Journal of Science and Medicine in Sport (2007) **10**, 311—319

Journal of Science and Medicine in Sport

www.elsevier.com/locate/jsams

ORIGINAL PAPER

Foot morphology and foot/ankle injury in indoor football

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Accepted 14 July 2006

KEYWORDS
Foot morphology;
Indoor football;
Performance;
Injury

Summary While the pronated foot is implicated as a risk factor for sports injury in some studies, others suggest that a supinated foot posture increases the risk of overuse lower limb injuries. Athletes in a given sports discipline may tend to have a similar foot morphology, which varies from that observed elsewhere. Further, the foot morphology that is beneficial for performance in a sport may be detrimental with regard to injury. Intra- and inter-rater reliability of the Foot Posture Index (FPI-6) as a measure of foot morphology was determined (ICC (2,1) 0.88 and 0.69 respectively). Thereafter, in a prospective cohort study using the FPI-6, 76 adolescent male indoor football (Futsal) players were measured and followed monthly over one competition season. Coach-rated ability and reports of any overuse injuries at the ankle and/or foot over this period were obtained. A significant negative linear relationship was found between the mean FPI-6 scores and coach-rated ability ($p = 0.008$), with supinated and under-pronated postures related to higher ability level. Overall, 33% of injuries at the ankle and/or foot were classified as overuse. Foot Posture Index scores of less than 2, indicating the supinated and under-pronated feet, were found to be associated with a significant increase in the risk of overuse injury ($p = 0.008$). The greater rigidity of these foot types may assist adolescent, male, indoor football players to perform at a higher level in their sport. Unfortunately, these players are also more likely to sustain ankle and/or foot overuse injuries.

Introduction

The relationship between foot morphology and lower extremity injury is unclear, with both high and low arches reported as making the foot more prone to injury.[1—3] Excessive foot pronation has been implicated as a risk factor for injuries in football,[4] netball[5] and in the development of medial tibial stress syndrome.[6,7] Interestingly, supinated foot types have also been found to be associated with increased risk of sustain-

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doi:10.1016/j.jsams.2006.07.012

ing overuse injuries.[8,9] Other prospective studies have even suggested that a pronated foot type is a protective factor against injury.[10—12] Reasons for these divergent views remain unresolved; however, they may be due to problems related to sports-specific requirements, the different methodologies employed, varying semantics and foot type measurement methods.

It is likely that the functional requirements of participants' feet vary between sporting disciplines such that the optimal foot type for footballers is different from that for marathon runners. Indeed, sport-specific foot morphology of athletes engaged in various sporting disciplines has recently been demonstrated.[13] An association was determined between sporting disciplines and a footprint measure used to indicate arch height for young, adult, elite and non-athletic males. This cross sectional study found that footprints of gymnasts and wrestlers significantly differed from those of soccer players, weightlifters and handball players, while gymnasts and handball players differed from non-athletic controls. While footprint measures provide only a single-plane assessment of a multi-planar entity, the results support the notion that there is a degree of sport-specific athletic selection which occurs according to an athlete's longitudinal arch height, such that athletes in a particular discipline may display similar foot morphology. A natural selection process would suggest that athletes with a less than optimal foot type for their chosen sport would either sustain an injury that limits participation or simply fail to attain their desired level of performance.

Foot type is not readily characterised with a single measure such as arch height or footprint indices.[14,15] In spite of this, single measures are commonly employed in practice. Traditional measures of foot type have problems in the areas of validity, reliability, definition and clinical applicability.

The absence of clinically useful, valid and reliable measures of foot posture gave rise to the development of the 8-point Foot Posture Index (FPI-8).[16] The FPI is a criterion based rating system for weightbearing foot alignment, quantifying the degree to which a weight bearing foot can be considered to be in a pronated, supinated or neutral position, providing an indication of the overall foot posture.[16,17] The FPI assessment is quick and easy to perform and allows a multiple segment, multiple plane evaluation that offers some advantages over existing clinical measures of foot posture.[17,18] The FPI attaches a score on a 5-point scale between −2 and +2 to each of the measures that constitute it. The resulting aggregate score for the original eight-item version of the FPI (FPI-8) ranges from −16 (supinated characteristics) to +16 (pronated characteristics) on a 33-point scale.[16] More recently, a final version has been proposed comprising six-items (FPI-6) and has an aggregate score ranging from −12 to +12 on a 25-point scale.[17] This final version contains only those items that passed through a thorough validation process against three-dimensional and dynamic motion tracking of the lower limb using the Fasttrak™ electromagnetic system.[17] Furthermore, the FPI-6 has been significantly correlated to radiographic arch height (r = 0.36—0.59), and concluded that it provides valid information regarding the structure of the medial longitudinal arch.[19—21] The reported inter-tester reliability of the FPI-8 has been reported as moderate to excellent in a variety of populations (Intraclass correlation coefficients (ICC) = 0.58—0.91).[22,23] The FPI-8 has also demonstrated acceptable intra-tester reliability in the literature (ICC = 0.61—0.92).[6,20,22—24] To date, reliability of the final FPI-6 version has not been reported in the literature

Despite the commonly held belief that a ''neutral'' foot type (neither pronated nor supinated) is the ideal or ''normal'', research utilising both the FPI-6 and FPI-8 has revealed paradoxically that the ''normal'' or average foot (found most commonly in the population) is not a ''neutral'' foot (neither pronated nor supinated). Rather the average foot type in the sampled populations is a mildly to moderately pronated foot.[8,17,19,21]

It could be expected that foot posture would have more of an influence on ability and injury in fast sports where the focus of the game is on agility and rapid changes of direction. Indoor football or Futsal is one such sport. Futsal requires frequent accelerating and stopping, jumping, tackling and irregular and feigned movements.[25] Periods of play are spent in single-leg stance on the non-dominant foot while the dominant foot manipulates the ball and the player simultaneously fends off incoming opponents (Fig. 1). These techniques place stresses through the ankles and feet, potentially increasing the risk for injury and highlighting the importance of foot function. Because the playing level of a footballer is not wholly determined by ability, and since other factors influence a player's selection, rating of ability may be best determined by experienced coaches. Therefore, the aim of this study was to determine whether foot posture, as measured by the FPI-6, was associated with coach-rated ability levels and reports of ankle/foot overuse injury in adolescent male Futsal players.

Figure 1 Futsal game showing the predominant position of non-dominant single leg stance and dominant foot manipulation of the ball while passing opponents.

Methods and procedures

Reliability pre-testing was performed on 10 participants by 3 examiners using the FPI-6 with the methodology described below. One examiner was a practising podiatrist with 9 years of clinical experience (6 years of using the FPI-8); another was a manipulative physiotherapist with 18 years of clinical experience, (no experience with the FPI-6) and the other a third year physiotherapy student with some supervised clinical experience. Two 2-hour training sessions were held for the examiners to learn the procedures and rating system for the six constituent measures prior to the initial testing session. The final FPI-6 score, a number between −12 (extremely supinated) and +12 (extremely pronated), was used to determine the intra- and inter-rater reliability of the examiners. The appropriate form of the reliability index was determined as the ICC (2,1), from Portney and Watkins,[26] and values were computed using the Reliability subroutine in SPSS 12.01 for Windows. All three examiners demonstrated excellent[27] intra-rater reliability with the FPI-6, giving ICC (2,1) values of 0.91 (95% CI = 0.69—0.98), 0.81 (95% CI = 0.41—0.95) and 0.92 (95% CI = 0.73—0.98). With an ICC (2,1) value of 0.69 (95% CI = 0.33—0.90) inter-rater reliability was classed as good[27] for the three examiners.

Participants

Advertisements were placed around Dural Sport and Leisure Centre, Sydney and Beenleigh Indoor Sports Centre, Brisbane, inviting male Futsal players aged between 12 and 17 years to participate. Seventy-six adolescent male Futsal players ranging in age from 12 to 17 (mean = 14.5 years, S.D. ± 1.67) volunteered to participate. Of these, 30 players were in the 12—13 age group, 25 in the 14—15 years and 21 in the 16—17 age group. Participants were asymptomatic for foot or ankle pain at the beginning of the Futsal competition season, as participants were required to bear weight fully on both feet for measurement of the FPI-6. All participants gave informed consent, which was also obtained from parents/guardians of adolescents under 16 years of age, and The University of Sydney Human Research Ethics Committee approval for the study was obtained.

Procedure

Demographics (age, previous ankle/foot injury) and player profile details (current playing level and playing load) were collected in a questionnaire completed by each participant in the presence of an examiner (LC or LN) and weight and height were measured. The questionnaire was modified from a previous study[28] and was piloted on eight adolescent Futsal players to ensure face validity.

Participants stood in their comfortable angle and base of gait, with their arms by their sides and looking straight ahead to assess the FPI-6. Only one foot of each participant (dominant leg) was assessed in order to satisfy the data independence requirement for statistical analysis, and as insignificant differences in foot type have been reported between the left and right limb of individuals.[5,18,29] Each item was scored on the 5-point scale, whereby positive scores are assigned to features consistent with pronation, and negative scores are indicative of a supinated function. The six constituent measures required to assess overall foot posture are as follows (Fig. 2) [17,18]:

1. *Talar head palpation.* The talar head is palpated with the thumb and index finger. A neg-

Patient Name ________________		ID Number ____________		
	FACTOR	PLANE	SCORE Date ______________ Comment __________	
			Left (-2 to +2)	Right (-2 to +2)
Rearfoot	1. Talar head plapation	*Transverse*		
	2. Curves above and below lateral malleoli	*Frontal/ transverse*		
	3. Inversion/eversion of the calcaneus	*Frontal*		
Midfoot/ forefoot	4. Bulge in the region of the talonavicular joint	*Transverse*		
	5. Congruence of the medial longitudinal arch	*Sagittal*		
	6. Abduction/adduction of the forefoot on the rear foot (too-many-toes)	*Transverse*		
	TOTAL			

Figure 2 The data-collection form outlining the six clinical measures of the Foot Posture Index (FPI-6).

ative score indicates that the talar head is more prominent on the lateral side than the medial while a positive score indicates the converse.

2. *Curves above and below the lateral malleoli*. Degree of supra and infra lateral malleolar curvature is visualised from behind the ankle in line with a bisection of the rearfoot. A negative score denotes that the infra malleolar curvature is straighter than the supra malleolar curvature and vice versa for a positive score.
3. *Inversion/eversion of the calcaneus*. The frontal plane orientation of the calcaneus relative to the weightbearing surface is assessed from behind the patient in line with the long axis of the foot. A negative score is assigned when an inverted orientation is visualised while a positive score indicates an everted orientation.
4. *Bulge in the region of the talonavicular joint*. Bulging in this area is associated with a pronated foot, whereas indentation is observed in the supinated foot.
5. *Congruence of the medial longitudinal arch*. A negative score indicates a high arch which is acute posteriorly. A positive score indicates a low arch with some flattening in the central portion.
6. *Abduction/adduction of the forefoot on the rearfoot*. Viewed from behind the patient in line with the long axis of the heel, a negative score indicates visibility of more medial toes while a positive score indicates the opposite.

Ability rating

Two national level coaches who have 29 years of combined (16 plus 13) experience (20 years at national level) were asked to rate all players according to ''Futsal playing ability for their age''. To do this they used the simplest form of scale, one with 3 points, where the lowest point represented low to average ability (27 players or 35%), the middle point represented average to good (18 players or 24%) and the highest point represented good to excellent Futsal playing ability (31 players or 41%).[30] When coaches individually rated players, they agreed on 63 of the 76 participants (83%) then met to obtain consensus on the remaining 13 players.

Injury

As the Futsal season spanned an 8-month period, it is likely that injury reports collected at the end of the season would be inaccurate due to poor recall bias. To minimise the effect of poor recall, all participants were contacted monthly for the 8 months over the 2004/2005 New South Wales (Australia) Futsal competition season to obtain data for injuries sustained to the ankle and/or foot. Information relating to ankle/foot injury and training/playing load (hours/week) was recorded. As the index injury was overuse ankle and/or foot injury, the load hours were simply combined since it is likely that the cause is related to exposure rather than intensity. The sample in the current study comprised adolescent amateur players; hence absence from training and/or competition was largely a matter of individual and/or parental choice. Accordingly injury was defined as any tissue damage, pain and/or physical complaint of the ankle/foot affecting performance or resulting in absence from training or games. This enabled the collection of data on injuries that would otherwise be missed if the participant failed to seek medical treatment or to take time off from Futsal training and/or competition. The type of injury was categorised as traumatic or overuse, with an overuse injury defined as one that did not occur from a single event such as a collision or overstretch. In order to establish the highest level played over the season, all participants were asked this at the final phone call.

Data analysis

Using SPSS version 12.0.1 for Windows (SPSS Science, Chicago, IL), descriptive statistics were calculated for demographic characteristics, coach-rated ability and the FPI-6 to characterise the sample. Pearson's product-moment correlation coefficients were calculated to determine the strength of the relationship between FPI-6 and Futsal ability. Analysis of variance (ANOVA) with linear and quadratic contrasts was used to examine trends across different levels of Futsal ability in terms of the FPI-6 score. Further, Pearson's correlations were calculated to determine the associations between FPI-6, coach-rated ability, highest playing level over the season, training/playing load (hours/week), previous ankle/foot injuries, overuse ankle/foot injuries and all traumatic ankle/foot injuries. Because the distribution of overuse injuries was not symmetrical, a binary variable of overuse ankle/foot injury (yes/no) was entered as the dependent variable in a forward stepwise binary logistic regression, with ability, playing level, training/playing load, number of acute ankle/foot injuries and FPI-6 score as predicted variables. Following this analysis, to examine the relationship between the number of overuse ankle/foot injuries and foot posture, a receiver operator characteristic (ROC) curve was constructed. To develop decision thresholds for the FPI-6 as a significant ankle/foot injury predictor, sensitivity and specificity values and a summary measure, Youden's index (sensitivity + specificity − 1), were calculated for the range of FPI-6 scores. Youden's Index is the best summary measure of a diagnostic test's ability,[31] since its maximum gives a cut-point for predicting injury status.

Results

Demographics

When considering the FPI-6 as a 25 point scale whereby negative scores imply a supinated foot type and positive scores a pronated foot type,[17] 71

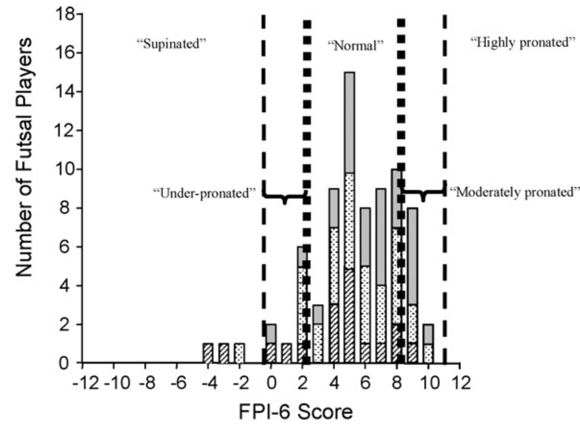

Figure 3 Foot Posture Index (FPI-6) distribution of the 76 Futsal players for the three ability groups. Key: (▩) ''Low to average'' ability category; (⚄) ''Average to good'' ability category; (▨) ''Good to excellent'' ability category.

(93%) of the participants scored more than 0 and can therefore be defined as ''pronated''. Two participants (3%) scored 0 and are defined as having a ''neutral'' foot type and only 3 participants (4%) could be described as having a ''supinated'' foot type.

For the sample of 76 male Futsal players, the FPI-6 scores obtained ranged from −4 to +10 (mean = 5.36, S.D. ± 2.92) (Fig. 3). Using the statistical criterion of 1S.D. either side of the mean to signify the ''normal'' foot posture range (as opposed to the ''neutral'' foot type),[32] FPI ''normal'' values were between +3 to +8 (71%), and were clearly pronated. A score between 1 and 2S.D. above the mean (FPI-6 = +9 to +11), indicating a moderately pronated foot type, was found in 13% of participants, while a score 2S.D. above the mean (FPI-6 = +12) was highly pronated and was not seen in any participants. At the other end of the scale, a score between 1 and 2S.D. below the mean (FPI-6 = +2 to 0) was found in 12% of participants and referred to as under-pronated, while a score 2S.D. below the mean (FPI-6 <−1) seen in 4% of participants was referred to as supinated.

Futsal playing ability

A significant negative linear relationship ($F_{1,73} = 7.55$, $p = 0.008$) was observed in the means of the FPI-6 scores across the three ability groups such that FPI-6 scores decreased with increases in rated Futsal ability (Fig. 4). No significant quadratic component was identified, indicating that the two steps down in FPI-6 scores across ability levels were not significantly different ($F_{1,73} = 0.99$, $p = 0.724$).

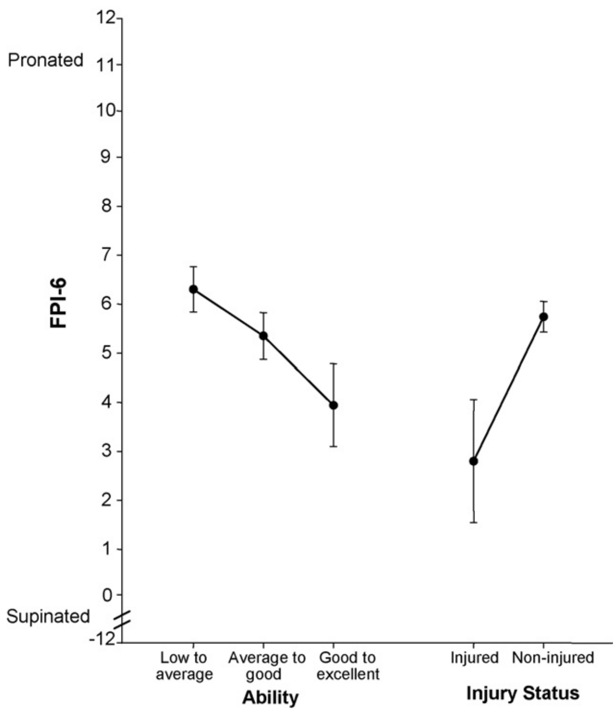

Figure 4 Relationship between mean Foot Posture Index (FPI-6) score (±1S.E.), the three levels of coach-rated ability and overuse ankle and/or foot injury status.

Using bivariate correlation, a significant positive association was found between ability and highest playing level over the 2004/2005 season ($r = 0.702$, $p < 0.001$), supporting the validity of coach ratings. Correlations were also calculated to determine the strength of the relationship between the FPI-6 score and coach-rated ability. A significant negative association between the FPI-6 score and coach-rated ability ($r = -0.304$, $p = 0.008$) was found, suggesting that the more able players exhibited a less pronated foot type than the remainder of the sample. Since $r^2 = 0.092$, a small but important component of the variance (9.2%) in rated performance in Futsal is therefore accounted for by an athlete's foot type.

Ankle/foot overuse injury

Overall, 32% of the 76 Futsal players sustained at least one ankle/foot injury during the season. A total of 33 injuries to the ankle/foot was reported. Overuse was implicated as the cause in 11 (33%) of the injuries, with the number of injuries in any one player ranging from 0 to 2 over the season. Of the 76 players, 66 reported no overuse ankle/foot injuries, 10 reported a single injury and one player reported two injuries. Bivariate correlations were performed on FPI-6, current and past injury, ability and load (Table 1). Participants were grouped according to whether or not they sustained an ankle/foot overuse injury throughout the season. An independent groups *t*-test showed that there was a significant difference between the mean values of the FPI-6 score for the injured and non-injured groups ($t = 3.15$, $p = 0.002$) (Fig. 4).

Binary logistic regression analysis showed that the FPI-6 score was the only significant variable (Wald Test, $\chi^2 = 7.14$, $p = 0.008$) to enter the prediction equation, with the Nagelkerke coefficient of determination (R^2) indicating that 18.5% of the variance in overuse ankle/foot injuries was explained by the FPI-6 score alone. Using only the FPI-6 and a constant, 88% of ankle/foot overuse injuries could be predicted with the following equation:

$$\text{Predicted overuse injury state} = -0.5 - 0.313 \times \text{FPI-6 score}.$$

To further examine the overuse injury-predictive capability of the FPI-6 score, this variable was evaluated by calculating the area under the ROC curve. The area obtained was 0.736 (95% CI = 0.555—0.916, $p = 0.017$, S.E. = 0.092). The FPI-6 score was therefore a significant predictor of ankle/foot overuse injury. From ROC curve calculations, Youden's Index was maximum at an FPI-6 score of 2 (Youden's Index = 0.394, sensitivity = 89.4%, specificity = 50%) indicating that individuals with scores below this were at risk of foot/ankle overuse injury.

Discussion

For adolescent male Futsal players, having an under-pronated to supinated foot type with a FPI-6 score of +2 or less, is associated with a significant increase in the risk of incurring an overuse ankle/foot injury. This is in accordance with previous findings that suggest that supinated and under-pronated feet may be more vulnerable to overuse injuries in a rapidly-paced, hard floor sport.[8,9] However, adolescents with such foot types are also rated by coaches as having higher levels of ability.

The aim of the current study was to determine whether foot type, as categorised by the FPI-6, was associated with ability and ankle/foot overuse injury in adolescent male Futsal players. While individual components may yield either negative or positive scores, the FPI-6 represents a summary of the results from all six constituent measures. Scores at either extreme of the FPI-6 are regarded as pathological, with values as low as −12 seen in Charcot-Marie-Tooth disease, while people with tibialis posterior dysfunction may score closer to +12.[18] There are problems inherent in doubling the data set by using the data from both limbs for a

Table 1 Bivariate correlations between Foot Posture Index (FPI-6), coach-rated ability (Ability), highest playing level (Level), overuse ankle and/or foot injuries (Overuse), all traumatic ankle and/or foot injuries (Traumatic), playing/training load in hours/week (Load) and previous ankle and/or foot injuries (Past)

	Ability	Level	Overuse	Traumatic	Load	Past
FPI-6						
Pearson correlation	−0.304**	−0.249*	−.339**	−.039	−.261*	0.040
Significance (2-tailed)	0.008	0.030	0.003	0.741	0.023	0.734
Ability						
Pearson correlation		0.702**	0.148	0.073	0.776**	−0.050
Significance (2-tailed)		<0.001	0.203	0.530	<0.001	0.666
Level						
Pearson correlation			−0.21	0.251*	0.854**	−0.099
Significance (2-tailed)			0.857	0.029	<0.001	0.397
Overuse						
Pearson correlation				0.039	0.064	0.008
Significance (2-tailed)				0.741	0.581	0.948
Traumatic						
Pearson correlation					0.204	−0.039
Significance (2-tailed)					0.077	0.739
Load						
Pearson correlation						−0.124
Significance (2-tailed)						0.287

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

measure that is essentially the same side-to-side (r = 0.80 left to right).[29] Accordingly, the FPI-6 mean value (5.36 ± 2.92) for the dominant side of the 76 male Futsal players was assessed, which is consistent with previously reported mean values of 4.9 ± 3.9[8] using the FPI-8.

It has previously been found that athletes tend to exhibit sport-specific foot morphology,[13] so the findings of this study extend this notion to suggest that different foot types may exist within a sport and be associated with player ability level. Consistent with this, a significant negative linear relationship was found between the mean FPI-6 score and coach-rated ability groupings, suggesting that under-pronated to supinated feet are associated with higher player performance in Futsal. The FPI-6 has been found to explain 41% of the variance in ankle/subtalar position at mid-stance during ambulation using three-dimensional motion tracking of the lower limb.[17,18] This infers that biomechanical function of the foot can be partly predicted using the FPI-6 and may explain the observed relationship between foot type and performance. An under-pronated to supinated foot type provides a more rigid lever for propulsion during explosive running and rapid changes of direction.[33,34] Increased rigidity of the foot and less ground contact area may mean that during take-off, less energy and time is dissipated to resupinate the foot, sparing these for use in changes of direction, cutting and ball control, which are frequently required from athletes in Futsal. In contrast, a pronated, relatively mobile foot has more surface contact with the ground,[33,34] may require greater energy and time to prepare the foot for propulsion and rapid changes of direction. While the highest ability group observed in the current study appear more supinated than players of lesser ability (Fig. 4), an FPI-6 score of +3.94 would not be seen as highly supinated in a population sense.[8] Therefore, while players with under-pronated to supinated feet may be better suited to the demands of Futsal, their increased propensity for injury may limit players with greater degrees of supination. Whether it is possible to enhance the Futsal performance of a pronated player by footwear and/or orthotic intervention would be an interesting area for future investigation.

While the more able, under-pronated to supinated players were the most commonly injured, a confounding factor may have been exposure to a higher playing/training load. When overuse injury was correlated with playing/training load (hours/week) it was found that this was not the case. Furthermore, no significant relationship was found between traumatic ankle/foot injuries and FPI-6 score (Table 1). While past research has pointed to previous history of ankle/foot injury as a common risk factor for future injury,[3,4,33] the results of the current study suggest that previous ankle/foot injury in male adolescent Futsal players is not a risk factor for overuse ankle/foot injury (Table 1). Reasons for the divergent findings may lie in differing population demographics, with few studies separating ankle/foot injuries into traumatic and overuse categories.

The current investigation of foot type and overuse ankle/foot injuries in a large sample of male adolescent Futsal players has found that the FPI-6 score is a significant predictor of subsequent overuse ankle/foot injury. The higher-arched and hypomobile midfoot characteristics of under-pronated to supinated feet may not adequately adapt to the playing surface in Futsal, increasing the demand on the surrounding musculoskeletal structures to maintain stability and resist injury. Repetitive forces applied to these musculoskeletal structures by the demands of the game, combined with the implications of the growing skeleton, may explain the increased risk of ankle/foot overuse injuries for individuals scoring less than +2 on the FPI-6. Interestingly, this cut point for identification of risk is very similar to the current study's definition of ''under-pronated'', whereby an FPI-6 score of 2.44 lies 1S.D. below the group mean. Because 34% of the population lie between the mean (FPI-6 = 5) and 1S.D. below the mean (FPI-6 = 2), this suggests that to achieve the ability effect and to incur the injury risk, a foot needs to be in the most extreme (16%) of the population in terms of the level of supination. These results provide some evidence that early screening of foot posture may identify adolescent male Futsal athletes who are at an increased risk of overuse ankle/foot injury, enabling them to institute preventative action to minimise overuse injury.

While the findings of this study may be generalisable to adolescent males in other high demand court sports (e.g., handball, basketball), further research is required to determine the relationship between foot type, injury and ability in females, other age groups and different sporting disciplines.

To reduce the risk of overuse ankle/foot injuries, research is needed on the best ways of managing under pronated to supinated feet, possibly through appropriate footwear or orthoses. Investigation into the effects of any shoe materials to absorb the shock transmitted from the floor through the rigid foot and for any associated effect on foot stability and football performance is warranted. This may enable adolescents with high ability to continue playing Futsal, developing their skills with reduced risk of injury.

Conclusion

The FPI-6 measure of foot morphology was found to have good inter-rater reliability, and when employed with a group of adolescent male Futsal players, showed that an under-pronated to supinated foot type was associated with higher coach-rated ability. At the same time, an under-pronated to supinated foot type was found to be at significantly higher risk of overuse ankle/foot injuries in adolescent Futsal players. These findings suggest that early screening of foot posture may identify athletes who are both likely to achieve in Futsal, while simultaneously being at an increased risk of overuse ankle/foot injuries.

Practical implications

- The Foot Posture Index is a quick, easy to perform, reliable, valid and clinically applicable measure of foot posture.
- Screening of adolescent male Futsal players to identify those players who may be at risk of ankle/foot overuse injury.
- Possibility of improving Futsal performance of pronated feet through orthoses, footwear, taping and motor control.
- Possibility of reducing injury in supinated Futsal players by footwear, socks, orthoses, floor surface and addressing range of motion.

Acknowledgements

The researchers gratefully acknowledge the New South Wales Futsal Association and the staff and players of Dural Sport and Leisure Centre, Sydney for their generous assistance in data collection.

References

1. Razeghi M, Batt M. Foot type classification: a critical review of current methods. *Gait Posture* 2002;**15**:282—91.
2. Kaufman K, Brodine S, Shaffer R, et al. The effect of foot structure and range of motion on musculoskeletal overuse injuries. *Am J Sports Med* 1999;**27**:585—93.
3. Murphy D, Connolly D, Beynnon B. Risk factors for lower extremity injury: a review of the literature. *Br J Sports Med* 2003;**37**:13—29.
4. McManus A, Stevenson M, Finch C, et al. Incidence and risk factors for injury in non-elite Australian football. *J Sci Med Sport* 2004;**7**:384—91.
5. Hopper D, Bryant A, Elliott B. Foot types and lower limb injuries in elite netball players. *Sports Med* 1994;**84**: 355—62.

6. Yates B, White S. The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. *Am J Sports Med* 2004;**32**:772—80.
7. Bennett J, Reinking M, Pluemer B, et al. Factors contributing to the development of medial tibial stress syndrome in high school runners. *J Orthop Sports Phys Ther* 2001;**31**:504—10.
8. Burns J, Keenan A, Redmond A. Foot type and overuse injury in triathletes. *J Am Podiatr Med Assoc* 2005;**95**:235—41.
9. Korpelainen R, Orava S, Karpakka J, et al. Risk factors for recurrent stress fractures in athletes. *Am J Sports Med* 2001;**29**:304—10.
10. Giladi M, Milgrom C, Stein M, et al. The low arch, a protective factor in stress fractures. *Orthop Rev* 1985;**14**:81—4.
11. Cowan D, Jones B, Robinson J. Foot morphologic characteristics and risk of exercise related injury. *Arch Fam Med* 1993;**2**:773—7.
12. Michelson J, Durant D, McFarland E. The injury risk associated with pes planus in athletes. *Foot Ankle Int* 2002;**23**:629—33.
13. Aydog S, Tetik O, Demirel H, et al. Differences in sole arch indicies in various sports. *Br J Sports Med* 2005;**39**:5—7.
14. Menz H. Alternative techniques for the clinical assessment of foot pronation. *J Am Podiatr Med Assoc* 1998;**88**:119—29.
15. Weiner-Ogilvie S, Rome K. The reliability of three techniques for measuring foot position. *J Am Podiatr Med Assoc* 1998;**88**:381—6.
16. Redmond A, Burns J, Crosbie J, et al. An initial appraisal of the validity of a criterion based, observational clinical rating system for foot posture. *J Orthop Sports Phys Ther* 2001;**31**:160.
17. Redmond A, Crosbie J, Ouvrier R. Development and validation of a novel rating system for scoring standing foot posture: the foot posture index. *Clin Biomech* 2006;**21**:89—98.
18. Redmond A. *Foot posture in neuromuscular disease: development and evaluation of a novel method for quantifying change in foot posture using Charcot-Marie-Tooth disease as a clinical model* [PhD]. Sydney: Department of Paediatrics and Child Health Faculty of Medicine, University of Sydney, 2004.
19. Scharfbillig R, Evans A, Copper A, et al. Criterion validation of four criteria of the foot posture index. *J Am Podiatr Med Assoc* 2004;**94**:31—8.
20. Menz H, Munteanu S. Validity of 3 clinical techniques for the measurement of static foot posture in older people. *J Orthop Sports Phys Ther* 2005;**35**:479—86.
21. Evans A, Scharfbillig R, Scutter S. The validity of clinical podiatric foot measures- sonographic and radiological research. *Australasian J Podiatr Med* 2004;**38**: 7—11.
22. Evans A, Copper A, Scharfbillig R, et al. Reliability of the foot posture index and traditional measures of foot position. *J Am Podiatr Med Assoc* 2003;**93**:203—13.
23. Noakes H, Payne C. The reliability of the manual supination resistance test. *J Am Podiatr Med Assoc* 2003;**93**: 185—9.
24. Burns J, Crosbie J. Weight bearing ankle dorsiflexion range of motion in idiopathic pes cavus compared to normal and pes planus feet. *Foot* 2005;**15**:91—4.
25. Reilly T. Energetics of high-intensity exercise (soccer) with particular reference to fatigue. *J Sports Sci* 1997;**15**:257—63.
26. Portney L, Watkins M. *Foundations of Clinical Research: Applications to Practice*. 2nd ed. London: Prentice-Hall International; 2000.
27. Fleiss J. *The Design and Analysis of Clinical Experiments*. New York: Wiley & Son; 1986.
28. O'Toole R. *Ankle range of motion and history of lower limb injury in basketball players* [Honours Thesis]: School of Physiotherapy, Faculty of Health Sciences, University of Sydney; 2001.
29. Menz H. Two feet, or one person? Problems associated with statistical analysis of paired data in foot and ankle medicine. *Foot* 2004;**14**:2—5.
30. Cameron M, Adams R. Kicking footedness and movement discrimination by elite Australian Rules footballers. *J Sci Med Sport* 2003;**6**:266—74.
31. Biggerstaff B. Comparing diagnostic tests: a simple graphic using likelihood ratios. *Stat Med* 2000;**19**:649—63.
32. Kuzma J. *Basic Statistics for the Health Sciences*. Mountain View, CA: Mayfield; 1998.
33. Neely F. Biomechanical risk factors for exercise-related lower limb injuries. *Sports Med* 1998;**26**:395—413.
34. Cote K, Brunet M, Gansneder B, et al. Effects of pronated and supinated foot postures on static and dynamic postural stability. *J Athletic Train* 2005;**40**:41—6.