Validation of 3D Accelerometry to Measure Static and Dynamic Postural Stability

Timothy C. Sell, Nicholas R. Heebner, Jonathan Akins, Megan Turcheck, Scott M. Lephart
Department of Sports Medicine and Nutrition, University of Pittsburgh, Pittsburgh, PA

EXPERIMENTAL DESIGN
A descriptive study evaluating the ability of a three dimensional accelerometer to distinguish between tasks of different difficulty and compare measures of postural stability with force plate measures

INTRODUCTION
• Evaluation of postural stability in sports medicine is important for both rehabilitation and evaluation of injury risk
• Laboratory measures of postural stability typically incorporate force measurement platforms which provide high reliability, but can be expensive and lack portability
• Clinical measures, despite being highly portable, typically do not include a dynamic balance component and may not have the resolution needed to discriminate for risk of injury in an athletic population
• Accelerometers may provide a compromise between the two in order to provide high resolution and the portability necessary for large-scale studies in athletic populations
• Accelerometers are easy to use, portable, and have greater resolution compared to current clinical measures

SUBJECTS
Thirteen healthy, physically active males (Age=23.3±4.1 yrs; Ht=176.8±4.6 cm; Wt=76.2±9.4 kg)

PURPOSE
• To examine the ability of a three dimensional accelerometer to quantify relevant static and dynamic postural stability measures

RESULTS
• Means and SDs of postural stability measures are shown in Table 1
• Kruskal-Wallis tests revealed significant differences between static and dynamic tasks and between individual static tasks (Table 1)
• The Spearman’s ranked correlations were low to moderate but were statistically significant (Table 2)

EQUIPMENT
• Center of Mass (COM) accelerations were collected using one custom wireless, tri-axial ±16g accelerometer (ZeroPoint Technologies, Johannesburg, South Africa; 42 x 39 12 mm, 31 grams; Figure 1) sampling each axis at 1000 Hz
• Ground reaction forces (GRFs) were collected using a Kistler force plate (Kistler Instrument Corp, Amherst, NY) sampling at 1000 Hz and integrated with Nexus software (Vicon Motion Systems, Centennial, CO)

PROCEDURES
• COM accelerations and GRFs were collected simultaneously during five successful trials of eight static postural stability tasks of different difficulty. Tasks included double-leg (DLEO / DLEC), double-leg on foam (DLEO-F / DLEC-F), tandem (TEO / TEC), single-leg (SLEO / SLEC) stances and were performed in eyes-open (EO) and eyes-closed (EC) conditions (Figure 2). Dynamic postural stability was assessed using forward (AP; Figure 3) and lateral (ML) jump landing tasks
• Static tasks were collected for 10 seconds and dynamic tasks were collected for 3 seconds after initial contact
• Root mean square (RMS) of accelerations were calculated for each direction and resultant for each task (static and dynamic postural stability)
• Standard deviation (SD) of GRFs were used to calculate static postural stability utilizing a force plate and the dynamic postural stability index (DPSI) was used to calculate dynamic postural stability from GRF data

STATISTICAL ANALYSIS
• The Kruskal-Wallis test was used to determine any significant differences between tasks
• Spearman’s ranked correlations were used to determine the relationship between the force plate and accelerometer measures

Table 1. RMS Results of Accelerations During Each Task and Between Task Comparisons

<table>
<thead>
<tr>
<th>Accelerometer</th>
<th>DLEO</th>
<th>DLEC</th>
<th>DLEO-F</th>
<th>DLEC-F</th>
<th>TEO</th>
<th>TEC</th>
<th>SLEO</th>
<th>SLEC</th>
<th>DPSI-AP</th>
<th>DPSI-ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axis</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>AP</td>
<td>0.099 ± 0.119</td>
<td>0.095 ± 0.116</td>
<td>0.090 ± 0.116</td>
<td>0.102 ± 0.115</td>
<td>0.142 ± 0.111</td>
<td>0.140 ± 0.111</td>
<td>0.078 ± 0.110</td>
<td>0.085 ± 0.101</td>
<td>0.359 ± 0.086</td>
<td>0.293 ± 0.069</td>
</tr>
<tr>
<td>ML</td>
<td>0.010 ± 0.012</td>
<td>0.011 ± 0.014</td>
<td>0.011 ± 0.010</td>
<td>0.014 ± 0.012</td>
<td>0.017 ± 0.017</td>
<td>0.027 ± 0.024</td>
<td>0.055 ± 0.039</td>
<td>0.067 ± 0.043</td>
<td>0.380 ± 0.110</td>
<td>0.358 ± 0.106</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.983 ± 0.017</td>
<td>0.984 ± 0.018</td>
<td>0.984 ± 0.017</td>
<td>0.981 ± 0.017</td>
<td>0.977 ± 0.017</td>
<td>0.977 ± 0.015</td>
<td>0.983 ± 0.020</td>
<td>0.983 ± 0.020</td>
<td>1.068 ± 0.051</td>
<td>1.067 ± 1.170</td>
</tr>
<tr>
<td>Resultant</td>
<td>0.995 ± 0.016</td>
<td>0.995 ± 0.016</td>
<td>0.995 ± 0.015</td>
<td>0.994 ± 0.017</td>
<td>0.994 ± 0.021</td>
<td>0.993 ± 0.020</td>
<td>0.994 ± 0.016</td>
<td>0.994 ± 0.014</td>
<td>1.199 ± 0.050</td>
<td>1.170 ± 0.061</td>
</tr>
</tbody>
</table>

Table 2. COM Acceleration and GRF Correlations

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Corr.</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP</td>
<td>0.406</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>ML</td>
<td>0.758</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.477</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Resultant</td>
<td>0.464</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

DISCUSSION
• Results demonstrated the ability of an accelerometer to distinguish between static and dynamic tasks and was significantly correlated to force plate measures
• Additionally, accelerometers may offer greater resolution than current clinical measures of postural stability

SIGNIFICANCE
• Accelerometers may provide a valid measure of postural stability that is easy to use, portable, and may have greater resolution than traditional clinical measures
• This technology should enable researchers to collect higher resolution postural stability data in the field and in the clinic