

Original Research

# Improved Hip Flexibility and Gluteal Function Following a Daily Lunge-and-Reach Stretching Intervention

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### Background

A sedentary lifestyle contributes to hip flexor tightness. Some evidence suggests that tight hip flexors may contribute to impairments in gluteal function.

### Purpose

The purpose of this study was to determine the effects of a daily lunge-and-reach stretching program on hip flexor length and gluteus maximus strength, power, and endurance in healthy college-aged adults.

### Study Design

Cohort Study

### Methods

Twenty-three participants with hip flexor tightness (15 females, 8 males; average age  $24.0 \pm 2.58$  years) totaling 46 limbs were tested. Twelve participants were randomly assigned to the experimental group, while the remaining eleven were placed in the control group. Hip flexor length was measured with the Modified Thomas Test using an inclinometer. Gluteal power was measured on each lower extremity using a single-leg broad jump for distance with a tape measure. Gluteal strength was measured with prone hip extension using a handheld dynamometer and luggage scale. Gluteal endurance was measured with a single-leg bridge using a stopwatch. Participants in the intervention group performed five minutes of a lunge-and-reach stretch daily for six weeks.

### Results

Statistically significant changes were found for the Modified Thomas Test (mean change  $5.92 \pm 3.73$  deg,  $p=0.01$ ) and single-leg broad jump for distance (mean change  $12.39 \pm 11.23$  cm,  $p=0.02$ ) for the intervention group. No significant change was found for gluteal strength or single-leg bridge endurance ( $p=0.23$  and  $p=0.26$ , respectively) for the intervention group. All measurements demonstrated high reliability ( $ICC=0.92-0.99$ ).

### Conclusion

These results suggest that the lunge-and-reach stretch can be used to improve hip flexor length and gluteal power in a young, healthy population. Clinicians, coaches, and athletes may find these improvements beneficial for rehabilitation or performance.

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## Level of Evidence

Level 3

### INTRODUCTION

Sedentary behaviors, characterized by prolonged sitting and minimal physical activity, are increasingly prevalent.<sup>1</sup> One study<sup>2</sup> observed that Americans sit 9.5 hours per day on average, substantially more than older population-based studies.<sup>3</sup> This lifestyle is associated with a host of poor health outcomes,<sup>4-6</sup> including various musculoskeletal issues such as loss in passive hip extension range of motion (ROM).<sup>7</sup> Whether it be at school, work, or in a car, prolonged sitting typically involves hip flexion at approximately 90 degrees, potentially resulting in sustained shortening of the anterior hip musculature throughout the day. Muscles of particular interest include the primary hip flexor muscles, the psoas major and iliacus.<sup>8,9</sup> Such persistent hip flexor shortening can lead to poor lumbar stability, altered movement patterns, and potential dysfunction in the gluteal musculature.<sup>10-14</sup>

Opposing the hip flexor muscle group is the gluteus maximus. The largest of the gluteal muscles, the gluteus maximus is essential for hip extension, external rotation, and pelvic stabilization during functional movements.<sup>15,16</sup> Weakness or inhibition of the gluteus maximus can lead to increased risk of injury including anterior cruciate ligament sprain,<sup>17,18</sup> patellofemoral pain,<sup>19,20</sup> hamstring strain,<sup>21</sup> or difficulty performing functional activities such as rising from a seated position or climbing stairs. Studies have demonstrated increases in gluteal function from strengthening interventions, but relatively few have been performed on stretching interventions.<sup>22</sup>

Little research has investigated the dynamic interplay between the hip flexor and extensor muscles. One systematic review with meta-analysis found that stretching tight hip flexors had a positive impact on performance parameters.<sup>23</sup> Mettler and colleagues found that a three-week hip flexor stretching program led to increased passive hip extension, but no change in lumbo-pelvic-hip running mechanics.<sup>24</sup> Most closely related to the current investigation, a study by Mills and colleagues found that individuals with restricted hip flexor muscle length demonstrated less gluteus maximus activation.<sup>14</sup> That study by Mills and colleagues was the first of its kind comparing gluteal function between those with and without restricted hip flexor length.<sup>14</sup> The primary finding was that those with restricted hip flexor length displayed decreased gluteus maximus activation during a bilateral squat measured with surface electromyography. They theorized that their findings may be due to greater relative activation of hamstrings to aid hip extension in those that have restricted hip flexor length. The implications of the Mills et al. study suggest a need for further investigation into potential interventions to enhance gluteal function in individuals with limited hip flexor mobility.

Therefore, the purpose of this study was to determine the effects of a daily lunge-and-reach stretching program on hip flexor length and gluteus maximus strength, power,

and endurance in healthy college-aged adults. It was hypothesized that the stretching program would lead to significant improvements in hip flexor flexibility and gluteal muscle function.

### METHODS

The investigators conducted a cohort study involving twenty-three healthy young adults (15 females, 8 males). Healthy participants between the ages of 18 and 35 were recruited from a local university via flyers and social media posts following Institutional Review Board approval. Individuals were excluded if they reported any of the following conditions: lower extremity, back, or spinal surgeries within the previous six months; lower extremity injury that prevented participants from performing daily or sport activities for three consecutive days within the previous six months; or current pregnancy. Further inclusion criteria were the capability of kneeling on one knee with the other foot planted on the ground (similar to a lunge position), and hip extension less than 15 degrees during the Modified Thomas Test. Upon inclusion to the study, participants were matched based on Modified Thomas Test scores and then randomly assigned to either an experimental group (n=12) or a control group (n=11) that performed no stretching intervention. All participants' height using a stadiometer and weight using a scale were measured to calculate body mass index (BMI). Performance of the lunge-and-reach stretch was demonstrated to the experimental group following data collection. Additionally, the experimental group was provided with a handout including pictures and a compliance log to track participation. Participants were discouraged from discussing any details regarding the study with anyone. Throughout the intervention period, weekly emails were sent to remind participants in the experimental group of the stretching regimen.

Prior to testing, participants were asked to sign an informed consent form and complete a medical history questionnaire. For baseline testing, participants were asked to wear loose, athletic clothing and be prepared for physical activity. Each participant was provided with a demonstration and instructions on how a researcher would perform a Modified Thomas Test to measure hip flexor flexibility using an inclinometer. A previous study reported excellent intra-rater reliability utilizing the Modified Thomas Test (ICC: 0.99).<sup>14</sup> Once placed supine in the testing position, each participant was cued to "hug one leg as tight as possible" and "completely relax the other leg" to obtain an accurate measurement of hip extension ROM in degrees. To maintain consistent spinal alignment, participants received verbal and tactile feedback to ensure neutral lumbar spine and pelvic positions. The measurement with the inclinometer was taken by a researcher at the midpoint of the anterior thigh, halfway between the greater trochanter and lateral femoral condyle. Each participant was measured three times bilaterally with an inclinometer, alternating be-

tween limbs. This method of measurement was modeled after a previous study that reported good reliability.<sup>25</sup> One researcher performed all hip extension ROM testing using a Modified Thomas Test, utilizing the same inclinometer for each trial on both pre-test and post-test measurements.

Participants' hip extension strength was assessed in prone positioning utilizing a handheld dynamometer or a luggage scale. Strength assessment of the gluteus maximus via handheld dynamometer has demonstrated high reliability (ICC=0.81) in a previous study.<sup>26</sup> And an additional study has shown no significant difference ( $p=0.99$ ) using a luggage scale in place of a handheld dynamometer albeit measuring shoulder scapular plane abduction strength.<sup>27</sup> Participants assessed with dynamometry were positioned in prone on a treatment table with a mobilization belt placed around the table and lower extremities just proximal to the knee flexed to 90 degrees. The dynamometer was positioned between the assessed distal posterior thigh and the mobilization belt. Participants assessed with the luggage scale were positioned prone on a treatment table with the distal thighs off the edge of the table. A mobilization belt was placed around the distal thigh of the limb to be assessed, and the luggage scale was anchored to the belt directly below. A dynamometer and/or luggage scale was used to quantify participants' strength in kilograms. Measurements were taken bilaterally for three trials in an alternating fashion. Participants were cued to "push their foot toward the ceiling", gradually building force until they could "push as hard as they could". During each trial every participant received motivation by the researcher cuing "push, push, push, harder, harder, harder!". Once at maximal effort, participants were cued to "hold, hold, hold" for 3-5 seconds before relaxing. Peak force was recorded, and the mean over three trials was used for analysis.

Following hip extension strength measurement, participants moved to a separate room and completed the single-leg broad jump test on each lower extremity with a different researcher. The single-leg broad jump test followed similar methods used in previous studies that reported good to excellent reliability (ICC 0.84-0.98).<sup>28</sup> A tape measure was placed on the floor parallel to the plane of jumping and secured with tape. Performance of the single-leg broad jump was explained and demonstrated to the participant by the researcher. Participants were allowed three trials per leg starting with the left leg, alternating which leg was assessed each trial. Participants were instructed to keep footwear donned. Participants were instructed to begin with their toes behind a strip of white tape at the start of the tape measure and were allowed to hop only from the trial leg with no aid from the other leg. A successful trial consisted of the participant jumping from the single assessed leg and landing on the same leg with no loss of balance, use of upper extremity and/or opposite lower extremity to steady, or movement of the trial leg after landing to steady themselves. Upon a successful landing, the participant was instructed to steady themselves with the opposite lower extremity without moving the trial extremity. If loss of balance, use of other extremities, or motion of the trial leg (hopping) after landing occurred, the participant

was asked to repeat the trial until a successful trial was performed. The researcher then used a carpenter's square immediately in front of the participants' toe box to determine the distance hopped on the tape measure. Once the distance was measured, the number was relayed in centimeters to an additional researcher to record.

After the single-leg broad jump for power, participants were measured for gluteal endurance via the single-leg bridge test measured in seconds, previously found to be a valid and reliable measure of gluteal endurance.<sup>29</sup> Performance of the single-leg bridge was explained and demonstrated to each participant. The participants' arms were instructed to be crossed over the chest, and the non-trial lower extremity was instructed to be in terminal knee extension. The hips were to remain neutral and level. Participants were instructed to hold the trial position until fatigue. Participants were asked to lie on a low mat table, assuming a hook-lying position with a knee flexion angle of 135°. A previous study compared gluteal activation levels based on the degree of knee flexion and concluded that while performing a modified single-leg bridge, an angle of 135° preferentially activates the gluteal complex instead of incorporating the hamstrings.<sup>30</sup> To assess gluteal endurance, once in the proper testing position, the participants were instructed to push through the heel of the foot of the trial leg to bring the hips into the air. Verbal cues which consisted of "Keep the hips level. Keep the arms crossed over the chest and knee straight. Push through the heel into the table." were given by the researcher throughout the trial for the participant to maintain form. Failure of the participant to maintain full hip extension or equal pelvic height from the table would result in the trial conclusion. Each participant performed one trial per leg with the right lower extremity assessed first. A one-minute rest period was taken before assessment of the left lower extremity. A single researcher conducted the testing and observed the time in seconds utilizing a stopwatch, while another researcher simultaneously recorded the data.

Upon completion of initial testing, the stretching protocol was explained through demonstration and verbal cues to the experimental group. [Figure 1](#) demonstrates the stretch from the anterior view, key components include assuming a lunge position, leaning forward, while simultaneously reaching with the ipsilateral arm overhead to the contralateral side. [Figure 2](#) demonstrates the stretch from the lateral aspect. All were reminded that they would receive an email to notify them to either perform the intervention (experimental group) or to continue with their normal activity level (control group). Those that were in the experimental group were also provided with an instructional handout and a compliance log to track completion of the intervention. The stretching protocol given to the experimental group consisted of the lunge-and-reach stretch ([Figure 1](#) and [2](#)) to be performed bilaterally, five stretches per leg, 30 seconds per stretch, daily, for six weeks.

Reassessment of the same measures in the same fashion occurred after the six-week intervention. The researchers measuring collecting data were blinded regarding assignment to intervention or control groups.



**Figure 1. Lunge-and-reach stretch, anterior view**



**Figure 2. Lunge-and-reach stretch, lateral view**

#### STATISTICAL ANALYSIS

Data were analyzed using SPSS v23.0 (SPSS Inc, Chicago, IL). Intraclass correlation coefficients (ICC) were calculated to assess the reliability of all measures. Pearson correlation coefficients were used to analyze the relationship between BMI and hip flexor flexibility. Paired t-tests were used to compare pre- and post-intervention values within each group. Independent t-tests were used to compare BMI and

changes between the experimental and control groups. The significance level was set at  $p < 0.05$ . The intervention group's average self-reported stretching compliance was determined by averaging the percentage of days each participant reported completing the stretches.

#### RESULTS

Data gathered from 46 total limbs were analyzed (mean age =  $24.0 \pm 2.58$  years; mean BMI =  $24.34 \pm 3.52$  kg/m<sup>2</sup>; 15 females, 8 males) after four limbs (two participants, one from each group) were excluded as statistically significant outliers of average jump distances for each lower extremity using the standard 2.0 x interquartile rule. This left 12 participants (24 limbs) in the intervention group and 11 participants (22 limbs) in the control group.

All data were normally distributed and showed equal variance. [Table 1](#) displays the demographics of the 25 participants initially recruited for the study. The mean changes in dependent variables are shown in [Table 2](#). The results of the independent t-tests are shown in [Table 3](#). [Table 4](#) shows the reliability of the Modified Thomas Test, hip extension strength test, and single-leg broad jump test were high (ICC = 0.92-0.99).

BMI was not statistically different between groups. BMI was found to be negatively correlated with hip flexor flexibility in the stretching group at a moderate confidence level ( $r = -0.483$ ). The self-reported stretching compliance of the stretching group was  $79.0 \pm 8.53\%$ .

#### DISCUSSION

The primary aim of this study was to investigate the relationship between hip flexor length and gluteal function utilizing a hip flexor stretching regimen in healthy college-aged participants. This study focused on the performance of a single, simple stretch for participants. The results showed that the stretching program led to significant improvements in passive hip extension ROM, supporting the initial hypothesis that the stretching program would improve hip flexor flexibility. Although an increase in passive flexibility was found after the stretching program, only speculation can be inferred regarding the underlying mechanism. Increases in muscle extensibility can be achieved either by structural changes of the tissue (e.g., passive and series elastic components)<sup>31</sup> or a person's tolerance to an uncomfortable stretch sensation.<sup>32,33</sup> Magnusson et al. concluded that the improvements in ROM after stretching for 20 days were not accompanied by changes in tissue properties, but were rather the consequence of an improved tolerance to stretching sensation.<sup>32</sup> Similarly, Folpp et al. reported that stretching five days per week for four weeks resulted primarily in improvements in a participants' tolerance to the stretch.<sup>33</sup> Mettler et al. speculated that due to the short duration of the intervention period (three weeks), the observed changes in passive hip extension were due to greater stretch tolerance.<sup>24</sup> Conversely, a study by Guissard and Duchateau investigated the effects of 30 sessions of static stretching on the plantarflexor muscles over a 6-week time

**Table 1. Participant demographics**

|                          |        | Stretching Group | Control Group | Overall      |
|--------------------------|--------|------------------|---------------|--------------|
| BMI (kg/m <sup>2</sup> ) |        | 23.79 ± 4.16     | 25.11 ± 2.11  | 24.34 ± 3.52 |
| Age (years)              |        | 23.86 ± 2.17     | 24.24 ± 3.05  | 24 ± 2.58    |
| Gender                   | Male   | 5                | 4             | 9            |
|                          | Female | 8                | 8             | 16           |

BMI = body mass index

**Table 2. Mean changes in dependent variables**

|                                        | Limbs (n) | Mean Change      |
|----------------------------------------|-----------|------------------|
| <u>Modified Thomas Test</u>            |           |                  |
| Control Group                          | 22        | 2.59 ± 4.62 deg  |
| Stretching Group                       | 24        | 5.92 ± 3.73 deg  |
| <u>Hip Extension Strength</u>          |           |                  |
| Control Group                          | 22        | 2.05 ± 5.39 kg   |
| Stretching Group                       | 24        | 0.42 ± 3.62 kg   |
| <u>Single-Leg Broad Jump for Power</u> |           |                  |
| Control Group                          | 22        | 4.83 ± 10.36 cm  |
| Stretching Group                       | 24        | 12.39 ± 11.23 cm |
| <u>Single-Leg Bridge for Endurance</u> |           |                  |
| Control Group                          | 22        | 0.86 ± 16.34 sec |
| Stretching Group                       | 24        | 6.25 ± 15.40 sec |

n = number of limbs, deg = degrees, kg = kilograms, cm = centimeters, sec = seconds

**Table 3. Results of independent t-test**

|                                       | p-value | Mean Difference in Change Scores | 95% Confidence Interval of the Difference |       |
|---------------------------------------|---------|----------------------------------|-------------------------------------------|-------|
|                                       |         |                                  | Lower                                     | Upper |
| Modified Thomas Test (deg)            | 0.01*   | 3.33                             | 0.84                                      | 5.81  |
| Hip Extension Strength (kg)           | 0.23    | -1.63                            | -4.34                                     | 1.08  |
| Single-Leg Broad Jump for Power (cm)  | 0.02*   | 2.98                             | 0.44                                      | 5.52  |
| Single-Leg Bridge for Endurance (sec) | 0.26    | 5.39                             | -4.05                                     | 14.82 |

\*Statistically significant at the 0.05 level; deg = degrees, kg = kilograms, cm = centimeters, sec = seconds

**Table 4. Intraclass Correlation Coefficient for dependent variables**

|                                          | Intraclass Correlation (ICC) | 95% Confidence Interval |       |
|------------------------------------------|------------------------------|-------------------------|-------|
|                                          |                              | Lower                   | Upper |
| Pretest Modified Thomas Test             | 0.92                         | 0.85                    | 0.96  |
| Posttest Modified Thomas Test            | 0.94                         | 0.88                    | 0.97  |
| Pretest Hip Extension Strength           | 0.99                         | 0.98                    | 0.99  |
| Posttest Hip Extension Strength          | 0.99                         | 0.99                    | 0.99  |
| Pretest Single-Leg Broad Jump for Power  | 0.98                         | 0.96                    | 0.99  |
| Posttest Single-Leg Broad Jump for Power | 0.99                         | 0.98                    | 0.99  |

period. The results showed that the torque–angle relationship was progressively shifted towards a reduced passive stiffness of the muscle–tendon unit.<sup>34</sup> The authors of that study suggest that neural changes contributed to muscle

lengthening by reducing muscle resistance caused by tonic reflex activity.<sup>34</sup> In line with Guissard and Duchateau's findings, and considering the comparable duration of the interventions, it is possible that the enhanced flexibility

observed in the current study is also related to a combination of reduced passive stiffness within the muscle-tendon unit and decreased tonic reflex activity.

It has been well established that stretching musculature will increase the ROM of the joint that the muscles overlay. A systematic review regarding effects of static stretching by Bryant and colleagues published in 2023 found that of the 18 studies included in the review, all concluded that static stretching increased ROM.<sup>35</sup> Stretching and its relation to muscle strength is a connection that is more obscure, and evidence can be found on either side of the argument. A review of studies discussed that an acute bout of static stretching leads to a reduction in maximal voluntary strength.<sup>36</sup> The reason for this reduction in overall muscle performance is largely attributed to a reduction in musculotendinous stiffness. Furthermore, a 2024 systematic review of literature published by Warneke and Lohmann conferred with previous systematic reviews that acute bouts of stretching result in immediate significant maximal strength decreases.<sup>37</sup> Reasoning for this reduction in maximal strength output has been explained by compliance changes in the muscle-tendon unit as well as diminished M-wave EMG amplitude. However, the design of the current study was intended to investigate the effect of chronic stretching on strength, among other outcomes. The effect of chronic stretching on muscle strength differs from that of acute stretching. A review by Rubini and colleagues reports an increase in strength following three- and eight-weeks of flexibility training which may be attributed to hypertrophy of the stretched musculature.<sup>38</sup> A study by Kokkonen and colleagues found that over an eight-week intervention period, weight training resulted in only an 8.8% improvement in leg press one repetition maximum, while weight training plus static stretching resulted in a 30.8% increase in leg press one repetition maximum.<sup>39</sup> The authors of that study attribute the strength gains observed to morphologic changes due to tissue overload, namely inducing Z-line ruptures, increasing protein synthesis, and growth factor production.<sup>39</sup> The results of the current study found a negligible change in hip extension force production (this study's measure of strength) in the intervention group. This lack of strength gain may be due to insufficient duration of stretching throughout the intervention as the studies included in the Rubini review consisted of 10-20 minutes of stretching per session, while the current study consisted of only two-and-a-half minutes of stretching per limb per session. An additional factor that may have negatively impacted the strength outcome was a lack of additional strength training during the intervention period. Concurrent strength and flexibility training proved to be effective in improving strength gains in the study by Kokkonen and colleagues.

Research exploring the effects of stretching on muscle stiffness and the stretch-shortening cycle may provide rationale for the current study's observed improvements in single-leg broad jump as a measure for gluteal power. An article by Hunter and Marshall suggests that "stretching should not be ignored as a possible source of improvement in stretch-shortening cycle tasks ... [such as a counter-

movement jump], at least for athletes who are inflexible."<sup>40</sup> Wilson and colleagues concluded in separate study that chronic stretching can lead to a reduction in maximal stiffness of the series elastic component, ultimately increasing an individual's ability to store and release elastic energy for concentric muscle contractions.<sup>41</sup> More closely related to the current study is a systematic review with meta-analysis by Konrad and colleagues that investigated the effects of stretching the hip flexor group on muscle performance.<sup>23</sup> This review summarized that a single bout of hip flexor stretching of up to 120 seconds led to a positive effect on jump performance and furthermore no detrimental effects were reported relating to sport-specific performance. Konrad et al. went on to discuss that while stretching other muscle groups up to 120 seconds appears to diminish force production (like in the plantarflexors), the hip flexors have "special characteristics." The special characteristics of the hip flexors include their relationship to the lumbar spine, where increased tightness may negatively impact lumbopelvic position and therefore movement patterns. Furthermore, Konrad et al. went on to discuss that stretching of hip flexors does diminish hip flexor muscle performance, but conversely this improves the movement conditions for the antagonist muscles, namely the hip extensors.<sup>23</sup> The presence or lack of appropriate stiffness appears to be a key factor to take into consideration when discussing static stretching and its relation to muscle function. The results of the current study suggest that chronic effects of stretching lead to increased ROM, allowing an individual (with appropriate stiffness) to store and then utilize more elastic energy within their hip extensors during single-leg broad jumping.

Several studies have shown ways to increase broad jump distance, but primarily through strengthening interventions. One study by Lievens and colleagues investigated the effects of three experimental groups to plyometric training.<sup>42</sup> The researchers observed that all three plyometric training periodization interventions lead to increases in standing broad jump distance (5-29 cm; 10-22 cm; and 1-18 cm), compared to the control group over eight weeks.<sup>42</sup> Dodd and Alvar found participants who engaged in complex training (defined as combining heavy resistance and high-velocity/plyometric training) increased standard broad jump by 1.80% from pre- to post-assessment, in comparison to heavy resistance alone (0.67%), or plyometrics alone (1.10%).<sup>43</sup> The current study observed a mean change in single-leg broad jump distance of  $12.39 \pm 11.23$  cm (8.39% improvement from pretest) in comparison to the control group with a mean change of  $4.83 \pm 10.36$  cm (3.27% improvement from pretest). The unique contribution of this study was the demonstration of improved broad jump performance through a stretching-only intervention, without incorporating strength or plyometric training.

Limited hip flexor length can negatively impact functionality throughout the kinetic chain, contributing to low back pain and issues with lower extremity function. Research suggests that those with lower back pain will concurrently demonstrate increased hip tightness and a reduction in gluteal mass. Amabile and colleagues investigated



gluteus maximus cross-sectional area of participants and found that the cross-sectional area was significantly smaller in the low back pain group compared to the control group.<sup>44</sup> Another study that included patients with lower back pain investigated treatment of tight hip flexors. In their study, Avrahami and Potvin observed a reduction in pain and disability scores with concurrent increases in hip flexor length in participants with low back pain.<sup>45</sup> The observed improvement in scores can be explained by the hip flexor's biomechanical role. Originating from the lumbar spine, the hip flexors influence pelvic position and lower extremity mechanics, which can directly impact muscle activation and neuromuscular control. Choi and colleagues investigated lumbar movement and muscle activation and found decreased hip flexor length, increased erector spinae activation, reduced gluteus maximus activation, and reduced endurance of erector spinae in participants with low back pain.<sup>46</sup> Choi et al. concluded their study by indicating that treatment of patients with non-specific chronic low back pain should address the length of hip flexors as well improve gluteal muscle contraction.<sup>46</sup> Taken together, this evidence in conjunction with the current study findings suggest that improving hip flexor length can improve lower extremity function.

In regard to assessment of gluteal endurance, no significant differences were found between the experimental and control groups; however, the changes between pre-test and post-test measures favored the experimental group. The change for the experimental group was an increase of 6.25 seconds, while the change for the control group was an increase of 0.86 seconds. Lehecka and colleagues have demonstrated a standard error of measure (SEM) of 8.9 seconds in the seminal study of the endurance test used.<sup>29</sup> So although the group difference did not exceed this SEM, the trend was towards an increase in gluteal endurance.

While the findings of this study provide valuable insights into gluteal function in relation to hip flexor length, limitations should be considered when interpreting the findings. Only healthy, college-aged individuals who met inclusion criteria participated in the study, limiting the external validity of the findings to other populations. Additionally, participants in the control group were not instructed to discontinue their regular exercise routine. As a result, it is possible that variations in physical activity levels among the control group influenced the  $2.59 \pm 4.62$  deg mean

change in hip flexor flexibility and/or the 3.27% improvement seen in single-leg broad jump. Furthermore, no data were collected regarding the control group's exercise or stretching routines during the intervention period, limiting the ability to account for this potential effect on data analysis. Future research should consider implementing overall activity monitoring or standardized reporting measures to better control for these potential confounding variables. Additionally, the instrument used for hip extension strength measurements began with a handheld dynamometer, but due to equipment malfunctions, further assessment was performed with use of a luggage scale. However, while the luggage scale is not considered the gold standard for assessment of strength, the measurements in this study did show high reliability (ICC = 0.988). On another note, the method used to measure endurance did not isolate the gluteus maximus completely. A previous study aimed at investigating muscle activity during a single leg bridge and reported that knee flexion of 135 degrees best isolates the gluteus maximus but still elicits some gluteus medius activity.<sup>30</sup> Further investigation with similar methods should be applied to other populations to determine whether the findings are consistent across different groups. Investigation with participants over 60 years of age may reveal important findings when interested in maximizing gluteal muscle function for performance of activities of daily living.

## CONCLUSION

The daily lunge-and-reach stretch can effectively improve hip flexor length and gluteal power, in the form of single-leg broad jump distance, in healthy young adults. Clinicians, coaches, and athletes may find this stretching program beneficial for addressing hip flexor tightness, enhancing functional movement, and potentially improving athletic performance. Further research is needed to explore the long-term effects of this stretching program and its impact on different populations and functional outcomes.

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