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Differences in Abdominal Muscle Activation Patterns of Younger and Older Adults Performing an Asymmetric Leg-Loading Task

Cheryl L. Hubley-Kozey, PhD, Edwin Y. Hanada, MD, MSc, Sarah Gordon, MSc, John Kozey, PhD, Melissa McKeon, MSc

Objectives: To determine whether differences exist between younger (20-50 years) and older adults (>65 years) in abdominal muscle amplitudes, temporal patterns, and three-dimensional (3D) pelvic motion, while performing an asymmetric leg-loading task.
Design: Cross-sectional.
Setting: Neuromuscular function laboratory.
Participants: Ten healthy younger (33.3 :: 7.7 years) and 10 healthy sex- and body mass index–matched older adults (69.0 :: 6.6 years).
Intervention: Surface electromyograms from 6 abdominal muscle sites bilaterally and pelvic motions were simultaneously recorded.
Main Outcome Measure(s): Root mean square (RMS) amplitude during the leg extension phase was calculated for each muscle. Ensemble average waveforms for the total exercise were analyzed using principal component (PC) analysis. Total angular displacement of the pelvis was calculated. Student's *t* tests were performed on demographic and angular displacement data. Three-factor mixed model analysis of variances (group, muscle, side) tested main effects and interactions ($P < .05$) for the RMS amplitude and PC scores from the temporal waveforms. Bonferroni post-hoc analyses tested pair-wise differences.
Results: There were no between-group differences for the pelvic motions. Three PC patterns captured 85% of the variance in the waveforms. The external oblique (EO) RMS amplitudes were significantly ($P < .05$) higher than those of the other three muscle sites similar for the PC1 scores which captured overall amplitude. The PC2 score for the internal oblique (IO) was significantly higher ($P < .05$) than that of all other muscles, illustrating a higher initial amplitude compared with later in the movement. There was a significant group by muscle interaction for PC3 scores, demonstrating group differences in temporal patterns.
Conclusions: Both groups were able to minimize lumbopelvic motion and recruited their abdominal muscles to similar overall amplitudes, with the IO muscle activated to higher amplitudes early in the movement task. The older adult group demonstrated a distinctive drop in abdominal activity during the leg-lowering phase of the exercise and less symmetry among muscle sites.

INTRODUCTION

Low back pain (LBP) affects up to 50% of adults older than 65 years ~~[1]~~ and is the most common musculoskeletal complaint in adults older than 75 years [1]. Neuromuscular impairment of the trunk musculature has been reported in older adults and linked to functional deficits, including impaired mobility [2-5]. LBP has been associated with spinal instability, and the importance of the trunk muscles to maintain spinal stability has been previously established [6,7]. In particular, the abdominal muscles have been shown to play a significant role in the treatment of LBP, prompting the development of exercise protocols to improve the stabilizing roles of these muscles [2,6,8-10]. These protocols aim to actively train trunk stabilizers using leg-loading tasks in supine-lying [8], kneeling [6], or by using stability balls [9].

Although abdominal muscle activation amplitudes [11-13] and temporal patterns [14] are reported for younger adults, there is a paucity of data with respect to abdominal muscle

Responses of older adults to these dynamic stabilizing exercises. Older adults may have more difficulty performing stabilizing exercises because of impaired abdominal muscle function and decreased strength that can result from greater fat infiltration in abdominal muscle composition and a decrease in abdominal muscle thickness reported [15] for older adults. With the enormous potential impact of LBP on the daily function of older adults, an understanding of how the abdominal muscles respond to exercise progressions will be valuable for developing a treatment plan involving exercises for older adults.

One dynamic stability protocol is performed in supine-lying and uses an abdominal hollowing maneuver before performing alternate leg-loading tasks [8,10]. The leg-loading tasks provide a dynamic stability challenge to the abdominal musculature by altering the loading of the lumbopelvic region throughout the exercise. The goal of this exercise protocol is for the individual to minimize pelvic and lumbar motion while performing the exercises by engaging the abdominal musculature in an appropriate sequence. This exercise progression has been examined with respect to muscle activation responses for working-aged adults [11], illustrating a low amplitude (less than 40% of maximum, even for the highest progressive level). Differences were found in muscle activation amplitudes [12,16] and temporal patterns [14] between those with and without LBP. Therefore, both amplitude and temporal characteristics of the electromyographic (EMG) waveforms have provided important information on neuromuscular responses to dynamic challenges. Whether older adults have similar responses is unknown, but it is imperative that this be studied to develop appropriate exercise protocols for older adults with LBP. A feasibility study provided descriptive data on amplitude measures for both abdominal and back extensor muscles for a group of older adults, performing the first three levels of this protocol [17]. However, no temporal data or no comparison to a younger control group was provided.

Therefore, the purpose of this study was to determine whether there are differences in the amplitude and temporal recruitment patterns of the abdominal muscles and three-dimensional (triplanar) pelvic motion between younger and older adults performing an exercise protocol that uses an asymmetric leg-loading task [11]. We hypothesize that (1) the older adults would have higher amplitudes because of lower abdominal muscle strength, (2) the older adults would have decreased coordination of muscle activation over time, and (3) the maximum motion of the pelvis would be greater for the older adults, indicating that they had more difficulty controlling pelvic motion.

METHODS

This study protocol was approved by the Dalhousie University Research Ethics Board (REB) and Capital District Health Authority REB. Healthy adults were recruited through local e-mail advertisements and word of mouth to participate in the study. Before participation, all individuals were required to read and sign an institutional-approved informed consent.

Participants

Two groups of healthy cohorts consisted of (1) adults 20 to 50 years and (2) sex- and body mass index–matched participants older than 65 years. Participants were excluded if they had (1) a history of LBP in the past year, (2) previous abdominal or back surgery, (3) previous spinal fracture, or (4) any other major musculoskeletal, cardiorespiratory, or neurologic condition.

Screening and Questionnaires

All participants were interviewed with a general health screening questionnaire to determine any medical conditions that may exclude them from participation. If they were still eligible for the study, individuals were asked to attend two testing sessions: the first session was an introductory session and the second was the testing session.

During the first session, a postural and neurologic assessment was completed by a physiotherapist (S.G.) to screen for any obvious fixed abnormal spinal postures (kyphosis, lordosis, or scoliosis) and lower extremity neuromuscular deficits (myotomal strength, dermatomal sensation, and reflexes). The older adult group was required to complete a mental status examination to ensure adequate cognitive ability to participate in the research study (score > 23) [18]. Standard demographic data were collected from each participant, including age, sex, occupation, number of abdominal training sessions per week, number of aerobic exercise bouts of at least 30 minutes per week [11], and anthropometric data including mass (kg), height (m), and waist circumference (cm). Body mass index (BMI) was calculated from the height and mass measures. The Kendall test was used to grade minimal abdominal muscle function [19].

Participants were introduced to the asymmetric leg-loading task through instruction and demonstration provided by a physiotherapist (S.G.). Individuals then practiced the exercises. Once the participants were able to demonstrate that they were able to perform the exercises correctly, they were given an instruction sheet and asked to practice the exercise on three separate occasions before returning for the second session. Each participant was asked to record the number of practice sessions they completed on their own.

Electromyography (EMG)

During the second session, surface EMG (3-AMT-8, Bortec, Canada) was collected during the exercise trials using standard procedures [11], including standard skin preparation with shaving and light abrasion with an alcohol water solution. Twelve (12) pairs of Meditrace Ag/Ag Cl surface electrodes (10 mm diameter, bipolar configuration 30 mm center-to-center) were placed over 6 bilateral muscle sites (Figure 1). These included the left and right sides of the

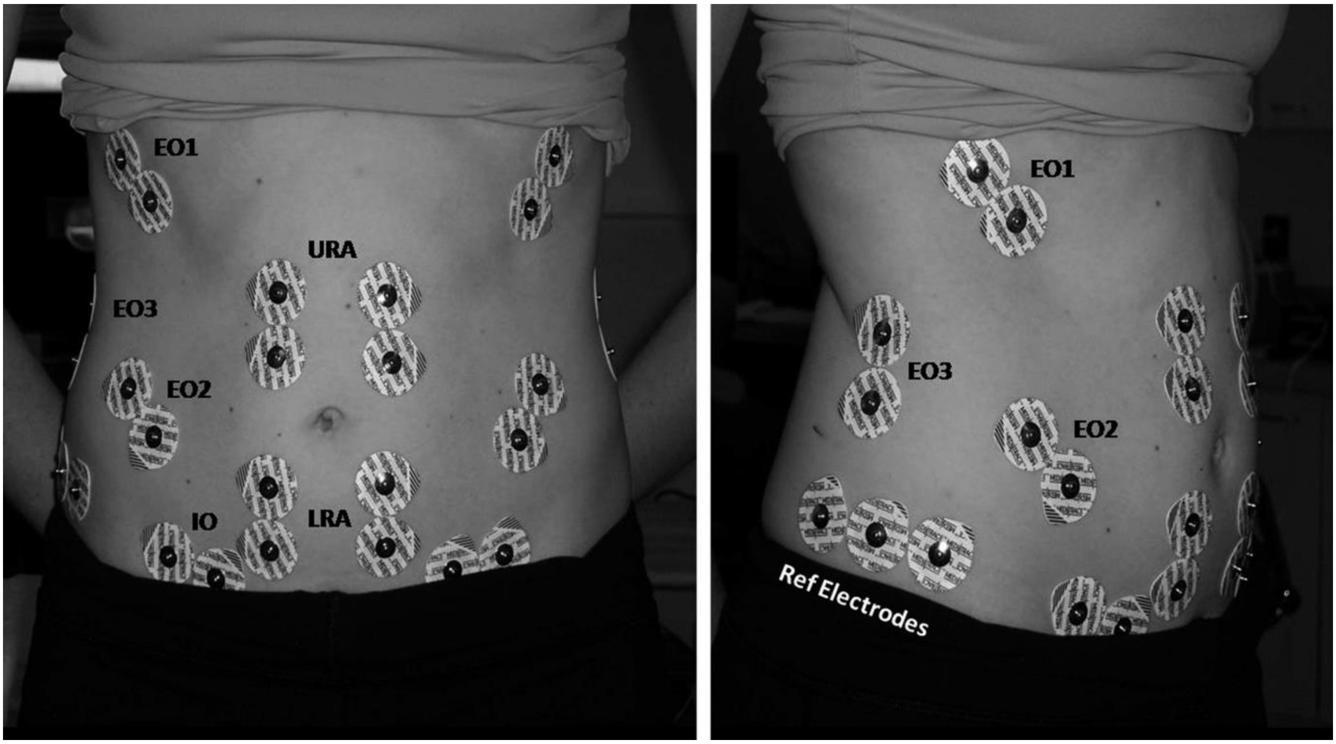

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Figure 1. Surface electromyography electrode placement: lower and upper rectus abdominus (LRA and URA); anterior (EO1), lateral (EO2), and posterior external oblique (EO3); and internal oblique (IO). Reference electrodes were placed on the left iliac crest. See text for details of placement.

(1) lower rectus abdominis (LRA), centered on the muscle belly midway between the umbilicus and the pubis [16]; (2) upper rectus abdominis (URA), centered on the muscle belly midway between the sternum and the umbilicus [16,20]; (3) external oblique anterior fibers (EO1), over the 8th rib adjacent to the costal cartilage [21]; (4) external oblique lateral fibers (EO2), 15 cm lateral to the umbilicus oriented at 45° [22]; (5) external oblique posterior fibers (EO3), midpoint between the lowest part of the ribcage and the iliac crest [23]; and (6) internal oblique (IO), centered in the triangle formed by the inguinal ligament and lateral border of the rectus abdominis sheath and the line between

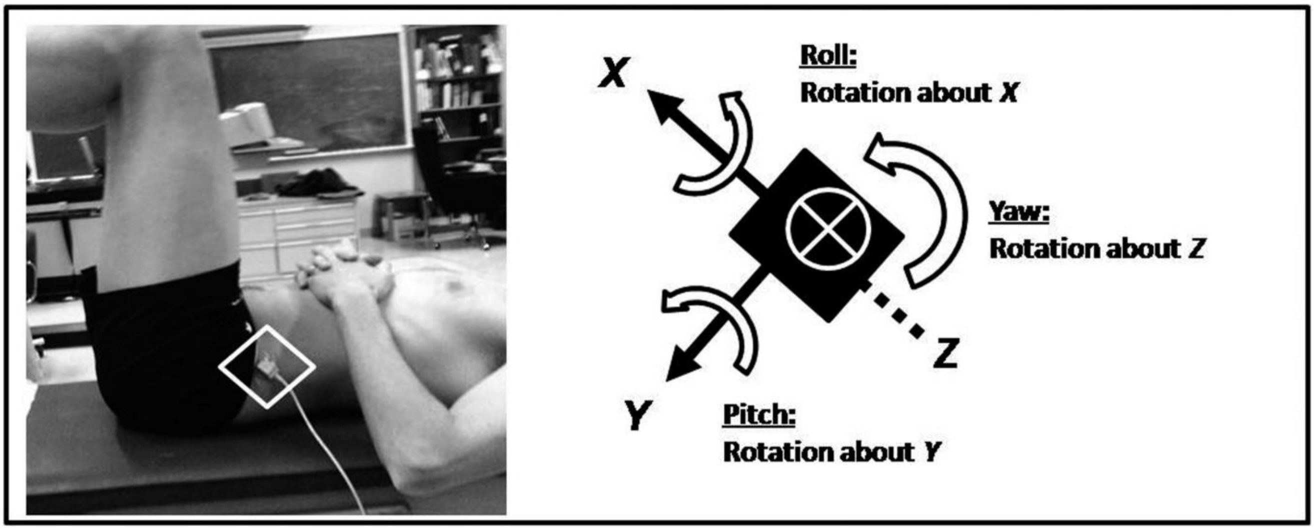

Figure 2. Flock of Birds sensor placement on the iliac crest. Yaw describes motion about the *z* axis, pitch describes motion about the *y* axis, and roll describes motion about the *x* axis.

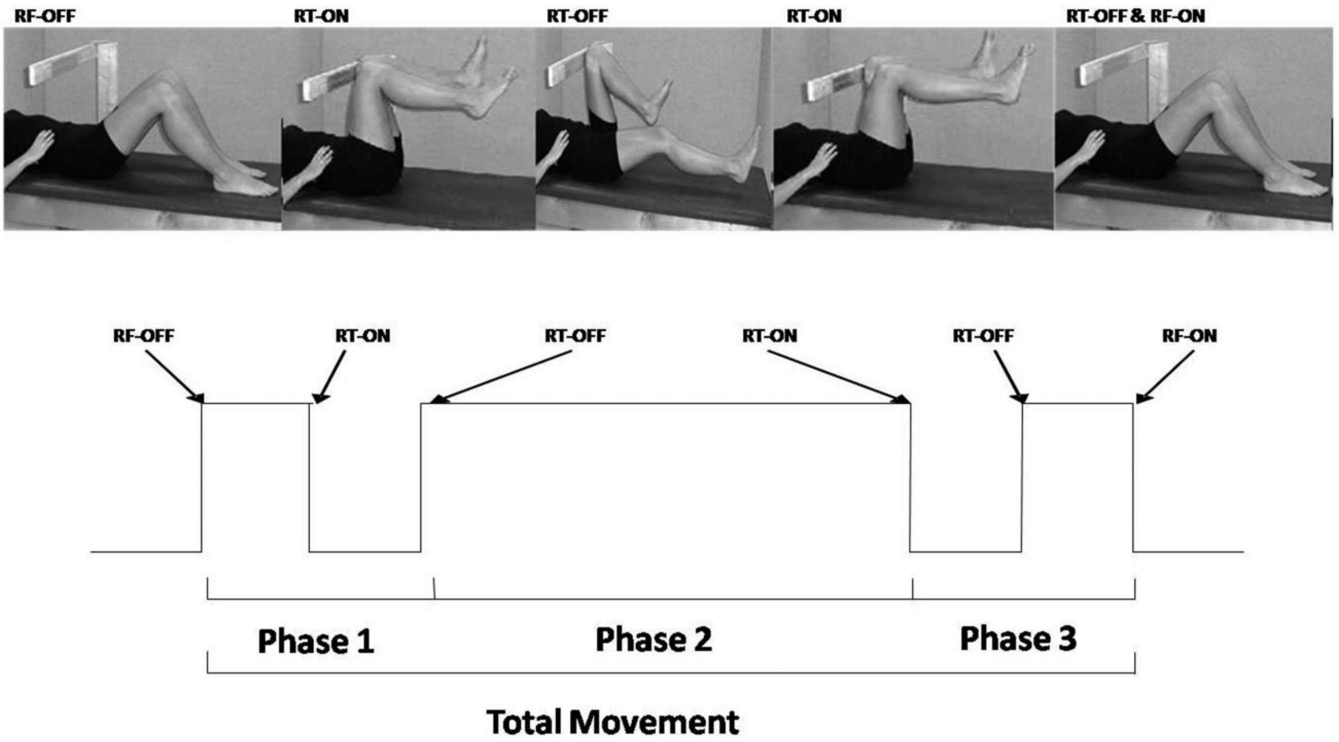

Figure 3. Asymmetric single leg-loading task. Electronic switches are located on the right foot (RF), which contacts with the metal plate located on the table, and the right thigh (RT), which contacts with the wooden frame, to identify temporal event markers so that the motion may be divided into distinct phases. Phase 1 consists of the RF off the table to the RT off the wooden frame. Phase 2 consists of the single leg loading in which the leg is fully extended. Phase 3 consists of the RT on the wooden frame followed by a return to starting position.

the anterior superior iliac spine [21]. Reference electrodes were placed on the iliac crest.

Motion Capture

An electromagnetic Flock of Birds Motion Capture system (Ascension Technology Corporation, Burlington, VT) recorded the angular motion of the pelvis throughout the exercise task in three-dimensional (3D) space with respect to a global coordinate system. The sensor was placed on the anterosuperior portion of the left lateral iliac crest (Figure 2). Therefore the measurements were not related directly to anatomic references. The motion data were used to confirm that the participants were able to maintain their lumbar pelvic position throughout the exercise task and whether both groups were similar.

Leg-Loading Task

Participants were asked to perform the asymmetric leg-loading task as shown to them in the first session [11]. The start and end position of each exercise level was standardized, with participants lying supine with knees flexed to 90° (Figure 3). Participants were asked to produce an abdominal hollow maneuver in preparation for the exercise. Then participants were asked to lift their right leg until the hip was flexed to 90° and the thigh was in contact with a wooden frame; the left leg was then lifted to the same position. The right leg was then fully extended (knee and hip extension). The right hip and knee were then flexed back to position and the thigh was in contact with the wooden frame. The left leg and then the right leg were subsequently lowered to the starting position [10,11]. The task was broken into phases of leg lift, leg extension, and leg lower using external event markers as indicated in Figure 3.

Normalization Exercises

After the exercise task, a series of standardized maximal voluntary isometric contractions (MVIC) aimed at the different abdominal muscles were performed [24]. The MVICs consisted of resisted sit-up [22], resisted v-sit-up [8], resisted axial rotation both left and right [22], and resisted lateral bend both left and right [22]. The older adults did not perform the v-sit-up. The other normalization exercises were shown to be feasible and were completed without discomfort by older adult participants [25], although 2 older adult participants were asked not to perform maximal efforts because of a preexisting heart condition.

Table 1. *Demographic characteristics of younger adult and older adult groups*

Group	Age (y)	Height (m)	Mass (kg)	BMI	Waist Girth (cm)	Abdominal Training	Aerobic Training	TST Sessions
Younger adults (n � 10)	33.3 (:':7.6)*	1.7 (:':0.9)	76.1 (:':9.3)	25.9 (:':2.4)	81.2 (:':9.4)	1.9 (:':2.0)	6.2 (:':4.5)	3.3 (:':0.8)
Males (n � 5)	32.6 (:':6.2)	1.8 (:':0.6)	86.3 (:':12.2)	27.1 (:':2.4)	88.2 (:':6.9)	1.1 (:':1.1)	7.2 (:':6.4)	3.4 (:':1.4)
Females (n � 5)	34.0 (:':9.6)	1.6 (:':0.3)	66.0 (:':7.1)	24.9 (:':2.1)	74.2 (:':5.2)	2.4 (:':2.5)	5.2 (:':1.1)	3.2 (:':0.45)
Older adults (n � 10)	69.0 (:':3.6)*	1.7 (:':0.9)	75.7 (:':13.7)	26.1 (:':2.5)	88.9 (:':13.1)*	1.7 (:':2.1)	3.2 (:':2.9)	4.3 (:':1.6)
Males (n � 5)	66.4 (:':0.5)	1.8 (:':0.5)	85.5 (:':10.3)	27.4 (:':2.5)	96.6 (:':14.4)	2.2 (:':2.2)	3.6 (:':3.3)	3.4 (:':1.5)
Females (n � 5)	71.6 (:':3.4)	1.6 (:':0.7)	65.9 (:':8.8)	24.8 (:':1.9)	81.1 (:':5.3)	1.2 (:':2.2)	2.8 (:':2.8)	5.2 (:':1.3)

Results are presented as mean (:':SD).

Abdominal training � number of abdominal training sessions each week; TST sessions � number of practice sessions between first and second test sessions.

*Indicates a significant difference of $P < .05$ between groups.

Data Analysis

The EMG signals were amplified (AMT-8, Bortec, Canada, bandpass 10-1000 Hz, CMRR 115 dB, input impedance �10 GO) and digitized at 1000 Hz using Labview (National Instruments, Austin, TX, version 7), and the angular motions were recorded at 100 Hz using a custom built Labview program. Data were processed using Matlab software (The AQ: 5 Mathworks Inc, version R2007a). The EMG signals were filtered with a high-pass 30-Hz filter to remove the electrocardiogram [26]. Data were synchronized using an event marker that identified foot off, knee on, knee off, and foot on (Figure 3). The total exercise was defined from right foot off to right foot on the bed. The leg extension phase was defined from right knee off to right knee on the wooden cross-frame. The root mean square (RMS) amplitude for the EMG signal during the leg extension phase was calculated and normalized to the highest amplitude recorded during a 500-ms window from the MVIC trials for each muscle individually [12]. The raw EMG signals for the total time were also full-wave rectified and low-pass filtered at 6 Hz using a second-order Butterworth recursive filter. These waveforms were then time normalized to 101 data points for the total movement time (foot off to foot on) and amplitude normalized to MVIC. The waveforms for three trials were averaged to produce an ensemble average waveform for each muscle for each participant.

The EMG ensemble average waveforms were entered into a principal component (PC) analysis model [14]. In this case a covariance matrix was calculated and an eigenvector decomposition was performed on the covariance matrix. This resulted in a set of PCs that explained the principal patterns of variation in the measured EMG waveforms. For each waveform, a PC score was calculated providing a weighting of how much that PC contributed to the original measured waveform. Essentially, ensemble average waveforms that are similar in amplitude and shape will have similar PC scores [14]. Thus statistical testing of PC scores allows for quantitative comparisons of waveforms rather than simple qualitative descriptions. Those PCs that explained more than 85% of the variability in the measured waveforms [14,27] were included in the statistical analysis.

The angular displacement data were filtered at 1 Hz using a recursive second-order Butterworth filter [28]. The maximum difference in angular displacement in three dimensions—yaw (rotation about the z axis), pitch (rotation about the y axis), and roll (rotation about the x axis)—from the Flock of Birds sensor was calculated for the leg extension phase of the exercise. The motion data were synchronized to the EMG data via the external sensors with each motion profile normalized to 100% time.

Independent Student's t tests were performed on the demographic data and the angular displacements between groups. Three-factor (group, side, muscle) mixed model analysis of variances tested for significant differences ($P < .05$) in the RMS amplitude and for the PC scores. Bonferroni post-hoc tests were used to determine significant pair-wise differences when appropriate [29]. Statistical analyses were performed by Minitab (Minitab Inc, State College, PA, version 15) statistical software.

RESULTS

A total of 33 healthy younger and 16 older adults were recruited. Of these, 10 participants in each group were sex-matched (5 males and 5 females) and BMI-matched (BMI younger adults, 26 :': 2.4 and the older adults, 26 :': 2.5; Table 1). The two groups were statistically different for age T1 ($P < .05$) as expected; however, aerobic training was the only other variable that was different ($P < .05$) between the two groups as shown in Table 1. Eight of 10 participants in the younger adult group scored 2 for the Kendall test whereas in the older adult group there were only 2 participants who scored 2. Thus the younger adults had better Kendall scores than the older adult group.

The mean maximum 3D motions are found in Table 2. T2 There were no significant differences ($P > .05$) for any of the 3D angular displacement measures between groups, and all mean displacements were less than 5° (Table 2).

Table 2. *Maximum motion (in degrees) about the sensor for the leg extension phase for the older and younger adult groups*

Group	Yaw	Pitch	Roll
Young adults	3.1 (:':1.6)	2.9 (:':1.2)	4.6 (:':2.3)
Older adults	3.0 (:':1.1)	3.6 (:':2.7)	3.6 (:':2.8)

Mean (::SD).

Yaw describes motion about the z axis, pitch describes motion about the y axis, and roll describes motion about the x axis.

There were no significant differences (*P* < .05) between groups for the time needed to complete the total exercise (younger adults, 7.6 :: 4.4 s; older adults, 7.5 :: 4.3 s) or for each phase of the exercise. There was a statistically significant muscle main effect (*P* < .05) based on the analysis of variance for the normalized RMS amplitude during the leg extension phase, with the two RA and IO sites lower than the three EO sites. There were no other significant main effects or interactions for the RMS amplitude (Figure 4).

The ensemble average waveforms for the total exercise are found in Figure 5. The principal component analysis revealed 3 patterns that captured 85% of the variance in the EMG waveforms. PC1 captured the general shape and magnitude of the EMG waveforms (Figure 6A). This shape included a burst of activity as the second foot lifted off, a gradual increase and gradual decrease during leg extension phase, and a smaller burst coinciding with lowering the first foot back to the table. Waveforms for high and low PC1 scores are depicted in Figure 6B. There was a significant muscle main effect for PC1 scores that captured the amplitude of the waveform. Consistent with the RMS amplitude results, the two RA and IO sites were lower than the EO sites (Figure 6C). There were no other significant differences.

PC2 (Figure 6D) captured the difference in amplitude during the initial 20% of the exercise compared with the amplitude during the leg extension phase. A high score indicated a high initial activation (see high and low scores in Figure 6E). There was a significant (*P* < .05) muscle effect for the PC2 scores. Post-hoc tests revealed that the IO was higher than all other muscle sites. This is illustrated in the lower right panel of Figure 5 where the IO muscle is higher at time 0 and for the initial 10% of the total time than the three EO muscle patterns in Figure 5. There were no other significant results for PC2 scores.

PC3 captured the drop in activity around 50% and a burst before 80% of the movement time with a continual drop in activation during the final 25% of the exercise (see Figure 6G for the patterns and Figure 6H for the high and low scores). There was a significant group by muscle interaction and a significant muscle by side interaction (*P* < .05). The group by muscle interaction is depicted in Figure 6I, illustrating that the PC3 scores for the younger adults were close to 0 and were not different among muscles whereas the older adult group were all positive and there were significant differences among muscles (*P* < .003). The higher PC3 score for the EO2 and EO3 sites in the older group indicated that this pattern was more prominent in these muscles. ~~The drop in activation for both muscles was from approximately 30% to less than 10% MVIC.~~ Overall the group had a greater drop in activation amplitude from 75% to 100% time, which was not evident in the younger adult group (ie, the younger adult pattern was more similar to PC1). The muscle by side interaction did not detect differences between sides within a muscle or among muscles within a side.

DISCUSSION

These results illustrate that older and younger adults performed this single leg-loading exercise while minimizing lumbar pelvic motion to less than 5° in all directions. Elia et al [30] showed that those who were experts at performing similar exercises were able to minimize pelvic motion, in contrast to novices who had larger ranges of motion exceeding 9°. As both groups were able to minimize pelvic motion well below 9°, we inferred that the training sessions (similar number for both groups) were effective at training our participants to perform this exercise with minimal pelvic motion.

The demands on the abdominal muscle as percent MVIC were similar between groups, although the older adults had slightly higher amplitudes for all muscle sites except EO2. Although the small sample size and reduced power may explain why this amplitude difference was not significant, two methodological issues may also have led to this difference. First, 2 older adults were cautioned against doing maximal activations, and second, the older adults did not perform the v-sit-up for safety reasons. Although no significant differences were found in amplitude between the v-sit-up and the regular sit-up [24], this exercise may produce maximal activity in the two RA and IO muscles for some

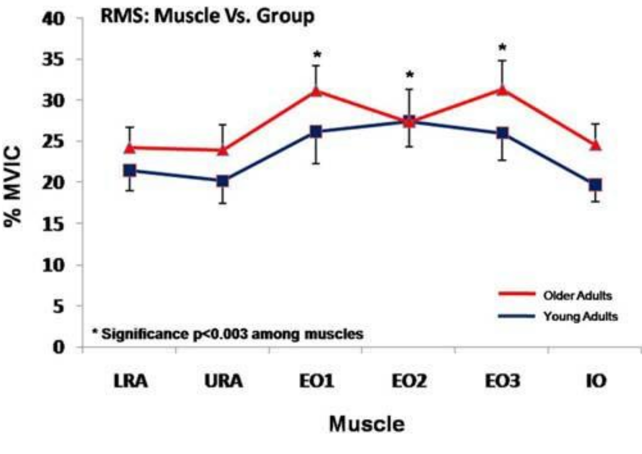

Figure 4. Root mean square amplitudes normalized to a percent MVIC for both younger and older adults groups during the leg extension phase of the asymmetric single leg-loading task. Values indicate mean and standard error. A significant muscle effect (*P* < .05) demonstrated that the LRA, URA, and IO sites are activated to a lower level than the three EO sites for both groups combined. No significant group effect (*P* < .05).

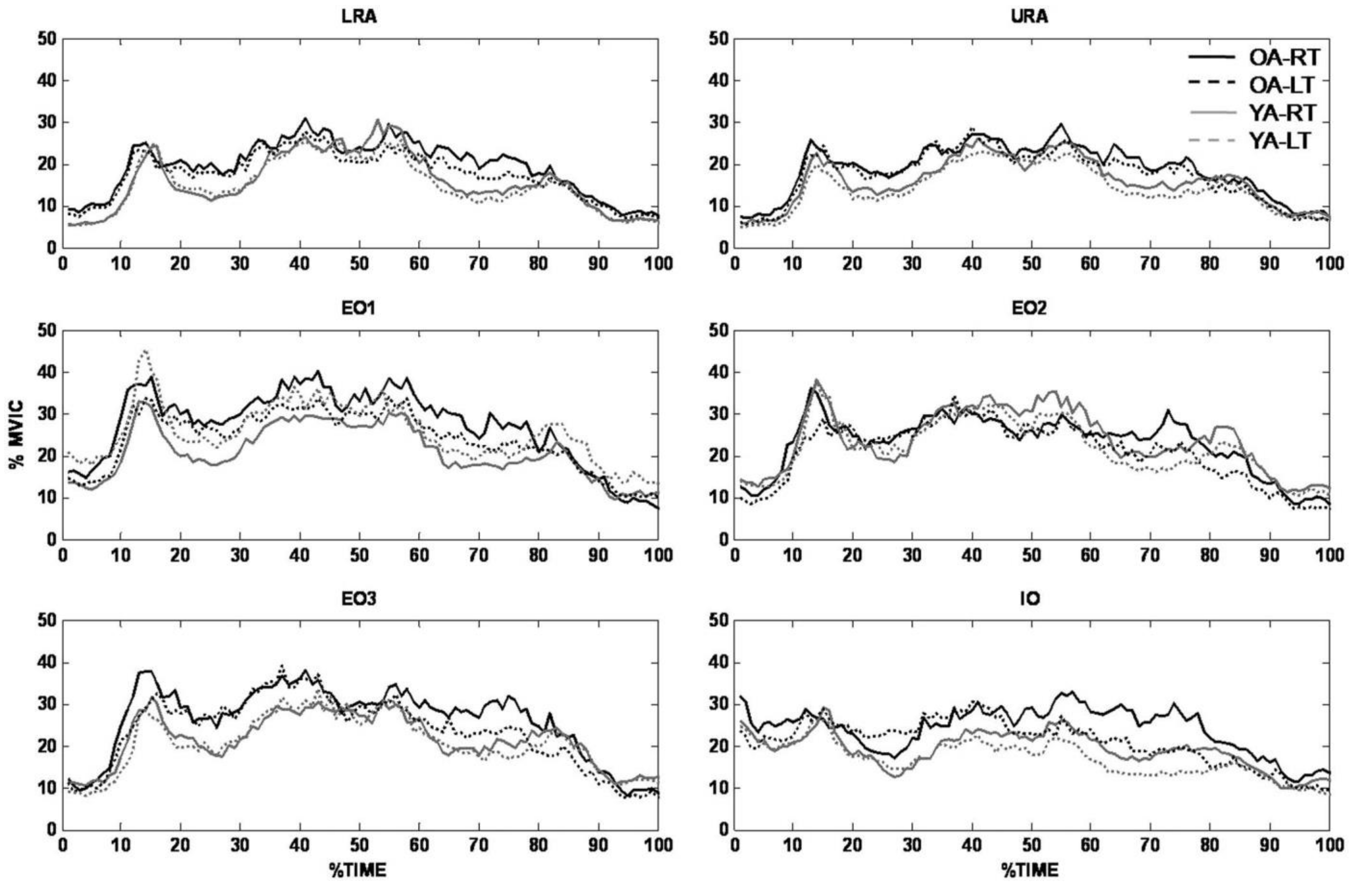

Figure 5. Ensemble average waveforms normalized to percent MVIC. Ensemble average waveforms for all 6 abdominal muscles, for both right (RT) and left (LT) sides, for the total exercise time for the younger adult (YA) and older adult (OA) groups.

participants. Both factors would result in an overestimation of the percent MVIC for the older adults, and subsequently, the differences between the two groups would be even smaller than what was found. This finding is contrary to our hypothesis that was based on reports of greater fat infiltration, less muscle tissue in the abdominal area, and lower abdominal muscle strength in older adults [15].

The general amplitude pattern was also not different between the two groups. The differential recruitment of the EO sites to higher amplitudes than the RA sites for both groups is consistent with findings from younger healthy adults [11]. The amplitude in the present study for the younger adults for EO2 and EO3 is comparable to the previously published study, but the two RA are higher and the EO2 lower in the present study. The difference in results could partly be explained by the younger age and lighter mass of the participants in the earlier study compared with the participants in the present study. Furthermore, the average abdominal training performed by the younger adults was less than twice weekly, which may explain the higher percent MVIC. In summary, the RMS amplitudes during the leg extension phase do not illustrate differences that were expected between groups. Consequently, these results support that this exercise is not a high-intensity exercise even for older adults, which is important to consider when prescribing supine-lying leg-loading stability exercises for this group.

The analysis of the waveform data provided additional information regarding the neuromuscular responses associated with this exercise task. PC1 captures the mean pattern and the magnitude of the waveform; thus the general statistical findings are consistent with the RMS results above. The general temporal pattern was consistent with the pattern presented for abdominal muscles of younger adults performing a similar task using a bilateral leg extension [27]. Increased activity was demonstrated at several times in the exercise: (1) just before 20% time, when the second leg was lifted off the table, (2) when the first leg was lowered around 80% time, and (3) from 25% to 50% time, when the leg was extended, with a gradual decrease from 50% to 75% time, as the leg was flexed. These activation amplitude changes are in response to the changing external moments of force and the changes in the counterbalancing force requirements of the abdominal muscles to minimize pelvic motion.

The other two patterns provide more information on the shape of the waveforms and the subtle differences in temporal responses produced by the muscles to the exercise challenge. Higher PC2 scores for the IO muscle indicate higher activity and an initial abdominal hollowing from time 0 until

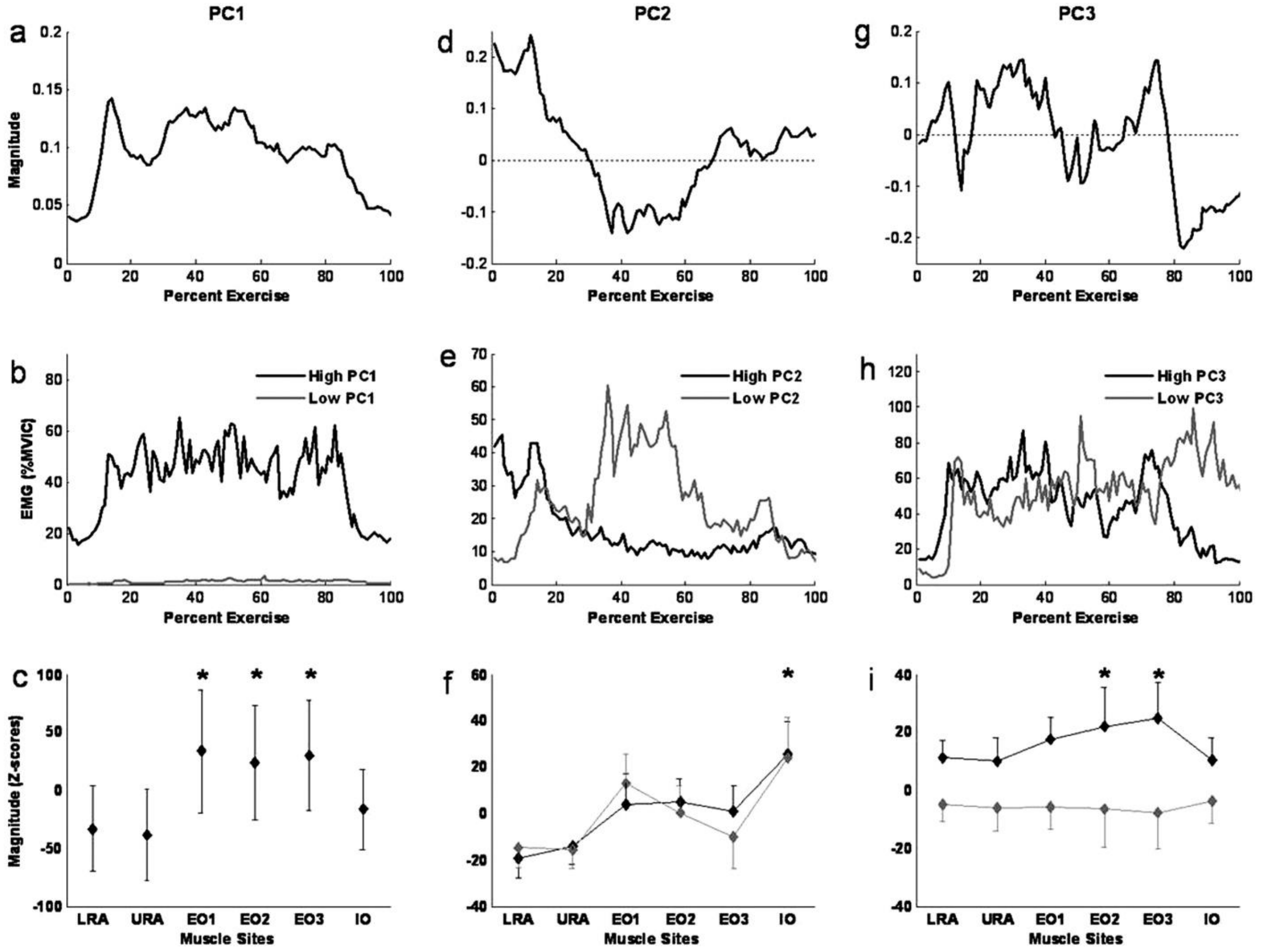

Figure 6. ~~PCA~~: **(A, D, G)** PC patterns for PCs 1, 2, and 3. **(B, E, H)** High and low scores for each of the patterns. **(C, F, I)** Significant effects and interactions for each of the 3 PCs. The RA and IO sites were significantly lower than the 3 EO sites (C). The IO muscle is higher at time 0 than the EO muscle sites (F), and the group by muscle interaction for EO2 and 3 is shown (I).

the second foot was lifted off the table in both age groups. The IO has been shown to be correlated to transverse abdominus muscle activity [31], and this muscle has been shown to be activated before postural perturbations in standing postures [32,33]. From a stabilization exercise training perspective, being able to activate this muscle is an initial step in an abdominal training progression [13], followed by training the muscles to respond to external moments in an appropriate manner.

The most compelling difference between the groups was the difference in the PC3 scores, which captured the variability in amplitude throughout the exercise. The PC3 score indicated that the older adults maintained consistent amplitude of activation throughout the initial 50% of the exercise, whereas the younger adults responded to the changes in task demand with distinct bursts and dips in activity throughout the exercise in response to leg-loading (ie, PC1). These results suggest an altered neuromuscular control for the older adult group. Older adults did not decrease activation when the force requirement was lower (ie, before leg extension), whereas younger adults did respond to the lower forces with reduced abdominal activity. Two possible explanations for the older adults' decrease in responsiveness could be (1) decreased proprioception, which has been shown at other joints [34,35], or (2) altered passive stability of the older adult spine [36,37], requiring older adults to engage the active stabilizing system throughout the exercise. In contrast, younger adults could rely on proprioception and a combination of passive and active stiffness. Older adults also had a distinct drop in activation amplitudes at around 50% time, which was consistent with a previous report for younger adults who had difficulty performing the task correctly [38].

The other notable difference between groups was the decrease in abdominal activity in the older adult group from 75% to 100% time, during the leg-lowering phase. This drop was most evident in the EO2 and EO3 sites, and this difference from the other muscle sites illustrates asynchrony in firing pattern in the older adult group, which is consistent with a previous finding for those with LBP [14]. Given that the exercise count was 8 seconds, there could have been an endurance issue related to maintaining this activity level, although this is questionable given the peak amplitudes ranged from 30% to 50% MVIC. The lack of significant differences among muscles for the younger adults suggests that a dynamic bracing strategy was being used with all muscles activated with a similar pattern, whereas the older adults were unable to maintain this bracing strategy because the two EO sites were different.

In summary, the differences between the groups were most apparent in the temporal patterns and coordination of activity, not simply the amplitude of activation. The decrease in activity noted in the older adult group, and the need for a controlled leg lowering during this task has therapeutic implications. This information has clinical value for establishing treatment goals and monitoring treatment outcomes of dynamic stability exercises for older adults. For example, a therapeutic exercise regimen for LBP in older adults may include low-level lumbar stabilization exercises such as the alternating leg-lowering task examined in the present study. This study demonstrates that older adults use slightly different activation patterns and strategies to reduce abdominal muscle relaxation during mid exercise, and the rapid decreases in activity during the leg-lowering provides specific training goals. If older adults have rapid, uncontrolled leg-lowering action during the terminal phase of this task, focusing on activating all muscles including the lateral and posterior EO fibers would be warranted. This task may provide a method to monitor progress of older adults during rehabilitation of lumbar-level spine pain, by providing insight on altered neuromuscular strategies.

The data in the current study provide a baseline for comparison of the neuromuscular strategies to correctly perform this asymmetric single leg-loading task between younger and older healthy adults. At the present time there is no other study that compares trunk muscle responses during stabilizing tasks between younger and older adults. A limitation of the study is the small sample size, and future studies could focus on a larger, more heterogeneous group that would allow for examining differences between men and women as well as among age groups. The next step for further studies should also include older adults with LBP. This will provide information on what neuromuscular strategies are altered with disease versus aging.

Conclusions

There were no differences in the ability of the older and younger adult groups to minimize lumbopelvic motion during this task, with both groups completing the task correctly. Both groups recruited their abdominal muscles to similar amplitudes based on the statistical analysis of both the RMS amplitudes and the PC1 scores. Furthermore, both groups activated the IO to higher amplitudes before the leg loading. The younger adults had patterns that were more responsive to the changes in demands from the leg perturbation, whereas the older adults used a strategy that required more constant amplitude or coactivation throughout the initial exercise. The drops in activity during mid and late exercise and the differences among muscles illustrate an altered neuromuscular control strategy for this healthy older adult group compared with young adults. These differences provide a focus for neuromuscular alterations that should be monitored during stability exercise protocols.

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