

Effects of Static Stretching on Electrodermal Activity, Electromyography, Muscle Force, and Muscle Fatigue

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Abstract

Many Americans exercise to live a healthy lifestyle and be fit. A common precursor to many exercises is some form of stretching. Previous research has shown that static stretching may impact our performance in exercising by decreasing muscle output and increasing fatigue. In this study, we tested the impacts of static stretching on forearm muscles measured by maximum clench force, force at 50% of original strength, electrodermal activity, and electromyography. We used 30 participants from Physiology 435 Spring 2018 semester to perform two sets of exercises, one including stretching prior to clenching a hand dynamometer and one without this addition. We concluded that there was no significant change in our measured variables between the two trials.

Introduction

Background Information

It is quite common for athletes young and old to hear about the importance of warming-up prior to exercise. The commonly accepted belief is that the warm-up is to prepare for optimum performance and reduce the risk of possibly injuring oneself. Research originally supported this belief, providing evidence that stretching prior to exercise reduced the risk of muscle injury (Smith, 1994; Safran et al., 1989), but more recent reviews tend to disagree, arguing that stretching is unlikely to prevent injury (Shrier, 1999; Pope et al., 2000) and is likely to cause significant reductions in strength, power, and speed dependent tasks (Shrier et al., 2012).

Static stretching is one of the most widely-accepted forms of warming-up prior to a workout. It is a stationary form of stretching that focuses on increasing the range of motion of a joint, where “a specific position is held with the muscle on tension to a point of a stretching sensation” (Page, 2012). While athletes swear by this passive stretch technique in order to increase their range of motion and potentially decrease their chance of injury during exercise, some static stretches have been linked to significant decreases in muscle output during

concentric isotonic muscle actions under various loads (Yamaguchi et al., 2006). Thus, the purpose of this study was to test the effect static stretching has on muscle performance.

Static stretches involve holding an appendage in a certain position for held a short period of time. While there is no standardized ideal stretch time, a common time of 30 second static stretches has shown to have an effect on leg muscle output and fatigue in sprinters (Nelson 2007). Other research suggests that “a 30-second duration is an effective amount of time to sustain a hamstring muscle stretch in order to increase range of motion. No increase in flexibility occurred when the duration of stretching was increased from 30 to 60 seconds” (Bandy et al., 1997). Yamaguchi had his subjects perform 30 second stretches prior to their muscle performance test which is also consistent with our study.

There are several different muscle groups in the body that can be utilized to show the effects of static stretching on muscle performance. We will be looking deeper into the forearm muscles, as their output is easily measured through grip strength in a laboratory setting. The forearm consists of several muscles categorized generally as either flexors or extensors. Muscles like the flexor carpi radialis, the flexor carpi ulnaris, the supinator, the brachioradialis, and a mix of extensor muscles work together to flex the forearm, pronate or supinate the wrist, and use the fingers. The forearm and grip strength is a crucial for performing many exercises such as gripping and lifting one’s body when rock climbing, a common work-out activity. According to Nicros rock climbing training center, there are two essential forearm stretches to perform prior to rock climbing: the finger flexor stretch and the finger extensor stretch. The finger flexor stretch targets the muscles that directly affect grip strength, while the finger extensor stretch targets the extensor muscles and the brachioradialis on the back of the forearm.

The physiological responses we measured to determine the effects of static stretching on muscle output and fatigue include electrodermal activity (EDA), electromyography (EMG), maximum grip strength, and time it takes for muscle strength to fatigue to 50% of original strength. Maximum grip strength and time to fatigue to 50% of original strength are the key measurements to determine if static stretching affects muscle performance. EDA of the arm is a measure of variation in skin conductance due to changes in sweat gland activity by way of the sympathetic nervous system. EDA and EMG are reliable methods for measuring and comparing muscle activity across conditions, in order to assess muscle fatigue (Greco et al., 2017).

Based on the breadth of research on the physiological effects of static stretching, we hypothesized that after performing the flexor and extensor stretches of the hand, maximum grip strength and time it takes to fatigue to 50% of original strength will decrease compared to resting measurements taken. The decrease in maximum grip strength and increase in muscle fatigue would be due to muscular contractions from a static stretch. The stretch would decrease the ATP concentration and the sensitivity of thin filaments to Ca^{2+} , thus inhibiting the power-stroke of the cross-bridges (Widmaier et al., 2015). We hypothesized an overall decrease in EDA and EMG during the grip test as a result of stretching due to muscle exertion prior to testing grip strength, thus leading to an overall decrease in muscular force and output.

Materials

The physiological measurements that we recorded in this experiment are electrodermal activity (EDA), electrical activity of the forearm, maximal voluntary grip force, and time taken to reduce maximal voluntary grip force to 50%. Measurements for EMG was taken using electrodes, Electromyography (EMG) II (Model 5-1000, manufactured by BIOPAC Goleta, CA).

BIOPAC Electrode Lead Set (Model SS2L) and BIOPAC disposable Electrodes EL503 were utilized in conjunction with the EMG to record electrical activity of the flexor carpi ulnaris, the flexor carpi radialis, and the brachioradialis muscles of the forearm during the experiment. Maximal voluntary force (kg) and time to reduce force to 50% maximum (seconds) were measured using the BIOPAC Hand Dynamometer, model SS25LA. The BIOPAC electrodermal transducer, model SS3LA, Serial Number 12123846 were continuously measure electrodermal activity. A computer with access to Microsoft Excel and Word programs were used for statistical analysis.

Methods

Participation

A total of 30 students (19-22 years old) from Physiology 435 class at University of Wisconsin-Madison during Spring 2018 semester participated in the study. For confidentiality, we assigned each participant a random number as an identifier. The experiment was performed two separate times with the same students, minimum of 12 hours apart, under different conditions. In the first set of experiments, there was no stretch performed before the participant clenched the hand dynamometer. In the second trial, static stretches of the forearm were performed before the exercise. The sets were randomized using a random number generator. Average participation time for each volunteer was around 10 minutes total.

First (non-stretch) Set

The participant came in and signed consent form before the experiment began. The EMG was hooked up to the participant's dominant forearm. The electrodermal transducer was attached at the participant's finger of non-dominant hand throughout the experiment. The Biopac Hand

Dynamometer was held in the participants' dominant hand and they were asked to rest their arm on their thigh in order to relax the muscles in the shoulder and upper arm prior to clenching. The students then performed a maximal contraction using the dynamometer, and held the intensity until their contraction fell below 50% of their maximum.

Second (stretch) Set

Participants were instrumented in the same manner as the first set. In addition, two stretches were performed, for 30 seconds each: a flexor stretch (figure I) and an extensor stretch (figure II) on flexor carpi ulnaris, the flexor carpi radialis, and the brachioradialis muscles of the lower arm. The electrodermal transducer was also attached at the participant's fingers of non-dominant hand throughout the experiment. The Biopac Hand Dynamometer was held in their dominant hand and the participant rest their forearm on their thigh in order to relax the muscles in the shoulder and upper arm. The students then performed a maximal contraction using the dynamometer, and hedld the intensity until their contraction fell below 50% of their maximum.

Data Analysis

Microsoft Excel, VassarStats, and Biopac were used to analyze the data collected. We performed a paired two sample t-test for means analysis in order to determine the statistical significance ($p < .05$) between measurements taken during baseline visit and after doing static stretches. Our variables of interest were maximal voluntary force (kg), time to reduce force to 50% maximum (seconds), electrodermal activity (μS), and electromyography (Hz). We presented our data using bar graphs (maximal force, electrodermal activity, time to reduce force to 50% maximum) and line graphs (fatigue).

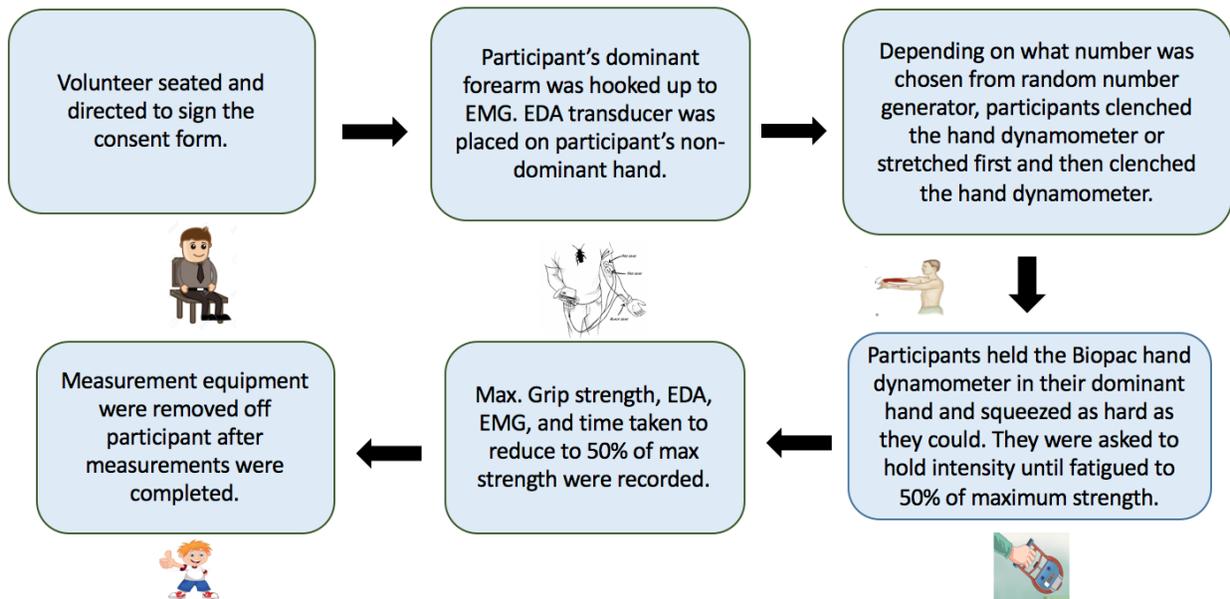
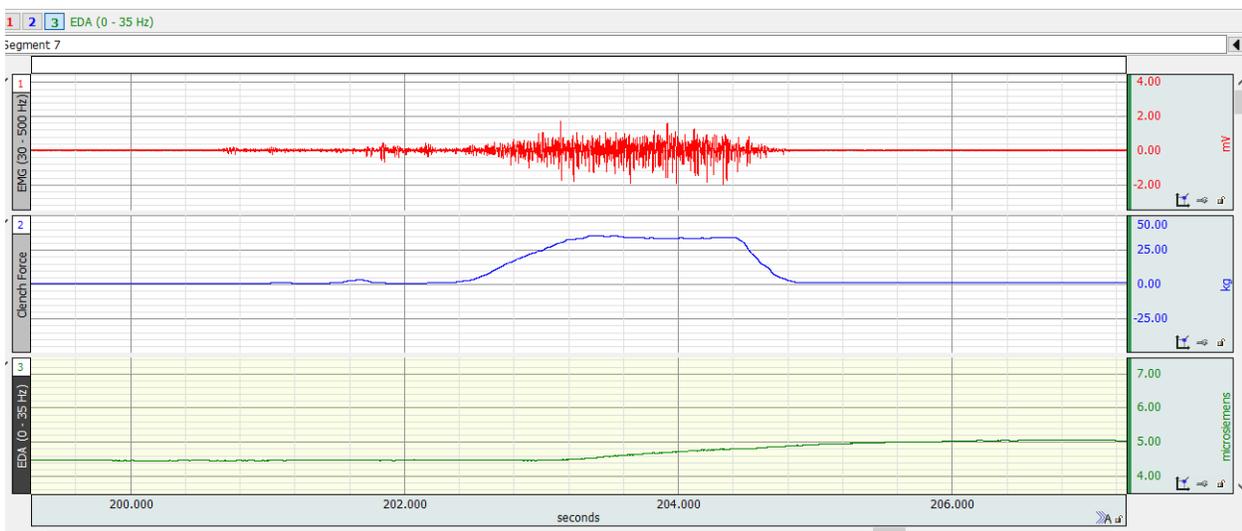


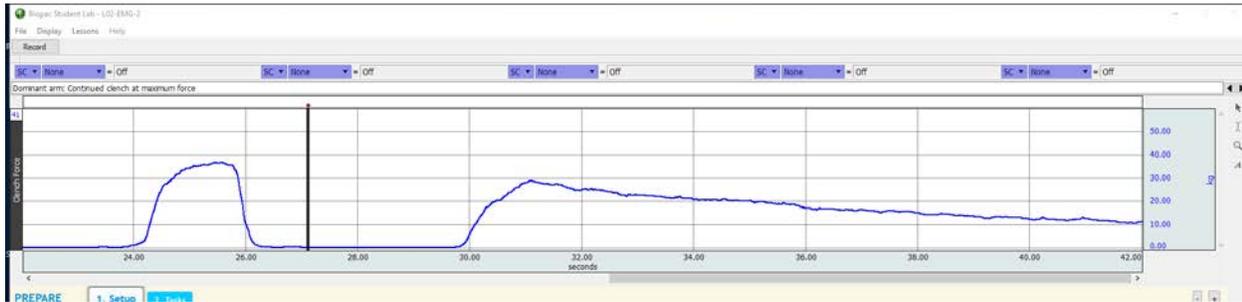
Figure 1. The timeline shown above describes, in summary, the procedure each participant underwent during the study including cartoon visual representations to aid in demonstrating the process.

Positive Controls



EMG, Max Force Grip, EDA

Figure 2. The image above displays EMG amplitude, maximum clench force, and EDA data when a participant performed the experiment.



Max Force Grip, EMG, and Time to Fatigue

Figure 3. This image demonstrates an example measurement of grip force without stretching prior to clenching the dynamometer. This screenshot also demonstrates the fatigue measurement, time until participants grip force falls to 50% of max.

Examples of Flexor and Extensor Forearm Stretches



Figure 4. The images shown above are to help visual the forearm stretches participant's performed before clenching the hand dynamometer during the "stretched" trial. The two pictures on top represent finger flexor stretch and on the bottom two show the finger extensor stretch.

Results

Maximum Force

The average maximum force for the participants' stretch trial was 20.951 kg and 20.855 kg for the non-stretch trial. A two tailed paired t-test determined a p-value of .976 with a confidence interval of $p \cong 0.05$. There is no significant difference in maximum force exerted between stretch and non-stretch trials

Time Until 50% Grip Strength

The average time until 50% grip strength for the stretch trial was 19.167 seconds and 19.654 seconds for the non-stretch trial. A two-tailed paired t-test determined a p-value of .912 with a confidence interval of $p \cong .05$. There is no significant difference in grip times until 50% of original maximum grip strength.

Maximum EDA

The average Maximum EDA measurement for the stretch trial was 9.842 μ S and 9.114 μ S for the non-stretch trial. A two tailed paired t-test determined a p-value of .585 with a confidence interval of $p \cong 05$. There is no significant difference in maximum EDA.

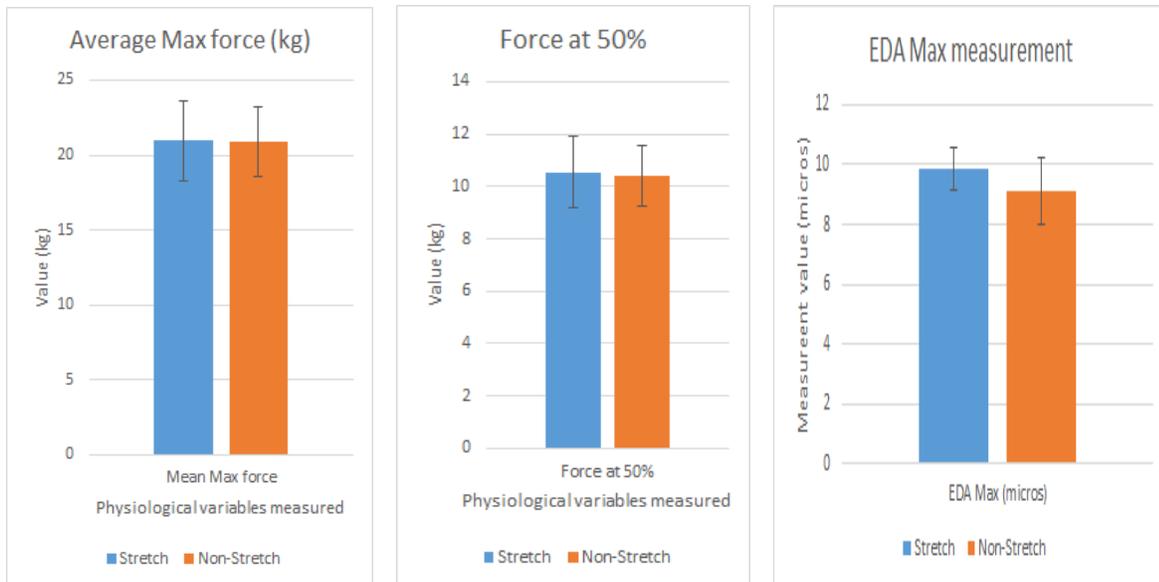


Figure 5. The bar graph above depicts average maximum clench force in kilograms, average time taken for participant to fatigue to 50% of original strength in seconds and average maximum EDA in microsiemens on the x-axis. The y-axis displays the number values for measurement. The trial that included the stretch before the hand grip is shown in red, while the trial that did not included a stretch before clench is shown in black.

Average EMG during grip

EMG data was taken as an average in proportional, one quarter, intervals throughout the subject's grip to identify any significant changes. The first quarter (25%) had a p-value of .721, the second quarter (50%) had a p-value of .757, the third quarter (75%) had a p-value of .389, and the final quarter (100%) had a p-value of .889. The combined EMG data from the start to finish of the grip had a p-value of .391. With a confidence interval of $p \leq .05$, there is no significant difference in EMG measurements between the two groups for the intervals or total EMG measurements.

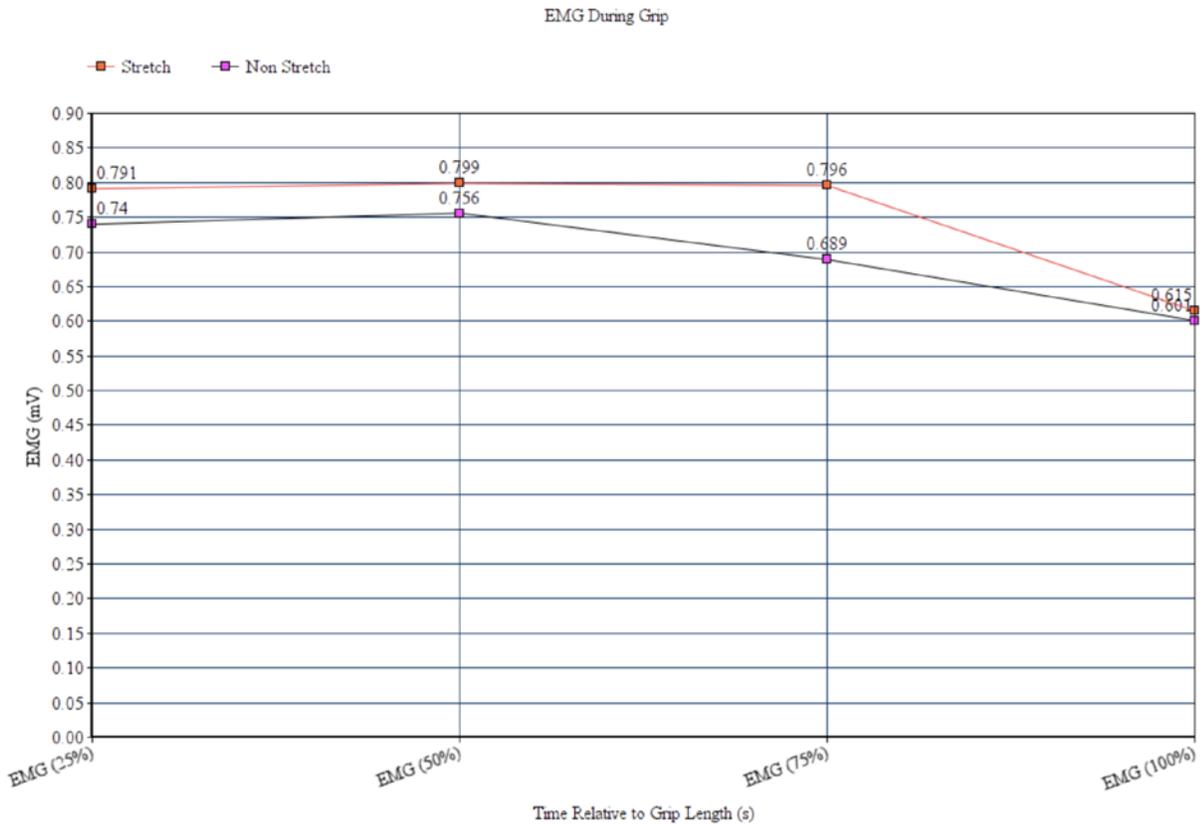


Figure 6. The line graph above depicts the average maximum value of EMG given in millivolts measured over 25%, 50%, 75%, and 100% time intervals of total time. Time relative to how long the clench was held is displayed on the x-axis, while the values for EMG are displayed on the y-axis. The red line represents the trial that included a stretch, while the pink line represents the trial omitting the stretch.

Discussion

It was hypothesized that we would see a significant decrease in max clench force and time to fatigue to 50% of maximum original strength, an decrease in EMG activity, and a decrease in EDA activity when participants stretched before clenching the hand dynamometer. Based on the evidence shown above, we reject our hypothesis for clench force, time to 50% fatigue, EMG, and EDA. We hypothesized that the collective depolarization of muscle fibers, as shown by EMG activity, would be decreased; however, EMG data not only showed higher activity in the stretch trial, but also sustained a higher level for longer before decreasing as

compared to the non-stretch trial. Although there was a higher level of EMG activity measured for the stretched-induced clenches, the increase was not significant as shown figure 6. EDA activity did show a slight increase for the participants that stretched prior to the grip test, this was due to the increase in muscle exertion raising the local body temperature and causing sweat glands to open in order to release the heat. Although there was a slight increase in EDA activity these results were also not significant as demonstrated by the overlapping error bars in figure 5 and a p-value greater than 0.05.

Although it was found by sources such as Marek et al. that “static stretching caused significant deficits in strength, power output, and muscle activation” (2005), our results could have been influenced by many possible external factors. First being that the muscles of the forearm were stretched for too short of a duration of time to see an effect. For example, static stretching did induce a slight increase in EMG activity throughout the grip, perhaps a longer stretch could have influenced a larger EMG change and, therefore, altered muscle output. Another factor could have been that we only stretched a limited amount of muscles. There are a variety of muscles in the lower and upper forearm that impact clench force. We limited our stretches to only muscles that of the lower forearm, wrist and fingers. A larger sample size with more trials under each condition could also have been used to obtain a larger and more representative range of data.

We made several assumptions in the construction of this study. We assumed that both the EDA and EMG electrodes consistently and accurately recorded data during each trial. It was assumed that each participant entered each trial at their non-stretch baseline so as to not alter our non-stretch data. In addition, it was assumed that participants did not perform any extensive physical exertion prior to the trial as this would influence all recorded data.

The practice of stretching has neither been diminished nor strengthened by this study. We have concluded that stretching elicits no increase or decrease in muscle output. Specifically, exploring the optimal stretch duration could have changed the outcome of this study. Further research into the benefits of stretching will have implications in both sports and medicine. Learning how to maximize muscle output and reduce the risk of injury/re-injury can be of benefit to everyone.

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