INTRODUCTION

Previous literature suggests that there is a relationship between foot structure and injury patterns [1]. The correlation between arch structure and injury may be related to the fact that foot structure influences its function. Several studies have considered both arch height and arch flexibility to be a defining characteristic of foot structure. In their recent study of high-arched runners, Williams et al [2] found varying levels of arch flexibility, which led to differing lower-extremity movement patterns and loading.

It is often assumed that high arches tend to be stiffer, while low arches tend to be more flexible. However, recent literature suggests that arch height does not necessarily dictate arch flexibility [2]. Therefore, the purpose of this study is to use a proposed arch stiffness classification system to categorize both the arch height and arch flexibility of individuals’ feet and determine the tendency for certain arch height types to cluster toward certain arch flexibility types. Based on the assumption that high arches are stiffer while low arches are more flexible, a different distribution of arch flexibility types was expected for each of the arch height categories.

METHODS

Volunteers were drawn from pool of incoming military cadets, of whom 1124 agreed to participate in this study. All procedures were reviewed and approved by the Institutional Review Board, and all subjects gave informed consent prior to participation in the study. After the removal of erroneous data, a total of 1056 subjects, 882 men and 174 women, were included in the study (18.4 ±1.4 years, 1.76 ±0.80 m, 76.1 ±12.7 kgs). The right foot was characterized for each participant: Arch height index was measured using the Arch Height Index Measurement System, and arch height index (AHI) was calculated [3]:

\[
AHI = \frac{\text{Dorsal Height at 50% Total Foot Length}}{\text{Truncated Foot Length}}
\]

Arch flexibility, (AHF) was defined as the change in arch height (distance from the dorsal surface to the ground) from sitting to standing due to the change in load borne by the arch during these activities [3]:

\[
\text{AHF} = \frac{A_{H_{\text{sitting}}} - A_{H_{\text{standing}}}}{0.4 \times BW} \times 100 \text{ [m/kN]}
\]

The data were then used to create a classification scheme for AHF. Due to the skewness of the AHF data, the median value was established and a system of quintiles was used to classify five AHF categories: Very Stiff, Moderately Stiff, Average, Moderately Flexible, and Very Flexible.

The distribution of AHF types was then compared amongst AHI categories. This was accomplished by identifying the number of individuals of AHF type in each AHI category. AHF type was based upon the classification system proposed in this paper, and AHI category was based upon previous cutoff values for cavus, rectus, and planus proposed by Hillstrom et al. [4]. The distribution was compared using a Chi-Square Test of Goodness of Fit.

RESULTS AND DISCUSSION

The classification scheme based upon the quintiles is shown in Table 1. The median AHF value was 14.75 mm/kN. Of the 1056 feet, an approximately equal distribution (range = 210 – 212 feet/category)
were classified in each of the five AHF types. For the AHI categorization, 68 feet were classified as cavus, 225 were classified as rectus, and 763 were classified as planus. The test of goodness-of-fit suggested that, amongst AHI types, there were a significantly disproportional number of feet that were classified in each of the AHF categories ($p < 0.01$). As shown in Figure 1, the largest proportion of cavus feet was very stiff, and the smallest proportion was very flexible. This was also true of the feet in the rectus arch height category; although a large portion of the rectus feet also demonstrated neutral arch flexibility. Conversely, the largest proportion of planus feet was very flexible, and the smallest proportion was very stiff. The planus group demonstrated a very obvious step-wise increase in the proportion of individuals in each category from very stiff to very flexible. However the distribution of AHF categories within the cavus and rectus feet is less defined.

The purpose of this study was to expand our understanding of arch flexibility as a measure of foot structure. From this study, we proposed a five-category classification scheme for arch flexibility. It is important to note that the classification scheme proposed in the current study is based upon a population of healthy men and women between 18 to 25 years. Future studies should be carried out to determine whether the classification scheme can be applied to children, older adults, or a pathological population.

Despite the skew towards planus feet enrolled in the study, the results supported the hypothesis: there was a significantly different distribution of the arch flexibility types between arch height types. Specifically, the planus feet were much more likely to be very flexible, while the cavus and rectus feet were more likely to be stiffer. This relationship was most evident for the two extreme arch flexibility categories (very stiff and very flexible).

CONCLUSIONS

The results of the current research supports the common belief that cavus feet tend to be very stiff, while planus feet tend to be very flexible. However, the results of this study also demonstrate that there was a distribution of arch flexibility types amongst the arch height types. Therefore, at least two foot classification methods are useful to fully characterize foot structure.

REFERENCES


Table 1: Proposed cutoff values for arch flexibility categories and distribution of feet ($n = 1056$) amongst arch flexibility and arch height categories

<table>
<thead>
<tr>
<th>Arch Flexibility Category</th>
<th>Quintile</th>
<th>Cutoff Value, mm/kN</th>
<th>Number of Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Stiff</td>
<td>0 – 20%</td>
<td>AHF &lt; 9.91</td>
<td>22 56 133</td>
</tr>
<tr>
<td>Stiff</td>
<td>20 – 40%</td>
<td>9.91 ≤ AHF &lt; 13.54</td>
<td>17 51 142</td>
</tr>
<tr>
<td>Neutral</td>
<td>40 – 60%</td>
<td>13.54 ≤ AHF &lt; 16.00</td>
<td>8 52 153</td>
</tr>
<tr>
<td>Flexible</td>
<td>60 – 80%</td>
<td>16.00 ≤ AHF &lt; 20.54</td>
<td>15 32 164</td>
</tr>
<tr>
<td>Very Flexible</td>
<td>80 – 100%</td>
<td>AHF &gt; 20.54</td>
<td>6 34 171</td>
</tr>
</tbody>
</table>