An Electromyographic Analysis of Selected Asana: Males vs. Females

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Abstract

Objective: The purpose of this study was to use surface electromyography (EMG) to examine the muscle activation of the tibialis anterior (TA), gastrocnemius (GA), rectus femoris (RF) and biceps femoris (BF) muscles during various yoga poses (asana). Muscle activation was then compared between poses and between males and females.

Design: The study was a single occasion descriptive design.

Subjects: Twenty healthy yoga practitioners (10 males, 10 females) with less than five years of experience were recruited.

Setting: Subjects participated in a one time only visit for data collection at the Motion Analysis Laboratory at Quinnipiac University.

Interventions: EMG activity was recorded during maximum voluntary isometric contractions (MVIC) of the TA, GA, RF, and BF using the Biodex Multi-joint System®. Subjects then performed the following yoga asanas while EMG activity was recorded: downward facing dog, chair pose, half-moon pose, and tree pose. Each asana was held for fifteen seconds and performed three times.

Outcome measures: Raw EMG data were collected using a 4th order Butterworth filter with cutoff frequencies of 20 and 500Hz and the root mean square was obtained. Asana data were then normalized with the subjects’ individual MVIC. Integrated EMG was calculated for RF, TA, HS, GS, in each asana. A factorial linear mixed models regression analysis was performed. Compared to males, females had higher RF mean peak integrated EMG across all poses (p=.02), and higher GA and BF mean peak during the HM pose only (p's <=.01). Significant differences between poses were also noted in the TA and BF for selected comparisons. Results: There were significant main effects by pose, primarily in CH, HM and TR poses. Gender appears to affect RF, GA and HM output in specific poses only.

Conclusion: The study revealed differences in males v. females for some, but not all muscles. The actual pose (asana) appears to impact EMG output more than gender, however, further study is warranted.

Keywords: Yoga; Electromyography; Posture; Asana

Abbreviations: Electromyography (EMG), tibialis anterior (TA), gastrocnemius (GA), rectus femoris (RF), biceps femoris (BF), maximum voluntary isometric contractions (MVIC), Root Mean Square (RMS), Downward Facing Dog (DD), Chair (CH), Tree (TR), and Half Moon (HM).
Introduction

Four in ten (38%) Americans use some form of complementary or alternative medicine to alleviate pain, stress or anxiety in their lives[1]. Of the types of complementary and alternative medicine available, 6.1% use yoga[1]. Research has shown that a regular yoga practice can decrease stress and anxiety[2,3], decrease symptoms of post traumatic stress disorder in veterans[4,5], decrease symptoms of depression[6-8], improve quality of life[9,10] and reduce the risk of falling in older adults[11-13]. Recently, researchers have added the study of muscle work during yoga asana to the growing body of yoga research.

Electromyography (EMG) "is the study of muscle function through the inquiry of the electrical signal the muscles emanate" [14]. Surface EMG, where electrodes are placed on the skin overlying a muscle, has been used to study many types of rehabilitative exercises[15-17]. Zeller et al[15] studied 9 women and 9 men performing various squatting activities. The authors found that women produced significantly more EMG when compared to men, during a single leg squat in the rectus femoris muscle only. No other significant differences based upon gender were found. Dwyer et al[16] examined five lower extremity muscles during three exercises. The authors found that women generated greater EMG activity in the gluteus maximus and rectus femoris in all three exercises when compared to men. In contrast, Bouillon et al[17] found no differences in EMG output based upon gender. Although some of the exercises studied resemble asana, none of the previously reviewed studies assessed EMG output during yoga asana. Only recently have researchers used surface EMG techniques to study yoga asana.

Surface EMG techniques have been employed to study upper extremity[18,19] lower extremity[18-21] and core muscles[22] during various asana[18-22]. Each asana studied produced a unique pattern of muscle firing that was based on several factors, such as gender of the practitioner[18], skill level of the practitioner[18,20] specific pose[18-21] and biomechanical factors like position of the trunk and/or pelvis[22]. Although some gender differences have been found, studies are small and have not concentrated specifically on these differences[19,21]. The Yoga Empowers Seniors study (YESS) examined subjects over the age of 65 during various asana[23]. Again, both muscle work and joint forces depended upon the actual pose chosen. No EMG data on gender differences was provided. Gender differences in EMG output have been found in some, but not all exercises studies and again, some, but not all asana studied.

Studying the work of muscles during asana will provide rehabilitation professionals with objective information to apply yoga as a therapeutic intervention. Currently, only a few small studies exist and researchers agree that more work investigating asana via EMG is needed. No research exists specifically comparing EMG output during Asana in males versus females. Therefore, the purpose of this study was to use surface electromyography (EMG) to examine the muscle activation of the tibials anterior (TA), gastrocnemius (GA), rectus femoris (RF) and biceps femoris (BF) muscles during various yoga poses (asana). The secondary purpose was to compare the effects of pose and gender on EMG output.

Materials and Methods

Participants

The Human Experimentation Committee/Subject Review Board (HEC/SRB) at Quinnipiac University granted approval of the experiment. Twenty healthy subjects (10 males, aged 23.2 (±1.8 years) and 10 women, aged 22.8 (± 0.6 years) were recruited via email and word of mouth. All subjects were novice yoga practitioners (less than 5 years). Subjects were notified of the potential risks and benefits of participating in the study and signed the informed consent form. Subjects were excluded from the study if they had acute orthopedic injury, a silver allergy, or a consistent yoga practice of greater than 5 years.

EMG Measurement

The surface electrodes used for EMG collection were MA300 (Motion Lab Systems, Baton Rouge, LA). EMG signals were collected via a single-ended amplifier with a common mode rejection ratio (CCMR) of 130 db. Subjects wore a battery operated 8-channel transmitter that transferred the EMG signal to a receiver where the signal was further amplified (2 time for a total gain of 2,000 times). Motion Monitor (Innsport, Chicago, IL) software was used to obtain the EMG signal. MVICS of the tibialis anterior (TA), medial head of the gastrocnemius (GA), rectus femoris (RF), and biceps femoris (BF) were collected using the Biodex Multi-joint System ® following the protocol provided by its corresponding operational manual [24]. Subjects were provided with a standard 68” x 24” x 1/8” yoga mat to perform the asana and standard yoga block to allow for modification of poses if necessary.

Procedure

All tests were administered by TK, TM, and AM. The experiment was conducted in the Motion Analysis Lab at Quinnipiac University. Each subject participated in a single data collection session. Subjects were given a brief orientation to the testing protocol with informed consent prior to initiation of the study. All tests and measures were performed using the dominant lower extremity, determined by eliciting stepping strategy.

The sites for electrode placement were initially prepared by shaving, if needed, and the skin was then thoroughly rubbed with 70% isopropyl alcohol until erythema was present.
Surface EMG recording electrodes were placed parallel to the muscle fibers on desired muscles based on the recommendations from the SENIAM Project[25]. For TA, the electrode was placed at one third on the line between the tip of the fibula and the tip of medial malleolus. For GA, the electrode was placed on the most prominent bulge of the medial head[25]. For RF, the electrode was placed midway on the line from the anterior superior iliac spine to the superior part of the patella[25]. For BF, the electrode was placed at midway on the line between the ischial tuberosity and the lateral epicondyle of the tibia[25]. Once electrodes were applied, the correct position was confirmed by observing EMG activity on the oscilloscope while an investigator applied manual resistance to each muscle[25]. Electrodes were secured in place with pre-wrap, medical tape, and CoFlex® Bandage.

Each subject performed an MVIC for each muscle using the Biodex Multi-joint System ® and the corresponding protocol outlined in the manual[24]. RF and BF were collected at 90 degrees of flexion of the knee while the TA and GA were collected at 0 degrees of knee flexion and 0 degrees of dorsiflexion of the ankle measured by a goniometer[24]. The subjects were instructed to contract each muscle maximally for 5 seconds with a gradual build up to the subjects’ max (to allow for maximal muscle recruitment) and a gradual decline from the max (to prevent injury) with consistent verbal encouragement. EMG amplitude signal was simultaneously recorded. Peak MVIC was used for normalization of each muscle.

After MVIC testing, subjects were given a 60-second rest before the recording of the asana. Each subject performed the following asana: Downward Facing Dog (DD), Chair (CH), Tree (TR), and Half Moon (HM). TM first demonstrated each asana, then cued subjects using standard language[26]. Subjects were given one practice trial prior to the onset of data recording began. For each pose, EMG data were recorded for three trials of 15 seconds, with up to a 60 second rest between poses to avoid subject fatigue. HM and TR were both recorded with the standing leg being the dominant leg.

Data Processing

EMG data for both the MVIC and the yoga asana were collected via a single-ended amplifier with common mode rejection ratio (CMRR) of 130 db. Subjects wore a battery operated 8-channel transmitter to transfer the EMG signal to a receiver where the data were further amplified (2 times for a total gain of 2,000 times). Software used to obtain the EMG signal was the Motion Lab Systems Software version 2.02. After MVIC data were collected, the subject performed the postures (DD, CH, TR and HM). Each posture was held for fifteen seconds and performed (3) times. Subjects were allowed a one minute rest between each trial. Raw EMG data were band pass filtered with using a 4th order Butterworth filter with cutoff frequencies of 20 and 500 Hz and stored on a dedicated PC in the Quinnipiac University Motion Analysis Lab. Root mean square (RMS) of the filtered signal was obtained using a window of 50 ms. Peak RMS was obtained from the middle one third of each trial (5 – 10 seconds). Peak RMS is obtained using the middle 3 seconds of each trial. MVIC for each muscle during each posture is calculated using peak RMS. The three trials of each posture from each muscle were averaged, then the, MVC for each muscle during each posture was calculated using peak RMS from the specific muscle being studied. Therefore, peak RMS from each muscle during MVIC was used to normalize the peak RMS of each muscle during each asana.

Statistical Analysis

A two-factor linear mixed model regression analysis was performed to determine differences in muscle output among the four poses, between males and females, and the interaction of gender with pose. Normalized integrated EMG data were grouped according to gender and pose. Significant interactions were followed by contrasts to determine in which poses muscle output differed by gender. Once gender differences in muscle output were determined, pairwise comparisons were performed to determine the effect of pose on muscle output. A preset α level of p < .05 was selected to determine statistical significance.

Results

To determine if differences existed among muscle output during asana, regardless of gender, an initial analysis was performed comparing muscles within each pose. As seen in Figure 1, differences in mean peak integrated EMG output exist among muscles, dependent upon pose. For the CH pose TA output was significantly higher than GA, RF, and BF (all p’s <.01), and BF was lower than GA and RF (p’s <=.01). Similarly, for DD TA was significantly higher than the other three muscles (all p’s <.01) and BF was lower than GA and RF (p’s <.01). Similarly, for DD TA was significantly higher than the other three muscles (all p’s <.01) and BF was lower than GA and RF (p’s <.01). For the HM and TR poses, TA and GA were comparable as was RF and BF, but both TA and GA were signifi-
cantly higher than RF and BF (p's <=.01).

**Pose & Gender Effect for Each Muscle**

Figure 2 shows mean TA peak activity by pose and gender. There was no interaction between pose and gender (p=.79) and no difference by gender (p=.16), but there was a significant main effect by pose (p=.021). Pairwise comparisons revealed greater TA peak during CH compared to DD (p=.01) and TR (p=.02). Also, there was greater activity during HM compared to DD (p=.046).

![Figure 2. No main effect of gender or pose is noted in the EMG output of the TA (p = .79). An effect of pose on EMG output is noted in the TA (p = .021).](image2)

Mean GA peak is shown in figure 3. There was a significant interaction between pose and gender (p=.025) indicating differences between gender was dependent on the pose. There was also an effect for pose (p<.01). Pairwise comparisons of pose revealed more GA activity during HM and TR compared to CH and DD (p's <.01). Follow-up contrasts of the interaction revealed no significant difference between genders during CH (p=.21), DD (p=.61), or TR (p=.10); however, females had greater GA peak activity during HM (p=.01).

![Figure 3. Both gender and pose effect EMG output of the GA (p = .25).](image3)

Figure 4 shows mean RF peak and there was no interaction between pose and gender (p=.84), but there were main effect for pose (p<.01) and gender (p=.02). Pairwise comparisons revealed more activity during CH pose compared to DD (p=.03), HM (p<.01), and TR (p<.01), but no significant differences between the latter three poses. Females had greater activity than males.

![Figure 4. Interactions of pose and gender are noted in EMG output of the RF (Pose: p < .01 and gender, p < .02).](image4)

The mean BF peak is shown in figure 5. There was a significant interaction of pose with gender (p=.02) and main effects for both pose (p<.01) and gender (p<.01). Pairwise comparisons for pose resulted in significantly higher activity during HM compared to the other three poses (all p's <.01) and less activity during DD compared to CH and TR (p's <.01). Follow-up contrasts of the interaction resulted in no difference between females and males during CH (p=.62), DD (p=.84), or TR (p=.20); however, females had significantly greater activity during HM (p<.01).

![Figure 5. Interaction between pose and gender (p = .02) and a significant main effect for pose alone and gender alone on EMG output of BF (p < .01).](image5)
Results revealed that muscle performance (as measured by peak integrated EMG) differs based upon the form, or the asana. Iyengar [27] suggests that asana are the major tools used to access the physical benefits of yoga. However, Iyengar [28] also suggests that poses such as TR and HM work all the lower extremity muscles and that CH pose promotes all lower extremity muscles to develop equally [28]. EMG analysis during asana reveals that, contrary to popular belief, muscle work depends on pose and, in some cases, depends on either gender or the interaction of gender with pose.

**Mean Peak Integrated EMG of the Tibialis Anterior Muscle (TA)**

The function of the TA during open chain activities is to dorsiflex the foot at the ankle joint and invert the foot at the subtalar and midtarsal joint [29]. During gait, the TA has several functions, but a notable one is to contract at initial contact to prevent the foot from slapping to the ground during stepping [30]. Additionally, other authors have found the TA to be active during balance activities on unstable surfaces [31] and during activities that require the individual to balance on one
foot (unilateral stance)[32]. The TA is active during various closed chain asana and may serve to stabilize the lower extremity during standing asana.

Figure 2 illustrates the TA activity by pose and gender. There was no interaction between pose and gender suggesting no gender differences in TA activity. Other authors who have studied TA activity have not analyzed differences in gender[31,32]. However, we note a significant effect of pose on TA activity. The TA is most active during CH pose, followed by HM, TR and DD. All these poses represent closed chain activities, therefore, TA activity is expected. The TA Mean Integrated Peak EMG is greatest in CH pose. CH pose resembles the “wall squat” studied in sporting literature[16,33]. However, these studies often concentrate on RF, BF and gluteus maximus activity, not on TA activity. TA activity is high during CH due to the position of the center of mass. With the center of mass posterior, an external plantar flexor moment is created, therefore the TA muscle must fire to draw the tibia forward and stabilize the lower leg. Increased TA activity in chair pose, regardless of sex, is therefore expected and needed to create lower extremity stability during the pose. Although the TA may serve a similar function in the HM and TR poses, it is most notable in CH pose. (See Figure 6)

**Mean Peak Integrated EMG of the Gastrocnemius Muscle (GA)**

The function of the GA during open chain activities is to plantar-flex the foot at the ankle joint and flex the knee[29]. Additionally, a main action of the GA is during the push-off phase of gait. The activity of the GA accounts for 93% of plantar-flexion torque during gait[30]. In our work we found the GA most active during unilateral activities.

Figure 3 illustrates a significant effect of pose on the mean peak EMG of the GA. Both HM and TR poses clearly present with greater GA activity when compared with DD and CH. DeRidder et al[31] and Cordova et al[32] also found increased GA activity in unilateral positions. DeRidder et al[31] attribute GA activity differences to foot position and ankle orientation. Although these variables contribute to GA activity, the position of the center of mass also affects muscle output. In the HM pose, the center of mass is behind the ankle, causing increased output in both the TA and GA to stabilize the lower extremity (See Figure 7). We see slightly less GA and TA activity in TR pose because the center of mass is almost directly over the foot in these poses. However, as with other authors[31,31], we still see high activity in these muscles. We hypothesize that, as with gait, the GA serves to stabilize the lower extremity in unilateral positions. Rather than use poses like HM and TR for general lower extremity strengthening, yoga teachers may consider use of unilateral poses to specifically target the GA and TA muscles. We also see an interaction between pose and gender with HM pose only.

A significant interaction was noted between pose and gender for HM. Females clearly demonstrated more GA output than males in this pose. Other authors who have studied differences in males V. females have primarily concentrated on the rectus femori, biceps femoris and gluteus maximus[15,16,34]. No work that we know of has been done comparing GA activity between males and females. We postulate that males may have greater baseline GA absolute strength when compared to females and thus require less EMG output to generate the same amount of stabilizing force. EMG output, even when normalized, does not represent a direct correlation with force output[14]. Further study of GA activity in unilateral poses is warranted.

**Mean Peak Integrated EMG of the Rectus Femoris Muscle (RF)**

As a two joint muscle, similar to GA, the RF has several actions. During open chain movements, the RF both extends the knee and flexes the hip[29]. Due to the electrode placement during our experiment, we concentrated on the knee extension function of the RF. We also chose postures that examined the closed chain action of RF. The action of RF in closed chain activities (ie: Squatting type motions) is widely accepted as an eccentric contraction to slow the progression of the movement of the knee towards flexion. Ayotte et al[33] found both high activation of the RF in the wall squat and in all other muscles studied and concluded that the wall squat produced the highest levels of EMG in all the muscles they studied. Our study found similarly high RF activation in CH pose, which is similar to a standard wall squat (See figure 6).

CH pose activates TA and RF significantly more than GA and BF. Authors that study RF during wall squats often do not include TA in their investigations[33,34]. Iyengar[28] suggests that “the leg muscles develop evenly” (page 89) when performing the CH pose (or utkatasana) as part of a regular practice. We agree, and the data support, that all four muscles studied activate during CH pose. However, the most activity occurs in RF and TA. Yoga teachers and practitioners may consider using the CH pose as a specific strengthener of the RF and TA. However, to ensure balanced lower extremity muscle activation, other standing poses should be used. The most significant differences we found in RF activation were when we compared males to females.

We found that females had significantly more RF peak EMG output than males for all four poses. Youdas et al[34] and Zeller[15] also found that females produced greater EMG activity in the RF than males. Both authors noted the difference in the single-leg squat activity. Our study found that regardless of the form (or asana) females generate greater RF mean peak EMG. Zeller[15] attributes the difference in EMG output to the intrinsically wider pelvic bone found in females. Female yoga practitioners would benefit from a combination of both
unilateral and bilateral asana. Unilateral asana (such as tree pose, See Figure 7) may place undo strain on the anterior cruciate ligament[15] and all the lower extremity joints. Varying the lower extremity position and combining both bilateral and unilateral poses will reduce the strain on all the joints and the anterior cruciate ligament.

**Mean Peak Integrated EMG of the Biceps Femoris Muscle (BF)**

The function of the BF is two fold, to flex the knee and to extend the hip[29]. Due to electrode placement, we studied the BF actions at the knee. Figure 5 shows the mean peak EMG activity of BF in all poses. The HM pose is the only pose with significantly more BF activity when compared to other poses. Figure 8 clearly shows the force vector in HM as falling anterior to the knee joint and posterior to the ankle joint. This location creates an extension moment at the knee and a plantarflexion moment at the ankle. Therefore, the BF contracts to flex the knee (to counteract the extension moment) and the TA contracts at the ankle to dorsiflex the foot (to counteract the plantarflexion moment). The EMG activity we see in HM is directly related to the location of the center of mass and the resultant force vector. Yoga students who have difficulty with the HM pose will benefit from being instructed to move the weight directly over the standing foot to ensure optimal location of the center of mass. We also see significantly more BF activity in HM in females when compared to males.

In contrast, Youdas[34] and Zeller[15] suggest that females are RF dominant, noting more RF activity in single limb support activities when compared to men. Although we noted that women do in fact have more RF activity, in all poses, not only unilateral, we also noted that women have more BF activity then men in unilateral poses. Youdas[34] concludes that men are BF dominant and females are RF dominant. Zeller[15] attributes the increased output of the RF in women to intrinsically wider pelvis found in women. Our findings suggest that women present with greater mean peak EMG output in BF and RF, regardless of the nature of the activity. Differences in mean peak EMG output between males and females may be due to data collection methods, rather than actual differences.

Pincivero et al[35] used median frequency and EMG amplitude, rather than mean peak EMG to study gender differences. They found no significant differences in RF or BF output between males and females. However, they studied only one open chain activity. Bouillon et al[17] also found no differences in percent MVC of the RF or BF when comparing males and females. These authors used stepping up and stepping down activities and normalized all step heights to a percent of the subjects' height and leg length. The authors contend that these normalization processes represent one reason that they found no differences. Gender differences in EMG activity warrants further investigation.

**Conclusion**

In conclusion, we found that muscle output as measured by surface EMG differs based upon the position (asana) that the practitioner assumes. Additional analysis revealed both differences between males and females and a difference between a pose with bilateral lower extremities versus unilateral. While limited research currently exists in this area, our study provides baseline data upon which future studies can be established. Future studies may include a larger subject pool, additional muscles (particularly the gluteus medius and abdominal muscles) and possibly upper extremity muscles. Although unilateral poses like TR and HM generate the largest amount of lower extremity EMG, no studies have been done examining upper extremity EMG during arm balances.

Limitations of this study include a small sample size and the use of inexperienced practitioners. Experienced practitioners may present with different muscle output patterns. One possible area of further investigation could include following these inexperienced practitioners over time to examine changes in EMG output patterns with experience. Additionally, the start time of EMG collection is determined by the practitioners. Therefore, no consistent start time of data collection exists. Finally, no consideration of the type of yoga practice was made.

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**Author Disclosure Statement**

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