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DIAGNOSTIC METHODS: Original Research

# A comparison of EMG output of four lower extremity muscles during selected yoga postures

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ABSTRACT

The purpose of this study was to use surface electromyography (EMG) analysis to examine the muscle activation of the anterior tibialis (TA), gastrocnemius (GA), rectus femoris (RF) and biceps femoris (BF) muscles during several yoga poses: tree pose (Vrksashana), half moon pose (Ardha Chandrasana) and warrior III (Virabadrasana) when compared to a rest pose (mountain pose). Ten healthy females with more than 3 months of continuous yoga experience who practiced at least 1.5 h per week were recruited. EMG activity was recorded from the aforementioned muscles during mountain pose ("rest") for 30 s, three times. Subjects then performed the following yoga poses in a randomized sequence while surface EMG activity was recorded: tree pose, half-moon, and warrior III. Each pose was held for 20s to 30 s and performed three times. EMG data were band pass filtered and the root mean square (RMS) was obtained. The peak RMS of each of the resting trials was obtained and averaged to produce an average peak resting RMS value. The study revealed significantly greater EMG activity in TA and GA in all three poses when compared to BF and RF. BF produced greater EMG activity than RF in warrior III. In conclusion, single limb yoga poses require increased use of the ankle musculature when compared to thigh musculature.



## 1. Introduction

Healthcare practitioners throughout the United States continue to recommend yoga to improve emotional and physical well-being in their patients (Kelley et al., 2014). Yoga is a unique form of exercise used to improve health and fitness by incorporating the mind, body and spirit. Reported benefits of yoga include increased circulation, improved respiration, improved cardiac function, improved mental well being and focus, increased flexibility and increased muscle strength (Kelley et al., 2014). Although studies exist examining the effects of yoga, a paucity of literature exists using surface electromyography (EMG) to quantify muscle output during yoga poses (asana). However, EMG has been used to quantify muscle activity during other types of exercise.

Extensive research exists investigating various rehabilitation exercises using surface EMG. Ayotte et al. (2007) used EMG data to analyze multiple lower extremity muscles during five unilateral weight bearing exercises. In that study, twenty-three "physically active subjects" performed 5 exercises (wall squat, mini-squat, forward step up, lateral step up, and retro step up). Subjects performed a warm up and were able to practice each exercise prior to starting. Maximal voluntary isometric contraction (MVIC) data were collected, followed by a 5-min rest before exercise testing began. The average of this data was calculated and the percent MVIC was determined. The authors found that for all 4 muscles, there were statistically significant differences in the mean EMG signal amplitude across the 5 exercises (Ayotte et al., 2007). This information may be applied in a clinical setting when prescribing unilateral WB exercises to target specific lower extremity muscles (Ayotte et al., 2007). The protocol used by Ayotte et al. (2007) compliments the protocol used in this study, and the authors support the need for further research regarding surface EMG of muscle activity in specific exercises. Rather than use MVIC, other authors have used gait as a baseline measurement to compare muscular work during yoga poses.

Wang et al. (2013) investigated the physical demands associated with seven standing asana. In this case, surface EMG output of the gluteus medius, hamstrings, vastus lateralis and gastrocnemius were analyzed. The EMG activity recorded during the poses was compared to EMG output during gait at a self-selected walking speed. The authors concluded that the four muscles analyzed demonstrated an increase in activity during certain asana when

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compared to walking. Salem et al. (2013) had similar results when comparing EMG activity of the gluteus medius, hamstrings, vastus lateralis, gastrocnemius, rectus abdominis and erector spinae muscles of the subject's dominant limb during 9 asana. The authors normalized the EMG output in each pose to the EMG data that resulted from walking. Researchers concluded that each pose elicited different muscle activity at the hip, knee and ankle (Salem et al., 2013).

Ni et al. (2014) evaluated how muscle utilization patterns vary based on skill level of the practitioners. There were 36 yoga practitioners with at least 3 months of yoga practice experience. Participants fell into 1 of 3 categories, novice, advanced, or yoga instructor. These authors concluded that the 11 different poses examined, elicited different muscle activity in all participants. Authors also noted that the activation pattern of the muscles varied, based on the skill level of the yogi (Ni et al., 2014). The conclusions from this study reveal that there is a need to use the skill level of the participants for inclusion/exclusion purposes. Ni et al. (2014) further conclude that certain poses can be used to target specific groups of muscles. Further research into yoga will allow healthcare professionals to devise a practice specifically designed to suit the practitioner's needs.

Based on the previous literature, the magnitude of EMG output for various muscles varies depending on the pose or activity being performed (Ayotte et al., 2007; Wang et al., 2013; Salem et al., 2013; Ni et al., 2014). Due to the large variation observed in the multiple EMG studies, further EMG research is needed regarding specific yoga poses. The prior research also reveals a shift from normalizing EMG data to an MVIC (Norcross et al., 2010) (due to its unreliability) to the use of a more reliable variable, such as walking or quiet standing (Salem et al., 2013). Therefore, for the current study, a static activity (quiet stance, or mountain pose), was used to normalize data. The purpose of this study was to assess the EMG output of four lower extremity muscles, rectus femoris, biceps femoris, tibialis anterior, and gastrocnemius of experienced yoga practitioners during three single limb poses (half moon pose, warrior III and tree pose) compared to quiet standing (mountain pose).

## 2. Materials and methods

### 2.1. Participants

The Human Experimentation Committee/Subject Review Board (HEC/IRB) at Quinnipiac University granted approval for the experiment. Ten healthy female subjects, with a mean age of 23.9 years were recruited (see Table 1). Potential participants were recruited through emails, word of mouth and Facebook posts delivered to local yoga instructors, Quinnipiac University faculty, staff and students and other known yoga practitioners. Inclusion criteria included being experienced yoga practitioners aged 18–55.

**Table 1**
Participant demographics.

| # | Age | Years of Experience | Current practice (hrs/week) | Height |
|---|---|---|---|---|
| 1 | 23 | 5 | 3 | 5′ 2″ |
| 2 | 23 | 5 | 3 | 5′ 5″ |
| 3 | 24 | 5 | 4 | 5′ 5″ |
| 4 | 23 | 5 | 3 | 5′ 2″ |
| 5 | 23 | 1 | 1.5 | 5′ 1″ |
| 6 | 22 | 3 | 2 | 5′ 3″ |
| 7 | 25 | 1 | 2 | 5′ 3″ |
| 8 | 24 | 5 | 1.5 | 5′ 1″ |
| 9 | 27 | 1 | 2 | 5′ 3″ |
| 10 | 25 | 8 | 2 | 5′ 5″ |
| **Mean** | **23.9** | **3.9** | **2.4** | **5′ 3”** |

Experience was defined as: at least 3 months of continuous yoga experience with a minimum of 1.5 h of practice per week (Ni et al., 2014). Exclusion criteria included absence of any of the inclusion criteria, history of neurologic pathology, orthopedic surgery on either lower extremity within the last three years, and any lower extremity or low back pain. Prior to participating in the study, subjects were given a brief overview of the study and were educated on the potential risks and benefits of participating. Subjects then signed an informed consent form. Subjects were also told they could drop out of the study at any time without consequences.

### 2.2. Procedure

Each subject participated in a 45-min single data collection session at the Quinnipiac University Motion Analysis Lab. Subjects read and signed the informed consent form before proceeding with participation. Subjects were asked which their dominant leg was, and this leg was used as the stance leg for all poses.

The skin was scrubbed with 76% isopropyl alcohol until erythema was present, and disposable electrodes were placed over the bellies of the following muscles: Tibialis Anterior (TA), Gastrocnemius (GA), Rectus Femoris (RF), and Biceps Femoris (BF). Electrode placement was determined by the SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) protocol. One ground electrode was placed on the medial tibial condyle of the testing leg. Researchers confirmed correct EMG placement by placing a peripheral nerve stimulator on the electrodes and noting a twitch contraction of the muscle. Electrodes were then secured by pre-wrap, medical tape and CoFlexR Bandage to prevent movement during asana. Leads were attached to a battery operated 16-channel transmitter.

Baseline EMG data were collected during mountain pose (tadasana), or quiet standing (Wang et al., 2013) via a single-ended amplifier with common mode rejection ratio (CMRR) of 130 db. Subjects wore a battery operated 16-channel transmitter to transfer the EMG signal to a receiver where the data were further amplified (2 times for a total gain of 2000), The subject was instructed to stand in anatomical position (mountain pose), legs shoulder width apart, arms supinated and abducted to 30°. EMG data were recorded for 30 s, three times. The subjects then performed half moon pose (ardha chandrasana), tree pose (vrksasana), and warrior III pose (virabhadrasana III). The order of the poses was randomized, and each pose was explained to the subject in detail based on standard language (www.yogabasics.com). EMG data were recorded for all poses and performed for a minimum of 20 s, three times, with a 60-s break in between to prevent fatigue. Data collection began once the subject reported that they were set in the pose.

### 2.3. Data processing

The raw EMG data were band pass filtered using a 4th order Butterworth filter with cutoff frequencies of 10 and 500 Hz. The root mean square (RMS) of the filtered signal was obtained using a 250 ms window. The peak RMS of each of the mountain pose trials was obtained and averaged to produce an average peak resting RMS value. The RMS data of tree, warrior III and half moon pose trials were then divided by the average peak resting RMS value and multiplied by 100 to normalize the pose RMS data to the resting trials. The average normalized EMG of the pose trials for the middle 10 s of the trial was then obtained for each trial of each subject.

### 2.4. Statistical analysis

A linear mixed model, with random intercepts for subject and for trials nested within subject, and a fixed effect for muscle group was performed to determine if muscle output differed based upon pose. Normalized EMG data (using the RMS) were used for all statistical analysis. A significant factor effect for muscle was followed by Bonferroni post-hoc paired comparisons between muscle groups. The models were run separately for each of the poses. A preset $\alpha$ was set at $p < .05$ and analyses were performed using SPSS v24.

## 3. Results

During warrior III pose, TA, BF and GA each demonstrated significantly more EMG output when compared to RF ($p < .000$) (See Fig. 1). There were no other statistically significant differences among TA, BF and GA during warrior III pose.

Similar to the warrior III pose, TA and GA had significantly greater EMG activity when compared to RF during half moon pose ($p < .000$). (See Fig. 2). TA and GA also showed a significantly greater amount of EMG activity than BF ($p < .000$). BF did not show a significantly different amount of EMG activity when compared to RF in the half moon pose.

Finally, during the tree pose, TA and GA showed significantly greater EMG activity over RF ($p < .000$), and BF ($p < .000$) (See Fig. 3). However, there was no statistically significant difference between RF and BF.

## 4. Discussion

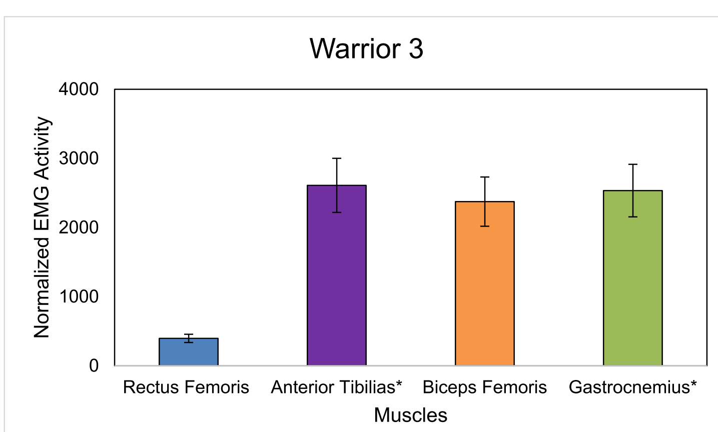
The purpose of this study was to use surface EMG to examine the muscle activation of the anterior tibialis, gastrocnemius, rectus femoris, and biceps femoris muscles during three yoga poses: tree pose (Vrksashana), half moon pose (Ardha Chandrasana) and warrior III (Virabadrasana) when compared to a rest pose (mountain pose). The authors found that overall, the TA and GA muscles were more active in all of the poses when compared to the RF and BF muscles.

MVIC is a commonly used method to normalize the results of EMG data to compare muscle activity among poses and/or subjects (Norcross et al., 2010). However, there have been some recent claims that MVIC is unreliable, as there is no true way to identify if the subject is recruiting all of their muscle fibers and giving their maximum effort (Norcross et al., 2010). This limitation was eliminated in the current study, as EMG activity was normalized to quiet standing (mountain pose). Instead of comparing EMG data to a "maximum" output, the authors normalized the data to an assumed minimum.

The results of this study revealed that muscle performance differs between different single limb yoga poses. TA and GA had significantly greater EMG activity when compared to RF during both half moon ($p < .000$) and tree pose ($p = .000$). Therefore, it is evident that the ankle musculature is dominant in single limb support activities. This use of ankle musculature may indicate that subjects utilized an ankle strategy throughout each pose.

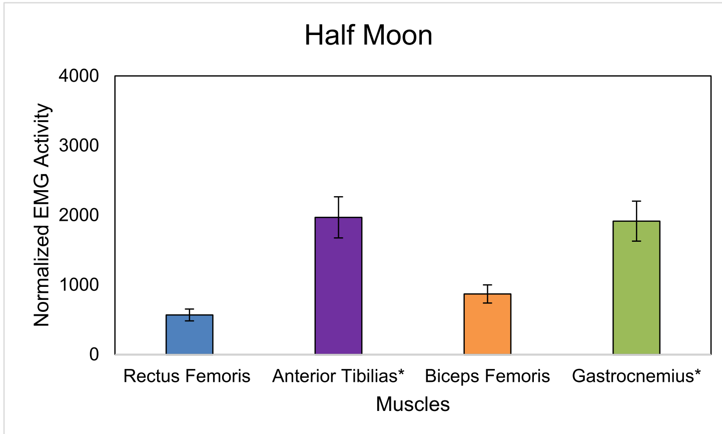
The ankle strategy restores the center of mass (COM) to a position of stability through body movement at the ankle joints. When balance is lost in an anterior direction in quiet standing, the gastrocnemius activates to produce a plantar flexion torque that is able to slow and reverse the body's forward motion. This dominant action of the GA is followed by activation of the hamstrings and paraspinal muscles to maintain the hips and knee in an extended position (Neumann, 2009). Without the synergistic response of the hamstrings and paraspinals, the activation of the GA would cause the COM to rapidly move forward, possibly resulting in trunk flexion. When a person falls backward from quiet standing, the muscle activity is different. The anterior tibialis fires initially and creates a dorsiflexion torque, followed by activation of the quadriceps and abdominal muscles (Shumway-Cook and Woollacott, 2012). It is clear that in all three poses, the GA and TA were activated more than RF and BF secondary to the dramatic anterior displacement of the subject's COM. All participants utilized their ankle strategy to stabilize themselves in each of the single limb poses. When examining the amount of average EMG output, warrior III clearly elicits greater EMG output at the ankle when compared to tree and half moon. After considering the components of the ankle strategy, it is clear that this increased ankle output is due to the anterior displacement of the subject's center of mass in warrior III when compared to tree pose or half moon (where 9 out of 10 subjects used a yoga block for support).

Warrior III also differed slightly in that biceps femoris demonstrated significantly more EMG output when compared to RF ($p < .000$). This increase in BF output might be explained by the large anterior displacement of the subjects' center of mass. To maintain an upright stance, the biceps femoris must contract to produce a hip extension torque in conjunction with gastrocnemius, which is producing a plantar flexion torque at the ankle. It is



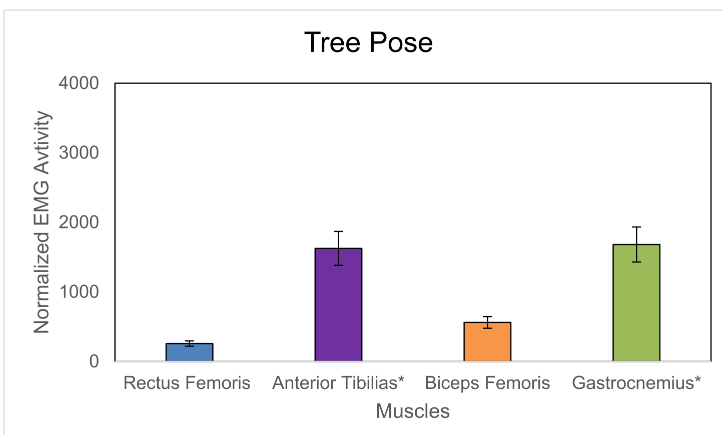

* indicates significantly greater EMG output compared to RF at the P<.000 level

**Fig. 1.** EMG data, warrior III. * indicates significantly greater EMG output compared to RF at the P < .000 level.




*Indicates significantly greater EMG output compared to RF at the P<.000 level

**Fig. 2.** EMG Data, half moon. *Indicates significantly greater EMG output compared to RF at the P < .000 level.




*Indicates significantly greater EMG output compared to RF at the P<.000 level

**Fig. 3.** EMG Data, tree pose. *Indicates significantly greater EMG output compared to RF at the P < .000 level.

unclear why the biceps femoris was not also significant in half moon pose, as the center of mass is also largely anterior to the base of support.

There are several limitations to this study. Firstly, the sample size is very small, therefore it is difficult to assume that the findings of this data can be applied to all populations. Secondly, every subject tested was female, therefore, further research is needed with male subjects. Finally, only surface EMG was used to determine muscle activity. In this case, there is no way to determine that the activity being recorded was truly from the muscle that was intended on being tested. More research would need to be conducted in different genders, age ranges and level of expertise to be able to apply the findings to the general population.

## 5. Conclusion

In conclusion, this study found that in all three yoga poses (half moon, warrior III, and tree) the average EMG data in the ankle musculature (TA, GA) were more active than that in the thigh (BF, RF). This information is useful for a variety of reasons and can be used for several different populations. For example, there is evidence to suggest that strengthening the TA and GA muscles are helpful in preventing falls in the elderly. It is also useful information for Physical Therapists to use in the clinic, so that a patient may use these yoga poses as an exercise prescription to strengthen the ankle muscles instead of traditional strengthening exercises. Finally, yogis who want to improve their unilateral poses can use this information to choose which poses will be beneficial to strengthening the ankle muscles, thereby improving their poses.

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## References

Ayotte, N., Stetts, D., Kennan, G., Greenway, E.H., 2007. Electromyographical analysis of selected lower extremity muscles during 5 unilateral weight-bearing exercises. J. Orthop. Sports Phys. Ther. 37 (2), 48–55.

Kelley, K., Aaron, D., Hynds, K., Machado, E., Wolff, M., 2014. The effects of a therapeutic yoga program on postural control, mobility and gait speed in community-dwelling older adults. J. Alternative Compl. Med. 00 (0), 1–6.

Neumann, D.A., 2009. Kinesiology of the Musculoskeletal System, second ed. Elsevier, St. Louis.

Ni, M., et al., 2014. Muscle utilization patterns vary by skill levels of the practitioners across specific yoga poses (asanas). Complement. Ther. Med. 22 (4), 662–669.

Norcross, M.F., Blackburn, J.T., Goerger, B.M., 2010. Reliability and interpretation of single leg stance and maximum voluntary isometric contraction methods of electromyography normalization. J. Electromyogr. Kinesiol. 20, 420–425.

Salem, G.J., Yu, S.S., Wang, M.Y., Samarawicharme, S.D., Hashish, R., Azen, S.P., Greendale, G.A., 2013. Physical demand profiles of hatha yoga postures performed by older adults. J. Evid Based Compl. Altern. Med. https://doi.org/10.1155/2013/165763.

Seniam. Recommendations for sensory location based on individual muscles. Available at: http://seniam.org/. Accessed June 27, 2016.

Shumway-Cook, A., Woollacott, M., 2012. Motor Control: Translating Research into Clinical Practice. Wolters Kluwer Health/Lippincott Williams & Wilkins, Philadelphia.

Wang, M.Y., Yu, S.S., Hashish, R., Samarawichrame, S.D., Kazadi, L., Greendate, G.A., Salem, G., 2013. The biomechanical demands of standing yoga poses in seniors: the Yoga empowers seniors study (YESS). BMC Compl. Altern. Med. 13 (8), 1–11. https://doi.org/10.1186/1472-6882-13-8. http://www.yogabasics.com/asana/warrior-iii/. (Accessed 27 June 2016).