COMPARISON OF THREE METHODS FOR MEASUREMENT OF FOOT PROGRESSION ANGLE MAGNITUDE AND ASYMMETRY

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INTRODUCTION

The contribution of foot progression angle (FPA) to lower extremity musculoskeletal impairments is the focus of a growing body of orthopedic literature. Symmetry of gait variables is considered one of the characteristics of a normal gait pattern in healthy adults. Development of multi-segment foot models have allowed for the evaluation of foot kinematics during gait to discriminate between normal and pathologic foot function. The purpose of this study is to assess and compare the magnitude and asymmetry of FPA obtained from motion capture with existing validated methods of determining FPA.

METHODS

Subjects. Fourteen healthy subjects (8 F, age=34±15.6 years, height=1.68±0.09 m, weight=71.6±14.4 kg, BMI=25.2±3.2 kg/m²) volunteered and signed an informed consent approved by the university Institutional Review Board. All data were collected and analyzed by a single experienced tester.

FPA measurement. Motion capture. Bilateral kinematic and kinetic data were collected using an 8-camera video-based motion capture system (Vicon, Los Angeles, CA, USA). Subjects were fitted with 10 mm diameter spherical retro-reflective markers on the bilateral lower extremities. Foot and shank marker placement and segmentation are described by Carson et al (2001). Subjects performed four barefoot walking trials at a self-selected speed over a 6 m walkway with an embedded force plate (Advanced Medical Technology, Inc., Watertown, MA, USA) to determine force output. Inked-moleskin method. During the fourth motion capture walking trial subjects were fitted with pre-cut moleskin shaped like triangles and squares on the plantar surface of the foot. Paper spanning the length of the walkway was placed within the capture volume to allow simultaneous collection of motion capture and inked-moleskin data. Moleskin pieces were aligned with the center of the heel and 2nd metatarsal head landmarks corresponding to two of the foot markers used to define the foot segment (inferior calcaneus--ICAL and distal 2nd metatarsal--D2MT). Subjects walked at a self-selected speed. EMED-ST P-2 pressure platform. Dynamic plantar pressure distribution was obtained on both feet for three trials of barefoot walking at a self-selected speed over a 3.6m walkway with an embedded pressure distribution platform (Novel Inc., St. Paul, MN, USA). The 2-step method was utilized for the collection of pressure maps. Data Processing and Analysis. Kinematic convention for all FPA measurements was to designate external FPA (toe-out) as negative and internal FPA (toe-in) as positive. Motion capture. All kinematic data was processed using Visual 3D software (C-motion, Inc., Rockville, MD, USA). The foot was modeled as a single, rigid body segment. FPA was calculated as the magnitude of transverse plane rotation of the foot segment around the local superior-inferior axis at midstance (50% stance). Inked-moleskin method. Data were measured and analyzed as described by Boenig (1977). FPA was measured using 2° increment goniometer. The FPA values obtained from the foot step onto the force plate collected from the inked-moleskin and motion capture trial is the comparison used in the analysis. EMED-ST P-2 pressure platform. FPA was determined as the measured angle between the line of progression (a line drawn parallel to the printed paper) and a line representing the anterior-posterior bisection of the digitized pressure map of foot plantar surface using a 2° increment goniometer. These methods are described by Hastings et al (2010). FPA asymmetry was defined as the absolute difference between right and left mean FPA values ([RFPA-LFPA]) for each method. Mean FPA and absolute difference values were assessed using a one-way analysis of variance (ANOVA), with post-hoc
testing using least significant difference. Level of association for obtaining mean FPA (right and left) between methods was assessed using Pearson Product Moment coefficient (r).

RESULTS AND DISCUSSION

Mean FPA: There were no significant differences in mean FPA between methods (FPA=8.8±4.2° to 10.5±4.6°). Methods for determining mean FPA were highly correlated (r=0.74-0.83). Pairwise difference values between the methods are presented in Table 1. FPA Asymmetry: All three methods yielded similar side-to-side difference values (p=.661). Pairwise difference values are given in Table 1. All three methods detected a similar difference in right and left FPA, with approximately 64% (9/14) of subjects demonstrating an absolute difference of at least 4 degrees, and 5/14 (36%) exhibiting an absolute difference of at least 6 degrees (Figure 1).

CONCLUSIONS

The results of this study suggest that determination of mean FPA and asymmetry in FPA in normal, healthy subjects using motion capture yield similar values to existing validated methods within the precision of the goniometer. In addition, the presence of asymmetry in FPA may be a common characteristic of a normal gait pattern in persons without musculoskeletal pathology. We conclude that motion capture potentially provides a reproducible method of simultaneously assessing FPA characteristics and foot and ankle mechanics.

REFERENCES


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Table 1: Pairwise mean differences (degrees) and correlations for mean FPA values between methods

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<tr>
<th></th>
<th>Ink/MC</th>
<th>Ink/EMED</th>
<th>EMED/MC</th>
<th>P</th>
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<tr>
<td><strong>Right</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean FPA</td>
<td>0.97</td>
<td>1.36</td>
<td>0.39</td>
<td>.741</td>
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<tr>
<td><strong>Left</strong></td>
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<tr>
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<td>0.34</td>
<td>.970</td>
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<td>Mean Absolute R/L</td>
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<td>0.78++</td>
<td>0.43++</td>
<td>.661</td>
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<tr>
<td>r</td>
<td>0.74</td>
<td>0.83</td>
<td>0.77</td>
<td>.000</td>
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Ink=Inked moleskin method; MC=motion capture; Mean Absolute R/L=[RFPA-LFPA]
+: Comparison of FPA values for the foot on the force plate
++: Comparison of FPA values for the foot on the force plate and averaged EMED trials

Figure 1: Absolute difference in mean FPA values (deg) between right and left for each method.