Different Foot Positioning During Calf Training to Induce Portion-Specific Gastrocnemius Muscle Hypertrophy

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1Metabolism, Nutrition, and Exercise Laboratory, Physical Education and Sport Center, Londrina State University, Londrina, Brazil; 2Department of Physical Education, Federal University of Paraná, Curitiba, Brazil; and 3Department of Physical Education, Federal University of Paraiba, João Pessoa, Brazil

Abstract
Nunes, JP, Costa, BDV, Kassiano, W, Kunevaliki, G, Castro-e-Souza, P, Rodacki, ALF, Fortes, LS, and Cyrino, ES. Different foot positioning during calf training to induce portion-specific gastrocnemius muscle hypertrophy. J Strength Cond Res 34(8): 2347–2351, 2020—The aim of this study was to compare the changes in gastrocnemius muscle thickness (MT) between conditions such as which foot was pointed outward (FPO), foot was pointed inward (FPI), or foot was pointed forward (FPF). Twenty-two young men (23 ± 4 years) were selected and performed a whole-body resistance training program 3 times per week for 9 weeks, with differences in the exercise specific for calves. The calf-raise exercise was performed unilaterally, in a pin-loaded seated horizontal leg-press machine, in 3 sets of 20–25 repetitions for training weeks 1–3 and 4 sets for weeks 4–9. Each subject’s leg was randomly assigned for 1 of the 3 groups according to the foot position: FPO, FPI, and FPF. Measurements with a B-mode ultrasound were performed to assess changes in MT of medial and lateral gastrocnemius heads. After the training period, there were observed increases in MT of both medial (FPO = 8.4%, FPI = 3.8%, and FPF = 5.8%) and lateral (FPO = 5.5%, FPI = 9.1%, and FPF = 6.4%) gastrocnemius heads, and significant differences for magnitude of the gains were observed between FPO and FPI conditions (p < 0.05). Positioning FPO potentiated the increases in MT of the medial gastrocnemius head, whereas FPI provided greater gains for the lateral gastrocnemius head. Our results suggest that head-specific muscle hypertrophy may be obtained selectively for gastrocnemius after 9 weeks of calf training in young male adults.

Key Words: triceps surae, ankle, plantar flexion, muscle growth, muscle architecture, nonuniform muscle hypertrophy

Introduction
Muscle hypertrophy is one of the main outcomes that may be obtained with repeated bouts of resistance exercise. Although region-specific hypertrophy is particularly aimed by bodybuilders (1), muscle growth does not occur in the same magnitude in all muscle regions (1,16,20,31), irrespective of the training status (i.e., trained or untrained). Varying exercise choice seems to be a viable strategy for potentiating overall muscle gains in response to a resistance-training program (8). In addition, performing the same exercise under different joint positions (which some may consider different exercises as well) has been proposed for obtaining region-specific muscle growth (1,6,7,20).

The triceps surae muscle group consists of the soleus and gastrocnemius lateral and medial heads. The soleus is a single-joint plantar flexor, and gastrocnemii are multijoint muscles that cross the knee and the ankle. If varying foot position induces portion-specific hypertrophy of the triceps surae (20), performing different exercises may contribute to its development. This could be particularly important for the gastrocnemius because it is deemed as difficult to respond to hypertrophy stimuli (1,28). Although performing plantar flexion with the knee flexed may induce greater hypertrophy in the soleus than when the exercise is executed with the knee extended (18,20), the position of the feet seems to influence the recruitment of the gastrocnemius muscles (2,14,18,19). For instance, Marcorti et al. (14) observed a greater activation of the medial head when the feet were pointed outward and a greater activation of the lateral head with feet pointed inward. However, these findings are not universal (18).

Given the wide gap between acute muscular activation and muscle hypertrophy (29,30), long-term experimental studies are needed to determine whether the foot position influences the training-induced effect on gastrocnemius muscle growth. Therefore, this study was designed to compare the changes in gastrocnemius muscle thickness (MT) when the calf-raise exercise was performed with the foot pointed outward (FPO), foot pointed inward (FPI), or foot pointed forward (FPF) after 9 weeks of progressive resistance training in young men. It was hypothesized that the increase in the MT of the medial gastrocnemius would be greater for the FPO condition, whereas the FPI condition would be better for improving the lateral head gastrocnemius. Also, it was expected that the FPO condition resulted in intermediary growth because it may elicit intermediate activation.

Methods
Experimental Approach to the Problem
This study is part of a larger research project designed to analyze the effects of whole-body resistance-training protocols in young
male adults. The current investigation was executed over a period of 11 weeks. Weeks 1 and 11 were used for ultrasound measurements, whereas the progressive training program was performed for 9 weeks (weeks 2–10). Subjects performed 7 exercises, 6 of which for the major muscle groups (e.g., bench press, lat pull-down, triceps pushdown, biceps curl, leg press, and leg curl) in addition to the unilateral calf-raise exercise. Subjects were assessed before and after intervention for measures of gastrocnemius MT. Eight subjects were randomly chosen (random.org) and were evaluated on 2 days of week 1 (separated by 72 hours) to determine the reliability of the MT measurements.

Subjects
Recruitment was conducted through social media and home delivery of flyers in the university area. Interested subjects completed detailed health history and physical activity questionnaires and were subsequently admitted if they met the following inclusion criteria: 18–35 years of age; male; free from cardiac, orthopedic, or musculoskeletal disorders that could impede exercise practice; not consume drug or supplement ergogenic aids; not be involved in the practice of resistance training over the 4 months before the start of the study, but should have a training experience of at least 6 months. From the 52 volunteers, 29 met the criteria, were evaluated on arrival at the laboratory on measurement days, subjects verified that they had been fasting for 8 hours and had not consumed drug or supplement ergogenic aids; not be involved in the practice of resistance training over the 4 months before the start of the study. This investigation was conducted in accordance with the Declaration of Helsinki and was approved by the Federal University of Pernambuco Ethics Committee.

Procedures
**Gastrocnemius Muscle Thickness Measurement.** Measures of gastrocnemius MT were obtained at weeks 1 (before training) and 11 (after training) using a B-mode ultrasound (Logiq book; GE Healthcare, Madison, WI), with a 7.5-MHz linear probe (8L-RS; GE Healthcare). All procedures were performed in the morning by the same experimenters in pre-training and post-training. On arrival at the laboratory on measurement days, subjects verbally certified that they had been fasting for 8 hours and had not performed vigorous exercise for the previous 48 hours. After that, lines were drawn on the subjects’ skin with a dermatographic pen on the sites of which images were taken. Ultrasound measurements started after subjects were lying down in the prone position for 10 minutes. Image acquisitions of the lateral gastrocnemius were taken at the proximal third between the lateral epicondyle of the femur and the lateral malleolus of the fibula, whereas measurements of the medial head were taken with the probe positioned in the thickest and more laterally prominent site of the lower leg (from a posteroanterior view). A generous quantity of water-soluble transmission gel was applied over the skin of the muscle being assessed, with caution not to depress the skin. Images were acquired with the probe placed perpendicular to the tissue interface and were recorded at 25 Hz, with a field of view of 60–100 mm depth. Two experimenters participated in measurement procedures so that one handled the probe (and drew the lines on the skin as well), and the other was responsible for freezing the images (once the first considered that the quality was satisfactory). The MT of both gastrocnemius heads was defined as the distance between the superficial and deep aponeuroses. The images obtained before and after training were overlapped (PhotoFiltre Studio; v. X10.13.1. Houilles, France) to visually check if sites where MT would be estimated were the same (1 image had its opacity ~40–60% reduced). The MT length was determined using the ImageJ software (v. 1.50; NIH, Bethesda, MD). Values of coefficient of variation, intraclass correlation coefficient, standard error of measurement, and minimum detectable difference were of 2.8%, 0.97 (ranging from 0.90 to 0.99), 0.052 cm, and 0.103 cm for the medial gastrocnemius MT assessment and were of 3.4%, 0.98 (ranging from 0.93 to 0.99), 0.059 cm, and 0.117 cm for the lateral gastrocnemius, respectively (9).

**Calf Training.** The supervised resistance-training program was performed 3 times per week (Mondays, Wednesdays, and Fridays) in the afternoon period for 9 weeks. Calf-raise exercises were performed unilaterally, in a pin-loaded seated horizontal leg-press machine (Ipiranga; Fitness Line, Presidente Prudente, Brazil) in 3 sets of 20–25 repetitions for training weeks 1–3 and increased to 4 sets for weeks 4–9. Subjects were instructed to perform 1 set with 1 leg, to rest a few seconds enough to self-adjust the body posture, and then to perform 1 set with the other leg. The rest period was 60–90 seconds after finishing 1 set for both legs. Subjects were instructed to alternate the leg to begin the calf-raise exercises to minimize potential effects of residual fatigue. Calf-raise exercises were performed in the maximum range of motion, with the knee extended, in a tempo of 1:1.2 seconds (concentric, concentric peak, and eccentric phases, respectively), and subjects were cued to “squeeze the muscle” on each repetition, mainly during the concentric peak phase (26). When near to momentary muscular failure (last ~3–5 repetitions), subjects were released to carry out the movement at a velocity that was capable of, but maintaining the execution of the 1-second peak contraction phase, focusing on “squeezing” the targeted muscle portion. The foot was positioned on the platform supported by metatarsals (14). For the FPO or FPI condition, subjects positioned their foot at 45° externally or internally rotated (including both ankle and femur rotation, as necessary), respectively, or when this amplitude was not achieved, at the maximum angle according to the subject’s articular mobility. For the FPF condition, the foot was positioned forward-pointing, with no lateral or medial rotation. Duct tape was used in the leg-press platform as a guide to be followed (14). The training load was progressively increased each week by 5–10%, according to the number of repetitions performed during each training session to ensure that the subjects kept performing the sets to (or very near to) failure in the established repetition zone (5).

**Statistical Analyses** Normality was checked by Shapiro-Wilk’s test. Levene’s test was used to analyze the homogeneity of variances. These assumed
differences on the effects of different foot positions (FPO vs. FPI vs. FPF) on gastrocnemius muscle hypertrophy were examined with analysis of covariance of the raw difference between pre-intervention and postintervention measures with baseline values as a covariate to eliminate any possible influence of initial score variances on outcomes. Interpretation of data was based on 95% confidence intervals (CIs) of the change score (e.g., when 95% CI of the raw delta did not overlap the 0, there was a difference between the baseline score). The p values for group comparisons were also presented. When the F-ratio was significant, Bonferroni’s post hoc test was used to identify the differences between pre-training and post-training raw data. A p ≤ 0.05 value was accepted as statistically significant. The effect size (ES) was calculated as post-training mean minus pre-training mean, divided by pooled pre-training SD (3). An ES of 0.00–0.19 was considered as trivial, 0.20–0.49 was considered as small, 0.50–0.79 was considered as moderate, and ≥0.80 was considered as large (3). The data were expressed as mean, SD, and 95% CIs. The data were stored and analyzed using SPSS software, v. 23.0 (IBM Corp., Armonk, NY).

Results

Table 1 displays the values of gastrocnemius MT before and after training. After the training period, there were observed increases of small-to-moderate magnitude on MT of the medial and lateral gastrocnemius for FPO, FPI, and FPF conditions. A significant effect of the condition was observed for the increases in the medial gastrocnemius (F = 4.048; p = 0.025), in which the Bonferroni post hoc test revealed a significant difference occurred only between FPO and FPI conditions, with a greater increase for the FPO condition (p = 0.021). Similarly, a significant effect of the condition was observed for the increases in the lateral gastrocnemius (F = 4.259; p = 0.021), with a significant difference only between FPO and FPI conditions, favoring the FPO condition (p = 0.020).

Figure 1 shows the relative changes on MT of both medial (FPO = 8.4%; FPI = 3.8%; and FPF = 5.8%) and lateral (FPO = 5.5%; FPI = 9.1%; and FPF = 6.4%) heads of the gastrocnemius.

Discussion

The main finding of this study was that the foot position can influence the magnitude of increases in MT of the gastrocnemius, in which the FPO induced greater gains on the medial head, whereas the FPI potentiated the lateral head muscle growth. Moreover, the FPF condition resulted in similar relative gains for both heads and did not present significant differences in comparison with FPO and FPI conditions. This indicates that changing the foot position can potentiate hypertrophy of a head of the gastrocnemius without impairing the increase of the opposite head significantly. The initial hypotheses were confirmed, and, based on the findings, portion-specific calf muscle hypertrophy is related to the ability to exercise muscle portions selectively, especially when the foot is pointed outward or inward.

The relationship between muscular activation and hypertrophy is somewhat argued as complex and uncertain (29,30). However, the main point that supports such a line of reasoning is that, when comparing training intensities, high loads and low repetitions vs. low loads and high repetitions exhibit different muscular activations (evaluated by surface electromyography [sEMG]), although both training protocols seem to induce similar muscle growth (24,29,30). A possible justification for this may lie in the method used, i.e., sEMG, which not necessarily correspond to the mechanical stress experienced by the muscle fibers (15,30). Indeed, a previous study showed that when measuring muscular activation using fiber type-specific glycogen depletion obtained by essays of muscle biopsies, high and low load performed until failure elicited similar results (15). Regardless, the proposed poor relationship between sEMG and hypertrophy responses (29,30), however, possibly cannot be generalized to experimental designs

Table 1

Table 1: Training effect on medial and lateral gastrocnemius muscle thickness (cm).†‡

<table>
<thead>
<tr>
<th></th>
<th>FPO</th>
<th>FPI</th>
<th>FPF</th>
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<tbody>
<tr>
<td>Medial gastrocnemius MT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>1.99 ± 0.26</td>
<td>2.01 ± 0.26</td>
<td>2.02 ± 0.19</td>
</tr>
<tr>
<td>Post</td>
<td>2.15 ± 0.27‡</td>
<td>2.09 ± 0.27§</td>
<td>2.14 ± 0.22‡</td>
</tr>
<tr>
<td>Meandiff</td>
<td>0.16 (0.12–0.21)</td>
<td>0.08 (0.03–0.12)</td>
<td>0.12 (0.07–0.17)</td>
</tr>
<tr>
<td>ES</td>
<td>0.69</td>
<td>0.33</td>
<td>0.50</td>
</tr>
<tr>
<td>Lateral gastrocnemius MT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>2.07 ± 0.32</td>
<td>2.04 ± 0.35</td>
<td>2.05 ± 0.28</td>
</tr>
<tr>
<td>Post</td>
<td>2.18 ± 0.32‡</td>
<td>2.22 ± 0.37§</td>
<td>2.18 ± 0.31‡</td>
</tr>
<tr>
<td>Meandiff</td>
<td>0.11 (0.08–0.15)</td>
<td>0.18 (0.15–0.22)</td>
<td>0.13 (0.09–0.17)</td>
</tr>
<tr>
<td>ES</td>
<td>0.35</td>
<td>0.58</td>
<td>0.42</td>
</tr>
</tbody>
</table>

†FPO = foot pointed outward (n = 16); FPI = foot pointed inward (n = 16); FPF = foot pointed forward (n = 12); MT = muscle thickness; ES = effect size.
‡Pre-training and post-training data are presented as mean and SD, whereas meandiff as mean and 95% confidence intervals.
§p < 0.05 vs. baseline.

Figure 1. Percentage changes from pre-training to post-training period for medial and lateral gastrocnemius muscle thickness. FPO = foot pointed outward (n = 16); FPI = foot pointed inward (n = 16); and FPF = foot pointed forward (n = 12). †p < 0.05 difference between FPO and FPI conditions.

The horizontal lines represent mean and 95% confidence intervals, whereas each circle represents a leg.
comparing different muscles or regions of a same muscle after the performance of an exercise. That is, a greater activation of a given muscle compared with the other involved ones during an exercise seems to indicate at least that this muscle or portion is more likely to be hypertrophied. It is worthy to note that this study did not perform any muscular activation analysis, and these comparisons and inferences are based on sEMG data reported elsewhere (14,19).

Other studies have also shown that differences between the magnitude of intra--muscle-group and inter--muscle-group hypertrophy may be related to differences in muscular activation, such as greater hypertrophy of the pectoral major compared with the triceps brachii after chest-press training (17) and corresponding findings in studies on muscular activation (22,27), selective hypertrophy and activation of the heads of the quadriceps femoris (7) and the triceps brachii (31), and greater hypertrophy and activation of the quadriceps femoris compared with the hamstrings after squat training (4,11). Nonetheless, controversies exist (1,6,7), and there are many determinants that dictate muscle hypertrophy so that muscular activation should not be considered a surrogate marker for muscle growth.

The gastrocnemius is a single muscle unit but is a bipennate muscle. It may be possible to increase the recruitment of a specific portion selectively once it has 2 compartments and one has its own innervations (1,14,19). Thus, the strategy used to focus on “squeezing” the muscles during each repetition might have also contributed to current findings because this tends to increase the activation of the targeted muscles (21,26,27). Moreover, it can be speculated that, during the calf-raise exercises, FPO and FPI conditions caused greater specific stretching of the medial and lateral heads of the gastrocnemius, respectively. Because of neuromuscular compartmentalization, each gastrocnemius head has its own moment arms and length-tension curves during ankle movements (10,12,13). Therefore, based on the length-tension relationship, when each head was exercised in a more elongated condition, determined by the foot position, the activation of greater muscle fibers was necessary to produce torque, then, under a greater overload that ultimately caused a greater muscle growth (10). That is, the medial gastrocnemius was at a disadvantage in the FPO condition, as well as the lateral gastrocnemius in the FPI condition; thus, in these conditions, each portion should be more forced to perform the exercise (14). Previous findings have indicated that the gastrocnemius architecture also is modulated by ankle inversion and eversion (12). Although the present investigation did not have measured any of these factors, when the gastrocnemius is stretched during the calf-raise exercise, in the FPO condition, the ankle makes a slight inversion, whereas in the FPI condition, the ankle makes an eversion. With ankle inversion or eversion, the specific activation of the gastrocnemius portions might have increased. This, in turn, might have helped potentiating the stimuli for muscle growth, which is in accordance with the present findings.

The average increase in MT observed herein was of 6.5% (ES = 0.47). Although the triceps surae has been suggested as difficult to hypertrophy (1,28), this result is equivalent to gains presented in recent meta-analyses for other muscle groups when trained with volumes similar to this study (23,25). However, the training program included other exercises for the lower body, and this, despite having a high relation to practical settings, might have clouded the true magnitude of the effect of calf training on gastrocnemius MT. This study has other concerns to be addressed. First, the use of ultrasound to assess changes in the muscle size lacks the precision and sensitivity to detect subtle changes compared with direct imaging modalities, such as MRI. Also, although subjects were instructed to perform the movement at same execution velocity and range of motion, no device was used to monitor these factors strictly. Moreover, dietary intake and daily physical activity levels were not assessed, and whether these factors could exert some influence on the adaptations remains uncertain. Finally, this experiment was performed in young adult men, and results cannot be generalized to other populations of different sex, age, or training status.

In conclusion, the results of this study indicate that head-specific muscle hypertrophy may be obtained for gastrocnemius after 9 weeks of calf training in young male adults. Positioning FPO may induce greater gains in MT of the medial gastrocnemius head, whereas positioning FPI seems to be better suited for increasing the lateral gastrocnemius head.

### Practical Applications

Coaches and practitioners can choose the position of the foot if the training aim is to induce hypertrophy of the different portions of the gastrocnemius selectively. From the results of our study, pointing foot straight forward may be the ideal approach when the aim is to induce proportional improvement on both heads of the gastrocnemius, whereas pointing foot outward or inward may induce selective muscle growth, thus correcting muscle asymmetries and improving the aesthetic shape of the lower leg. Combining the FPO and FPI could maximize the gains on both heads, although future studies are needed to test such a hypothesis.

### Acknowledgments

The authors thank all subjects for their engagement in the study, the Coordination of Improvement of Higher Education Personnel (CAPES/Brazil) for the scholarship conferred to J.P. Nunes, B.D.V. Costa, W. Kassiano, G. Kunevaliki, and P. Castro-e-Souza (master), and the National Council of Technological and Scientific Development (CNPq/Brazil) for the grants conceded to A.L.F. Rodacki, L.S. Fortes, and E.S. Cyrino. The authors declare that they have no conflict of interest regarding the publication of this paper.

### References


