The Effect of Strength Shoes on Muscle Activity During Quiet Standing

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The goal of this work was to study the effect of Strength Shoes on the activity of leg and postural muscles to gain insight into the mechanisms by which the shoes may improve athletic performance. Surface EMG signals were obtained from the tibialis anterior, medial gastrocnemius, rectus femoris, biceps femoris, gluteus maximus, and erector spinae of 18 healthy athletic subjects. The subjects stood quietly while wearing either normal athletic shoes or Strength Shoes. EMG root mean square value was compared in each muscle using trimmed paired t-tests. Significant (p < .002) increases in EMG activity were found in the MG, TA, GM, and ES muscles when the subjects were wearing Strength Shoes as compared to normal shoes. These changes served to stiffen the ankle, counteracting the dorsiflexion moment created by the shoes, and to support an anterior leaning posture, which compensates for the anterior shift in center of pressure. No significant changes were detected in the activities of RF or BF muscles. Using Strength Shoes increased activity in the triceps surae complex and in other muscles that support the changes in postural requirements caused by the anterior shift in center of pressure.

Key Words: strength shoe, muscle, conditioning, plyometric training

Introduction

Strength® shoes are specially designed training shoes. Their basic design is that of an ordinary athletic shoe with a 4-cm platform from the forefoot to the midfoot (Figure 1). This prevents the wearer of the shoe from striking the ground with the heel during exercise, forcing the athlete to maintain a plantar flexion moment to keep his or her foot in a neutral flexion-extension angle. This results in elevated forces in the triceps surae muscles and is the basis for the plyometric training effect claimed by the manufacturer (Strength Footwear, Metairie, LA). The manufacturer maintains that this design "causes the calf muscles to support 100% of the body weight. This overload works the calf muscles in addition to the Achilles tendon." Use of the Strength Shoe program is promoted as an effective method for increasing speed, vertical jump, and calf girth. Studies regard-
ing the effectiveness of the shoes have yielded mixed results. One study suggested that these shoes are an effective tool to develop anaerobic power (Flarity et al., 1997), whereas another found a relatively high incidence of anterior tibial pain (shin splints) and no significant difference between jumping and sprinting performance after training with versus without the shoes (Cook et al., 1993). A third study by Porcarli et al. (1996) showed a tendency to improve sprinting and jumping by subjects training with Strength Shoes as well as a tendency to develop bigger calf muscles, although none of the differences were statistically significant.

The athletic community strives for ways to improve athletic performance by the use of various training methods and training devices. Rarely have the changes in muscle activity associated with these methods been considered with respect to their involvement in enhancing performance. Using these shoes certainly affects the biomechanics of motion and posture. Together with the training effect on muscle strength, there are compensatory activities in balance and posture muscles that need to counteract the change in ground reaction force distribution.

Given the contradictory results of previous studies, this study investigated the changes in postural muscle activity as a result of using Strength Shoes during quiet standing. Information on muscle activity may provide insight into some of the changes in posture required because of the use of these shoes.

Methods

Eighteen subjects (10 males, 8 females), all involved in recreational or college level sports, participated in this study. After obtaining informed consent according to institutional guidelines, the subjects were prepared for surface electromyographic recording. Their skin was cleansed and lightly abraded with an alcohol pad. Disposable Ag/AgCl surface electrodes of 1-cm diameter (Ferris, Burr Ridge, IL) were applied with a 2.5 cm
interelectrode distance over the bellies of the following muscles: tibialis anterior (TA), medial gastrocnemius (MG), rectus femoris (RF), biceps femoris (BF), gluteus maximus (GM), and erector spinae (ES) and oriented along the orientation of muscle fibers. The erector spinae electrodes were located at the L3-4 level, 4 cm lateral from the spinal processes. A reference electrode was placed over the lateral aspect of the iliac crest. The raw EMG signals were detected by a six channel amplifier (LSU Bioengineering Labs) with gain of 1000, common mode rejection ratio of 90 dB, and frequency pass-band between 6–500 Hz. These signals were then acquired by a 12 bit A/D board at a rate of 1000 samples per second and stored for further processing and analysis.

After the instruments were applied to the subjects and the presence of noise and cross-talk free signals was ascertained, the subjects were asked to stand quietly. Four seconds of EMG were recorded in each trial. After each trial, the collected signals were assessed for consistency. Because we were interested in the steady state muscle activity, trials in which the subject swayed in a visually obvious manner, or in which there were phasic bursts of EMG activity were discarded to reduce variability. Four trials were recorded, two wearing normal athletic shoes, and two wearing Strength Shoes. The sway exclusion criteria resulted in approximately five discarded trials. In those trials with Strength Shoes, subjects were instructed to stand on the platforms, not allowing the hindfoot to rest on the floor.

The root mean square (RMS) value of each recorded signal was calculated for each trial. The RMS value for each muscle under each condition was pooled (e.g., all TA RMS values with normal shoes). A paired, trimmed t test was performed on the resulting RMS values for each muscle to compare its activity while wearing normal versus Strength Shoes. This paired analysis compensated for the variability in EMG amplitude between subjects and muscles, in essence making each muscle in the normal shoe condition a within-subject control.

**Results**

Figure 2 shows two samples of EMG signals recorded from 1 subject, one with normal shoes and one with Strength Shoes. The activity in the MG is clearly elevated in the trial with Strength Shoes. Changes in the other muscles are more subtle: slight increases in the TA, ES, and GM.

The results of the statistical analysis of the pooled data are summarized in Table 1. In Strength Shoes, the mean ES RMS increased from 0.036 to 0.050 mV, in the GM from 0.015 to 0.035 mV, in the BF from 0.029 to 0.39 mV, in the MG from 0.044 to 0.15 mV, and in the TA from 0.011 to 0.041 mV. The mean RMS level in the RF decreased from 0.018 to 0.014 mV. The increases in activity in the ES, GM, MG, and TA were significant when the subjects wore Strength Shoes, whereas the activity in the BF was slightly higher but not statistically significant. The RF had a slight, non-significant decrease in its activity.

**Discussion**

The main objective of this study was to determine if changes in the activity of lower extremity and back muscles are affected by the use of Strength Shoes. The authors anticipated increased activity in the MG, as it and the other muscles in the triceps surae group are required to support body weight in order to keep the ankle in a neutral flexion angle. Less expected were the changes found in other muscles.
In order to understand the changes in muscle activities caused by the Strength Shoes, one must consider the biomechanical effects of having an anterior platform such as elevated heels and an anterior shift of the ground reaction force center of pressure. This shift in the center of pressure creates a posterior moment with respect to the center of gravity, affecting moments in all of the lower extremity joints.

The anterior shift in center of pressure creates a dorsiflexion moment around the ankle, for which the triceps surae must compensate. The more than three-fold average increase in the triceps surae activity is accompanied by a near four-fold increase in TA activity. If one considers agonist/antagonist interaction only in the scope of efficient movement, it is natural to think that an increase of triceps surae activity would be accompanied by a decrease in the TA. However, the role of antagonist muscles is also to help stabilize the joint (Solomonow et al., 1986); such a dramatic increase in posterior muscle activity necessitates a stabilizing force from the anterior musculature. Further, the fact that the heel is off the ground in these shoes requires further stabilization by the antagonist muscles, as the tibio-talar compression forces due to weight bearing are absent when the subject wears Strength Shoes.

The profound changes in hip and trunk muscle activity may be explained when one considers the effect of the Strength Shoe in terms of the anterior shift in ground reaction forces, which requires postural adjustments. In order to compensate, subjects tend to assume a forward leaning posture aimed at maintaining their body center of gravity.
Table 1 Summary of Statistics

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Normal shoe MAV (mV)</th>
<th>Strength Shoe MAV (mV)</th>
<th>T</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erector spinae</td>
<td>0.0355 ± 0.0355</td>
<td>0.0498 ± 0.0438</td>
<td>-3.68</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>0.0146 ± 0.0097</td>
<td>0.0353 ± 0.0438</td>
<td>-3.86</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Biceps femoris</td>
<td>0.0296 ± 0.0447</td>
<td>0.0391 ± 0.0170</td>
<td>-1.68</td>
<td>.1030</td>
</tr>
<tr>
<td>Rectus femoris</td>
<td>0.0178 ± 0.0234</td>
<td>0.0142 ± 0.0170</td>
<td>0.94</td>
<td>.3534</td>
</tr>
<tr>
<td>Medial gastrocnemius</td>
<td>0.0438 ± 0.1559</td>
<td>0.1474 ± 0.0957</td>
<td>-8.41</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Tibialis anterior</td>
<td>0.0111 ± 0.0058</td>
<td>0.0414 ± 0.0508</td>
<td>-3.53</td>
<td>.001*</td>
</tr>
</tbody>
</table>

* p < .05 (statistically significant differences between normal and Strength Shoe trials).

in equilibrium with the ground reaction force. This posture also moves the trunk's center of gravity anteriorly with respect to the hip joint, therefore requiring more hip and back extensor moments to maintain the posture.

It was interesting that only minimal, nonsignificant changes were found in the hamstrings and quadriceps muscle groups. It was anticipated that the knee extension moment caused by the Strength Shoe platform would decrease the quadriceps activity required to maintain the knee extended. The very small initial RF activity reflects that, with normal shoes, the subjects were standing with their knees locked in full extension, requiring little knee extensor moment maintenance. Similarly, when a subject wore the Strength Shoes, the knee extensor activity was minimal, because of the added extension moment provided by the shoe platform. The difference between these two minimal activation levels is not statistically, and probably not physiologically, significant. Similarly, the nonsignificant increase in hamstrings activity reflects that, in both conditions, the knee is essentially locked in full extension and that the hip extension moment necessary to maintain posture is provided by the primary hip extensors.

In a previous study, Cook et al. found a high (2 in 6) incidence of anterior tibial pain in subjects using Strength Shoes. These patients were reported to have had "shin splints," but clinical diagnoses for these instances of pain were not reported. Given the large increase in baseline TA activity, and its largely fast-twitch, fatigueable fiber composition, one may speculate that TA fatigue may contribute to anterior tibial pain in athletes training with Strength Shoes. This may resolve with rest and a gradual return to activity, in order to give the TA time for remodeling and fiber conversion, in particular those motor units that would not be tonically recruited when wearing normal shoes, but which are called upon to stabilize the ankle when Strength Shoes are worn.

It is difficult to speculate, based on static muscle activity, whether these effects will translate to the performance of sports activities. One may consider that preferential training of muscles results in their increased activity during other tasks (Solomonow et al., 1989). An enhancement of hip and trunk muscle activity could have implications in improving athletic performance. When one considers sprinting, a common and important task in many athletic events, the hip and trunk muscles play a key role. Enhanced hip muscle activity could lead to more forceful and possibly faster cycling of the legs, which would increase the angular velocity produced at the hip. Enhanced trunk muscle
activity could provide an athlete with greater postural stability. This could have a beneficial effect on being able to keep the center of gravity in a more optimal position when performing a sport skill.

In summary, we conclude that Strength Shoes modify the activity levels of muscles beyond the lower leg in response to changing joint and postural stability demands. It is suggested that the reports of anterior tibial pain may be related to muscle fatigue in the tibialis anterior muscle, which takes on a vastly increased role in stabilizing the ankle. Further studies will be aimed at the long-term modifications in muscle activity and kinematics effected by this training tool.

References


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