Differences in sole arch indices in various sports

S T Aydog, O Tetik, H A Demirel, M N Doral

Background: There are controversial data about the relation between foot morphology and athletic injuries of the lower extremity. Studies in soldiers have shown some relationship, whereas those involving athletes have not shown any significant relationship. The reason for these differences is not clear.

Objective: To determine the effect of various sports on sole arch indices (AIs).

Method: A total of 116 elite male athletes (24 soccer players, 23 wrestlers, 19 weightlifters, 30 handball players, and 20 gymnasts) and 30 non-athletic men were included in this cross sectional study. Images of both soles were taken in a podoscope and transferred to a computer using a digital still camera. AIs were calculated from the stored images.

Results: The AI of the right sole of the gymnasts was significantly lower than that of the soccer players, wrestlers, and non-athletic controls (p<0.01). The AI of the right sole of the wrestlers was significantly higher than that of the soccer players, handball players, weightlifters, gymnasts, and non-athletic controls (p<0.03). The AI of the left sole of the gymnasts was significantly lower than that of the wrestlers and non-athletic controls (p<0.001). The AI of the left sole of the wrestlers was significantly higher than that of the soccer players, handball players, and gymnasts (p<0.007). The AI of both soles in handball players was significantly lower than those of the non-athletic subjects (p = 0.049). The correlation between the AI of the left and right foot was poor in the soccer players, handball players, and wrestlers (r = 0.31, 0.69, and 0.56 respectively), but was high in the gymnasts, weightlifters, and non-athletic controls (r = 0.96, 0.88, and 0.80 respectively).

Conclusion: The AIs of the gymnasts and wrestlers were significantly different from those of other sportsmen studied, and those of the gymnasts and handball players were significantly different from those of non-athletic controls.

METHODS

Subjects

AIs of 124 male elite athletes (27 soccer players, 24 wrestlers, 19 weightlifters, 32 handball players, and 22 gymnasts) and 30 non-athletic men as a control group were evaluated. Age, age at onset of training, and history of bone/soft tissue injuries in the foot and ankle were recorded.

Sole AI

Subjects were asked to stand still on the podoscope. Digital still camera images of both soles were transferred from the podoscope to a computer. From the stored images, AI was calculated by division of the narrowest part of the sole by the width of the heel, then multiplication of the ratio by 100. All calculations were performed by the same clinician (STA). The clinician calculated another 30 AIs twice, with a one week interval between measurements, to determine intraobserver reliability. The intraclass correlation coefficient was 0.975; the same investigator evaluated all findings.

Statistical analysis

Because the AIs did not show a normal distribution, we applied non-parametric tests: the Kruskal-Wallis test for intergroup differences and the Mann-Whitney U test for the significant intergroup differences. Correlations between left and right sole AI were calculated by Spearman’s rank correlation test in the athletes and non-athletic controls. The significance level was accepted as p<0.05.

RESULTS

The mean (SD) age was 23.4 (3.6) years (range 18–30) for the athletes and 23.2 (3.2) years (range 18–28) for the non-athletes. The mean age at which sports training was initiated was 11.6 (2.8) years. There was no significant difference in
age between the athletes, but gymnasts started training at a significantly younger age than the other athletes (7.3 (1.4) years; p = 0.0004). Eight athletes (three soccer players, two handball players, one wrestler, and two gymnasts) who had been treated for foot and ankle fractures or dislocations were excluded from the study. Table 1 gives details of the subjects.

Table 2 presents the AIs of the athletes and non-athletic controls. The AI of the right foot in the gymnasts was significantly lower than that of the soccer players, wrestlers, and non-athletes (p<0.01). The AI of the right foot in the wrestlers was significantly higher than that of the soccer players, handball players, weightlifters, gymnasts, and non-athletes (p<0.03). For the left foot, the AI in the gymnasts was significantly lower than in the wrestlers and non-athletes (p<0.001), and the AI in the wrestlers was significantly higher than in the soccer players, handball players, and gymnasts (p<0.005). The AIs of both soles in handball players were significantly lower than in the non-athletic controls (p = 0.049).

Correlation between the AIs of the right and left foot was low in soccer players, handball players, and wrestlers (r = 0.31, 0.69, and 0.56 respectively), but high in gymnasts, weightlifters, and the non-athletic controls (r = 0.96, 0.88, and 0.80 respectively).

**DISCUSSION**

This study was designed to evaluate sole AIs in different sports. The AIs of gymnasts and wrestlers were found to be significantly different from those of the other sportsmen tested, and those of gymnasts and handball players were significantly different from those of the non-athletic controls. The AI was lowest in gymnasts and highest in wrestlers. Correlation between the right and left foot was lower in handball and soccer players (where there is leg dominance) and wrestlers (where there is no leg dominance), and higher in athletes in sports with no dominance and in the non-athletic controls.

There are controversial data in the literature on the relation between foot arch morphology (flat foot and pes cavus) and lower extremity injuries.1-4 Pes cavus and pes planus may be a causative factor in stress fractures of the femur, tibia, metatarsals, and different parts of the lower extremities in army recruits, but no such relation was found between pes planus and the incidence of lower extremity injury in athletes.4,5 The reason for these differences has not been elucidated. Differences in evaluation criteria, such as foot arches as mentioned in the longitudinal study of Volkov12 and arch indices as in the study of Klingele et al11 and the present study, may partially explain the different results between army recruits and athletes. Future prospective studies should thus be undertaken and carefully designed, bearing in mind the effect of foot morphology and possible predisposition to lower extremity injuries in soldiers.

Certain muscles in the foot and ankle either depress or support the arch, and their insufficiency may result in changes in the sole. For example, posterior tibial tendon ruptures and tenosynovitis result in flat foot.15 The posterior tibial, peroneus brevis/longus, flexor hallucis longus, flexor digitorum longus, and abductor hallucis longus muscles, for example, support the formation of the medial longitudinal arch, whereas the extensor hallucis longus and tibialis anterior muscles have a depressing effect on this arch.14,16 Exercise treatment for flat foot and pes cavus, with the exception of bony problems (rigid pes planus) such as talocalcaneal fusion, includes stretching and strengthening of the intrinsic and extrinsic muscle groups. Generally, these exercises are accepted as symptomatic therapeutic modalities.17,18

The AI is highest in childhood and lowest between the ages of 12 and 14. It increases slowly after the teenage years.11 The mean age of our study group was about 23 years, and the normal AI for people aged 20–30 is about 60 (32).11 We found that the AI for gymnasts was lower than seen in the other sports disciplines and in the non-athletic subjects. Another special feature of gymnasts was the lower age at which training was initiated. In other words, gymnasts start intense training, involving the stretching and strengthening of foot muscles, when the musculoskeletal system is immature. Wrestlers, on the other hand, perform isometric exercises for the foot muscles. We could not find any study in the literature documenting changes in AI or foot arch types in relation to particular sports. Klingele et al11 showed that endurance runners and alpine skiers have a higher prevalence of longitudinal foot arch insufficiency. The reason for the differences in gymnasts and wrestlers may be a coincidental finding, a sports related adaptation, or that a low or high AI favours gymnastics or wrestling. More prospective studies, which are time consuming and expensive, are needed to clarify whether these results are sports related. Studies such as this cross sectional one could provide preliminary information for prospective studies.

**Table 1** Details of the subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Age</th>
<th>Age at which started training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer</td>
<td>24</td>
<td>22.7 (3.45)</td>
</tr>
<tr>
<td>Wrestling</td>
<td>23</td>
<td>23.8 (2.50)</td>
</tr>
<tr>
<td>Weightlifting</td>
<td>19</td>
<td>23.0 (1.76)</td>
</tr>
<tr>
<td>Handball</td>
<td>30</td>
<td>24.3 (5.13)</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>20</td>
<td>22.9 (3.78)</td>
</tr>
<tr>
<td>Total</td>
<td>116</td>
<td>23.4 (3.64)</td>
</tr>
<tr>
<td>Non-athletic</td>
<td>30</td>
<td>23.2 (3.16)</td>
</tr>
</tbody>
</table>

Values are mean (SD).

*Significantly younger age than other athletes (p<0.01).

NA, Not applicable.

<table>
<thead>
<tr>
<th>Number</th>
<th>Age</th>
<th>Age at which started training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer</td>
<td>52.42 (16.06)</td>
<td>48.76 (23.79)</td>
</tr>
<tr>
<td>Wrestling</td>
<td>68.22 (13.66)</td>
<td>63.77 (13.04)</td>
</tr>
<tr>
<td>Weightlifting</td>
<td>51.85 (29.73)</td>
<td>47.67 (31.42)</td>
</tr>
<tr>
<td>Handball</td>
<td>44.86 (22.14)</td>
<td>41.99 (23.00)</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>30.06 (28.97)</td>
<td>30.56 (31.69)</td>
</tr>
<tr>
<td>Non-athletic</td>
<td>55.77 (22.60)</td>
<td>53.73 (22.92)</td>
</tr>
</tbody>
</table>

p<0.01

*Gymnastics showed significant difference from other sports (p<0.01).

**DISCUSSION**

This study was designed to evaluate sole AIs in different sports. The AIs of gymnasts and wrestlers were found to be significantly different from those of the other sportsmen tested, and those of gymnasts and handball players were significantly different from those of the non-athletic controls. The AI was lowest in gymnasts and highest in wrestlers. Correlation between the right and left foot was lower in handball and soccer players (where there is leg dominance) and wrestlers (where there is no leg dominance), and higher in athletes in sports with no dominance and in the non-athletic controls.

There are controversial data in the literature on the relation between foot arch morphology (flat foot and pes cavus) and lower extremity injuries.1-4 Pes cavus and pes planus may be a causative factor in stress fractures of the femur, tibia, metatarsals, and different parts of the lower extremities in army recruits, but no such relation was found between pes planus and the incidence of lower extremity injury in athletes.4,5 The reason for these differences has not been elucidated. Differences in evaluation criteria, such as foot arches as mentioned in the longitudinal study of Volkov12 and arch indices as in the study of Klingele et al11 and the present study, may partially explain the different results between army recruits and athletes. Future prospective studies should thus be undertaken and carefully designed, bearing in mind the effect of foot morphology and possible predisposition to lower extremity injuries in soldiers.

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**What is already known on this topic**

There may be a relation between foot morphology and athletic injuries of the lower extremity.

**What this study adds**

The sole arch indices of gymnasts and wrestlers were found to be significantly different from those of soccer players, weightlifters, and handball players, and those of gymnasts and handball players were significantly different from those of non-athletic controls.
The correlation between the right and left sole AIs was lower in handball and soccer (where there is leg dominance) and wrestling (where there is no leg dominance), and higher in sports with no leg dominance and in non-athletic controls. These differences support the idea of sport specific adaptation of sole AIs, but further studies are required.

In conclusion, we found that the foot AIs of gymnasts and wrestlers were significantly different from those of athletes in other sports, and those of gymnasts and handball players were different from those of non-athletic men.

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