Age-Related Differences in the Effect of a Perceived Threat to Stability on Postural Control

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Background. Studies indicate that the strategy for postural control may be affected by psychological factors, and that young adults respond to perceived threat to stability by increasing their ankle stiffness. The objective of this study was to compare the postural control strategy adopted by young and old adults when faced with postural threat induced by manipulating surface height.

Methods. Sixty elderly (mean age 77.5 ± 4.4 years) and 20 young volunteers (mean age 21.5 ± 3.7 years) participated in the study. Movement of the center of pressure (COP) was recorded for 60 seconds with a portable force-plate, as participants stood with eyes open and closed, both at ground level and 85 cm above ground level. Analysis of variance and Tukey–Kramer tests were conducted to determine the effects of age, postural threat, and vision on mean power frequency (MPF), on amplitude variability both in the anterior–posterior (AP) and medio-lateral (ML) directions, and on mean COP sway velocity, with the significance level set at \( p = .05 \).

Results. Postural threat did not affect COP measures for the young adults, whereas it induced greater changes in MPF in the AP and ML directions in the elderly participants. A similar trend was observed in the elderly group for amplitude variability in the ML direction and for mean COP sway velocity.

Conclusions. In comparison with young adults, elderly adults tend to have an exaggerated postural response to conditions that are perceived as threatening to stability. This response involves primarily increases in MPF, with limited compensatory decreases in amplitude variability observed only in the ML direction.

Approximately 30%–50% of adults 65 years old or older experience at least one fall (1,2), rendering falling a major health issue among active community-dwelling elderly individuals (3,4). Fear of falling has been shown to be strongly associated with a history of falls, although fear is also often expressed by individuals who have never experienced a fall (5,6). Community-dwelling elderly persons experiencing a fear of falling may be making a rational assessment of their impaired balance capabilities. Thus, the increased incidence of falls among those adults expressing a fear can be attributed to a predisposition due to their inherently impaired balance capabilities. As fear of falling often leads to decreased mobility and curtailment of activity (5,7–9), it may indirectly contribute to a further deterioration in motor and balance capabilities and to an increased incidence of falls (9–12).

Psychological factors, such as fear, have also been shown to have a direct influence on postural control. Such effects have been demonstrated during quiet stance (13–18), during performing voluntary postural tasks (19), during unexpected perturbations (20), as well as during locomotion (21–23). Yet, findings on the difference in balance performance between elderly participants with and without fear of falling are not consistent (10). Therefore, it is difficult to determine whether the changes in postural control strategy observed in fearful elderly participants are related to actual physiological deterioration in postural control or to psychological factors, such as fear.

Studies designed to dissociate inherent physiological deterioration in balance control from normal adaptive responses to fear of falling have incorporated the analysis of postural control under conditions that vary in the level of their perceived threat to stability (14–16,18,20–24). In these studies, fear of falling is manipulated indirectly by altering the height of the support surface and by controlling the ability to perform protective stepping. These studies have demonstrated that the strategy for postural control of young adults during stance is scaled to the level of postural threat (14), with the perception of threat inducing a backward shift in the mean anterior–posterior (AP) position of the center of pressure (COP); a decrease in the COP amplitude variability; and an increase in the mean frequency of the COP displacement (14–16,24). The combination of decreased amplitude variability and increased movement frequency suggests that placing individuals in threatening conditions induces a cautious stiffening strategy, which is also demonstrated by unstable elderly individuals during perturbation tests (25).

In a study of postural control of young and old adults under similar threatening conditions and during a concurrent cognitive task, an observed age-dependent decrease in the area of COP movement may indicate a similar strategy of control in elderly persons (21). Age-dependent changes in postural control are further substantiated in studies examining the effects of postural threat on gait (21,22) and obstacle negotiation (23).

The purpose of the present study was to determine whether changes in the postural strategy adopted by elderly participants when faced with a postural threat include decreases in sway amplitude with concurrent increases in mean sway frequency, as observed in young adults. Perception of threat was manipulated by changing the height of the support surface and by the elimination of visual input.
METHODS

Participants
Sixty elderly (43 female), independently ambulating community-dwelling volunteers (mean age 77.5 ± 4.4 years) and 20 young (11 female) volunteers (mean age 21.5 ± 3.7 years) participated in the study. Exclusion criteria were: neurological impairments; major musculoskeletal disorders; uncorrected visual or vestibular problems; significant pain that limited functioning, or a fall within the month prior to testing. Six of the elderly participants reported falling once in the last year, and eight reported falling 2–3 times. On a dichotomous question (yes/no), 26 participants reported fear of falling and 15 claimed that fear limited their daily activities. The study was approved by the Ethical Review Board of the University of Haifa, and written informed consent was obtained from all participants.

Procedure
COP measures were collected with a portable 50 × 50 × 3 cm AMTI force-plate (ACCUSWAY PLUS; Advanced Mechanical Technology, Inc., Watertown, MA) at a 50 Hz sampling frequency. To create a condition of postural threat, the force-plate was placed on a 160 × 180 cm surface, which was raised 85 cm above ground level. Participants approached the surface via three portable steps. The force-plate was placed at mid-position, 50 cm away from the front edge, so as to allow for at least one protective step in each direction. Participants were tested barefooted and were instructed to stand quietly with their hands by their sides. The participants’ heels were positioned 15 cm from the force-plate’s edge, with a 10-cm distance between their heels and with their feet at a 30° angle to each other. The duration of each trial was 60 seconds, and 1-minute rest periods were allowed between trials. The participants were first tested on the raised platform (High), followed by testing on ground level (Low). At each level, testing was performed both with eyes open (EO) and with eyes closed (EC), and the order of sight condition was randomized.

Based on the inverted pendulum model, it is hypothesized that the combined decrease in amplitude variability and the increase in mean power frequency (MPF) of the COP displacement represents the adoption of an ankle-stiffening strategy (15). In accordance with previous studies examining the influence of postural threat on the control of upright stance in young participants (14–16), the following summary measures were used: MPF in both the AP and medio-lateral (ML) directions (MPF-AP and MPF-ML); and amplitude variability of COP in both the AP and ML directions (SD-AP and SD-ML). Also analyzed was the mean COP velocity (AvV), which represents the COP path length, normalized to stance time. A logarithmic transformation was applied to the COP summary measures so as to meet normal distribution requirements for statistical analysis. The analysis consisted of separate mixed-model three-way analyses of variance (ANOVA; 2 × 2 × 2) for each variable. Participants constituted a random factor nested within the participant group, and the three independent fixed factors were age (young vs old), sight condition (EO vs EC), and postural threat (high vs low). ANOVAs were followed by preplanned comparisons based on adjusted Tukey–Kramer tests. Statistical significance was set at $p = .05$, and analysis was performed using SAS, version 6.09 (SAS Institute, Cary, NC).

RESULTS

Figures 1–3 present the means and standard deviations of MPF-AP, MPF-ML, SD-AP, SD-ML, and AvV of the young and old participants standing with EO or EC on both low- and high-level surfaces. Table 1 presents a summary of the main and the interaction effects of the ANOVA for each dependent variable, and Table 2 presents a summary of the Tukey–Kramer tests comparing each group’s performance on a high versus a low surface.

ANOVA indicates significant increases in MPF-AP with increasing age and surface height, as well as with EC. Tukey–Kramer tests comparing the effect of postural threat separately in each group indicate that postural threat induces increases in MPF-AP only in elderly participants, which explains the significant interaction effect between age and postural threat. No main effects on MPF-ML were found for age, vision, or postural threat. A significant interaction effect between age and postural threat in this parameter indicates...
that threat-induced increases in MPF-ML are greater in the elderly participants, as supported by the within-group Tukey–Kramer tests.

SD-AP was not affected by age or threat. In both groups, SD-AP was significantly affected by visual condition, with the SD-AP increasing significantly in both groups as vision was eliminated ($p = .002$ and $p = .003$ for Tukey–Kramer comparisons between EO and EC in the young and the old participants, respectively). ANOVA results revealed a trend toward an overall effect of age on SD-ML ($p = .064$), indicating a tendency for SD-ML to increase with age. This result is supported by the Tukey–Kramer tests, which indicate an effect of threat only in the elderly participants, with a resulting marginal interaction effect ($p = .069$) between age and postural threat.

As indicated by the ANOVA, AvV increased significantly with age and with postural threat, as well as when vision was eliminated. A trend toward an interaction effect observed between age and threat ($p = .064$) indicates a tendency for this variable to increase more in the elderly participants as postural threat increases. This result is supported by the Tukey–Kramer tests indicating a significant effect of surface height only in the elderly participants. In fact, individual Tukey–Kramer tests comparing the effect of surface height in each stance position indicate a significant effect of postural threat only in the elderly group when their eyes were closed ($p = .0001$).

Although vision had a main effect in three of the variables (MPF-AP, SD-AP, and AvV), an interaction effect between age and vision was observed only for AvV. A significant interaction effect between visual condition and postural threat was observed for MPF-ML. However, no interaction effect between age, threat, and vision was obtained for any of the variables.

**DISCUSSION**

The purpose of this study was to compare the postural control strategy adopted by old and young participants under conditions perceived as threatening. Also examined was whether postural adjustments to postural threat are accentuated by the occlusion of vision. Contrary to previous studies (14–16,19,24), the postural control strategy of the young adult participants in our study was not significantly altered when they were placed under a condition that could be perceived as threatening. The discrepancy between these results most likely stems from differences in research methodology, which may have rendered the threatening condition used in this study less intimidating. Thus, whereas our participants stood on a raised surface of comparable height to the one used in previous studies, additional environmental constraints, such as restrictions in forward and sideways protective stepping (14–16,24), perturbations (24), or toe rising (19), were not imposed in the present study.

Although the young adults were not affected by the relatively minor threatening condition used in this study, the same condition induced some significant changes in the postural control of the elderly participants. Of the two parameters representing a “stiffening” response (amplitude variability and MPF), a significant effect of age was demonstrated only for MPF in the AP direction. Whereas a similar age effect was not demonstrated in the ML direction, the interaction effect between age and threat noted in MPF in both directions indicates that sway MPF of elderly adults is more susceptible to the effect of threat than is that of the young adults. Such threat-induced increases in MPF among elderly persons are similar to those observed in young persons under more threatening conditions (14–16). The interaction between vision and threat in MPF-ML indicates that the occlusion of vision may further heighten the threat-induced response.

The effect of threat on amplitude variability in elderly persons is less consistent. No effect of age or threat was observed for the amplitude variability in the AP direction. In contrast, age effect for SD-ML was near significance ($p = .064$). The mean SD-ML of the young participants remained 0.23 cm, regardless of the height of the stance surface, whereas the SD-ML of the elderly participants decreased significantly, from a mean of 0.31 cm to 0.26 cm,
when tested under the more threatening condition. This age-related decrease in amplitude variability is supported by a previous study demonstrating an age-related decrease in the COP area as postural threat increased (18).

Previous studies with young adults have demonstrated greater threat-induced changes in the AP direction, indicating that alterations in postural strategy may be aimed in the direction of the perceived threat (15,16). Yet, whereas the present study indicates age-related increases in MPF in both the AP and ML directions, the decrease in the amplitude variability is limited to the ML direction. A possible source for this difference may be the greater width of the raised surface used in the present study, which may have introduced a similar feeling of insecurity in all directions. However, deficits in stability and an increased risk of falling in elderly persons are commonly related to the control of ML stability (26,27), and control of lateral stability is suggested as important for falls prevention (28). Hence, the ability to generate stabilizing postural responses in the ML direction is of special importance among elderly populations.

AvV reflects the degree of balancing “activity” used to maintain the upright posture (25). This parameter has been shown to have the highest test–retest reliability among the COP measures (29) and to be the most consistent single parameter discriminating between test conditions and age groups (30). AvV may indicate that arousal levels are related to the degree of familiarity with testing conditions and to the perception of threat to stability (17,19).

In line with the findings of previous research (25,31), the quiet stance of our older participants was generally characterized by greater overall balancing activity. The observed age-related increased dependency on vision has also been previously demonstrated (32). Whereas the increases in balancing activity were previously demonstrated among elderly participants in relation to their fear of falling (33), in the present study the effect of postural threat on generalized postural activity in the elderly participants was clearly demonstrated only when the threat to stability involved both stance on a raised surface and the occlusion of vision. The greater threat-induced increases in MPF observed in the elderly participants also suggest that they react to conditions perceived as threatening by increasing their balancing activity. At the same time, one can not conclude from the greater psychological susceptibility to the perception of threat in the elderly group that their increase in balancing activity necessarily implies an increased risk of falling. Such risk is dependent on the associated compensatory changes in the COP amplitude variability, which allow for the control of the position of the COP to remain within the base of support. Although the elderly participants in the present study demonstrated a tendency to decrease amplitude variability in the SD-ML direction, they did not demonstrate a full “stiffening” strategy in both the AP and ML. This finding may indicate a deficiency in their ability to compensate for the effect of a postural threat on balancing activity.

Although care was taken to include in our study a representative sample of nondisabled community-living elderly participants, it is possible that the ability to appropriately compensate for threats to stability is dependent on covariants not controlled in this study. Such factors as fall efficacy, visual abilities, and functional capabilities may have a differential effect on the ability of elderly persons to adapt to psychological stresses affecting postural control. Further studies utilizing more threatening paradigms with better controlled groups of elderly participants are necessary for obtaining a better understanding of the effect of fear on the postural control strategies adopted by the elderly population.

Conclusion

The results of the current study indicate a propensity of elderly participants to increase MPF and overall postural activity when placed in conditions that are perceived as threatening to their stability. The observed compensatory changes in postural control, which served to tighten the control of the excursion of the COP by the elderly participants, were not as distinct as those reported in previous studies with young adults, and were primarily in the ML direction. Although the ability to modify posture in accordance with threats to stability is an important control mechanism that may decrease the likelihood of falling, the specific compensatory decreases in movement amplitude that are necessary to offset the increased arousal have yet to be determined, and the implications of these responses must be further explored.


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