The acute effects of static stretching of the gastrocnemius on limits of stability in young adults versus elderly adults

Matt Bugnet  
*University of Nevada, Las Vegas*

Kirk Player  
*University of Nevada, Las Vegas*

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THE ACUTE EFFECTS OF STATIC STRETCHING OF THE GASTROCNEMIUS ON LIMITS OF STABILITY IN YOUNG ADULTS VERSUS ELDERLY ADULTS

by

Kirk Player, SPT

Bachelor of Science
Utah State University
2008

A doctoral document submitted in partial fulfillment of the requirements for the

Doctor of Physical Therapy
Department of Physical Therapy
School of Allied Health Sciences
Division of Health Sciences

Graduate College
University of Nevada, Las Vegas
May 2011
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Date 5/4/11

This Doctor of Physical Therapy Research Project prepared by

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Doctor of Physical Therapy

Merrill Landers, Research Project Coordinator, Department of Physical Therapy

Harvey Wallmann, Chair, Department of Physical Therapy

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ABSTRACT

The Acute Effects of Static Stretching of the Gastrocnemius on Limits of Stability in Young Adults versus Elderly Adults

by

Matthew Bugnet, SPT
Kirk Player, SPT

Dr. Harvey Wallmann, PT, DSc, SCS, LAT, ATC, CSCS
Chair, Department of Physical Therapy
University of Nevada, Las Vegas

Dr. Merrill Landers, DPT, OCS
Research Project Coordinator, Department of Physical Therapy
University of Nevada, Las Vegas

Background and Purpose: Balance is an important part of everyday life for all individuals with many body systems interacting to achieve optimal balance. Proprioceptive organs aid in this interaction, while also acting as stretch receptors. Therefore, it is possible that stretching may influence the overall balance of the individual. The purpose of this study was to investigate the acute effects of stretching on dynamic balance of healthy young and elderly adults. The two groups were used to determine if stretching may discriminately affect balance at different ages. Subjects: Thirty healthy adults between the ages of 18 and 35 (mean=25.8, SD=2.3) and 18 healthy elderly adults ages 65 and older (mean=72.0, SD=7.0) were included in this study. All subjects were recruited using email and word of mouth advertising. Methods: Each subject performed the limits of stability (LOS) test twice before a 30 second static stretching protocol of the gastrocnemius and once thereafter. The LOS test was performed on the NeuroCom SMART Balance Master. Results: There was a significant difference between the young and the elderly groups for all outcome measures on the
LOS test at the first measurement ($p \leq 0.004$). All the components of the LOS test, but endpoint excursion, showed no significant treatment effect for the stretching protocol used, $p > 0.016$ with a Bonferroni corrected alpha of 0.01. Discussion and Conclusion: These results indicate that short duration static stretching has little or no effect on dynamic balance regardless of age. This study also found a difference between young and elderly subjects’ performance on the LOS test.
INTRODUCTION

Balance is important for the entire population from elite athletes to elderly individuals at risk for falls. For the elite athlete, balance deficits may affect performance. In the elderly, impaired balance may lead to falls, which contribute greatly to total health care costs in the United States and often lead to serious health complications, including death.\(^1\) The total direct cost of fall related injuries in people 65 and older is projected to reach $54.9 billion (amount adjusted to represent 2007 dollars) by 2020.\(^2,3\) In 2003, 13,700 people ages 65 and older died from falls and 1.8 million people were treated in emergency departments for nonfatal fall related injuries.\(^1\) The increase in falls among the elderly is associated with decreases in balance and reaction time with advanced age.\(^4,5\) Balance is also important in younger populations. There is a strong association with decreased balance and risk of ankle injuries among young athletes.\(^6-9\) Balance is not only important for injury prevention but also for optimal athletic performance.\(^10\) Marsh et al found shot-accuracy and balance to be positively correlated in female college lacrosse athletes.

Because balance is an important part of functional mobility across the lifespan, it is critical to understand how physical interventions affect it. Optimal balance is achieved by the interaction of many different systems within the body.\(^11-14\) The proprioceptive system is a major contributor to this interaction.\(^12,15\) It is possible that a change in proprioceptor function could lead to a change in overall balance.\(^14,16\) Because proprioceptors are sensitive to muscle tension and length, it is reasonable to assume that static stretching could affect their function by inducing a general neuroinhibitory effect.\(^11,12,17\) Because static stretching is commonly used in healthcare and recreational
activities alike, it would be advantageous to know the effects static stretching has on balance.

Previous studies have shown that static stretching has an acute adverse affect on reaction time, movement time, and power.\textsuperscript{12,18} Several studies have also explored the relationship of static stretching on balance, but the results of these studies are mixed.\textsuperscript{12,19-21} Costa et al found that short duration static stretching (15 seconds) improved balance, while long duration static stretch (45 seconds) had no effect on balance.\textsuperscript{19} This is contrary to the findings of Behm et al, who found a long duration static stretch (45 seconds) adversely affected balance.\textsuperscript{12} Nagano et al found a 3 minute stretch into dorsiflexion to adversely affect balance but that this reduction in balance was compensated for by visual input.\textsuperscript{21} Lastly, Lewis et al found stretching had no effect on balance as measured by computerized dynamic posturography (CDP) (Postural Evoked Response Test, Adaptation Test, Motor Control Test, Sensory Organization Test and Unilateral Stance Test protocols).\textsuperscript{20} Three of these studies researched the effects of stretching the entire lower extremity (LE).\textsuperscript{12,19,20} These methods may not allow for exploration of the acute effects of stretching on balance because of the amount of time required to stretch all the main muscle groups of the LE. Furthermore, all of these studies had subjects with a mean age in the twenties and none explored the effects of stretching on limits of stability (LOS).

The methods of the current research in this area vary greatly. The results of the current research also vary with conclusions of improved balance, impaired balance and no change.\textsuperscript{12,19-21} The paucity and variability of research findings on the effects of stretching on balance warranted the present study. The purpose of our study was to
investigate the acute effects of statically stretching a single influential muscle on the LOS of healthy adults between 18 and 35 years of age and of healthy elderly adults 65 years and older.

Methods

Subjects

Thirty healthy adults (14 males and 16 females) between the ages of 18 and 35 (mean=25.8, SD=2.3) and 18 healthy elderly adults (5 males and 13 females) ages 65 and older (mean=72.0, SD=7.0) volunteered for this study. Exclusion criteria included recent (within the last year) LE injury that could affect balance or proprioception (e.g., joint trauma, ankle sprain, peripheral nerve injury), any neurologic disease that could affect balance or LE strength (e.g., multiple sclerosis, poliomyelitis, Parkinson’s disease, cerebrovascular accident, etc.), impaired vision that is not corrected by eye glasses, current pregnancy, and any known balance disorder (e.g., vertigo, cerebellar disease, etc.). The younger group consisted of students recruited from the department of physical therapy at the University of Nevada, Las Vegas (UNLV). The elderly group was recruited from the Las Vegas community and from among the faculty of UNLV. Both groups were recruited via e-mail advertisements and by word of mouth. Before data collection began, the study was approved by the university’s institutional biomedical review board and each subject gave verbal and signed consent prior to participation.
**Instrumentation**

CDP was used to measure LOS using the NeuroCom SMART Balance Master. The LOS test is a measure of voluntary movement of one’s center of gravity (COG) within one’s base of support (BOS). CDP is widely used in balance research. The reliability of the LOS test using CDP has been reported to be moderate to high (ICC=0.632-0.846). The stretching procedure was performed using a platform that was set at a 30 degree angle.

**Procedures**

The LOS test is performed by having the subject stand on the force plate of the Balance Master. In front of the subject is a screen that shows them a cursor that represents their COG. The subject is instructed to maintain the cursor in the center box. Around the center box are 8 target boxes. The subject leans toward each of these targets when prompted to do so. The subject must maintain the leaning position until prompted to return to the center box. This is repeated for all 8 targets starting with the one directly in front of the subject and continuing in a clockwise fashion. Each subject was given standardized verbal instructions during an introduction to the testing instrument prior to the first LOS test. These instructions were, “begin by standing still and keeping the cursor in the center box. When you hear the signal to go, lean toward the designated target so that the cursor moves directly toward it. While leaning, keep your feet flat on the platform. Do not lean so far that you need to step or reach to maintain your balance. Once you have moved your cursor as far toward the target as possible hold it where it is and wait for the second signal then return the cursor to the center box” (Figure 1).

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* NeuroCom International, Inc.  
9750 SE Lawnfield Road  
Clackamas, OR 97015
Prior to testing, each subject was fitted with a safety harness. The testing procedure began with a pretest of each subject’s LOS, followed immediately by a 2 minute rest period during which each subject was instructed to sit quietly (Figure 2). After the rest period, the LOS test was repeated to demonstrate consistency in baseline LOS scores. Immediately after the second pretest each subject underwent the stretching procedure. The procedure consisted of stretching both gastrocnemius muscles simultaneously on the stretching platform 3 times for 30 seconds each time with a 15 second rest period between each stretch. The parameters of the stretching procedure were set to simulate a common stretching scenario used in the clinical setting and that also has been used in research.\textsuperscript{18} Since the gastrocnemius muscle is continuously active during normal standing, it is an influential muscle in maintaining balance.\textsuperscript{27} Therefore, it was chosen as the muscle group of interest for this study. Each subject was instructed to keep both knees straight and lean forward until a moderate stretch was felt in the back of both of their lower legs. For this study we defined a moderate stretch as being strong, but non-painful. The stretching procedure took place next to the measurement device in order to keep the time between stretching and measuring balance less than 10 seconds (Figure 3). Immediately after finishing the final stretch, the LOS test was once again administered (Figure 4).

Data Collection

The data collected from the LOS test included:\textsuperscript{28}

- Reaction time (time in seconds between the signal to move and the subject’s first movement);
• Movement velocity (average speed of movement, in degrees per second, of the subject’s COG);

• Endpoint excursion (distance of the first movement toward the intended target measured as a percentage of the total LOS distance. The endpoint is described as the point at which movement is no longer directed toward the appropriate target);

• Maximum excursion (the maximum distance reached during each attempt); and,

• Directional control (measurement of the relationship between movement directed towards the intended target and movement directed off target).

**Statistical Analysis**

All statistical analyses were performed using the PASW statistical package for Windows, release 17.0.† A 2 (group: young and old) X 3 (time: pretest 1, pretest 2, posttest) mixed factorial analysis of variance (ANOVA) was used to determine if there was an interaction between the young and elderly age groups and the effects of stretching the gastrocnemius for each of the 5 LOS parameters. Descriptive statistics were analyzed for each group and each LOS measurement.

**Results**

No statistically significant interaction between group and time was found for reaction time, F(2,92)=0.407, p=0.632 (Huynh-Feldt correction secondary to sphericity violation, p=.002) (Table 1). Because no interaction was found, main effects were analyzed. The main effect for time was not statically significant, p=0.379, but the group
main effect was, \(p<0.0005\). This suggested the young adult group had a faster reaction
time than the elderly group (Figure 5).

No statistically significant interaction between group and time was found for
movement velocity, \(F(2,92)=1.75, p=0.179\) (Huynh-Feldt correction secondary to
sphericity violation, \(p=.008\)). The main effect for time was statistically significant,
\(p<0.0005\). Pairwise comparison revealed that pretest 1 was significantly slower than
pretest 2 and the posttest, \(ps<0.005\). However, the difference between pretest 2 and the
posttest was not statistically significant, \(p=0.421\). The group main effect was significant,
\(p<0.0005\), suggesting that the young group had a higher velocity than the elderly group
(Figure 6).

No statistically significant interaction between group and time was found for
epsilonct excursion, \(F(2,92)=0.894, p=0.413\). The main effect for time was statistically
significant, \(p<0.0005\). Pairwise comparison revealed that endpoint excursion distance was
significantly different at each point of measurement and that the distances improved over
time, \(ps<0.039\). The group main effect also revealed a statistically significant difference,
\(p<0.0005\), with the young group having a larger excursion than the elderly group (Figure
7).

No statistically significant interaction between group and time was found for
maximum excursion, \(F(2,92)=0.514, p=0.584\) (Huynh-Feldt correction secondary to
sphericity violation, \(p=.022\)). The main effect for time yielded a statistically significant
change, \(p=0.001\). Utilizing pairwise comparisons, a significant difference was found
between pretest 1 and the posttest, \(p=0.05\), but no other statistically significant
differences were found, \(ps\geq0.068\). The group main effect yielded a statistically
significant difference, p<0.0005, again with the young group demonstrating a further excursion than the elderly group (Figure 8).

Lastly, directional control data were analyzed. A statistically significant interaction was found, F(2,92)=4.236, p=0.022 (Huynh-Feldt correction secondary to sphericity violation, p=.007). Because an interaction was found, simple main effects were analyzed using a Bonferroni corrected alpha of 0.01. Two repeated measures ANOVA analyses were conducted, one for the young group and one for the elderly group. Neither the young nor the elderly group changed significantly with time, p=0.059 and p=0.016, respectively. Three independent sample t-tests were then conducted, comparing the groups at each measurement. For all 3 points of measurement homogeneity of variance was violated (ps≤0.006) and subsequently corrected in the analyses. There was a statistically significant difference between the groups at the first pretest (p=.004) but not at the second pretest or the posttest, ps≥0.011 (Figure 9).

Discussion

One main finding of this study was that the stretching protocol used on the gastrocnemius had no effect on the LOS for either the young or the old. There was no difference between the measurements before and after stretching for either group in any of the composite scores analyzed except endpoint excursion. Based on our results, stretching the gastrocnemius using a commonly used protocol does not appear to acutely affect LOS. Another important finding of our research was that the group of young subjects performed better on almost every portion of the LOS test than the elderly subjects regardless of pre-testing condition, suggesting that one’s LOS decreases with
The stretching protocol used in the present study was designed to simulate stretching that is commonly used before athletic competition and in the physical treatment of movement disorders. The only previous study we found that explored the effects of stretching a single muscle group was performed by Nagano et al.\textsuperscript{21} In this study a long duration gastrocnemius stretch (3 minutes) was found to impede balance if not compensated for by visual input. Similar results were noted by Diener et al,\textsuperscript{16} who observed increased postural sway when proprioceptive input was restricted by ischemia from a pressure cuff at the ankle. However, increased sway was only observed when the subjects’ eyes were closed.

The literature indicates a longer stretch duration may impede balance more than a short duration. This is consistent with the findings of Costa et al.\textsuperscript{19} They found that a 15 second stretch improved balance, but a 45 second stretch did not have any effect. Considering these previous studies along with our own findings, it is possible that any decrease in balance as a result of static stretching may be largely compensated for by vision. The duration of the static stretch may be an important consideration when examining the effects of stretching on balance with longer durations leading to decreased balance.

All 5 components of the LOS test showed a significant difference between the young and elderly groups at pretest 1. These results suggest that dynamic balance, as measured by the LOS test, appears to decrease with age. These findings are consistent with Liaw et al.\textsuperscript{4} In their study, the researchers investigated static balance performance and found similar results between the young and elderly. Their elderly group included
healthy adults aged 60 to 80 years and their young group consisted of healthy subjects aged 16-39 years, which are comparable to the groups used in our study.

A difference was found for movement velocity, endpoint excursion and maximum excursion across the 3 points of measurement. The significance was found between the 2 pretests and between pretest 1 and the posttest for movement velocity. For endpoint excursion, a difference was found between all 3 tests. A difference was found only between pretest one and the posttest for maximum excursion. These findings suggest there may be a learning effect for these variables. Because there was a difference between the 2 pretests, the difference between the pretests and the posttest for endpoint excursion may be explained by a learning effect. Tarantola et al also found a learning effect when testing balance multiple times using a force plate to measure postural sway. Thus, these differences can be explained by the learning effect and not by any treatment effect.

Unlike all the other components, the difference between the 2 groups at pretest 2 and posttest were not significant for directional control. This may indicate that the elderly group demonstrated a greater learning effect than the young group between pretest 1 and pretest 2. These findings could also be the result of a ceiling effect, which restrained the young group’s improvement.

The stretch used was intended to primarily stretch the gastrocnemius, but it is likely that the soleus was also stretched to a lesser extent. The gastrocnemius and soleus are traditionally thought to act as one structural unit. However, this is an over simplification of a very complex interaction. These muscles have been shown to react differently during quiet standing. Di Giulio et al reported that the soleus and gastrocnemius are mechanically decoupled from each other and from body sway during
quiet standing based on EMG and ultrasound measurements.\textsuperscript{15} This means that during quiet standing, the soleus can be lengthening and the gastrocnemius can be shortening simultaneously. These muscles also differ in tendon qualities.\textsuperscript{15} Therefore, if the stretching protocol had substantially affected proprioception of the gastrocnemius, it would have presumably also affected the complex interaction of postural control.

The limitations of this study include a small sample of elderly subjects, which was biased toward females; this was due to limited access to a large elderly population and difficulty finding elderly individuals that met all the inclusion criteria. This study focused on stretching only the gastrocnemius muscle to reduce the time between stretching and testing in order to see the acute effects of stretching on LOS. This muscle was chosen because it has been shown to be important in helping to maintain balance, but many other muscles are also involved in balance.\textsuperscript{27} Therefore, this study was limited because it investigated the acute effects of stretching only the gastrocnemius muscle, future studies may investigate the acute effects of stretching other LE muscle groups to examine how they may acutely affect LOS. This study used a stretching procedure that is commonly used in the clinical setting, but low load long duration stretching is also commonly used in clinics and may have had more of an influence than the stretching procedure used in this study. Another limitation was that a stable pretest baseline was not established for many of the dependent variables. For example, it is difficult to know if the change that was found between the second pretest and the posttest for endpoint excursion was due to the stretching procedure or if it was just a continuation of the change found between the two pretests. It may be possible that the learning effect found between pretest 1 and pretest 2 would have been present between pretest 2 and the
posttest of the other 4 components of the LOS test if no stretching was performed. The change due to a learning effect could have been negated by decreases in dynamic balance caused by stretching and, therefore, no learning effect was observed after the intervention. This scenario is an important consideration. If the baseline measurements had stabilized before the stretching procedure, the relationship between the final pretest and the posttest would have been more apparent. Future studies could be performed that include 3 or more pretests to establish a stable baseline for all the outcome measures of the LOS test. Finally, another limitation of this study was that the systems that contribute to balance other than proprioception were not controlled for. Because the stretching procedure was meant to simulate a clinical situation we did not control for the influence of the other systems used to maintain balance (visual and vestibular systems). Patients can use those systems to compensate for a decrease in proprioception. There may be some clinical situations, however, in which patients have a compromise of one or both of these other systems and the proprioceptive system would play a much larger role in maintaining balance. From this study, it is unclear if stretching the gastrocnemius would affect patients with visual or vestibular impairments differently than healthy patients. Future research should be designed to explore this relationship, possibly using the NeuroCom Sensory Organization Test.

Conclusion

Although more research is needed to understand the effects of stretching on balance, the results of this study, along with the results of other comparable studies, indicate that shorter duration (30 seconds) static stretching has little or no effect on
balance in healthy adults. The results of this study also indicate that dynamic balance decreases with age.

Conflicts of Interest

The authors of this research have no conflicts of interest.
**Figure 1.** Visual representation of the limits of stability testing procedure.
Figure 2. Two minute rest period between pretest 1 and pretest 2.
Figure 3. Stretchnig procedure utilized between pretest 2 and posttest.
Figure 4. Graphical representation of study design.
Figure 5. Composite reaction time means and standard errors.

![Reaction Time Graph](image-url)
Figure 6. Composite movement velocity means and standard errors.
Figure 7. Composite endpoint excursion means and standard errors.
Figure 8. Composite maximum excursion means and standard errors.
Figure 9. Composite directional control means and standard errors.
Table 1. Means and standard deviations of composite LOS scores.

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Biomedical IRB – Expedited Review
Approval Notice

NOTICE TO ALL RESEARCHERS:
Please be aware that a protocol violation (e.g., failure to submit a modification for any change) of an IRB approved protocol may result in mandatory remedial education, additional audits, re-consenting subjects, researcher probation suspension of any research protocol in issue, suspension of additional existing research protocols, invalidation of all research conducted under the research protocol in issue, and further appropriate consequences as determined by the IRB and the Institutional Officer.

DATE: October 28, 2009
TO: Dr. Harvey Wallmann, Physical Therapy
FROM: Office for the Protection of Research Subjects
RE: Notification of IRB Action by Dr. John Mercer, Chair
Protocol Title: The Acute Effects of Static Stretching of the Gastrocnemius on Limits of Stability in Young Adults versus Elderly Adults.
Protocol #: 0909-3210

This memorandum is notification that the project referenced above has been reviewed by the UNLV Biomedical Institutional Review Board (IRB) as indicated in regulatory statutes 45 CFR 46. The protocol has been reviewed and approved.

The protocol is approved for a period of one year from the date of IRB approval. The expiration date of this protocol is October 27, 2010. Work on the project may begin as soon as you receive written notification from the Office for the Protection of Research Subjects (OPRS).

PLEASE NOTE:
Attached to this approval notice is the official Informed Consent/Assent (IC/IA) Form for this study. The IC/IA contains an official approval stamp. Only copies of this official IC/IA form may be used when obtaining consent. Please keep the original for your records.

Should there be any change to the protocol, it will be necessary to submit a Modification Form through OPRS. No changes may be made to the existing protocol until modifications have been approved by the IRB.

Should the use of human subjects described in this protocol continue beyond October 27, 2010 it would be necessary to submit a Continuing Review Request Form 60 days before the expiration date.

If you have questions or require any assistance, please contact the Office for the Protection of Research Subjects at OPRSHumanSubjects@unlv.edu or call 895-2794.

Office for the Protection of Research Subjects
4505 Maryland Parkway • Box 451047 • Las Vegas, Nevada 89154-1047
VITA

Graduate College
University of Nevada, Las Vegas

Matthew Bugnet

Degree:
Bachelor of science, Athletic Training, 2008
Weber State University

Doctoral Document Title: The Acute Effects of Static Stretching of the Gastrocnemius on Limits of Stability in Young Adults versus Elderly Adults

Doctoral Examination Committee:
Chairperson, Harvey Wallmann, PT, DSc, SCS, LAT, ATC, CSCS
Committee Member, Merrill Landers, PT, DPT, OCS