ORIGINAL ARTICLE

Differences in sole arch indices in various sports

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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.

The relation between foot arch morphology (flat foot and pes cavus) and lower extremity injuries is controversial.[1–9] Some authors have determined a relation between foot morphology and the incidence of lower extremity injury in army recruits,[1–4] whereas others were unable to obtain conclusive evidence in athletes.[5–9] The reason for the discrepancy remains unresolved, but a possibility is the sport specific foot morphology of athletes engaged in various types of sport.

Nowadays, performance athletes begin intense training at a very young age. Such training undertaken when the musculoskeletal system is immature may result in specific changes in the body. It is well known that, when there is a unilateral overload—for example, in tennis players—an athlete may exhibit an obvious discrepancy, such as increased external rotation and decreased internal rotation compared with the opposite side.[10] Although it is not clear, there are some data showing that sport specific training and repeated movements may have an effect on the arch index (AI) of the sole. An increased incidence of flat foot in runners[11 12] and alpine skiers,[11] and subnormal transverse foot arch in soccer and tennis players[11] have been reported. As there are very few published reports comparing sole AIs of participants of different sports, we conducted this study. Gymnasts were included in view of their participation in sports training at a very early age, weightlifters, because they lift tremendous weights in training sessions, handball players, as representatives of indoor sports, and soccer players and wrestlers, as these are two of the most popular sports.

The purpose of this cross sectional study was to determine the effects of various sports on the AI. We evaluated the foot arch types and AI of a total of 116 high level athletes and 30 non-athletic men using images obtained from a podoscope.

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 widest part of the heel, then multiplication of the ratio by 100.[13] 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

Table 1 Details of the subjects

	Number	Age	Age at which started training
Soccer	24	22.7 (3.45)	12.7 (2.28)
Wrestling	23	23.8 (2.50)	11.4 (1.71)
Weightlifting	19	23.0 (1.76)	11.5 (1.78)
Handball	30	24.3 (5.13)	12.8 (3.03)
Gymnastics	20	22.9 (3.78)	7.3 (1.44)*
Total	116	23.4 (3.64)	11.6 (2.79)
Non-athletic	30	23.2 (3.16)	NA

Values are mean (SD).
*Significantly younger age than other athletes ($p<0.01$).
NA, Not applicable.

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.[1–9] 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.[1–9] The reason for these differences has not been elucidated. Differences in evaluation criteria, such as foot arches as mentioned in the longitudinal study of Volkov[12] and arch indices as in the study of Klingele *et al*[11] 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.[13] The mean age of our study group was about 23 years, and the normal AI for people aged 20–30 is about 60 (32).[13] 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 al*[11] 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 2 Right and left sole arch indices and correlation between right and left arch index in different sports

	Right foot	Left foot	r Value
Soccer	52.42 (16.06)*†	48.76 (23.79)†	0.310
Wrestling	68.22 (13.66)*†	63.77 (13.04)*†	0.562‡
Weightlifting	51.85 (29.73)†	47.67 (31.42)	0.884‡
Handball	44.86 (22.14)†	41.99 (23.00)†	0.690‡
Gymnastics	30.06 (28.97)*	30.56 (31.69)*	0.965‡
Non-athletic	55.77 (22.60)*†	53.73 (22.92)*	0.799‡

$p<0.01$
*Gymnastics showed significant difference from other sports ($p<0.01$).
†Wrestling showed significant difference from other sports ($p<0.03$).
‡Showed significant difference in both arch indices ($p<0.01$).

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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REFERENCES

1 **Cowan DN**, Jones BH, Robinson JR. Foot morphologic characteristics and risk of exercise-related injury. *Arch Fam Med* 1993;**2**:773–7.
2 **Franco AH**. Pes cavus and pes planus. Analyses and treatment. *Phys Ther* 1987;**67**:688–94.
3 **Giladi M**, Milgrom C, Stein M, *et al*. The low arch, a protective factor in stress fractures. A prospective study of 295 military recruits. *Orthop Rev* 1985;**14**:709–12.
4 **Kaufman KR**, Brodine SK, Shaffer RA, *et al*. The effect of foot structure and range of motion on musculoskeletal overuse injuries. *Am J Sports Med* 1999;**27**:585–93.
5 **Michelson JD**, Durant DM, McFarland E. The injury risk associated with pes planus in athletes. *Foot Ankle Int* 2002;**23**:692–733.
6 **Simkin A**, Leichter I, Giladi M, *et al*. Combined effect of foot arch structure and orthotic device on stress fractures. *Foot Ankle* 1989;**10**:25–9.
7 **Dahle LK**, Mueller M, Delitto A, *et al*. Visual assessment of foot type and relationship of foot type to lower extremity injury. *J Orthop Sports Phys Ther* 1991;**14**:70–4.
8 **Barrett JR**, Tanji JL, Drake C, *et al*. High- versus low-top shoes for the prevention of ankle sprains in basketball players. A prospective randomized study. *Am J Sports Med* 1993;**21**:582–5.
9 **Beynnon BD**, Renstrom PA, Alosa DM, *et al*. Ankle ligament injury risk factors: a prospective study of college athletes. *J Orthop Res* 2001;**19**:213–20.
10 **Hawkins RJ**, Mohtadi N. Rotator cuff problems in athletes. In: DeLee JC, Drez D, eds. *Orthopaedic sports medicine*. Philadelphia: WB Saunders Company, 1994:631–2.
11 **Klingele J**, Hoppeler H, Biedert R. Statistical deviations in high-performance athletes. *Schweiz Z Sportmed* 1993;**41**:55–62.
12 **Volkov BM**. Influence of considerable athletic training on the foot condition of young athletes at a boarding school with a cross-section of sports [abstract]. *Arkh Anat Gistol Embriol* 1977;**72**:32–4.
13 **Staheli TS**, Chew DA, Corbett M. The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. *J Bone Joint Surg [Am]* 1987;**69**:426–8.
14 **Kapandji IA**. *The physiology of the joints. Vol 2: lower limb*. Edinburgh: Churchill Livingstone, 1976.
15 **Solomon L**, Warwick D, Nayagam S, eds. In: *Apley's system of orthopaedics and fractures*. 8th ed. London: Arnold Publishers, 2001:495.
16 **American Academy of Orthopaedic Surgeons**. Athletic training and sports medicine. In: *The foot*. 2nd ed. Rosemont, IL: American Academy of Orthopaedic Surgeons, 1991:425–32.
17 **Hsu JD**, Mann DC, Imbus CE. In: Jahss MH, ed. *Disorders of the foot and ankle*. Philadelphia: WB Saunders Company, 1992:881–2.
18 **Rose GK**. In: Jahss MH, ed. *Disorders of the foot and ankle*. Philadelphia: WB Saunders Company, 1992:907–19.