Neuromuscular Adaptations in Elderly Adults are Task-Specific During Stepping and Obstacle Clearance Tasks.

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ABSTRACT

Int J Exerc Sci 4(1) : 77-85, 2011. Elderly adults have a diminished movement capacity due to physiological and neurological declines associated with advancing age. Previous research suggests that elderly adults use altered neuromuscular patterns to conduct activities of daily living (ADLs). Limited research has addressed these altered activation strategies in obstacle clearance, stair ascent and stair descent. The purpose of this study was to compare neuromuscular activation patterns in young and elderly adults during these tasks. Eleven young and 10 healthy elderly adults performed five downward stepping, upward stepping and obstacle clearance trials. Surface EMG was measured from the quadriceps, hamstrings, gastrocnemius and tibialis anterior muscles. A 2x3 (group x condition) repeated measures analysis of variance was used to determine significant differences in muscle activation intensity. An *apriori* alpha level was set at $p<0.05$. The results showed that elderly adults exhibited greater activation intensity than the young adults in all movement conditions. The significant differences in muscle activation intensity in the elderly adults were limited to the musculature driving the tested movement. The findings of the current study support previous research that elderly adults perform ADLs at a greater relative intensity than young adults. Furthermore, the current study shows that the disproportionate increase in muscle activation intensity is limited to the muscles that functionally drive the required task.

KEY WORDS: Downward Stepping

INTRODUCTION

Increasing age has been associated with diminished muscular and neural capacities. Diminished neuromuscular function has a deleterious effect on the ability of elderly adults to complete activities of daily living (ADLs) resulting in a lower quality of living (25). In response to limited motor capacity, elderly adults adopt altered movement strategies to complete ADLs (7, 8, 11-13, 16, 17, 21, 22, 25). Previous research has shown that elderly adults use unique movement strategies during normal gait (7, 16, 17, 21, 22) and downward stepping (8, 11, 12). These altered movement strategies include decreased gait velocity, step length, stride length and time of single leg support (3, 9, 10, 30). In addition, elderly adults often exhibit reduced pelvic rotation, hip flexion or extension and ankle plantarflexion during level walking (19). The unique kinematic and kinetic patterns adopted by elderly adults are the result of altered underlying neuromuscular activation patterns (8, 12, 13, 20). It is well known that elderly adults modulate their neuromuscular activity patterns to complete ADLs; however, a central question in aging research pertains to the task-specific nature of the modulation of neuromuscular activation patterns in elderly.

Many research studies have examined the responses of elderly adults to balance perturbations during quiet standing and level walking (15, 20, 27-29, 31, 32). However, these studies do not present a unified understanding of the response of elderly adults to balance perturbations during either quiet stance or level walking. Some research has shown that elderly adults exhibit slower, larger neuromuscular responses to a balance perturbation (31); however, other studies have shown that elderly adults activate their lower extremity musculature earlier, for a longer period of time and with a greater magnitude than young adults (20, 24, 29). While perturbations to balance affect young and elderly individuals in everyday life, previous perturbation paradigms do not represent natural balance perturbations. Previous perturbation paradigms have included ankle weights (20) and sliding force platforms (26-29, 31).

A common balance perturbation elderly adults experience during ADLs is single-leg stance during obstacle clearance, upward stepping and downward stepping. While the kinematics and kinetics of downward stepping have been previously investigated (8, 11, 12), there is a dearth of literature pertaining to the movement strategies in the elderly during obstacle clearance and upward stepping. Previous research pertaining to obstacle clearance has been mostly limited to the attentional demand (18, 23), kinematics (2, 4) or inter-segmental coordination (6, 14). There is also limited knowledge pertaining to the effects of advancing age on movement patterns during stair ascent or upward stepping. Therefore, the purpose of the current study is to compare neuromuscular activation strategies of young and elderly adults during obstacle clearance, upward stepping and downward stepping activities. It was hypothesized that elderly adults would have disproportionately greater muscle activation intensities during all tasks compared to their young counterparts. Furthermore, we hypothesized that the increases in muscle activation intensity will be movement and function specific rather than a general increase in all muscle activation amplitudes.

METHODS

Subjects

Eleven young healthy adults (5M, 6F) and ten healthy elderly adults (5M, 5F) participated in the current study. Young subjects, aged 18 and 26 years, were recruited from the student population at the University of Texas of the Permian Basin. Elderly subjects, aged 75 to 85 years, were recruited from the greater Midland-Odessa area using flyers, printed advertisements and word of mouth. All subjects were apparently healthy at the time of testing and had a medical history free of major lower extremity injury including ankle, knee or hip joint replacement surgeries. Subjects were excluded from the study if they had experienced or had diabetes, kidney disease, liver disease, heart attack, stroke, angina, heart failure, osteoporosis or skin cancer. Each subject signed an informed consent statement prior to participation in the study. All participants signed an informed consent. The current study was conducted according to the ethical standards established in the 1964 Declaration of Helsinki and were approved by the Advisory Committee on Human Experimentation at the University of Texas of the Permian Basin.

Laboratory Testing
All participants had anthropometric measures taken prior to testing including age, height, mass and BMI. All measurements and EMG recordings were performed on the right lower extremity. Muscle activation was assessed using an eight lead surface electromyography (sEMG) system (PocketEMG, BTS Bioengineering, Italy). EMG recording and foot switch data were recorded at 2,000 Hz using MyoLab Software (BTS Bioengineering, Italy). The skin over the rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), semimembranosus (SM), biceps femoris (BF), tibialis anterior (TA), medal (MG) and lateral heads of the gastrocnemius (LG) and the head of the fibula were shaved, alcohol washed and abraded to minimize electrical resistance. Surface electrodes (Ambu, Blue Sensor M, M-00-S/50) were placed according to previously documented recommendations {Perotto, 1994 #271} and precise location of the muscle belly was determined using manual muscle testing. Elastic wraps were placed snuggly over the thigh and shank to minimize movement artifact and cross-talk.

Experimental Protocol
Each participant performed five successful trials in each experimental condition including upward stepping, downward stepping and obstacle clearance. The upward stepping condition was characterized by the participant stepping onto a box of a height of 12cm with the right limb and completed with the initial contact of the left limb. The downward stepping condition entailed the participant stepping down onto the right limb from a box of 12cm of height and was completed with contact of the contralateral limb. The obstacle clearance conditions could be described as stepping over a 10cm obstacle during level walking. The imposed obstacle was placed approximately half the distance between the beginning and end of an 8 meter walkway and adjusted in the antero-posterior direction to match the natural stepping pattern of each subject. In the obstacle clearance condition, the right limb stepped over the obstacle, followed by the contralateral limb. All conditions were performed at the subject's self-selected walking speed. Walking speed was maintained within 10% (mean ± 5%) of the average speed obtained during three practice trials.

Data Analysis
EMG signals were amplified (x10k) and band-pass filtered (50Hz-400Hz) before being sampled at 1000Hz per EMG channel. EMG data were the smoothed and rectified using the root mean squared (RMS) with a smoothing window of 20Hz (Visual 3D, C-Motion, Inc., Rockford, MD, USA). EMG data were analyzed during the swing and stance phases of each movement. Each

phase was determined based on foot switches placed beneath the calcaneus and the head of the first metatarsal. The swing phase was calculated as the period between first metatarsal lift off and the following heel strike. The stance phase was calculated as the period between heel strike and first metatarsal lift off. Mean value of the RMS curve was determined during the swing and stance phase of each experimental condition. EMG data for each trial were normalized to the highest mean EMG value across all trials in all conditions and calculated as the quotient of the trials mean EMG divided by the subject's highest mean EMG value across all trials and conditions. A two x three (group x condition) repeated measures analysis of variance (ANOVA) with Scheffe's post-hoc was used to determine differences in activation intensity between young and elderly adults in each movement condition. Alpha level was set at $p<0.05$.

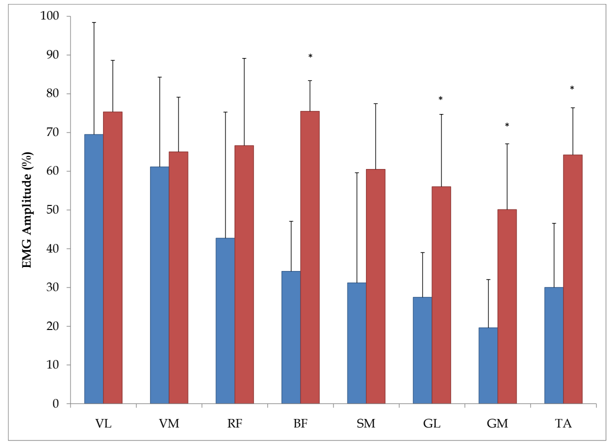
RESULTS

Table 1. Anthropometric measurements of young and elderly subjects.

Group	Age (yrs)	Height (m)	Mass
Young	22.9 (1.4)[a]	1.69 (0.25)	77.9
Elderly	80.9 (3.1)	1.60 (0.05)	64.7

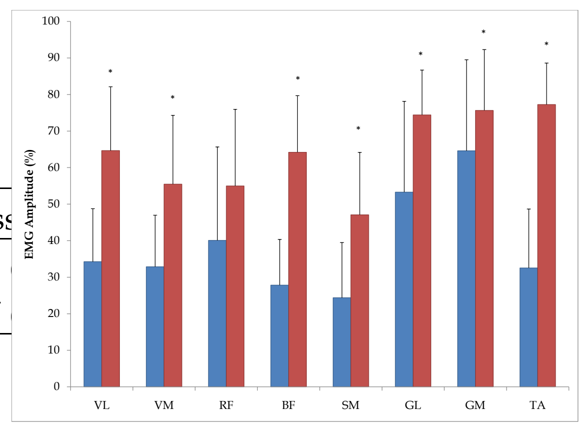
Note:
[a]: Significant difference between elderly and young subjects

Upward & Downward Stepping
Young and elderly adults had similar height and mass measurements (Table 1). In the downward stepping task, the elderly and young adults activated their knee extensor musculature to similar magnitudes including the VL, VM and RF in the stepping task (Figure 1). Knee flexor

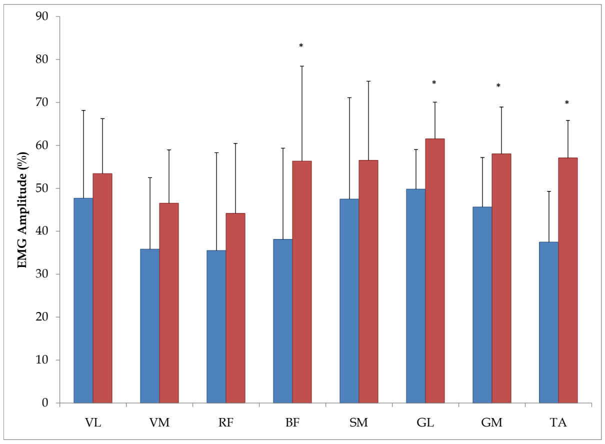


activity was similar between the elderly and young adults except a greater activation in the BF of elderly participants during the downward stepping task ($p<0.001$). Elderly adults also activated their plantarflexors (GL: $p=0.002$; GM: $p<0.001$) and dorsiflexors (TA: $p<0.001$) stronger than young adults in the downward stepping task.

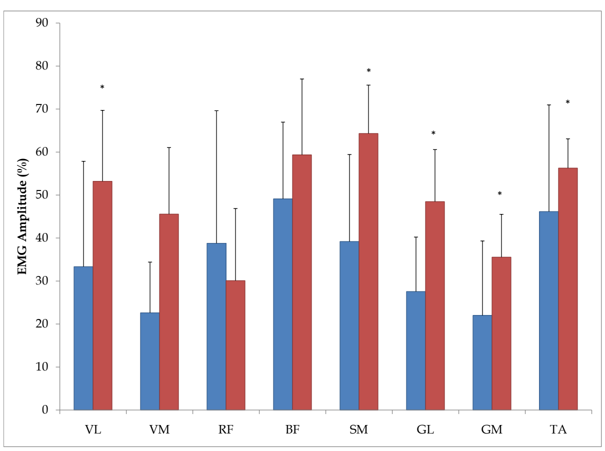
In the upward stepping task, the elderly



adults activated their lower extremity musculature more than the young adults (Figure 2). The elderly participants activated their knee extensors stronger than the young adults (VL: $p=0.003$; VM: $p=0.012$). Additionally, elderly adults exhibited a greater magnitude of knee flexor muscle activity (BF: $p<0.001$; SM: $p=0.028$). Elderly adults also activated their plantarflexors and dorsiflexors stronger than the young adults (GL: $p<0.001$; GM: $p<0.001$; TA: $p<0.001$) during the upward stepping task.



Obstacle Clearance
In the obstacle clearance condition, the elderly adults exhibited different muscle activation patterns than the young adults (Figure 3). Though the activation patterns



of the knee extensors were similar between the elderly and young adults, the elderly adults activated their BF stronger than the young adults ($p=0.045$). Furthermore, the elderly adults exhibited greater activation intensity in their GM ($p=0.050$) and GL ($p=0.040$) as well as TA ($p=0.045$) compared to the young adults.

In the trailing limb during obstacle clearance, the elderly adults used a different neuromuscular activation pattern compared to their young counterparts (Figure 4). In the trailing limb, the elderly adults activated their VM stronger than the young adults ($p=0.001$). However, activation intensity of the RF and the VL were similar in elderly and young adults. In the knee flexors, the SM had greater activation intensity in the elderly compared to young adults ($p=0.011$), however no differences were observed in BF activation intensity. The GL and GM exhibited greater activation intensity in the elderly compared to young adults (GL: $p=0.002$; GM: $p=0.044$). Furthermore, elderly compared to young adults had greater TA muscle activation intensity ($p=0.003$).

DISCUSSION

The purpose of the current study was to investigate the differences in neuromuscular activation patterns between elderly and young adults during two common activities of daily living. It was hypothesized that the elderly adults would have a disproportionate increase in the amplitude of muscle activity due to the physiological and neuromuscular declines found in previous research (13, 20). The decline in movement capacity associated with advancing age leads to altered kinematic and kinetic patterns during ADLs including walking (7, 16, 17, 22) and downward stepping (8, 11). Furthermore, it has been repeatedly demonstrated that elderly adults adopt unique neuromuscular patterns during walking (20) and downward stepping (12). Previous research has posited that elderly adults work at a greater relative effort than young adults during activities of daily living (13) which manifest in greater amplitudes of muscle activation.

In the current study, the effects of neurological and physiological decline were exhibited in all movement conditions tested. The amplitude of muscle activity was not similar between elderly and young adults demonstrating that mechanical and neuromuscular strategies used to accomplish ADLs are altered with advancing age to produce an effective movement outcome. These data support the hypothesis as well as previous research findings showing that elderly adults exhibit greater muscle activation intensity than young adults in level walking (20, 21) and stepping tasks (12).

Walking up and down stairs is an important and formidable activity for elderly adults. While it is possible to make changes to one's living space to avoid stair ascent and descent, these changes can be costly and time consuming. During the stepping tasks, elderly adults activated their lower extremity musculature more than young adults. The significant greater muscle activation intensities in elderly compared to young adults were task dependent. During the downward stepping task, old adults had disproportionately greater activation of the ankle musculature including the lateral and medial gastrocnemius and the tibialis anterior. In this task, the ankle is initially responsible for slowing descent and controlling movement of the center of mass. Though a distal to proximal shift in joint torque generation with advancing age has been previously reported during level walking (7), these data suggest that extrinsic ankle musculature is used initially to control center of mass descent during a downward stepping task. It should be noted that there is no direct relationship between muscle activation intensity and torque generation, however a limited relationship has been previously reported (5). These data demonstrate that in a downward stepping task, old compared to young adults exhibit a task-specific adaptation by disproportionately increasing activation of extrinsic ankle musculature.

Conversely, in the upward stepping task the elderly adults had significantly greater activation of the quadriceps and hamstrings muscles than the young adults. In the upward stepping task, the quadriceps muscles are responsible for extending the knee while the hamstrings muscles extend the hip propelling the subject upward onto the step. Given a similar relative mechanical demand and a diminished mechanical capacity, the elderly adults had a greater relative load compared to young adults. To accomplish this task, the elderly adults activated their quadriceps and hamstrings more than the young adults. In addition to increased activation intensity of the quadriceps and hamstrings, the elderly adults exhibited greater tibialis anterior activation intensities. The tibialis anterior is an ankle dorsiflexor and tibialis anterior activation would result in a reduced need to flex the hip and knee joints to place the foot on top of the step. These data further support the previous findings within this study and previous research by showing that old adults perform activities of daily living at a greater relative effort (13). These data also demonstrate that the increased activation intensities in elderly compared to young adults are functional and task specific.

Obstacle clearance is an important component of avoiding trips and falls in the elderly population. Many research studies have examined the components of gait that lead to falls (1) and the attentional demand of obstacle clearance. However, fundamentally no research has focused on the neuromuscular aspects of obstacle clearance in the elderly population. Similar to the stepping tasks, the differences in muscle activation intensity between young and elderly adults were functional. Ankle musculature had significantly greater muscle activation amplitudes in elderly compared to young adults. As the leading limb, the foot and ankle are being prepared for initial contact as they clear the obstacle. Muscle activation intensity was disproportionately higher in the elderly compared to young adults in preparation for foot strike due to a diminished capacity to produce force. Furthermore, during the trailing limb condition, the elderly adults had significantly greater activation in the quadriceps, hamstrings and ankle musculature. Each of these muscle groups is responsible for supporting the participant on a single limb while also propelling the participant forward and over the obstacle. These data continue to support previous research findings showing that old adults exhibit greater relative muscle activation intensities in the lower extremity during activities of daily living (7, 13, 20). These data also support the notion that the disproportionately greater activation intensities in elderly adults are functional, contribute to the completion of the task and are not mal-adaptations.

The findings of the current study support previous research findings and presents new findings pertaining to the nature of adaptation in neuromuscular activation patterns of elderly adults in stepping and obstacle clearance tasks. These data demonstrate that elderly adults activate lower extremity musculature more than young adults during a given task. More specifically, the elderly adults have disproportionately greater muscle activation in the musculature responsible for driving or controlling the movement rather than an overall increase in muscle activation regardless of muscle function. These findings suggest specificity in adaptation with advancing age as opposed to mal-adaptation within the aging neuromuscular system resulting in impaired movement. Particularly, in response to diminished movement capacity due to neurological and physiological declines with advancing age, activation patterns within the lower extremity of elderly adults are altered to produce an effective movement strategy, which allows for the successful completion of activities of daily living. Therefore, the altered neuromuscular activation patterns associated with advancing age seem to be beneficial adaptations and are specifically targeted toward the musculature required for completing a given task.

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In loving memory of Amber Zant Bice.

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