ELECTROMYOGRAPHY ANALYSIS OF FOREARM MUSCLES DURING VARIOUS YOGA POSES

Abby J. Carey, Ashley L. Hawke, Stephanie L. Carlson-Ballone, Randall L. Jensen

School of Health & Human Performance
Northern Michigan University, Marquette, MI, USA

The current study examined muscle activity via electromyography of the flexor carpi radialis (FCR), ulnaris (FCU), and extensor carpi radialis (ECR), ulnaris (ECU) during two variations of three separate yoga poses. Nine participants (n=9) performed three different yoga poses: plank, side-plank, and upward dog; in two separate variations, (V1) with the wrists in a passive hyperextended position, and (V2) with the wrists in a neutral position where the participants made a fist and performed the pose in that position. There were no differences between poses or variations for ECR. A difference was found between variations, but not poses for ECU. FCR and FCU were different between poses, but not variations. The only interaction was for the FCR. Due to the increased muscle activity in V2, performing yoga in V1 position may allow a yoga session to be completed with less fatigue and risk for injury.

KEYWORDS: EMG, side-plank, plank, upward dog

INTRODUCTION: There is a widely accepted belief that practicing yoga will assist in the improvement of mental and physical health due to its ability to down-regulate the sympathetic nervous system as well as the hypothalamic-pituitary-adrenal axis (Ross & Thomas, 2010). A 2010 study found that over 20.4 million people practice yoga in the United States alone (Ross & Thomas, 2010). Throughout the years the population of yoga participants nearly doubled from 5.1% in 2007 to 9.5% in 2012 (Swain, & McGwin, 2016).

The muscles of the forearm are used during common yoga poses to support the body and aid in transition between poses; specifically, the flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), extensor carpi radialis (ECR), and extensor carpi ulnaris (ECU) (Wolff, 2018). Due to the popularity of the practice, finding ways to minimize injury to these muscles as a result of fatigue is vital. Injury is common in any type of physical activity, with yoga being no exception (Lee, Huntoon, & Sinaki, 2019). Soft tissue, musculoskeletal, and mechanical injuries are of the most common and notable injuries yoga participants may experience (Lee et al., 2019). Typically, as muscle activity begins to increase, the risk for injury does as well, this can be attributed to the fact that more motor units are being recruited and the muscle is beginning to fatigue (Lee et al., 2019). As muscles begin to fatigue the participant is at a greater risk for failure of pose, muscle and joint injury (Lee et al., 2019). Due to an increase in wrist injuries as a result of overuse or fatigue during yoga, the topic of wrist positioning may influence the prevention of wrist fatigue and injury (Wolff, 2018). There are little to no standard guidelines of optimal wrist and hand position in yoga, therefore, many common yoga positions are performed with a hyperextended wrist (Polovinets, Wolf, & Wollstein, 2018). Recently, accommodative variations, such as performing the pose with a neutral wrist, have been proposed as a way to combat and reduce injuries to the wrist and forearms.

Electromyography (EMG) analysis is key in identifying motor unit recruitment (Farber, Smith, Kvitne, Mohr, & Shin, 2008), and is helpful in assisting injury prevention. EMG of the forearm muscles has been investigated in the exercise community when using a hyperextended wrist, but has not been extensively investigated when performing exercises with a neutral wrist. Comparing muscle motor recruitment during variations of different yoga poses may allow for a better idea as to which wrist position elicits greater motor unit amplitude, therefore leading to greater incidents of muscle fatigue and potentially injury (Kwon, Lee, Lee, Seo, Jung, & Choi 2013). Therefore, the purpose of the current study was to examine differences in muscle activity of the FCU, FCR, ECU, and ECR during neutral and hyperextended wrist positions of the plank, side plank, and upward facing dog in yoga.

METHODS: For this study, nine participants, (n = 9; mean ± SD: age = 24 ± 4 yrs; body mass = 82.1 ± 16.0 kg; height = 175.3 ± 12.4 cm) volunteered. Inclusion criteria required subjects to have familiarity with the practice of yoga as well as no upper body injury in the six months prior to involvement in the study. Northern Michigan University's Institutional Review Board approved the study (Approval Number: HS17-882). All participants provided informed consent. Prior to testing, participants had surface EMG electrodes placed on the forearm muscles of their dominant hand, identified by which hand they wrote with. Electrodes (Noraxon, Scottsdale, AZ, USA) were placed on the flexor carpi ulnaris (FCU), flexor carpi radialis (FCR), extensor carpi ulnaris (ECU), and extensor carpi radialis (ECR). All electrodes were placed on the belly of each particular muscle. After the electrodes were placed, subjects were seated into a Biodex dynamometer (Biodex Medical Systems Inc, Shirley, NY, USA), where two maximal voluntary isometric contractions (MVC) were performed. The MVCs required participants to flex and extend their wrist against resistance with as much force as capable. Integrated EMG (iEMG) data were collected at 1000Hz using a band pass filter of 5 to 500 Hz.
Following MVCs, a certified yoga instructor demonstrated to subjects how to perform three yoga poses - plank, side plank, and upward dog. Prior to testing, familiarization trials of each pose were completed. All three poses were completed in two variations: a hyperextended (V1) and a neutral wrist position (V2). During the side plank pose, participants completed the pose bearing their weight on their dominant side. Each pose was repeated three times, for 10 seconds, in V1 and V2 for a total of six trials per pose. One minute of rest was administered between each trial. All 10 seconds of the trial were analyzed.
For data analysis, the third trial of each pose and variation was used. Mean iEMG data were analyzed and exported through Noraxon myoMUSCLE (MR3.310, Noraxon, Scottsdale, AZ,USA). To assess differences between poses in comparison to variations, a two-way Repeated Measures ANOVA was performed to compare percentages of MVC ihEMG for all four muscles. A Greenhouse-Geisser correction was used if sphericity was violated; and Bonferoni correction was used for pairwise comparisons with IBM© SPSS (v. 26, IBM, NY, USA). Significance level was set at $p < 0.05$.

RESULTS: Results of the two-way Repeated Measures ANOVA are illustrated in Figure 1. There were no significant differences between poses ($F(2,16) = 2.810$; $p = 0.090$) or variations for ECR ($F(1,8) = 5.132$; $p = 0.053$). A significant difference was found between variations ($F(1,8) = 25.900$; $p = 0.001$), but not poses ($F(2,16) = 1.519$; $p = 0.254$), for ECU. Additionally, significant differences were found between poses for FCR ($F(2,16) = 5.740$; $p = 0.038$) and FCU ($F(2,16) = 5.420$; $p = 0.040$). There was no difference for variations for FCR ($F(1,8) = 0.115$; $p = 0.743$) or FCU ($F(1,8) = 2.988$; $p = 0.122$). A significant interaction was only observed for pose and variation for FCR ($p = 0.033$).

DISCUSSION: The purpose of the current study was to examine possible differences between a neutral and extended wrist position in three yoga poses: plank, side plank and upward dog. Results of the study may provide information on which position would be best for yoga participants to use in reference to pose stamina, along with wrist injury prevention.
The positioning of wrists during plank, side plank, and upward dog is a necessary consideration to make when reviewing the results. In V1, the wrists were in passive extension, with the force of the body weight maintaining the wrist in a locked position. When holding a pose in V2, the wrist shifts to an isometric hold of neutral, along with complete hand and finger flexion. This is due to the need to maintain balance in V2. With the variation between poses, an increase in motor unit recruitment was generally observed for V2. This is shown in Figure 1B, where %MVC of the extensor carpi ulnaris increased significantly between V1 and V2. However, there was a significant interaction for the flexor carpi radialis (Figure 1C), as illustrated by the decrease in %MVC for side plank and increase in %MVC for plank from V1 to V2.

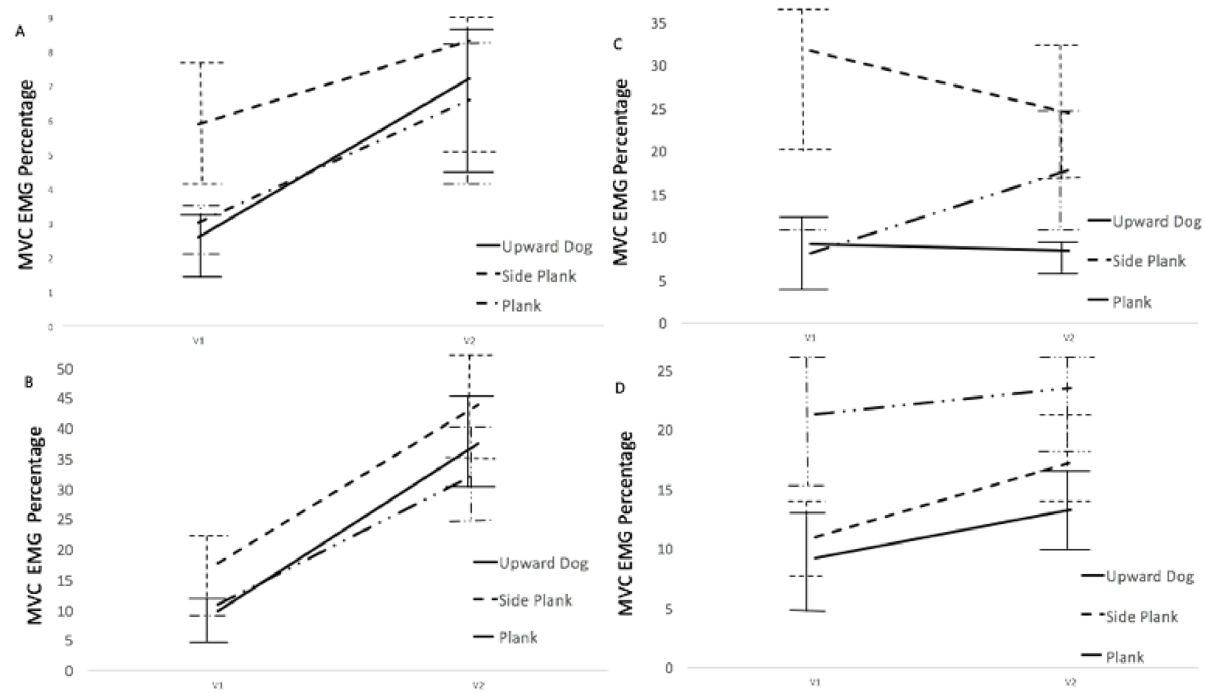

Figure 1: Figures above show mean iEMG percentages for forearm muscles; extensor carpi radialis (A), extensor carpi ulnaris (B), flexor carpi radialis (C) and flexor carpi ulnaris (D). Significant differences were found for flexor carpi radialis and ulnaris between poses; with an interaction of poses and variations seen in flexor carpi radialis. There was also a difference between V1 and V2 for extensor carpi ulnaris.

The increase of EMG % for V1 may be a result of a balancing issue, as the participant must hold their weight on one arm as opposed to two arms. This may result in pose corrections via muscle activity, causing an increase in motor unit recruitment. Further research should investigate muscle activity related to movement aspects. The passiveness of the arm positioning in V1 is also important in the reduction of error, as participants are more likely to perform poses with proper form during yoga poses (Kwon et al., 2013).

The brain and its somatosensory region play a large role in passive movements and reduction of error (Kwon et al., 2013). When holding a position, the sensorimotor cortex and ipsilateral cerebellum, both of which are important for motor coordination, work together via the sensory inputs to assist in sensing joint position (Kwon et al., 2013). Because of this, the brain is not required to actively process the joint position the wrist needs to be in hyperextension, as it will allow the wrist to lock into place by use of the sensory inputs coming from the ground. This is important, especially for activities such as yoga, because it allows the brain to focus on other movement inputs, and reduce error of the position (Kwon, et al., 2013). Therefore, it was expected to see the V1 positioning recruiting less motor units, because of position's more passive nature.

As previously mentioned, V1 allowed for less motor units to be recruited in all muscles and poses, with exception of the side plank for flexor carpi radialis. These results suggest that the muscles of the forearm will fatigue at a slower rate during V1 than (Fallentin, Jorgensen, & Simonsen, 1993). When muscles begin to fatigue, there is a greater chance for injury to occur, as there are fewer motor units to recruit. This results in the joint having to bear responsibility of stabilizing the wrist, which may lead to loss of balance due to lack of muscle support. (Tosovic, Than & Brown 2016). Based on the current study findings, the ECU was the only muscle to reach 50% of the MVC for side plank (Figure 1B), suggesting the ECU will be the first muscle to fatigue in side plank if held for extended periods. Since the %MVC was lower in V1 than V2, it should be recommended to participants that these yoga poses be performed in V1.

Further considerations should be made in future research of the topic, such as an addition of more participants, additional poses to test, other muscles to assess, and holding each pose for longer periods of time. These changes may help in solidifying the findings of the current study.

CONCLUSION: Due to the increased motor unit recruitment with the wrists in a neutral position (with exception of Flexor Carpi Radialis in upward dog and side plank), it would be in the participants' best interest to perform yoga with wrists in passive extension in order to complete the yoga session with less fatigue and less risk for injury.

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ACKNOWLEDGEMENTS: The authors would like to thank all participants for their valiant effort in participating.