 (±230.00)</td>
<td>455.70 (±177.35)</td>
<td>507.05 (±291.46)</td>
</tr>
<tr>
<td>Mean initial foot angle (degs)</td>
<td>38.36 (±6.34)</td>
<td>36.16 (±9.94)</td>
<td>39.56 (±10.15)</td>
<td>35.57 (±10.15)</td>
</tr>
<tr>
<td>Mean initial knee flexion angle (degs)</td>
<td>11.87 (±5.57)</td>
<td>7.49 (±4.92)</td>
<td>11.80 (±7.26)</td>
<td>13.16 (±9.30)</td>
</tr>
<tr>
<td>Mean heel impact velocity (m.s⁻¹)</td>
<td>2.37 (±0.24)</td>
<td>2.51 (±0.37)</td>
<td>2.5 (±0.41)</td>
<td>2.57 (±0.50)</td>
</tr>
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</table>
SUMMARY

It has been found that three different tennis-playing surfaces have resulted in a greater peak impact force during performance of a tennis specific movement than that obtained for a baseline concrete surface. At present this result cannot be explained using analysis of group kinematic data for selected kinematic variables. Individual peak impact results may only be explained to a limited extent using kinematic adjustment. It is therefore suggested that additional kinematic variable analysis and joint stiffness assessment may reveal further patterns of either individual response or explanation for the baseline condition yielding the lowest peak impact magnitude.

REFERENCES


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