TOPICS IN EXERCISE SCIENCE AND KINESIOLOGY

Original Research

Simultaneous Acute Stretching with Whole Body Vibration does not have an Additive Effect on Extensibility of the Hip Adductor Muscles

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ABSTRACT

Topics in Exercise Science and Kinesiology Volume 5: Issue 1, Article 8, 2024. Static stretching of hip adductor muscles is often included in traditional warm-up, though little research has been conducted to determine effective strategies for improving their flexibility. Combining whole body vibration (WBV) with static stretching has been proposed by some to be an effective method to improve flexibility without reducing force output. The purpose of this study was to investigate and compare the acute effects of static stretching, with and without WBV, on adductor muscle extensibility and strength. A randomized crossover design using a repeated measures ANOVA 2 X 2 (Condition X Time) was implemented on 40 participants (n = 20 males and n = 20 females) with limited adductor muscle flexibility. Following a stationary cycle warm-up, maximum voluntary contraction (MVC) and hip adduction range of motion (ROM) were measured pre- and postintervention, with ROM used as a surrogate measure of adductor muscle extensibility. Interventions included 60 seconds of static stretching of the adductor muscles with vibration (SSV) or without vibration (SS). Adductor muscle extensibility was increased ($p < 0.05$) from pre- to postintervention in both SSV (1.5°) and SS (1.2°) with no differences between interventions. These increases exceeded minimal detectable change at the 95% confidence level (0.6°) by two-fold. No differences were observed in MVC within or between conditions. Static stretching with or without vibration has a modest effect on acute improvement in hip adductor muscle extensibility without inducing an ergolytic strength decrement. Therefore, WBV as an adjunct to conventional stretching is unjustified.

KEY WORDS: Flexibility, range of motion, groin muscles, maximal voluntary contraction, static stretching, ergolytic effect

INTRODUCTION

Athletes and fitness enthusiasts warm-up prior to physical activity with the aim of achieving a state of readiness and improving sports or workout performance while reducing the risk of injury. To this end fitness professionals, sports coaches and clinicians actively seek effective methods to increase flexibility in participants, especially in those that have reduced muscle extensibility. Among physically active individuals, hamstring, calf and groin muscle tightness is common.

Until recently, strategies for improving flexibility in the groin have been understudied. We have heretofore published a series of papers that have investigated the prospects of improving extensibility of hip adductor muscles through selected warm-up procedures. The protocols included a short submaximal aerobic component followed by one of the following stretching methods: passive static stretch, active static stretch, 3-dimensional dynamic stretch, foam rolling, manual joint mobilization and a lunge stretch. Taken together, these interventions resulted in small but significant acute increases in hip adductor flexibility as evidenced by 1.0-1.7^{o} increases in hip abduction range of motion (ROM) without compromising strength output (4, 10, 12).

Whole-body vibration (WBV) is another intervention purported to improve outcomes for flexibility (8, 11, 14, 15, 19) and strength/power training (7, 13-16, 18-19). Many of the early flexibility and strength studies used a generalized non-specific protocol where subjects stood in a partial squat on a vibrating platform whereafter it was determined if the procedure affected flexibility and/or strength. In the present literature review we focused on 10 studies that were designed to apply an acute stretching intervention targeting specific muscles while simultaneously applying the weight of a limb or of the entire body on a vibrating device or platform (5, 6, 7, 9, 16, 17, 18, 22, 23, 25).

Currently there is no consensus about what may be the optimal amplitude and frequency for use of WBV for flexibility improvement. In recent reviews it was suggested that vibration was most effective for improving flexibility when administered at an amplitude of 2-4 mm and at a frequency of 30–40 Hz, producing a gravitational acceleration of 5-10*g*. Furthermore, it was recommended that in future research 50 Hz and higher also be tested for effectiveness, and in subjects who are hypo-extensible prior to intervention (8, 11).

Furthermore, it is often reported that strength is compromised when static stretching intensity is high and durations are longer than 60 seconds. These reports have often led to avoidance of this method during warm-ups for physical performance (1, 25). However, research from our laboratory (10, 12) and others (3, 24) have observed that up to 60 seconds of static stretching at the point of discomfort resulted in no decline in isometric force output in muscles of the lower extremities.

Despite substantial research efforts, there is also no consensus on the effectiveness of WBV as a tool to improve flexibility and muscle performance compared with an equivalent stretching warm up without WBV (11, 14, 15). The inconsistency of results may be due, at least in part, to the variability in parameters such as subject training status, sex, exercise selection, and vibration protocols with respect to frequency, amplitude, duration, and amount of external load applied to the platform. Low precision testing methods (e.g. Sit and Reach test, split-leg test) could also be part of the problem in discerning the presence of small ROM gains. It also needs to be considered that WBV may simply not work better than other common warm-up practices. In fact, it is worth considering whether WBV might even be ergolytic (14, 17). We expect WBV to work better on individuals with hypoextensibility, and who are not able to move through the anatomical limit of their joint motion.

The present study was designed with the aim of testing whether a weight-bearing static adductor stretch would improve flexibility in tight hip adductor muscles when simultaneously applying WBV, and without compromising strength. We hypothesized that vibration would cause an additive effect on flexibility increases without causing a drop in hip adduction force output.

METHODS

Participants

We recruited recreationally active subjects, both male and female, who considered their groin muscles to be tight and who had that suspicion confirmed during subsequent prescreening in our laboratory. Forty individuals participated in this investigation (Table 1). It was part of a comprehensive effort divided *a priori* into separate research questions, where subjects experienced multiple stretching interventions and acted as their own control in a randomized crossover model.

Table 1. Participant characteristics (n = 40).

	Males (n = 20)	Females (n = 20)
Age (yr)	22.5 ± 1.8	23.6 ± 4.2
Height (cm)	181.7 ± 6.1	168.8 ± 6.3
Mass (kg)	88.8 ± 13.1	70.6 ± 10.3
Body Mass Index (BMI)	26.9 ± 3.7	24.8 ± 3.1

Values are mean ± standard deviation (SD).

Participants were volunteer university students and staff (ages 18–35 years) recruited through posted fliers and announcements. To be eligible for the study participants were required to demonstrate limited flexibility in their hip abduction ROM. A screening process was administered to verify limited hip abduction ROM as described by Hammer et al. (12). Only those who were unable to achieve 45° of passive hip abduction ROM were admitted into the study. Exclusion criteria included current or previous groin injury within the last 6 months, self-identification as physically inactive (exercise less than twice a week), and a reported current or recent pregnancy (within 6 months). None of the participants had previous experience with WBV. They were allowed to participate in their regular physical activities but were instructed not to exercise within 24 hours prior to testing and to refrain from additional stretching of muscles in the groin region for the duration of the study.

Because this was part of a larger overall study, eligible participants reported to the laboratory nine times in total (1 familiarization day and 8 testing days), at least 48 hours between testing days. Participants dressed in non-restrictive shorts and a T-shirt. For this manuscript, focus was placed on only three of the nine days (familiarization, static stretch with vibration and static stretch without vibration). The schedule of participants and stretches per testing day were selected using a random function generator in Excel® 2010 (Microsoft Corp., Redmond, Washington, USA) to eliminate effects from sequencing. All participants provided written consent, and the study was approved by the institutional review board at Central Michigan University. This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (20).

Protocol

The protocols for warm-up and for preintervention maximum voluntary contraction (MVC) (as a measure of strength) and ROM measurements (to measure muscle extensibility) were described previously by Hammer et al. (12). On a separate day 2–5 days prior to intervention each participant was familiarized with all warm-up, testing and stretching procedures, including practice, until the subject could complete each task satisfactorily. A standardized warm-up was performed using an upright cycle (750U, True Fitness Technology, St. Louis, MO). Hip adduction MVC and hip abduction ROM were measured while subjects were seated, semi-recumbent with 20–30° of hip flexion, on a Cybex Adductor/Abductor Machine (CAAM) (Model #1181-91Cybex International Inc., Medway, MA) as shown Figure 1.

Figure 1. Cybex machine (CAAM) was used for pre- and postintervention hip abduction ROM measurements.

A soft half bolster that was 7.62 cm in depth was placed in the lordotic curve for lumbar support. Subjects were secured in place with an 8 cm wide belt that was fastened around the waist to prevent arching of the back or movement of the pelvis during MVC testing. MVC's were recorded on an electronic dynamometer (model microFET2 Hoggan Health Industries, Inc., West Jordan, UT). For MVC determination participants were instructed, by script, to squeeze the pads together as hard as possible. No additional verbal encouragement was provided. The dynamometer was placed between the foot cradles to record peak bilateral adductor force (see Figure 2). This method was chosen as it is similar to the adductor squeeze test described by

Nevin and Delahunt (21). This procedure was repeated a second time following a 30-second rest interval.

Figure 2. Measurement of bilateral hip adductor MVC using squeeze test with hand-held dynamometer.

Following MVC, participants were re-fitted and aligned for ROM measurements and the load that caused movement into end hip abduction ROM was determined on the CAAM (Figure 1). The weight stack was initially loaded to a target of 30% of the participant's body mass (BM) and adjusted up or down to cause hip abduction and achieve optimal stretch of the groin muscles. For this study, an optimal stretch was considered to be at the point of discomfort and rated by the subject as a 7 out of 10 on the *Stretch Sensation Scale* (SSS) previously published by Hammer et al. (12). This predetermined baseline load was then used for each subsequent ROM measurement for the duration of the study.

Any load that caused a stretch exceeding the point of discomfort, and instead elicited pain or wincing, was deemed to be in excess of a tolerable stretching sensation for purposes of this study. Subjects allowed their hips to be gradually moved bilaterally into hip abduction and settled for about 5 seconds into their final stretch position. A ROM displacement recording was then quickly determined by reading the gap distance of displacement of the weight stack from the 0 mm starting position. The subject then rested in the seated position for 30 seconds, while unloaded, and was remeasured. The best of the two trials was recorded. The change in linear distance of the pulley strap (measured in millimeters using an affixed fiberglass measuring tape) had a correlation of $r = 0.998$ with simultaneous goniometric determination of the leg cradle during abduction from 0 to 90°. Each millimeter change in strap movement (weight stack displacement) equaled a 0.19° change in leg cradle angle and the corresponding hip joint abduction angle. Repeat ROM measurements within-day were shown to have a Pearson Correlation of $r = 0.960$. Simultaneous interrater ROM comparison had a correlation of $r = 0.995$. Between-day variability was found to be $r = 0.763$ (12). It is important to note that the hip abduction angles reported in this paper are greater than what they would have been with a normal clinical ROM measurement because the measurements in this study were taken from a seated position, and with a superimposed 20-30° of hip flexion set on the seatback of the CAAM. On intervention days subjects performed a 5-minute warm-up on a cycle ergometer (heart rate of 130–150 bpm; rating of perceived exertion of 12–14 on the Borg scale) and preintervention measures of ROM and MVC were taken. Subjects then performed one of the interventions and were remeasured. For this study interventional stretches were performed in a quadruped position while kneeling on a vibration platform (VibePlate, Lincoln, NE) covered with a 7 mm thin pad to protect the knees (Figure 3). Our protocol utilized a classic weight-bearing active static stretching position, with vibration (SSV) or without (SS) (2).

Figure 3. Weight-bearing active static stretching on the vibration platform (turned on or off) in the *frog straddle* position.

Subjects were instructed to flex at the hips and contract opposing muscles to abduct the legs until they reached a 7 on the SSS. As their muscles accommodated to that position, they moved the hips into greater abduction. If the platform performed at the stated manufacturer's preset peak-to-peak vibration of 2 mm and our selected frequency of 50 Hz the resulting acceleration was 6.03 *g*. In order not to introduce bias into their effort, subjects were not made aware of their results after any trial.

Statistical Analysis
A randomized crossover design using a 2 X 2 factorial repeated measurements analysis of variance (2-way RM ANOVA) was performed to test for an interaction between the stretching interventions for ROM and MVC. Statistical analyses were performed via SigmaPlot 13.0 (Systat Software, San Jose, CA). The independent variables were condition (SSV and SS) and time (pretreatment and posttreatment). The dependent variables were change in ROM and maximal

voluntary isometric contraction (MVC). A secondary analysis of sex as a between-subjects factor was also performed. A *p*-value of < 0.05 was used for statistical significance. If a difference was found, post-hoc analyses were performed using the Bonferroni pairwise comparison method. Minimum detectable change (MDC_{95}) for ROM and MVC was calculated as $SEM * \sqrt{2} * 1.96$. In crossover design studies it is important to verify whether long-term day-to-day increases in flexibility occurred which could potentially confound interpretation of the results. Thus, preintervention ROM on the first and last days of data collection was analyzed by a paired t-test. Going beyond group statistical analysis we took the liberty to look at individual data and determine whether there were subjects who responded especially favorably to either intervention.

RESULTS

P-values from 2-way repeated measures ANOVA for the main effects of condition (SSV vs. SS), time (pretreatment vs. posttreatment) and interactions (condition vs. time) are reported in Table 2. Descriptive statistics (mean ± SD) for change in hip adductor ROM and MVC from pre- to postintervention are shown in Table 3. No significant differences were observed between conditions preintervention. ROM from pre- to postintervention significantly increased for both the SSV and SS conditions ($p<0.05$). No significant differences were observed in MVC within or between conditions pre- or postintervention. MDC_{95} for ROM and MVC was 0.6° and 0.9 kg respectively.

Table 2. *P*-values for 2-way Repeated Measures ANOVA.

Main Effects and Interaction	ROM (degrees)	MVC (kg)
Condition (SSV vs SS)	0.497	0.581
Time (Pre- vs Post Treatment)	< 0.001	0.125
Interaction (Condition x Time)	0.311	0.443

The paired t-test did not reveal a significant difference between first session pretest ROM and final session pretest ROM, indicating that there were not significant increases in hip abduction ROM over the testing period. This indicates no carry-over effect of the stretching intervention across time. The ANOVAs for ROM and MVC revealed no significant interaction between sex and stretching interventions or strength outcomes, thus sexes were combined for each variable.

Table 3. Summary of flexibility and strength changes.

	SSV	SS
Hip Abduction ROM (degrees)		
Pretest mean (SD)	54.1 ± 4.9	53.8 ± 4.1
Posttest mean (SD)	55.6 ± 5.1	54.9 ± 4.3
Mean gain (SD)	1.5 ± 1.7*	1.2 ± 1.5*
MVC (kg)		
Pretest mean (SD)	23.4 ± 6.7	23.2 ± 6.9
Posttest mean (SD)	23.6 ± 6.5	23.5 ± 7.2
Mean gain (SD)	0.2 ± 2.3	0.3 ± 1.9

*SSV and SS interventions both produced a significant increase in ROM ($p < 0.05$), but there was no difference between conditions.

DISCUSSION

The main objective of this study was to determine if static stretching with WBV would achieve greater improvements in muscle extensibility than conventional static stretching alone. We found that an acute 60-second bout of static stretching produced an increase in adductor muscle extensibility with or without the addition of WBV and that there was no significant difference in improvements between either treatment. Therefore, we must reject our hypothesis that static stretching with WBV would be more effective than static stretching alone (Table 2). There were no differences in results between the sexes, and both the SSV and SS treatments had increases in ROM at least two times the calculated MDC_{95}.

The following discussion of literature only includes studies that administered vibration simultaneously with a stretching intervention because we believe this is an important similarity to our study. Not only is simultaneous vibration what we used in this study, but we also believe that the theoretical foundations for use of vibration to affect muscle extensibility, both the neurophysiological reflex effects and any potential mechanical effects that might contribute to muscle extensibility are going to be very short lived and no longer present after even a very short pause between vibration and stretching.

With the exception of 2 studies (5, 17) the majority of research, like ours, have found that simultaneously stretching with vibration produces an acute increase in muscle extensibility. Our finding that SSV was not better than SS at improving muscle extensibility is consistent with results reported in some studies (6, 7, 9, 25) but is contrary to reports from other studies that found SSV was better than SS (16 22, 23). These contradicting results could indicate any or all of the following:

- that vibration enhances the effects of stretching in some muscles or circumstances but not in others
- that the parameters necessary for vibration to be effective were achieved in some studies but not others
- that the methodologies of some studies were insufficient to produce accurate results

Previous studies in the literature have focused on many different muscles and areas of the body, different stretching protocols, and different vibration parameters. Furthermore, some studies provided true WBV while others only exposed part of the body to vibration. Studies have often not accounted for variations in amplitude of vibration as the energy is propagated through the body (damping effect), nor have they accounted for changes in the output characteristics of vibration plates as they are put under load. In the current study, we implemented stretching and measurement procedures that were more consistent than those in most other studies, including careful implementation of true full body vibration. Unfortunately, we were unable to verify that the vibration output characteristics stayed within specifications when subjects were stretching on the plate, though we do have our doubts because it has been demonstrated that load and load positioning on the platform can affect vibration amplitude in inconsistent and potentially detrimental ways (13). A comprehensive discussion of the messiness of unaccounted variables is beyond the scope of this paper and the reader is referred to our previous paper for further information (13).

This being an in-vivo study, it was impossible to measure muscle extensibility directly, so joint ROM was used as a surrogate. To establish validity for this substitution we were very careful to match the muscle targeted for stretching with a corresponding joint motion that was directly related to its elongation. The muscles of the hip adductor group (with the exception of gracilis) are single joint muscles that increase or decrease in length as a direct effect of changes in hip abduction/adduction position. The adductor muscles may also be affected by other motions of the hip, so other hip motions were kept consistent throughout the interventions and measurements. Under these circumstances we felt that use of ROM as a surrogate for muscle extensibility was reasonable.

A potential limitation to the use of hip ROM as a measure of adductor muscle extensibility would be the circumstance where a subject had limited movement due to hip joint structures (such as bone, capsule or ligaments) during intervention and measurement rather than the hip adductor muscles themselves. To mitigate this potential we purposefully selected subjects who had tight hip adductors and were therefore likely to receive a real stretch of the hip adductor muscles during intervention, and still have potential for improvement. We believe this is an important consideration compared to many other studies in the literature that likely included subjects with little or no potential for improvement because they already had normal muscle extensibility, or their ROM was limited by joint structures (eg. bone, capsule and ligaments) rather than tight muscles.

A minimal clinically important difference for hip abduction ROM has not yet been established, making it difficult to know what degree of ROM increase can be deemed beneficial. In this study we achieved an average improvement of less than 2° (~3%) within a short, 60 second warmup intervention. Although we consider this increase to be quite modest, it must be remembered that a stretching intervention in the clinical or sport performance world would consist of a longer, repeated series of stretching exercises over many days and weeks. Indeed, in this series of studies performed in our laboratory there was no persistent ROM gain detected in the hip adductors between the initial date of testing and subsequent testing sessions including the final session despite a stretch stimulus occurring twice per week for about 5 weeks. It is the cumulative effect over time that would be expected to have a real impact on exercise performance or injury prevention, and that is only likely to be achieved with the time interval between stretching sessions being short enough to provide a cumulative effect from time to time, before the person's muscle extensibility has reverted to its pre-stretch length. This would normally be achieved as part of a daily home or sports training program. Subsequent studies will need to further elucidate this.

A persistent and controversial consideration with stretching interventions is whether they have an important ergolytic side effect on force output. To address this consideration we measured pre- and postintervention MVCs as a secondary interest in this study. We found that MVC performance was neither hindered nor advantaged with the static stretching intervention in this study. This is consistent with previous studies from our laboratory (4, 9, 12) and others (3, 24). Studies that have previously demonstrated an ergolytic effect of SS generally included high intensity and/or long duration (> 60 seconds) stretching interventions (1, 25). From our experience we believe that up to 60 seconds of static stretching to the point of discomfort will not compromise muscle performance. In any case short of tissue injury, it is likely that compromise in muscle performance following static stretching intervention is short lived and the overall benefit will outweigh the risk. Nevertheless, it seems prudent not to perform intense or long duration stretching immediately prior to activities that require peak performances such as athletic competitions (17).

The addition of vibration to SS also had no effect on strength as was the case in most other studies reviewed (5, 7, 9, 15, 16, 18). In contrast, some other investigators found that vibration erased the decline in strength caused by static stretching (7, 25). In only one study it was determined that vibration actually showed an ergolytic effect with a decreased power output (17). It is important to note that some of the apparent contradictions in results could be related to studies using impairment tests of strength (eg. isometric tests, like in this study) vs functional measures (eg. jump tests).

Drawing conclusions based on group summary data risks overlooking significant individual responses when a small number of individuals in the groups may be different enough, for unknown reasons, to have a real response that is different than most of the individuals in the group. In this study there were 2 individuals that had more than 4° of improvement in ROM while stretching with vibration. Neither had a similar response without vibration. These individuals are just 5% of the study group, but they do suggest the possibility that they could represent a small subset of individuals that really can benefit from the use of vibration. Unfortunately, we have no way of knowing if these individuals were actually different as outliers, or if they simply fall in the tails of the distribution of a homogeneous group. Such is the plight of every clinician, coach, or personal trainer who must make a recommendation for an intervention to an individual, or for a piece of equipment necessary, such as a WBV plate, to provide such an intervention. Given the relatively high cost of a commercial vibration plate and the low probability of significant benefit, it seems unlikely that purchase of a WBV plate would be worth the price in most circumstances. On the other hand, given that WBV seems safe, and it is otherwise no more expensive to perform static stretching with vibration than static stretching alone after the equipment has been acquired, it may well be worth the investment in some circumstances.

The sensitivity provided by the adduction measurement methodology of this paper is concurrently a shortcoming because it is impractical for use in clinical or on the field applications. The interventions in this study (stretching and vibration) were also administered as a single bout that should not be generalized to the effects of stretching that would normally be administered as a long series of daily interventions over an extended period of time before hopefully producing the intended functional improvements. Although subject blinding in research may be considered ideal, it is near impossible when using WBV. For this study we used a 2X2 crossover design to mitigate the effects of subject awareness of the vibration condition. We are confident that this design provided credible insights to the effects of WBV on a stretching intervention. Finally, we are not confident that the vibration platform necessarily provided vibration characteristics according to manufacturer specifications as other research has suggested (13).

The only evidence of benefit from use of WBV with stretching is weak evidence derived from the response of 2 subjects, which may or may not indicate true change. Therefore, until more data is available that could define a subset of individuals who may benefit, we cannot recommend use of WBV as an adjunct to enhance the effectiveness of a conventional stretching program.

Our findings demonstrate that acute bouts of static stretching with or without WBV significantly increased hip adductor muscle extensibility without compromising force output. Unless subsequent research identifies a sub-population who might benefit from WBV, it is unjustified as an adjunct to conventional stretching.

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