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Original Article

Dynamic stretching improves muscle activation and pain pressure threshold but not isometric hand strength when compared to static stretching

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Abstract
Stretching is an important component of any exercise or therapy session. Two major types of stretching are typically implemented, static and dynamic. Prior research has shown utility for static stretching in pain management. However, it is unknown if dynamic stretching could provide different benefits on pain pressure threshold, hand grip strength, and muscular activation than static stretching. Thus, our goal is to explore the differences between dynamic and static stretching at three different times under stretching periods on pain pressure threshold, hand grip strength, and muscular activation. Sixteen young healthy adults participated in this repeated-measures study design. Two stretching conditions (static and dynamic) under three different times under stretch periods (30 seconds, 1 minute, and 2 minutes) resulted in a total of 6 stretching conditions. Initially, participants performed no stretch and then were tested on pain pressure threshold and hand grip strength. A linear mixed-effects model with pairwise comparisons with a Holm-Bonferroni correction and hedges g effect size were utilized for statistical inference. Stretching condition and time under stretching, and sex were considered fixed factors while the participant was entered in the model as a randomn effect (intercept and slope). Our results showed that 1 minute of dynamic stretching is superior to static stretching for 30 seconds, 1 minute, and 2 minutes on pain pressure threshold and muscular activation (p<0.05). However, differences were found in hand grip strength (p>0.05). Clinicians can consider using dynamic stretching as a non-invasive physical therapy mode to improve pain pressure threshold and muscular activation in young healthy individuals.
Key Words: **Stretching, Dynamic, Static, Pain Pressure Threshold, EMG**

Introduction

Stretching exercises have also been using in clinical settings to improve short-term the perception of pain intensity and favor recovery. Static and Dynamic stretching are two common modalities used in exercise, therapeutics, and general musculoskeletal pain management. Static stretching is characterized by the lack of motion in where the participant holds a stretch for a time of > 10 seconds while dynamic stretching involves controlled rhymic stretching of the musculature with no hold of the stretch. Early research has shown that dynamic stretching can improve muscular strength and function (Behm et al., 2016). Additionally, dynamic stretching has been shown to elicit greater athletic performance and surface electromyographical (sEMG) activation when compared to static stretching (Condon & Hutton, 1987; Dallas et al., 2014; de Weijer et al., 2003; Montalvo & Dorgo, 2019; Moore & Hutton, 1980). These positive performance effects from dynamic stretching result from increased muscular temperature, reduced muscle viscosity, greater neural activity, increased heart rate, and blood flow (Page, 2012).

Contrary to dynamic stretching, static stretching has been shown to decrease isometric strength (Jelmini et al., 2018). Moreover, less than 1 minute of stretching, has been shown to increase muscle relaxation leading to a decrease in muscular performance and physiological measures (de Weijer et al., 2003; Haddad et al., 2014; Peck et al., 2014). And even though short-duration static stretching (< 45 seconds of stretching) has little to no benefit in performance (i.e. strength and power) or physiological measures (i.e. muscle temperature, increased heart rate) (de Oliveira & Rama, 2016; Simic et al., 2013).

In the United States it is estimated that approximately 14-20% of the population reports living with pain or chronic musculoskeletal pain (Von Korff et al., 2016). Pressure algometry is a reliable tool to quantify pain (Pelfort et al., 2015). Pressure algometry or pressure pain threshold (PPT) is positively associated with knee strength (Henriksen et al., 2013). Following the same lines, muscle activation amplitude is associated with increasing torque (Karlsson & Gerdle, 2001). Thus, it is plausible that increases in muscular activation following a proper warm-up stretch could improve PPT. Static stretching is often utilized as a relaxation method during manual tasks (Page, 2012) and as a therapy to mitigate pain (Apostolopoulos et al., 2015). Moreover, static

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stretching increased PPT in the hamstring muscles in healthy young adults (Bretischwerdt et al., 2010) and ballet dancers (Ko et al., 2020).

As previously described, dynamic stretching yields greater positive effects than static stretching on static strength and muscle activation (Montalvo & Dorgo, 2019; Peck et al., 2014). Others have compared static stretching to other training methods such as muscle energy technique on mechanical neck pain (Phadke et al., 2016). Recently, a stretching program using global postural reeducation method involivning one weekly-60 minute stretching session for 12 weeks, showed improvements on pain, function, and quality of life (Lawand et al., 2015).

Problem Statement and Approach

However, and to our knowledge, the relationship between dynamic stretching and pain pressure threshold, and its comparison to static stretching and PPT has yet to be studied. Given the association between muscular strength and pressure pain threshold and muscular strength and muscle activation, we seek to determine which stretching modality would yield greater acute effects on PPT. Hence, the purpose of this study is to investigate the changes in isometric strength, muscular activation, and PPT level after two different stretching modalities, and three different stretching time durations. We hypothesized that participants would be able to generate greater peak isometric strength, muscular activation, and increased PPT after the dynamic stretching condition than in the static stretching condition, additionally, we also hypothesized that stretching time would magnify the positive benefits of dynamic stretching when compared to static stretching.

Materials and Methods

Sixteen college students participated in this repeated-measures study design. A priori sample size was computed on R using the "pwr" package, indicated that a minimum sample of 16 people was necessary to obtain a moderate-large effect size F = 0.38, power (β) of 0.80, and an alpha (α) level of 0.05. All methods were approved by the local Institutional Review Board (IRB #1708099-1). Participants signed informed consent prior their participation in the study. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (Navalta et al., 2019). Furthermore, all the participants had to complete one baseline and six randomized experimental stretching assessments: 1) static stretching for 30 seconds, 2) static stretching for 1 minute, 3) static stretching for two minutes, 4) dynamic stretching for 30 seconds, 5) dynamic stretching for 1 minute, and 6) dynamic stretching for two minutes. Each testing period was blocked by individua 15-minute window, in which the stretching condition was applied, then testing, and subsequent individual resting time to avoid fatigue.

The static stretching protocol consisted of retracting all the fingers beyond the maximal range of motion to stretch the wrist flexor muscles (Figure 1s). The dynamic stretching protocol consisted of flexing and extending all the fingers at a pace of 40 times per minute (Figure 2s). Participants were instructed to contract as forcefully as possible and retain this contraction until the PI would ask the participant to stop. After each stretching condition, subjects performed a maximal grip strength task consisting of grasping a hand-held dynamometer (Noraxon Inc., Scottsdale, AZ, USA) as forcefully as possible and holding the grip until grip strength decreased to 50% of the maximal strength (Figure 3s). PPT was measured immediately after the maximal grip strength test (Figure 4s) using a JTECH digital pressure algometer (JTECH Medical Industries Inc., Midvale, UT, USA).

Surface Electromyography (sEMG) was conducted using pre-gelled Ag/AgCl dual electrodes placed on the flexor carpi radialis muscle at roughly 50% of the distance between the origin and insertion of the muscle. The signal from the sEMG was filtered with a low bandpass of 10 Hz and a high pass of 450 Hz and then smoothed by RMS at a 50ms epoch window (Beringer et al., 2020). A digital hand-held dynamometer was also utilized to measure isometric strength. Both, the sEMG signal and the hand-held dynamometer were synced and collected via the Noraxon Myomuscle software 3.16.32 (Noraxon Inc., Scottsdale, AZ, USA). Variables of interest included pressure pain threshold, maximum isometric strength, sEMG peak amplitude, and sEMG median frequency analysis (slope, intercept).

Figure 1s. Subject performing static stretching.

Figure 2s. Subject performing dynamic stretching.

Figure 3s. Subject performing the isometric dynamometer test.

Figure 4s. Subject performing the pain pressure threshold test

Data were imported to RStudio Integrative Development Environment for statistical analysis using R language. Data distribution was assessed via the Shapiro-Wilk test and distribution plots. Individual mixed models were performed with stretching conditions (Baseline, Static, and Dynamic), stretching duration (30 seconds, 1 minute, 2 minute), and biological sex as a fixed factor, while the participant was selected as a random factor (intercept and slope).

A series of pairwise comparisons were conducted when appropriate. To control for any family-wise error rate that could have arisen due to the multiple comparisons, a Holm-Bonferroni correction was applied to the pairwise comparisons, resulting in a *p*-adjusted value (Bernards et al., 2017; Tan et al., 2021). Furthermore, effect sizes (Cohen's d) were computed with an applied correction using hedges' g (ES_g) for a small sample size. The interpretation of pairwise effect size were considered as: small = 0.2, medium = 0.5. and large = 0.8 (Cohen, 1988). Statistical significance for all analyzes was set at an alpha level of 0.05.

All Data and data analysis scripts are available at https://github.com/Samuelmontalvo/Stretching_PPT. Lastly, the following packages were utilized to complete the statistical analyzes: "tidyverse", "ggprism", "lme4", "lmeTest", "psych", and "rstatix".

Results

Descriptives and baseline measures are presented in table 1 as mean, standard deviation (sd), and standard error (SE).

Table 1. Descriptives and Baseline measurements for all participants and by Sex groups.

All (n=16)	mean	sd	SE
Age (yrs)	25.50	5.56	0.50
Height (m)	1.68	0.09	0.02
Weight (kg)	68.34	18.07	4.26
Systolic Blood Pressure	110.44	11.89	2.80
Diastolic Blood Pressure	73.11	10.33	2.43
$HR_{resting}$ (bpm)	73.06	10.40	2.45
Females (n=6)			
Age (yrs)	23.12	2.87	0.38
Height (m)	1.62	0.09	0.03
Weight (kg)	59.29	6.74	2.38
Systolic Blood Pressure	103.88	12.18	4.31
Diastolic Blood Pressure	67.62	10.32	3.65
HR (bpm)	72.00	14.60	5.16
Males (n=10)			
Age (yrs)	27.40	6.42	0.77
Height (m)	1.72	0.07	0.02
Weight (kg)	75.59	21.22	6.71
Systolic Blood Pressure	115.70	9.09	2.88
Diastolic Blood Pressure	77.50	8.40	2.66
$HR_{resting}$ (bpm)	73.90	6.06	1.92

Our initial model on PPT showed an effect of stretching condition [F(6,96)=2.70, p=0.01)], an interaction of biological sex [F(1,16)=4.81, p=0.04)], and random effect of participant (p<0.01). Post-hoc pairwise comparisons showed a moderate difference with a small effect between baseline and 1 minute of dynamic stretching (t(2.14), p.adj=0.04; ES_g (*small*) = 0.508), a small effect for 30 seconds of static stretching compared to 1 minute of dynamic stretching (t(2.23), p.adj=0.04; ES_g (*small*) = 0.226), and a moderate effect for 2 minutes of static stretching vs 1 minute of dynamic stretching (t(2.37), p.adj=0.03; ES_g (*moderate*) = 0.532) (Figure 1 & 2).

Our second model on hang grip strength showed no effect of stretching condition [F(6,96)=1.55, p=0.16)], an interaction of biological sex [F(1,16)=9.033, p<0.01)], and random effect of participant (p<0.01) (Figure 3). Our third on peak sEMG amplitude model showed an effect of stretching condition [F(5,80)=3.88, p<0.01)], not interaction of biological sex [F(1,16)=9.03, p<0.01)], and no random effect of participant (p=0.09). Pairwise comparisons showed a large effect difference between 1 minute of static stretching and 1 minute of dynamic stretching (t(0.86), p.adj<0.01) (Figure 4). Our fourth and last model showed on sEMG frequency (slope) showed no effect of stretching condition [F(5,80)=1.93, p=0.09)], not interaction of biological sex [F(1,16)=4.04, p=0.06)], and a random effect of participant (p<0.01) (Figure 5).

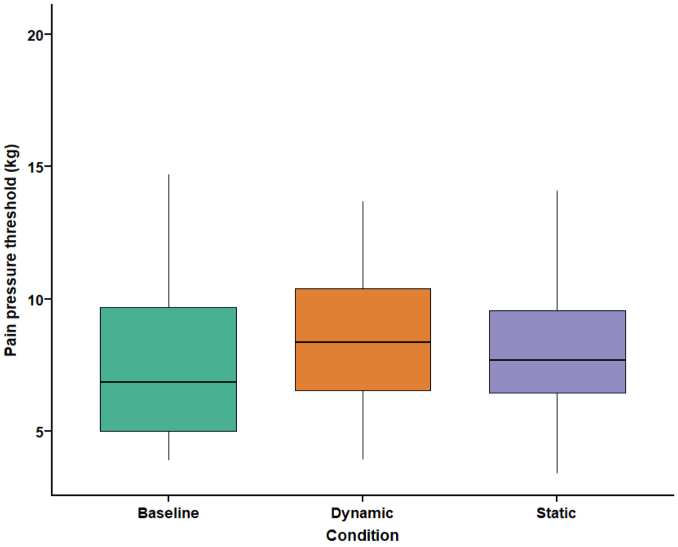

Figure 1. Pain pressure threshold (PPT) (kg) by stretching conditions.

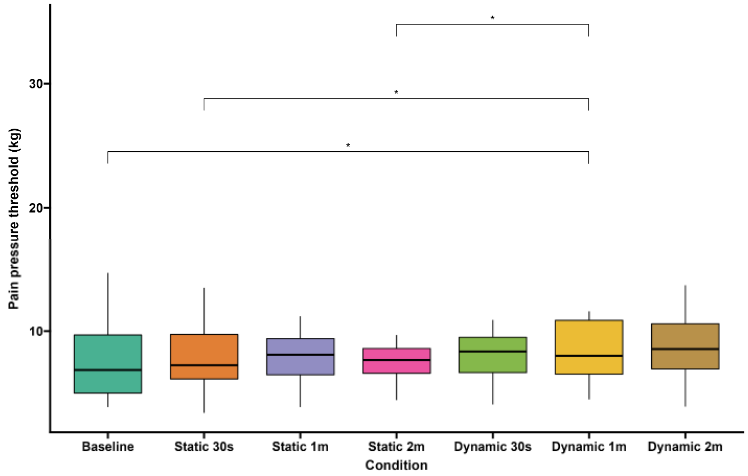

Figure 2. Pain pressure threshold (PPT) (kg) by stretching conditions with different times under stretching periods.

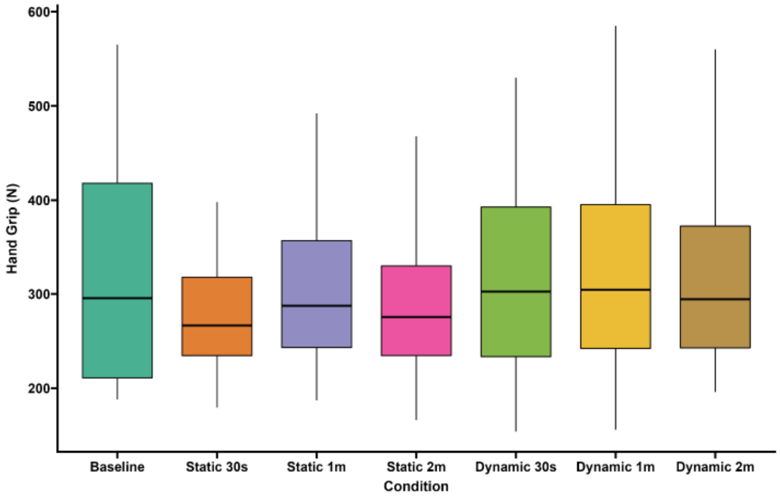

Figure 3. Hand grip strength (kg) by stretching conditions with different times under stretching periods.

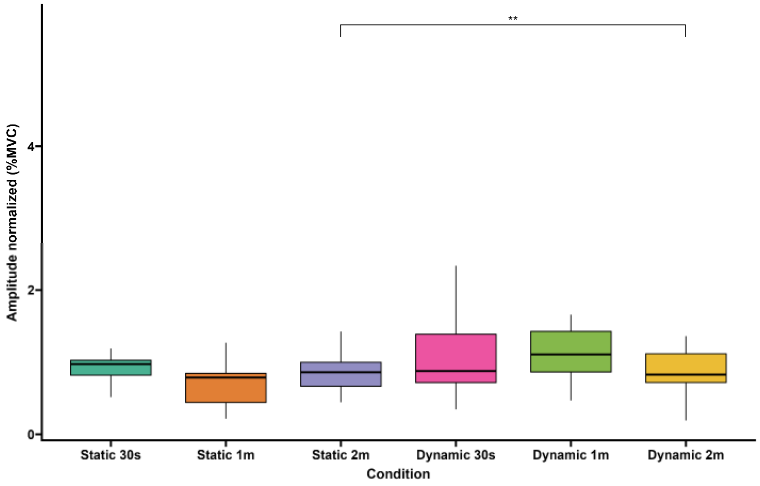

Figure 4. Normalized peak amplitude sEMG (%MVC) by stretching conditions with different times under stretching periods.

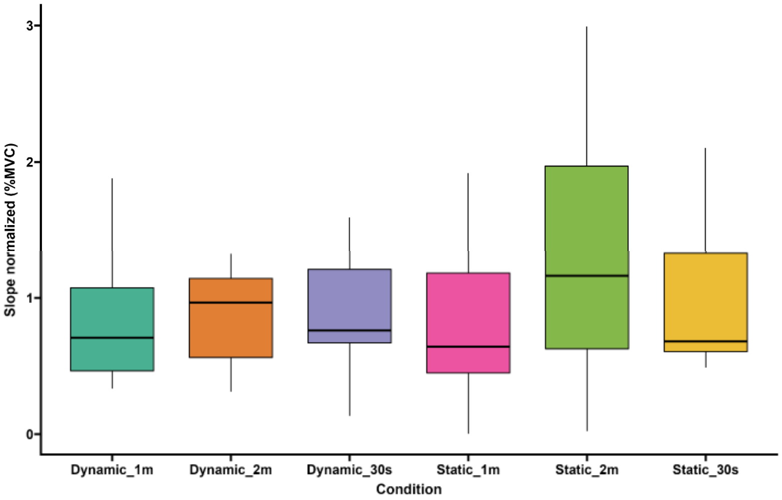

Figure 5. Normalized frequency (slope) sEMG (%MVC) by stretching conditions with different times under stretching periods.

Discussion

Our initial hypothesis was supported by our results. We observed that indeed, the Dynamic stretching condition, more specifically, the 1-minute yields greater tolerance to pain through the PPT. In addition to this, we reported that the Dynamic stretching at 2 minutes yielded significantly greater motor unit activation in peak EMG (% MVC) than the static stretching at 1 minute. Surprisingly, we observed no difference in EMG frequency (slope) or isometric strength among the stretching conditions.

Previously, we have reported that dynamic stretching improves PPT but not static stretching (Montalvo et al., 2021). However, we were unable to report measures of muscular activation (EMG). These findings could be attributed to the increase in the muscle temperature that is the result of the dynamic movement of the dynamic stretching (Page, 2012), which could have generated an acute analgesic effect (Lehmann et al., 1967). However, we did not measure the muscle's warmth, hence, the mechanisms through which dynamic stretching allows for a greater pressure pain threshold remain to be unknown. Moreover, our previous findings were limited to a small sample of 8 participants within our college.

Interestedly, our findings on isometric strength and isometric time to fatigue were not statistically significant. However, we observed that the dynamic 2-minute stretch yielded 8% greater values than static at 30 seconds and was far greater than any other stretching condition and baseline. Our static stretching findings are supported by previous research, in which static stretching for at least 45 seconds decreased handgrip strength and EMG activity (Jelmini et al., 2018); our findings indicated a decreased isometric force after the Static 1 minute and 2-minute, but no change in static at 30 seconds. Moreover, our ability to detect minimum differences could have been perhaps conflicted due to the Bonferroni correction to the multiple comparisons (Nakagawa, 2004); subsequent analysis of non-adjusted pairwise comparisons indeed showed that the dynamic stretching condition was different than the static conditions. Hence, we encourage replication with greater sample size and a reduction of the multiple stretching conditions to just 3 (baseline, static stretching, and dynamic stretching at a set time period) conditions to avoid the multiple-comparisons adjustment problem.

Furthermore, we must note that our study was composed of a small sample size. Our study was indirectly affected by the COVID-19 pandemic in 2021, when most human research studies ceased to continue. Given this, the sample of this investigation was concluded at 16 individuals. Moreover, the effect sizes that resulted after the interaction between dynamic stretching and PPT or EMG were large which denotes enough statistical power. Furthermore, we also adjusted using a Bonferroni correction to avoid any family-wise type error that could have appeared from the multiple statistical pairwise tests, which increased the confidence of our findings. However, given our small sample size, we were unable to do between-subjects analyses. For example, the relationship between static and dynamic stretching, and its effects on PPT, EMG, and Isometric strength on sex differences remain unknown. Along similar lines, it is unknown if the results found in this investigation would remain the same in other populations (geriatric population, athletic, blue-collar workers, office, etc.). Hence, replication of this study with a greater sample size and a variety of populations is encouraged. Finally, it is worth noting that individual responses to each type of stretching were observed. In a small number of cases, certain participants performed slightly better with static stretching during one of the static stretching conditions. While this may be considered a source of noise in the data, it is important for clinicians to carefully evaluate individual responses in order to identify the optimal practice. Recent pre-eliminary data from our laboratory has shown individual responses to each stretching type under multiple configurations (Montalvo, 2021). In general, it is recommended that clinicians prioritize dynamic stretches over static stretches.

Conclusion

Our data suggest that the participant's ability to tolerate pressure pain increase after dynamic stretching compared to isometric stretching. Although we did not observe a statistically significant increase in strength or motor unit activity via electromyography, we suggest that future studies might replicate the protocols within this study with several stretching and testing sessions of dynamic and static stretching, versus other types of stretches, a combination of the dynamic and static stretching, and alternating seating and standing positions. Furthermore, we conclude that individuals looking to increase their tolerance to pressure pain and motor unit recruitment at the arm flexors should select dynamic over isometric stretching.

Conflicts of interest - The authors do not have any conflicts of interest to declare.

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