Research Paper Review

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Association Between Foot Type and Lower Extremity Injuries: Systematic Literature Review with Meta-Analysis

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ABSTRACT

Study Design
Systematic literature review with meta-analysis.

Objectives
To investigate the association between nonneutral foot types (high arch and flatfoot) and lower extremity and low back injuries, and to identify the most appropriate methods to use for foot classification.

Methods
A search of 5 electronic databases (PubMed, Embase, CINAHL, SPORTDiscus, and ProQuest Dissertations and Theses), Google Scholar, and the reference lists of included studies was conducted to identify relevant articles. The review included comparative cross-sectional, case-control, and prospective studies that reported qualitative/quantitative associations between foot types and lower extremity and back injuries. Quality of the selected studies was evaluated, and data synthesis for the level of association between foot types and injuries was conducted. A random-effects model was used to pool odds ratio (OR) and standardized mean difference (SMD) results for meta-analysis.

Results
Twenty-nine studies were included for meta-analysis. A significant association between nonneutral foot types and lower extremity injuries was determined (OR = 1.23; 95% confidence interval [CI]: 1.11, 1.37; P<.001). Foot posture index (OR = 2.58; 95% CI: 1.33, 5.02; P<.01) and visual/physical examination (OR = 1.17; 95% CI: 1.06, 1.28; P<.01) were 2 assessment methods using distinct foot-type categories that showed a significant association with lower extremity injuries. For foot-assessment methods using a continuous scale, measurements of lateral calcaneal pitch angle (SMD, 1.92; 95% CI: 1.44, 2.39; P<.00001), lateral talocalcaneal angle (SMD, 1.36; 95% CI: 0.93, 1.80; P<.00001), and navicular height (SMD, 0.34; 95%

CI: 0.16, 0.52; P<.001) showed significant effect sizes in identifying high-arch foot, whereas the navicular drop test (SMD, 0.45; 95% CI: 0.03, 0.87; P<.05) and relaxed calcaneal stance position (SMD, 0.49; 95% CI: 0.01, 0.97; P<.05) displayed significant effect sizes in identifying flatfoot. Subgroup analyses revealed no significant associations for children with flatfoot, cross-sectional studies, or prospective studies on high arch.

Conclusions
High-arch and flatfoot foot types are associated with lower extremity injuries, but the strength of this relationship is low. Although the foot posture index and visual/physical examination showed significance, they are qualitative measures. Radiographic and navicular height measurements can delineate high-arch foot effectively, with only anthropometric measures accurately classifying flatfoot.

Level Of Evidence
Prognosis, level 2a.

ANALYSIS

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Background Information
There are 3 major structural categories for the human foot based on the height of the medial longitudinal arch: high arch (HA), normal/neutral arch (NA) and low arch/flat footed (FF). A variety of systems exist to classify foot structure and alignment, including, but not limited to, radiographic measurements, qualitative and semi-quantitative visual appraisal, direct anthropometric measurements, foot print analysis and analysis of captured images. To date, no real concrete evidence has been published regarding the best way to analyze foot arch height.

Recently, clinicians, trainers and members of the general public have become greatly interested in this topic, due to the belief that non-neutral foot morphology could lead to poor foot function, which could in turn lead to lower extremity injury (1, 2). However, formal reviews of the literature have provided conflicting evidence. It remains unclear whether one's foot type is associated with incidence of lower extremity injury and which assessment method is most accurate to determine foot shape. Therefore, the focus of this review was to provide an evidence-based summary on whether or not one's foot type is associated with their incidence of lower extremity injury, and to determine the most appropriate method for assessing foot type.

PERTINENT RESULTS

Thirty-four articles were included in the analysis (twenty-nine studies were included in the meta-analysis). The reviewers' rating of methodological quality for the studies included in the analysis ranged from good to excellent (k = 0.73 - 0.96, P < .001). The collection of studies included various

populations, namely military trainees, athletes, adults, elderly individuals and preschoolers.
A number of lower extremity injuries were considered for this analysis, including:

- Stress fractures
- Knee pain
- ACL injury
- Foot pain
- Heel pain
- Plantar fasciitis
- Ankle sprain
- Achilles tendinitis or rupture
- Iliotibial band syndrome
- Patellofemoral syndrome
- Blisters
- Medial tibial stress syndrome
- Foot Accident
- Rheumatoid arthritis
- Hip, knee or general arthritis
- General lower extremity injury or pain

Pertinent results include

- A significant association was found between non-neutral foot type (HA and FF) and lower extremity injuries across all foot-type classification methods in studies that classified foot type based on distinct categories (i.e. high arch or flat footed).
- The collection of pooled studies which assessed foot type with continuous variables showed that non-neutral foot types tended to significantly favor groups of subjects presenting with lower extremity injury. (WRITER'S NOTE: *the authors were not explicit regarding which assessment methods can be defined as continuous variables. The reader is left to assume which measurements fall into this category*).
- There was a near-significant effect favoring an association between a flat footed structure and more severe injury.

Subgroup analysis: High Arch (HA) and Flat Foot (FF)

- For studies using a classification approach to categorize foot type, a significant association between non-neutral foot types (both HA and FF) and injury was found. However, there was less heterogeneity for HA groups between studies.
- The studies using continuous scales showed a significant tendency for HA subgroups to present with lower extremity injury. The levels of heterogeneity in studies of both HA and FF analysis were high and medium, respectively, for these studies.
- Generally, regardless of the method of assessment, the effect size and level of association between FF and lower extremity injury was highly comparable to those in the primary analysis (WRITER'S NOTE: *the primary analysis was to compare the amount of lower extremity injuries between non-neutral foot types, as defined through the use of continuous variables, against neutral foot types. A statistical analysis was performed and an SMD score was given – see methods section).*

Subgroup Analysis: Methods of Foot Classification/Assessment

- The Foot Posture Index showed a significant association between non-neutral foot types and injury. There was also a low level of heterogeneity among studies.
- This was also true of methods using visual observation and/or physical examination, only the heterogeneity was high.
- Measuring navicular height, lateral calcaneal pitch angle and lateral talocalcaneal angle showed significant association with lower extremity injury and HA in studies that used a continuous scale to measure HA tendency. There was no heterogeneity between studies that measured navicular height.

Subgroup Analysis: Age group of subjects

- The association between HA and FF foot types and lower extremity injuries was significant, with a medium level of heterogeneity for subjects 18 years and older. For subjects younger than 18, there was a significant effect only in those subjects with a tendency toward an HA; these studies showed medium-to-high heterogeneity

Subgroup Analysis: Study Design

- Only prospective and case-control study designs employing distinct categories to classify foot type found a significant association between non-neutral foot type and injury, with low and medium heterogeneity, respectively.
- Prospective studies using continuous measures for foot assessment found a significant positive effect size in the subject groups presenting with lower extremity injuries and a tendency toward FF. In this case, prospective studies were better at showing a relationship between FF and lower extremity injury.
- No significant effect size for either foot-type tendency was seen for cross-sectional studies.

CLINICAL APPLICATION & CONCLUSIONS

HA or FF types, when compared to a neutral foot type (NF), are associated with lower extremity injury (OR = 1.23 – a low odds ratio). Additionally, in those studies reporting foot assessment as continuous measures, both HA and FF foot types showed significant effect sizes in subjects who presented with lower extremity injuries.

Based on their compiled data, the authors state that visual and/or physical examination and the Foot Posture Index were the strongest assessment methods. However, they do contend that observer subjectivity of these semi-quantitative and/or qualitative assessment tools, and their tendency toward observer bias, may undermine the accuracy of these appraisal tools. Specifically, because the Foot Posture Index is based on visual observation, it has similar reliability limitations to other qualitative methods, and should be interpreted with caution.

Radiographic measurement or arch height appears to be the gold standard for finding an HA foot type. However, because of the inherent risks from ionizing radiation, this might not be the best routine clinical or screening option. While navicular height has high intra-rater and inter-rater agreement for discovering an HA, the technique has not been validated against radiographic measures.

With regards to FF tendency, the navicular drop test and relaxed calcaneal stance position showed significant effect sizes in the groups presenting with lower extremity injury. However, while the navicular drop test showed good inter-rater reliability and validity compared to radiographic interpretation of arch height, the relaxed calcaneal stance position is inherently unreliable and therefore may be invalid.

The authors also state that in spite of these various anthropometric measures being good alternatives to radiographic measurements, they are often time consuming and laborious. Also, they are static measurements, and may not reflect the dynamic loads on the foot during locomotion.

Of significant note is the fact that subjects aged 18 years and older with non-neutral foot types consistently presented with a tendency toward lower extremity injury. On the other hand, subjects younger than 18 years of age with a tendency toward a high arch foot type had a significant association with lower extremity injury. The authors surmise that perhaps children and adolescents' feet are still developing, and appear flatter and more adaptable in order to accommodate for impending external factors that might cause injury.

In conclusion, both HA and FF foot types are significantly associated with lower extremity injury. Although this relationship is apparent, the strength of the relationship is low. Additionally, radiographic measurements, followed by navicular height measurements, are effective in identifying HA foot type, while the relaxed calcaneal stance position and navicular drop test (preferable) were effective in identifying a FF foot type.

STUDY METHODS

The PubMed, Embase, CINAHL, SPORTDiscus, and ProQuest Dissertations and Theses electronic databases were searched for titles and abstracts published between1966-2011. Based on the abstracts, articles were included if they were:

- Published in English
- Were cross-sectional, case-control/retrospective or prospective cohort in terms of study design
- Included subjects who were either screened or assessed in the weight bearing position, or included subjects who were asked to self-report their foot structure/type at the beginning of the study
- Outlined comparative groups at the beginning of the study
- Reported lower extremity or low back injuries during the study period
- Utilized either a qualitative or quantitative analysis reporting on the association between foot structure or type, and lower extremity or back pain

All of the full-text articles' lists of references were then searched for additional applicable studies.

The authors performed an SMD analysis to pool studies comparing subjects who had low back or lower extremity injuries to a control group, and reported foot-type assessments as continuous measures

(WRITER'S NOTE: *the individuals allocated to the control groups were presumably asymptomatic. However, the authors did not specifically indicate this. Additionally, while the authors do not state it overtly, it is believed that this is the "main analysis" they speak of in the results section*). Positive effect sizes were used to indicate a tendency toward non-neutral foot type for subjects in the injury group in cases where the outcomes were on a continuous scale. Conversely, negative effect sizes indicated a tendency toward a neutral foot type. Each article was graded based on a modification of the 6-point criteria proposed by Barnes et al. (3). The highest possible score for methodological quality was 6 points. Only articles scoring 3 or greater were included in the study. If the answer to any of the following questions was "yes", the article was awarded a score of 1 on each question. Conversely, if the answer was "no", the article was awarded a score of 0 for that question. The questions were:

1. Were the inclusion/exclusion criteria clearly defined?
2. Were there sufficient numbers included? (yes if n ? 100)
3. Was the level of evidence high? (yes if studies were well-constructed case control, retrospective or prospective cohort studies)
4. Were the injury and control groups comparable? (age, sex, physical characteristics, activity type and level)
5. Were methods/measures used to classify foot type appropriate? (yes, if quantitative or semi-quantitative measures)
6. Were appropriate statistical methods used? (yes, if confounding factors were adjusted either through matching or multivariate regression analysis)

Kappa statistics were used to assess inter-rater agreement of methodological quality. Odds ratios (OR) and their corresponding 95% confidence intervals (CI) were computed.

There was a tendency toward a neutral foot (NF) type for subjects in the control groups of the included studies. A total of 4 subgroup analyses were conducted. Firstly, pooled data were assessed separately for high arch (HA) and flat foot (FF) types, so a demonstrable association between each foot type and lower extremity or lower back pain could be determined. Secondly, a subgroup analysis was performed across different continuous and categorical measures utilized for foot-type classification or assessment to determine the most appropriate method of analysis. Third, the authors attempted to determine whether there is an association between foot type and lower extremity injury in subjects younger or older than the age of 18. Finally, a subgroup analysis was performed based on various study designs (prospective cohort, case-control/retrospective and cross-sectional).

Tests of heterogeneity among studies were performed using a chi-square test, and the extent of heterogeneity was rated based on the I2 statistic.

STUDY STRENGTHS / WEAKNESSES

Study Strengths

- A wide variety of databases were searched.
- The authors performed a systematic review of pooled estimates and effect sizes, and provided an evidence-based account for the relationship between non-neutral foot types and lower extremity injury.

Study Weaknesses/Limitations

- The search process through the electronic databases was conducted by a single reviewer, which could have biased the results.
- Many of the subjects included in the studies were military personnel or competitive/amateur athletes. These populations are known to place high demands on their feet. Therefore, the results may not be applicable to more sedentary populations, or other populations in general.
- Only a few studies included subjects younger than 18 years of age. Thus, the results stated above might not be completely applicable to this age group.
- Because the range of lower extremity injuries recorded in the review was so diverse, it is difficult to pinpoint the kind of injuries associated with either HA or FF.
- The studies included had a publication bias toward smaller studies that reported significant results.
- The authors gave no specific examples of which assessment of arch height can be considered a continuous variable. The reader can only assume that this means measurements such as radiographic measurement of arch height, navicular height, navicular drop, etc, and not just simply assigning a subject into a gross category like "high arch" or "flat footed.".
- The authors did not assess or comment on dynamic assessments of arch height.

Additional References

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