COMPARISON OF PROTOCOLS FOR DETERMINING THE SUBTALAR JOINT ANGLE

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ABSTRACT

Introduction: Many studies have analyzed the maximum subtalar pronation without any concern over the choice of model for determining this variable. Objective: To compare the maximum subtalar pronation and its moment of occurrence during the stance phase, determined based on two mathematical models consisting of two and four reference points, respectively. Method: Sixteen runners participated in two running economy tests on a treadmill at speeds of 16 and 17 km.h⁻¹. Result: The study showed significant differences in oxygen consumption between the speeds adopted, contrary to the values of maximum subtalar pronation and their moments of occurrence, which did not show any significant differences between the speeds, regardless of the mathematical model adopted. Comparing the two mathematical models, the values of maximum subtalar pronation showed significant differences, regardless of speed. However, the moments of occurrence of maximum subtalar pronation showed no significant differences. Conclusion: The measure of maximum subtalar pronation is influenced by the mathematical model adopted. However, the moment of occurrence of maximum subtalar pronation during the stance phase is independent of the model.

Keywords: Pronation. Subtalar joint. Running.

INTRODUCTION

During recent decades, the study of human gait has been widely spread among the various sports research centers.¹ Many surveys were developed aiming to study the relationship between physical activity and injuries, particularly those related to running.² Studies associating the behavior of the subtalar joint angle (subtalar pronation) and the type of shoe used for running activities, have achieved significant importance in the pursuit of a better understanding of lesions involving the hip, knee, ankle and foot.³ It is widely known in literature that excessive pronation of the subtalar joint of the foot (Figure 1), understood as foot eversion, dorsiflexion and abduction, which occur respectively in the frontal, sagittal and transversal planes, is closely related to joint injuries, particularly of the lower limbs.³ The maximum subtalar pronation value, generally reached between 20 and 40% of the stance phase (Figure 2), is mainly influenced by the running linear speed, by muscular unbalance and/or hypermobility joint, and by the running technique imposed by the runner.³,⁴

There are basically two mathematical models used by literature for the determination of subtalar pronation. The first model consists of the use of two reference points, both located in the subject’s shoe: marker 1 (M1), located on the lower edge of the shoe, above the sole, and marker 2 (M2), located at the center of the upper edge of the shoe, above the Achilles tendon. In this model, subtalar pronation can be determined through the angle formed between segment M1-M2 (S1) and the vertical axis \( y \) or between S1 and the axis parallel to the sole of the shoe. (Figure 3a) We can cite as an example of the use of this mathematical model the study of Ferrandis et al.⁵ Now the second model consists of the use of four reference points, distributed as follows: markers M1 and M2, the same as the previous model, marker 3 (M3), located at the origin of the Achilles tendon (calcaneal tendon), and marker 4 (M4), located at the origin of the gastrocnemius muscle. Subtalar pronation is determined by the angle formed between segments M1-M2 (S1) and the vertical axis \( y \) or between S1 and the axis parallel to the sole of the shoe. (Figure 3a) We can cite as an example of use of this mathematical model the study of Wit et al.⁶
Although both models are used extensively in the calculation of the subtalar joint angle, no study was developed comparing absolute values of maximum subtalar pronation and its moments of occurrence during the stance phase, determined by both methods. Accordingly, the goal was to compare the absolute values of maximum subtalar pronation and its occurrence moments during stance phase, determined by both methods, at two submaximal running speeds.

**METHODOLOGY**

The sample was composed of 16 active individuals, long-distance runners (10,000 m), selected in a non-random manner, as volunteers, registered with Federação do Atletismo do Estado do Rio Grande do Sul - FAERGS, exempt from physical problems and from pharmacological treatment.

The sample number (n) was calculated for this study based on the studies of Tartaruga et al.7 and Williams and Cavanagh, through Computer Programs is Epidemiologic Analyses - PEPI, adopting a significance level of 0.05, a power of 80% and a correlation coefficient (r) of 0.7. This study was approved by the Ethics Committee of Universidade Federal do Rio Grande do Sul (No. 2007716).

The data gathering activities were developed at Instituto Brasileiro de Tecnologia do Couro, Calçado e Artefato - IBTeC, using a Movement (RT250) treadmill, an Aerosport (KB1-C) portable gas analyzer connected to a Pentium II 200 MHz microcomputer, a Punix Progressive Scan digital camera with sampling frequency of 120 frames per second, a pair of scales and a Filizola stadiometer, a Starrett tape measure and a Caliper skin fold compass.

First of all the body mass, stature, leg length and body fat percentage (%F) data were measured with the use of the scales, the stadiometer, the tape measure and the skin fold caliper. For these measurements, the individuals were barefoot, dressed in a pair of shorts or swimming trunks. The measurement of the leg length was taken on both legs, calculating the distance between the greater trochanter of the femur and the ground. The shoes were weighed separately. The percentage of body fat was calculated by means of the Siri formula.9

The equation developed by Jackson and Pollock10, and validated by Petroski11 for men aged between 18 and 61 years was used to calculate the body density.

Skinfold and perimeter measurements were evaluated by a Physical Education professional with experience in anthropometric evaluations.

Afterwards the participants fixed the anatomical points. The choice of the anatomical points was based on the studies conducted by Ferrandis et al.5 and Wit et al.6 The nomenclature of the anatomical markers used in this study (4 in the posterior frontal plane of the left leg) was taken, among others, from the recommendations made by Wu et al.12 The anatomical markers were distributed according to Figure 4.

The accessories corresponding to ergospirometry were added at the end. A pneumotacograph with variation from 10 to 120 l.min⁻¹ was used for mean flow, coupled to a neoprene mask and to the gas analyzer.

Prior to the start of the tests the equipment was calibrated through gases with known concentrations and a calibration of volume was
Table 1 refers to the sample characterization data. The mean mass of the shoe used by the sample was 220.31 grams, with standard deviation of ± 87.16 grams.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>27.13</td>
<td>± 5.72</td>
<td>20.00</td>
<td>39.00</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>64.52</td>
<td>± 5.88</td>
<td>53.10</td>
<td>76.30</td>
</tr>
<tr>
<td>Stature (m)</td>
<td>1.74</td>
<td>± 0.08</td>
<td>1.64</td>
<td>1.85</td>
</tr>
<tr>
<td>Leg length (m)</td>
<td>0.82</td>
<td>± 0.04</td>
<td>0.76</td>
<td>0.92</td>
</tr>
<tr>
<td>Body density (g/ml)</td>
<td>1.08</td>
<td>± 0.00</td>
<td>1.07</td>
<td>1.08</td>
</tr>
<tr>
<td>Percentage of body fat</td>
<td>9.11</td>
<td>± 0.148</td>
<td>6.84</td>
<td>11.76</td>
</tr>
<tr>
<td>Performance in 10,000m</td>
<td>0:32:40</td>
<td>± 0:00:18</td>
<td>0:30:27</td>
<td>0:33:35</td>
</tr>
</tbody>
</table>

The filming sessions were scanned using the Dvideo software. After the manual and automatic scanning in two dimensions (2D), they calculated the maximum pronation of the subtalar joint using itself two mathematical models that take into consideration the existence of two and four anatomical points (Figure 5), through two routines developed in the Matlab software.

For the statistical treatment, the Shapiro-Wilk test was conducted first for verification of the normality of the data. As the maximum subtalar pronation and submaximal oxygen consumption data at the two submaximal running speeds, presented symmetrical behavior, parametric statistical tests were adopted. The descriptive analysis was carried out with mean and standard deviation and Student’s T-test for dependent samples, with \( p < 0.05 \). The statistical package used was the Statistical for Social Sciences Software - SPSS, version 10.0.

RESULTS

Table 1 refers to the sample characterization data. The mean mass of the shoe used by the sample was 220.31 grams, with standard deviation of ± 87.16 grams.
Table 2 contains the mean values, the standard errors and the minimum and maximum values of the variables oxygen consumption, maximum pronation angle and moment of occurrence of maximum subtalar pronation during stance phase, both calculated with the use of two and four points, at the speeds of 16 and 17 km.h\(^{-1}\).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean 16 km.h(^{-1})</th>
<th>Mean 17 km.h(^{-1})</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen consumption (ml.kg(^{-1}).min(^{-1}))</td>
<td>43.7(^a) ± 3.52</td>
<td>45.9 (±) 3.38</td>
<td>36.0</td>
<td>38.1</td>
<td>49.3</td>
</tr>
<tr>
<td>Maximum subtalar pronation – 2 pts (degrees)</td>
<td>2.5(^a) (±) 4.44</td>
<td>2.6(^a) (±) 4.76</td>
<td>5.6</td>
<td>13.8</td>
<td></td>
</tr>
<tr>
<td>Maximum subtalar pronation – 4 pts (degrees)</td>
<td>11.6 (±) 4.48</td>
<td>11.1 (±) 5.04</td>
<td>0.53</td>
<td>19.6</td>
<td></td>
</tr>
<tr>
<td>Moment of occurrence of maximum subtalar pronation during contact phase – 2 pts (%)</td>
<td>48.3 (±) 12.36</td>
<td>49.6 (±) 10.44</td>
<td>22.7</td>
<td>62.2</td>
<td></td>
</tr>
<tr>
<td>Moment of occurrence of maximum subtalar pronation during contact phase – 4 pts (%)</td>
<td>43.3 (±) 10.80</td>
<td>42.3 (±) 13.48</td>
<td>22.7</td>
<td>58.3</td>
<td></td>
</tr>
</tbody>
</table>

Note: Asterisks represent statistically significant differences between the speeds; letters represent statistically significant differences between the two mathematical models for the same speed. (*) for 16 km.h\(^{-1}\); \(\pm\) for 17 km.h\(^{-1}\). Negative values subtalar supination. Rate of significance adopted of 0.05.

Analyzing oxygen consumption, a significant increase was verified with the increase of the running speed. According to Williams and Cavanagh\(^b\), Kyrolainen et al.\(^d\), Tartaruga et al.\(^e\) and Nummela et al.\(^f\), oxygen consumption, directly influenced by the running speed, can significantly alter the magnitude of the biomechanical variables of human locomotion.

In our study, we did not verify a significant increase in maximum subtalar pronation with the increase of speed and of oxygen consumption, regardless of the mathematical model used. Tartaruga et al.\(^g\) verified that the maximum subtalar pronation increased significantly from 11 km.h\(^{-1}\) to 13 km.h\(^{-1}\) (5.87 \(±\) 4.66 degrees to 9.44 \(±\) 5.15 degrees) in the women, and from 14 km.h\(^{-1}\) to 16 km.h\(^{-1}\) (6.79 + 4.01 degrees to 9.69 \(±\) 3.14 degrees) in the men, demonstrating, contrary to our findings, that the running speed probably directly influences the behavior of the subtalar joint angle. Gheuleu and Madsen\(^i\) demonstrated that the increase of maximum pronation, and that of maximum supination, are directly connected to intensity of effort and not to increase of running linear speed. They adopted the speeds of 13.6 and 16.2 km.h\(^{-1}\).

The differences in the findings of our study in relation to the aforementioned studies are probably related to the speeds of 16 and 17 km.h\(^{-1}\). Although both gave rise to statistically significant differences in oxygen consumption, the difference in speed might not have been sufficient to result in significant changes in the angular behavior of the subtalar joint, regardless of the mathematical model used. Fromme et al.\(^j\) emphasize that speed alone is not capable of influencing the movement of the subtalar joint during running. Muscle fatigue has a significant influence on the angular behavior of the subtalar joint during human locomotion. In our study, the individuals remained running for 6 minutes at each speed. The running time might not have been sufficient to generate muscle fatigue, and consequently, to modify the maximum pronation angle at each one of the speeds adopted.

Likewise, the percentages of the stance phase of maximum subtalar pronation, calculated with two and four points, were not influenced by the change of speed either. The moment of occurrence of maximum subtalar pronation during the stance phase is probably also influenced by the muscle fatigue associated with the running speed.

Regardless of speed, maximum subtalar pronation presented statistically significant differences among the calculation methods adopted. The difference might be related to the movement resulting from segment S2, influenced by the rotation movements along the longitudinal axis and translation movements of the tibia. According to Mcclay and Manal\(^k\), the internal rotation of the tibia is one of the main causes of subtalar pronation, contributing significantly to its absolute value. Likewise, the pronation action of the foot provokes internal rotation of the tibia and of the femur, followed by the rotation of the entire leg. According to the authors, a tibial rotation of 11.1\(^\circ\) might entail dorsiflexion of the posterior part of the foot of 18.7\(^\circ\), which allows a higher risk of injury on the hip, knee and ankle.

**CONCLUSION**

This study verified that the maximum subtalar pronation value measured is influenced by the mathematical model adopted for the calculation of aforesaid variable. Using the mathematical model...
of two points, both located in the foot, results in lower values of maximum subtalar pronation in comparison with the mathematical model of four points, two in the leg and two in the foot. However, regardless of the mathematical model, the moment of occurrence of greatest subtalar pronation during the stance phase remains the same.

For studies aimed at determining the moment of occurrence of the highest subtalar production over the course of the stance phase, the use of both mathematical models is satisfactory. However, if the objective is to determine the magnitude of maximum subtalar pronation, a variable that significantly influences musculoarticular injuries in the ankle and knee region, the use of the four-point model is recommended due to the influence of tibial inclination.

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