The Effect of Load Carriage and Lower Extremity Strength on Plantar Pressures Obtained in the Barefoot Condition

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BACKGROUND
- Overuse lower extremity injuries, such as stress fracture, IT band syndrome and plantar fasciitis, are common in many active populations
- Improper load transfer during the stance phase of gait can cause injury to the forefoot and continue up the kinetic chain
- Plantar pressure measurements provide information on foot and ankle function during gait and weight bearing activity
- Abnormalities in these areas due to additional weight (military gear, sports equipment) or lack of muscular support may predispose an individual for injury

PURPOSE
- To establish if the addition of external load affects plantar pressure distribution in the barefoot condition
- To determine if isometric hip and ankle strength affects changes in plantar pressure distribution

SUBJECTS
Twenty-five physically active men (n=10) and women (n=15). Demographics shown in Table 1
- Physically active 3 days a week for a minimum of 30 minutes per day
- No current unresolved lower extremity injury
- No previous hip or ankle surgery
- Right leg dominant

EXPERIMENTAL DESIGN AND METHODS

INSTRUMENTATION
- Biodex System III Multi-joint System Pro
- Lafayette Instrument handheld dynamometer
- Novel emed®-x platform
- Dynamic plantar pressure

PROCEDURE
- Sidelying isometric ankle evertor strength and isometric hip abductor strength data was measured and recorded as percent of body weight (%BW)
- Plantar pressures in the barefoot condition were assessed using an emed®-x platform. Figure 1
  - Order of unloaded or loaded (10kg weighted vest) condition was determined by random assignment
  - Three-step approach at a self-selected pace for all trials
  - 5 trials with the right and left foot individually, until a total of 10 successful steps were recorded for both loaded and unloaded conditions

MAIN OUTCOME MEASURES
- Isometric ankle and hip strength (%BW)
- Averaged from 3 trials each
- Geometric plantar pressure variables (foot progression angle, subarch angle and arch index) were calculated within Novel Database Medical software package
- Average maximum force as a percent of body weight (MF%BW) and peak pressure (PP) for select regions of each foot as shown in Figure 2

STATISTICAL ANALYSIS
- All data were assessed for normality
- Changes in plantar pressure variables between an unloaded and loaded condition were assessed using a paired t-test or Wilcoxon signed-rank test
- To determine if there was a correlation between foot or hip strength and changes in plantar pressure, a Pearson Correlation Coefficient or Spearman's Rank Correlation Coefficients were used
- An alpha level of 0.05 was set a priori for all statistical analyses

RESULTS
- Average ankle evertor and hip abductor strength presented as percent body weight (%BW) is shown in Table 2
- Addition of external load significantly increased the following peak plantar pressure values: big toe, midfoot, lateral and medial hindfoot; the maximum force %BW of: metatarsal 1 – 4, total object, big toe, midfoot, 2nd toe, lateral and medial hindfoot; subarch angle; total contact area
- Significant negative correlations were found between changes with the addition of external load and right ankle strength as shown in Table 3
- No significant correlations were found with right hip strength or any left side strength variables

SUMMARY AND CONCLUSIONS
- Significant correlations suggest that increasing ankle evertor strength may offset increases in plantar pressure due to external load
- Early intervention utilizing an ankle strengthening program may help diminish the negative effects of carrying additional load and prevent future injury

Table 1. Demographics: Mean ± Standard Deviation

<table>
<thead>
<tr>
<th></th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>24.6 ± 4.8</td>
<td>171.0 ± 9.8</td>
<td>69.9 ± 11.9</td>
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<tr>
<td>Females</td>
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Table 2. Average Strength Values (%BW)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Ankle Evertor Strength (%BW)</th>
<th>Mean ± SD</th>
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<tbody>
<tr>
<td>Right Ankle Evertor</td>
<td>20.1 ± 4.6</td>
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<tr>
<td>Left Ankle Evertor</td>
<td>18.4 ± 3.6</td>
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<tr>
<td>Right Hip Abductor</td>
<td>139.5 ± 41.0</td>
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</tr>
<tr>
<td>Left Hip Abductor</td>
<td>138.1 ± 35.0</td>
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Table 3. Significant Right Foot Correlations

<table>
<thead>
<tr>
<th>emed Variable</th>
<th>Ankle Evertor Strength (%BW)</th>
<th>correlation coefficient</th>
<th>p-value</th>
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<tbody>
<tr>
<td>2nd Toe Maximum Force (%BW)</td>
<td>-.475</td>
<td>0.016</td>
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<tr>
<td>Total Object Contact Time (ms)</td>
<td>-.490</td>
<td>0.013</td>
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</tr>
<tr>
<td>Total Object Maximum Force (N)</td>
<td>-.499</td>
<td>0.011</td>
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