Short communication

How accurate is visual determination of foot strike pattern and pronation assessment

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ABSTRACT

Nowadays, choosing adequate running shoes is very difficult, due to the high number of different designs. Nevertheless, injury risks are usually underestimated by non-professional runners. In a prospective study, Macera et al. [2] reported that, each year, approximately one out of two runners gets injured. Assessing foot strike and pronation is paramount as directly linked to injury risk [3]. Moreover, shoes adapted to the runner’s technique and foot morphology may reduce the risk of injury [4]. As a consequence, retailers’ advices are usually based on the visual assessment of the customer’s running technique. Such method is subjective and requires an experimented examiner while objective methods require expensive material, such as 3D motion system and pressure insoles. Therefore, the aim of this study was to determine the accuracy of foot strike pattern and pronation assessment using video cameras, compared to a gold standard motion tracking system and pressure insoles. 34 subjects had to run at 8, 12 and 16 Km/h shod and 12 Km/h barefoot during 30 s trials on a treadmill. Agreement between foot strike pattern assessment methods was between 88% and 92%. For pronation, agreement on assessment methods was between 42% and 56%. The results obtained indicate a good accuracy on foot strike pattern assessment, and a high difficulty to determine pronation with enough accuracy. There is therefore a need to develop new tools for the assessment of runner’s pronation.

1. Introduction

Running has become a very popular sport in the last decades, thanks to its accessibility, ease of practice and health benefits [1]. Nevertheless, injury risks are usually underestimated by non-professional runners. In a prospective study, Macera et al. [2] reported that, each year, approximately one out of two runners gets injured. Assessing foot strike and pronation is paramount as directly linked to injury risk [3]. Moreover, shoes adapted to the runner’s technique and foot morphology may reduce the risk of injury [4]. As a consequence, retailers usually propose shoes with two main characteristics: soles with different drops to fit foot strike pattern (rearfoot, midfoot and forefoot strikers), and neutral shoes vs. shoes with arch support for pronators.

The Foot Strike Index (FSI) indicates the location of the centre of pressure when the foot hits the ground [5]. The foot is separated in three areas: rearfoot midfoot and forefoot. Altman et Davis [7] proposed a method called navicular drop (ND), where the navicular height difference was measured seated (without bodyweight) and in standing position (with bodyweight). Foot characteristic was defined as follow: Under pronation: ND < 4 mm, Normal pronation: 4–10 mm, Over pronation: > 10 mm. Clarke et al. [8] and then McClay et Manal [9] defined the rearfoot eversion (EVA) as the angle between tibia and heel, measured on the frontal plane. The following classification was defined: Under pronation: EVA < 8°, Normal pronation: 8–15°, Over pronation: > 15°.

Except for ND and a direct visual classification, all methods require extensive material and data processing. In this context, using video cameras could allow for accurate and straight forward foot strike pattern and pronation classification. The aim of this study was therefore to compare the accuracy of the previously cited methods with a visual determination from experts who analysed slow motion videos from cameras placed laterally and behind the runner: The lateral and the back visual classification methods (LVC and BVC respectively).

2. Methods

Thirty four healthy adults (12 females and 22 males) aged 21–46 years, height 158–193 cm, weight 51–92 kg, running at least once a week and without any symptomatic musculoskeletal injuries volunteered to participate to this study. The study was approved by the local ethic committee. All participants signed an informed consent form.

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before beginning the test.

Participants were first asked to run six minutes on a force plate treadmill (FMT170, Arsalis, The Nederlands) at self-selected speed, as a familiarisation and warm up [10]. Shoes were removed, ND measured, and markers placed on each barefoot using the Heidelberg Foot Measurement Method [11] for the back of the foot. The frontfoot markers were substituted by a 4 markers-cluster. A 30 s trial was then recorded by the motion tracking system at 100 Hz (Smart400, BTS Bioengineering, Italy) with the participants running at 12 km/h. Participants then wore their usual running shoes with pressure insoles (Pedar-X, Novel, Germany). Markers were fixed on each shoe using the same configuration (only the navicular marker was not repositioned). The participants had then to run 30 s at 8, 12 and 16 km/h. All trials were also recorded using a lateral (left) and a back camera at 240 Hz (GoPro 3, GoPro, USA). Direct comparison of running kinematics with vs without shoes was possible at 12 km/h.

Time of initial contact was determined using the ground reaction force recorded at 1000 Hz, for a 7% bodyweight threshold. Synchronized pressure insoles data were computed to determine FSI as foot strike pattern reference system. Three dimensional orientations of each were also computed (Smart Tracking, BTS Bioengineering, Italy) to calculate FSA and EVA. Finally, three experts (biomechanists) used LVC to determine foot strike pattern and BVC was used by three other experts (clinicians) to determine over, normal or under pronation of the foot.

Confusion matrix was built to determine accuracy, precision, sensitivity and specificity and compare consistency between foot strike pattern assessment methods and between pronation assessment methods using the average values over each trial. Accuracy between experts classification was also calculated. Finally, Intraclass Correlation Coefficient (ICC) was calculated to assess observer variability [12]. ICC values were interpreted according to often quoted guidelines: Poor <

\[\text{Table 1} \]

Overall accuracy, precision, sensitivity and specificity given in percent for the comparison between the foot strike pattern assessment methods.

<table>
<thead>
<tr>
<th></th>
<th>FSI-FSA (n = 93)</th>
<th>FSI-LVC (n = 101)</th>
<th>FSA-LVC (n = 128)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rearfoot (n = 65)</td>
<td>Midfoot (n = 11)</td>
<td>Forefoot (n = 17)</td>
</tr>
<tr>
<td>accuracy</td>
<td>92</td>
<td>92</td>
<td>91</td>
</tr>
<tr>
<td>precision</td>
<td>92</td>
<td>55</td>
<td>94</td>
</tr>
<tr>
<td>sensitivity</td>
<td>94</td>
<td>55</td>
<td>100</td>
</tr>
<tr>
<td>specificity</td>
<td>100</td>
<td>50</td>
<td>94</td>
</tr>
</tbody>
</table>

Values are given in % for Foot Strike Index (FSI), Foot Strike Angle (FSA), Lateral Visual Classification (LVC) comparison.

\[\text{Table 2} \]

Overall accuracy, precision, sensitivity and specificity given in percent for the comparison between pronation assessment methods.

<table>
<thead>
<tr>
<th></th>
<th>EV – BVC (n = 55)</th>
<th>EV – ND (n = 51)</th>
<th>ND – BVC (n = 102)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Under (n = 33)</td>
<td>Normal (n = 15)</td>
<td>Over (n = 7)</td>
</tr>
<tr>
<td>accuracy</td>
<td>56</td>
<td>49</td>
<td>42</td>
</tr>
<tr>
<td>precision</td>
<td>7</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>sensitivity</td>
<td>7</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>specificity</td>
<td>100</td>
<td>41</td>
<td>45</td>
</tr>
</tbody>
</table>

Values are given in % for Eversion Angle (EVA), Navicular Drop (ND) and Back Visual Classification (BVC) comparison.

\[\text{Fig. 1.} \]

Agreement between Foot Strike Index (FSI), Foot Strike Angle (FSA) and Lateral Visual Classification (LVC) (color boxes).
0.4 < Fair < 0.6 < Good < 0.75 < Excellent < 1 [13].

3. Results

The results between foot strike pattern determination methods are presented in Table 1 while results between pronation determination methods are presented in Table 2. Average standard deviation intratrails was 1.88’ for EVA and 2.00’ for FSA.

Experts proposed accuracy between 86% and 94% for LVC classification, with an excellent inter-assessors ICC of 0.89. For the barefoot condition, the accuracy between FSA and LVC was 75%, while shod condition gave 97%. Fig. 1 illustrates the relationship between FSI, FSA and LVC.

Concerning BVC, experts proposed accuracy between 73% and 76%, for a poor inter-assessors ICC of 0.05.

4. Discussion

Classifying foot strike pattern using a single camera placed laterally seems appropriate to determine rearfoot, midfoot and forefoot strikers. There is a good agreement between the three methods used in this project. Experts also gave accurate results for LVC as expected by Altman et Davis [6]. In their study, an overall 71% of correct classification between FSA and direct visual classification was observed. Barefoot condition also scored with lower agreement between FSA and LVC. The difference between shod and barefoot condition is probably due to the higher difficulty to determine two parameters: the initial contact, and the orientation of the foot. Indeed, the shoes offer more contrast than the barefoot on images. Concerning the shod condition, the few classification errors were probably caused by the difficulty to estimate both the initial contact and the angle of the foot at that time. The midpoint condition is the more problematic to assess and Fig. 1 provide a visual incentive that only few runners land midfoot.

Classifying the pronation of the foot using the back camera leads to different conclusions: the agreement between the ND, EVA and BVC methods is very low. This can probably be explained by the fact that the three different methods measure slightly different parameters: EVA determines only the rearfoot eversion at ground contact, ND classifies the foot in a non-dynamic way, while experts tried to estimate a mal-function (i.e., under or over pronation) of the foot that increases the risk of injury. The small number of under pronators also requires interpreting the confusion matrix with caution.

The fact that experts proposed different estimations illustrates two points: the difficulty to accurately define the pronation, even among experts, and the difficulty to observe the movement of pronation from back videos. Indeed, as described by Stacoff et al. [3], forefoot movement may also influence pronation at initial contact, implying a correlation between strike angle and pronation.

The difference between shod and barefoot running was measured only at 12 km/h. At different velocities, one may assume that the bias would be higher with footwear since there are many additional confounding factors (insole height, shoe drop, lateral support) that would likely make the assessment more difficult and more variable.

One limitation of the present study was that FSA and the EVA were calculated by using the markers of the Heidelberg foot model but with only a limited set of the available markers.

This study showed the benefit of using video camera to determine the foot strike pattern and the limitation when determining pronation during stance in running. Defining more accurately the foot pronation seems paramount since this factor is clinically important. Experts will also be able to determine pronation with a greater accordance to the definition and the inter-assessor ICC will probably increase.

Conflicts of interest statement

This document hereby discloses any financial and personal relationships with other people or organizations that could inappropriately influence the work title.

References