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THE EFFECTS OF VISUAL CONDITION, AGE AND GENDER ON POSTURAL CONTROL

by

Lesley-Anne Brown

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THE EFFECTS OF VISUAL CONDITION, AGE AND GENDER ON POSTURAL CONTROL

ABSTRACT

The purpose of the present study was to investigate the influences of three visual conditions on postural control among young and older adults and between males and females. The visual conditions were: eyes closed; eyes open with constant visual fixation; and eyes open with random visual fixation.

Twelve independent ambulatory older adults (n=6 males, n=6 females) (age range 65.2 - 77.3 yrs, $\bar{x}$ = 70.98 ± 4.14 yrs) and twelve younger adults (n=6 males, n=6 females) (age range 22.6 - 27.3 yrs, $\bar{x}$ = 24.41 ± 1.5 yrs) provided the subject sample for comparison.

Subjects stood on a force platform with feet together for a test period of 30 seconds. Root mean square values of centre of pressure of ground reaction force (CP) excursion in each of the primary planes of sway (RMSx & RMSy) provided the dependent variables quantifying magnitude of postural sway. RMSx and RMSy were normalized to base of support dimensions (RMSx/BOSx & RMSy/BOSy) which facilitated a comparison of relative stability between subjects of different body dimensions.

Older adults demonstrated a significantly greater magnitude of lateral sway than younger adults, substantiating an age-related deterioration in postural control. Also, normalized data supported an age-related difference. No statistically significant differences were found between age groups for magnitude of antero-posterior sway.

Males demonstrated significantly greater lateral sway than females. This difference was not noted when lateral sway was normalized to support base width suggesting that any

difference due to gender may be attributed to anthropometric and/or biomechanical differences. No statistically significant gender-related differences were noted for antero-posterior sway. These results confirmed the fact that gender is not a contributing factor predisposing an individual to instability.

The visual contribution to postural control was the same for younger and older adults and for males and females. Constant visual fixation was the condition which provided the most stabilization for all groups. All groups demonstrated a destabilizing effect in the lateral plane of sway for random visual fixation and for eyes closed.

Age-related differences in the control of upright stance cannot be exclusively attributed to deterioration in the perception or integration of afferent visual information.

DEDICATION

Dedicated to David Bryson Waddell:

I am fortunate to share in your spirit, and proud to call you my friend.

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CHAPTER I

INTRODUCTION

Postural control for older adults deserves special attention because of its importance in functional mobility and safety. Balance is of particular concern in this population as it may be impaired by disease or aging (Berg, 1989). One of the major concerns for the older adult is the high frequency of falls associated with advanced aging (Patla, Frank, & Winter, 1990). Scientific inquiry has linked impaired balance as a factor associated with falls in this age group (Tinetti, Williams, & Mayewski, 1986). According to statistics, one third to one-half of all people over the age of sixty-five fall at least once per year (Gibson, Andres, & Isaacs, 1987). Aside from the incidence of injury in these accidents, a major consequence of any fall is psychological trauma. In essence, a fear of future falls will be developed which may lead to a decrease in mobility and a subsequent decline in functional independence (Berg, 1989; Maki, Holliday, & Fernie, 1990).

The importance of postural control to the older adult is primary. If postural control can be preserved, the number of traumatic occurrences may decrease. Subsequently, the individual's level of confidence may increase, leading to an improved quality of lifestyle in this population.

One goal of research in the field of postural control is to reduce the frequency of falls that has been associated with advanced aging (Patla et al., 1990). To accomplish this goal, it becomes necessary to examine the cause of falls in older adults. Researchers have compared postural sway in young and older adults and have attempted to correlate increased sway with deterioration in nervous system function and an increased liability to fall (Sheldon, 1963; Woollacott, Shumway-Cook, & Nashner, 1986). In static balance studies, increased sway is often equated with an inferior postural control system (Patla et al., 1990). As suggested by Patla and colleagues (1990), this assumption may be questionable; a comparison between the sway profile and the potential instability of a mannequin is offered to demonstrate this possibility. In contrast to this viewpoint, interpretation of the results of the present study were based on the perspective that an increased sway profile suggests a decreased sensitivity of the postural control system which increases the tendency toward instability.

There has been considerable research to date detailing age-related differences in the postural response to constant visual fixation and to conditions absent of visual information (eyes closed). One aspect not usually dealt with is the effect of voluntary eye movements (visual saccades) on postural control.

Studies investigating the effects of saccadic retinal displacements conventionally demand alternating fixation at a constant frequency (Riach & Starkes, 1989; Uchida, Hashimoto, Suzuki, Takegami, & Iwase, 1979; White, Post, & Leibowitz, 1980). Such protocol affords consistent periods of fixation between eye movements and facilitates prediction of saccadic shifts (Raphan & Cohen, 1978). To date, the extent to which random periods of visual fixation between saccadic shifts affects postural control remains to be determined.

CHAPTER II

STATEMENT OF THE PROBLEM

It is well documented that postural control deteriorates with advancing age. The underlying neural and physiological changes responsible for this deterioration are less clear. The focus of the present study was to investigate whether age-related differences can be attributed to degeneration in the visual contribution to postural control.

The purpose of this study was to compare the influences of three visual conditions on postural control among younger and older adults, and among males and females.

The visual conditions were: eyes closed; eyes open with constant visual fixation; and eyes open with random intermittent visual fixation.

CHAPTER III

REVIEW OF LITERATURE

Postural control is the ability to maintain one's equilibrium in a gravitational field (Horak, 1987). Equilibrium is achieved when the vertical projection of the centre of mass (centre of gravity (CG)) of a stationary body falls within its base of support (Berg, 1989). The postural control system maintains equilibrium through integration of afferent information from proprioceptive, vestibular and visual receptors. These receptors provide feedback about internal and external conditions and therefore, the current state of equilibrium.

The most obvious task performed by the postural control system is maintenance of upright bipedal stance. During quiet standing, balance is characterized by a continuous series of muscular contractions that produce moments of force about the joints of the musculo-skeletal system and function to counteract the effects of gravity (Hayes, 1982). Minute fluctuations in the vertical projection of the centre of gravity result from this continual counter-action and, in conjunction with internal disturbances (respiration and heart rate), cause the body to rotate about the ankle joints. This continuous oscillatory motion of the centre of gravity is characteristic of upright bipedal stance and is clinically known as postural sway (Hayes, 1982; Winter, 1990). The extent of postural sway provides an index of the body's postural correction process (Hayes, 1982; Riach, 1985).

Postural adjustments occur in movement ranges difficult to detect with simple observation (Horak, 1987). Stabilometry, the recording and analysis of the continuous oscillation of the body over time, has become the method of choice for quantification of postural sway. The conventional protocol for assessing the postural control system has been the use of conditionally-variant static tests. These static tests provide indication of the ability to maintain upright stance during conditions when the postural system is stressed by different support (2 foot, 1 foot, tandem) and/or visual (eyes open, eyes closed) conditions. The implicit assumption of static balance studies is that postural control under stressed postural conditions can be extrapolated to postural performance during typical falling activities (Patla et al., 1990). Force plates, which record excursions of the body's centre of pressure are the measurement devices most commonly used (Hayes, 1982).

The centre of pressure of ground reaction forces (CP) represents the centre of distribution of the total force applied to the supporting surface (Murray, Seirig, & Sepic, 1975). CP is quantified as the net location of the vertical ground reaction force vector from a force platform (Winter, 1990). During quiet standing, the location of the CP (relative to the axis of rotation) multiplied by the magnitude of the vertical ground reaction force vector represents the torque generated by the ankle muscles to maintain static stance. CP represents the motor control signal output of the central nervous system (CNS) in response to imbalances of the body's centre of gravity (Patla et al., 1990). Fluctuations in CP reflect an attempt at correcting stability after a disturbance or the initiation of change in CG position (Murray, Seirig & Scholz, 1967; cf. Riach, 1985).

In a comparison of CP and CG displacement during quiet stance, Winter (1990), noted the dynamic range of CP displacement to be somewhat greater than that of CG excursion. As suggested by Riach (1985), the CP moves with greater amplitude than the CG to contain the CG within a narrower, more stable area.

Centre of pressure data can be analyzed from both a temporal and frequency domain. Temporal domain analysis characterizes the extent of sway by quantification of the amplitude of excursion in two perpendicular planes over time: (a) antero-posterior (a-p) and (b) medio-lateral (lat) (Riach & Hayes, 1987). Frequency domain analysis provides an analysis of the frequency composition of the CP excursion signal.

Frequency analysis may be used as a diagnostic evaluation of certain neuropathologies. Each of the three major sensory systems involved in postural control (visual system, vestibular system and proprioceptive system) operates at different sway frequencies (Diener & Dichgans, 1988). Visual stabilization of posture operates mainly in the low frequency range (0-0.1Hz). The working range of the vestibular system has also been estimated to be in the low frequency range (0-0.2Hz) for the utricular otoliths; the semicircular canals are sensitive to higher frequencies (0.2-2Hz) (Nashner, 1982). Proprioception involving muscle spindles is also high frequency sensitive (> 1Hz) (Diener & Dichgans, 1988; Riach, 1985). In addition, afferent and efferent pathways have various latencies depending on CNS level or distances involved (Riach, 1985). As a result of the differences in frequency sensitivity and pathway latencies, pathologies in receptors, pathways, and/or processing and effector systems may be detected through frequency analysis of the postural sway signal (Mauritz, Dichgans, & Hufschmidt, 1979; cf. Riach, 1985).

It is well documented that the extent of postural sway during quiet stance increases with advanced aging. Previous studies examining postural control during quiet stance have shown an increased sway for older adults compared to young adults (Era & Heikkinen, 1985; Hayes, Spencer, Riach, Lucy, & Kirshen, 1984; Maki et al., 1990; Pyykko, Aalto, Hytonen, Starck, Jannti, & Ramsay, 1985; Sheldon, 1963; Walt, Patla, Winter, & Frank, 1990;

Woollacott et al., 1986). Researchers have attempted to correlate such age-related increases in sway with deterioration in nervous system function and an increased propensity toward falling (Manchester, Woollacott, Zederbauer-Hylton, & Marin, 1989). This basic tendency toward instability has implications for the execution of voluntary movements or the ability to recover from unexpected perturbations (Stelmach, Phillips, DiFabio & Teasdale, 1989). Such activities may shift the centre of gravity outside the limits defined by the base of support, thereby predisposing instability.

Postural control has been shown to be further limited by conditions of reduced sensory information. Both younger and older adults have demonstrated increased sway during stance conditions limited by visual information (i.e. eyes closed) (Lee & Lishman, 1975; Woollacott et al., 1986). As suggested by Walt et al (1990), age-related differences in postural sway are accentuated by stressed postural conditions. Greater postural sway and an increased incidence of falls (Gibson et al., 1987) suggests that older individuals may be slower at detecting and correcting postural disturbances (Stelmach, Teasdale, DiFabio, & Phillips, 1989).

The nervous system mechanisms responsible for control of posture may be divided into component functions organized in a hierarchial manner (Pyykko et al., 1988; Woollacott et al., 1986;). The neural systems which comprise this postural control hierarchy have been suggested to contribute to changes correlated with the increased sway of aging adults (Woollacott et al., 1986). From lowest to highest, the possible levels of the nervous system's postural control hierarchy include: (a) the mono-synaptic stretch reflex, (b) the long-latency automatic postural response and (c) the integrative mechanisms which co-ordinate sensory inputs from visual, vestibular and somatosensory systems (Woollacott et al., 1986).

The mechanical significance of the mono-synaptic stretch reflex in the correction of postural disturbance is small. Previous research examining age-related changes in the mono-synaptic stretch reflex indicated an increased latency (Achilles and patellar tendon reflexes) with age (Woollacott et al., 1986).

The long-latency automatic postural responses, a higher level of the postural control hierarchy, are more effective than the mono-synaptic stretch reflex in compensating for any unexpected loss of balance (Woollacott et al., 1986). In an investigation of the effects of advancing age on automatic postural adjustments, Woollacott et al (1986), reported a slight (10-15 msec) increase for long-latency responses (in distal musculature) for older adults in response to rapid surface translations causing posterior sway.

The higher level integrative mechanisms are used to co-ordinate a convergence of sensory information derived from vestibular, visual and somatosensory receptors. These higher level mechanisms are slower than the mono-synaptic stretch reflex and the long-latency automatic postural response systems and operate primarily in the lower frequencies of postural disturbance (Stelmach et al., 1989b).

In a comparison of high and low frequency postural disturbances, Diener & Dichgans (1986) suggested that high frequency transient postural disturbances are compensated for in a reflexive manner. In contrast, the control of continuous upright posture appears to be dependent upon the quality of somatosensory information and its integration (through higher level mechanisms) with visual and vestibular information (Diener & Dichgens, 1988).

It is accepted that postural control during quiet stance is limited by advancing age and the quality of available sensory information (Stelmach et al., 1989a; Stelmach et al., 1989b; Woollacott et al., 1986). However, the underlying nervous system changes responsible for this increased sway are less clear. There are thus the following questions to be addressed: (a) are age-related deficiencies in the control of posture a result of deterioration in the afferent (peripheral) components and/or (b) do such deficiencies arise as a result of impairment in the central integrative mechanisms of the postural control system?

Sudden postural disturbances are quickly corrected through reflexive activity (Diener & Dichgans, 1988). Since the automatic postural response mechanisms may deteriorate with advancing age, the ability of the older adult to recover from a sudden destabilizing activity has been questioned (Sheldon, 1960; cf. Woollacott et al., 1986).

Woollacott et al (1986), noted an increase in the absolute latency of distal muscle responses (10-15 msec) for all older adults responding to high frequency support surface perturbations. In contrast to these findings, Stelmach et al (1989a), in a similar experiment were unable to demonstrate any age-related increases in muscle latencies: the elderly group responded to sudden perturbations in a similar manner to that of the young participants. From these results, it was suggested that postural reflex mechanisms of the older adult remain relatively intact (Stelmach et al., 1989a).

Despite discrepant findings regarding lower-level postural control, there is consensus that older adults are disadvantaged when posture must be controlled by the slower, higher level sensory integrative processes; as in the continuous regulation of upright stance (Stelmach et al., 1989a; Woollacott et al 1986).

The adaptive properties of the postural control system normally allow compensation for deficits in the performance of its components (Straube, Botzel, Hawken, Paulus, & Brandt, 1988). The functional ranges of the main individual sensory systems overlap which enables them to compensate partially for deficiencies (Paulus, Straube, & Brandt, 1984). Decreases in the effectiveness of any one of the peripheral sensory systems of postural control could decrease the redundancy of sensory information normally available to the participant. Redundancy of sensory inputs ensures stability in situations where one or more inputs is lost;

for example when walking in a dimly lit room (Woollacott et al., 1986). With loss of redundancy, integrative mechanisms normally cause a perceptual reweighting toward dependency on remaining inputs (Woollacott et al., 1986).

Recent research analyzing changes in the somatosensory, vestibular and visual systems with advancing age has shown significant deterioration in each of these systems (Manchester et al., 1989). Decreased cutaneous sensation and strongly diminished stretch reflexes result in an increased threshold of proprioceptive sensitivity with age (Pyykko et al., 1988); significant deterioration in the spatial visual sensitivity of the older adult to low frequency spatial information (Sekular & Hutman, 1980), and an age-related progressive reduction in the number of sensory cells within the peripheral vestibular system (Rosenhall & Rubin, 1975) are the primary changes noted.

Proprioceptive deterioration may be linked to the increased postural sway characteristic of the older adult and may reflect an inability to quickly detect instability. (Stelmach & Worringham, 1985). As suggested by Patla et al (1990), it is possible that older adults use a larger excursion of CP to compensate for reduced or impoverished proprioceptive feedback; increased dependence on proprioceptive feedback may be necessary to compensate for possible deficiencies in vestibular or visual sensitivity.

Cutaneous receptors in the sole of the foot and in the vicinity of the ankle joint react to stretch of the skin and provide sensory information regarding joint position (Stuart, Blinder, & Botterman, 1979; cf. Pyykko et al., 1988). The sensitivity of such receptors has been suggested to be significantly diminished in the older adult (Woollacott et al., 1986). In a comparison of proprioceptive acuity between older and younger adults, Stelmach, et al (1990), demonstrated a decreased threshold to excitability for ankle and knee joint receptors in older adults. As suggested, this decreased proprioceptive sensitivity may affect postural control by compromising the ability to detect subtle changes in joint position (Stelmach, Meeuwsen & Zelaznik, 1990).

Research on changes in vision with advancing age has revealed a significant deterioration in the sensitivity of the older adult to low frequency spatial information (Sekular & Hutman, 1980; Sekular, Hutman, & Owsley, 1980). Since visually guided behaviours such as postural stabilization may depend on low frequency spatial visual information mediated by peripheral visual inputs, it is conceivable that certain postural stabilization problems in the older adult may also be related to this diminished sensitivity to low spatial frequencies (Sekular & Hutman, 1980).

Physiological evidence suggests that primary vestibular functions are impaired in the older adult. Rosenhall and Rubin (1975), in a study of the degenerative changes in the human peripheral vestibular system, noted an age-dependent progressive reduction in the number of sensory cells and nerve fibres within the vestibular systems of individuals greater than 40 years of age. This progressive loss was suggested to be possibly attributed to an increased fragility of the sensory fibres with advancing age. Vestibular deterioration may be a contributing factor in age-related postural instability (Woollacott et al., 1986).

The effects of sensorimotor deficits in older adults have been demonstrated through investigation of postural control under conditions of sensory conflict. Research results have suggested that central integrative mechanisms remain intact in older adults; that any instability under sensory conflict conditions may be explained by reduced peripheral sensibility rather than by disruption of central integrative processes (Woollacott et al., 1986). Woollacott and colleagues (1986) demonstrated an instability for older adults under conditions limited by visual or functional somatosensory inputs, suggesting impaired peripheral vestibular function. In secondary tests, older subjects were able to maintain balance once visual information became available, even though these visual cues did not provide useful orientation (or movement) information. This finding suggests a normal ability to adapt to sensory conflict.

With subsequent trials, older adults demonstrated adaptation to the (centrally-demanding) destabilizing conditions. As suggested by Straube et al (1988), such adaptation may imply a general slowing of the central integrative mechanisms which are responsible for reconfiguring the postural control system to meet changing conditions. On initial exposure, these mechanisms were unable to provide immediate reweighting of the control strategy to account for conflicting sensory conditions.

In an attempt to test the hypothesis of a generalized slowing of the central control mechanisms, Stelmach et al (1989a), attempted to duplicate adaptation to possibly destabilizing conditions as previously demonstrated by Woollacott et al (1986). Despite relatively similar experimental conditions, Stelmach and colleagues were unable to demonstrate any initial destabilization. Sample selection variance between these experiments was the suggested difference: older subjects in the Stelmach (1989a) study, screened for musculo-skeletal deficits, neurological disease, drug use and physical activity, may represent an 'elite' sample of the older population.

Stelmach et al (1989a) were able to demonstrate a consistent increased range of sway for older subjects as compared to younger subjects. Such sway profiles were produced in response to low amplitude-low frequency ankle rotation perturbations intended to activate central integrative mechanisms. From these results it was suggested that older adults are at a greater disadvantage when postural control depends on slower, higher level sensory integrative mechanisms (Stelmach, 1989a).

Vision plays a major role in the multisensory process of postural control (Paulus et al., 1984). Under normal conditions, vision dominates proprioceptive and vestibular inputs (Straube et al., 1988). Visual stimuli provide for the perceptual interpretation of self motion. During quiet stance, small postural oscillations cause changes on the retinal surface and may contribute to the visually induced perception of self-motion. The "optic flow pattern" of the visual surround gives proprioceptive information about the amount and direction of sway (Gibson, 1966). By making postural adjustments to minimize movements of the visual images, the subject may reduce postural sway.

Visual stabilization of posture has been shown to be critically dependent on stimulus characteristics and performance of the visual system (Paulus et al., 1984). Visual perception of relative motion due to head sway is a critical feature in the visual stabilization of posture (Paulus, et al., 1984). In order to be detected visually, body sway must increase with increasing distance between the eyes and the nearest stationary visual contrast. Thus, the amount of retinal displacement caused by postural sway depends on the proximity of the visual target. For this reason, close targets are potentially more effective for visual stabilization of posture (Paulus, Hawken, Quintern, Straube, Krafczyk, Botzel, & Brandt, 1988; Riach & Starkes, 1989). As suggested by Paulus and colleagues (1984), a general improvement in postural sway while fixating close visual targets can be related to better resolution in the detection of relative motion of head sway.

The postural response to visual fixation may differ between the lateral and the antero-posterior planes of sway. Retinal image changes are greater in response to lateral sway than antero-posterior sway. As a result, visual targets may be more effective in reducing lateral sway (Riach & Starkes, 1989).

Discrepancy exists regarding the differential involvement of the central, peripheral and foveal visual fields in postural stabilization. Peripheral vision is defined as the area surrounding an elliptical area of central vision. Central vision encompasses approximately 20 degrees of visual field, the innermost 1-2 degrees being the foveal field (Riach & Starkes, 1989). Paulus et al (1984), measured postural sway under isolation of different areas of the visual field. As suggested, the central area of the visual field, compared with the peripheral field, dominates postural control; the foveal region provides a powerful contribution to lateral sway. The inferiority of the peripheral field in visual stabilization of posture was suggested to be related to a decrement in motion detection sensitivity towards the periphery.

Delorme & Martin (1986), exposed subjects to background or foreground visual motion in both the central and peripheral fields. In contrast to Paulus and colleagues (1984), these researchers noted significant effects for peripheral vision in postural regulation.

Visual perception of relative body movement depends on the amount of available information. More information on relative body movement is likely to be obtained from several structures in the visual field as compared with a single one. Paulus and colleagues (1984), demonstrated a decrease in lateral body sway from the eyes closed condition, during visual fixation on a central stationary illuminated contrast within a dark visual field. The addition of four peripheral stationary targets (to the existing central target) caused a further reduction in body sway, one-third less than for the whole field reference condition (eyes open).

Standard protocol for the posturographic recording of body sway has classically involved visual fixation on a target for a test period of 30-60 seconds. This protocol has been criticized as it represents only a fragment of the normal requirements of keeping the body in an upright position (Paulus et al., 1988). One aspect not usually dealt with is the intrusion of eye movements.

Eye movements may be classified to be either saccadic or smooth pursuit. Smooth pursuit eye movements fix images on the retina and provide a continuous flow of visual information. Saccadic eye movements move the eyes rapidly between points of fixation, inhibiting a continuous information flow (Raphan & Cohen, 1978)

Saccadic eye movements have been shown to be beneficial to postural stabilization. Uchida and colleagues (1979), demonstrated a decrease in postural sway in response to low frequency (.1 - 1.0 Hz) visual saccades induced by alternating flashing lights (Uchida et al., 1979). Riach and Starkes (1989) have also postulated stabilizing effects for visual saccades in young children. From these results, constant rate rapid retinal dislocation (saccades) appears to be advantageous to postural control.

Studies investigating the postural response to saccadic eye movements have conventionally employed alternating fixation at a constant frequency (Riach & Starkes, 1989; Uchida et al., 1979; White et al., 1980). Such protocol affords consistent periods of visual fixation between saccadic eye shifts. As a consequence, constant rate visual saccades facilitate prediction of subsequent saccadic shifts (Raphan & Cohen, 1978). To date, the postural response to random periods of visual fixation between saccadic eye movements remains to be determined.

CHAPTER IV

METHODS

4.1 Subjects

The present study investigated the influence of visual information and the effects of age and gender on postural control. All subjects were free from any known neuromuscular pathologies that may have adversely affected postural control.

Twelve independent ambulatory older adults (n=6 males, n=6 females) (age range 65.2 - 77.3 yrs, $\bar{x}$ = 70.97 ± 4.1 yrs) were selected from participants currently involved in a weight-training study at McMaster University. Subjects were selected from those classified as control group participants in the weight training study. These subjects had satisfied medical screening criteria and were not participating in any physical training interventions. A minimum age requirement of sixty-five years at the date of testing applied as a qualification for participation. Subjects were selected randomly from those meeting this age requirement.

Twelve younger subjects (n=6 males, n=6 females) (age range 22.6 - 27.3 yrs, $\bar{x}$ = 24.41 ± 1.5 yrs) were selected from the student population at McMaster University.

4.2 Visual Test Conditions

Three separate visual test conditions were used to examine the contribution of visual cues to postural control. The objective of employing three test conditions was to manipulate the sensory information available to the visual system. The visual test conditions were as follows: (a) EC: eyes closed; (b) EOFC (eyes open - fixation constant): eyes open with constant visual fixation on a light source at eye level one metre away; (c) EOFR (eyes open - fixation random): eyes open with random periods of visual fixation on alternating lateral light sources located one metre from the subject.

Three visual targets (light-emitting diodes) arranged laterally provided a visual environment for the eyes open conditions. The central light source alone was used as the visual target for the test condition demanding constant visual fixation (EOFC). Random intermittent visual fixation (EOFR) was achieved through manipulation of both location and duration of visual fixation. Two lateral light sources were activated alternately in an attempt to vary the required location of visual fixation. Subjects were instructed to fixate on the illuminated light source. Duration of illumination varied randomly between one, two, three, or four seconds. The central light source remained off throughout this condition. Surrounding light sources were turned off during test conditions to prevent visual distraction.

Each test condition was performed once per subject, for a total of three test trials per subject. The order of test trials was randomized among subjects.

4.3 Procedures

All participants were briefed as to the purpose of the study, the experimental protocol, and the testing equipment to be used. Information regarding the right to withdraw from participation was provided during this briefing session. All subjects were required to sign a consent form verifying their knowledge of the testing purpose and protocol (Appendix A).

Subjects were asked to remove footwear and stand with feet together and arms at sides for testing. Subjects were then asked to stand erect and as still as possible for a test period of 30 seconds on a firmly secured force platform (AMTI Model OR6-5-1). Based on the assumption that postural control for some individuals may be an exercise of conscious demand, subjects were challenged by a cognitive task during each test trial. This task involved mental arithmetic calculations comprised of counting backwards by multiples of two starting at any odd number greater than one hundred. All subjects were asked to count verbally in each trial. The rationale for this requirement was to impose adequate cognitive demand to distract subjects from conscious control of posture.

The strain gauge force platform (AMTI Model OR6-5-1) measured each subject's ground reaction force in the vertical direction (Fz) and moments of force (Mx and My) about the lateral (LAT) and antero-posterior (A-P) axes. Force and moment of force signals were sampled and amplified (AMTI SGA 6-3 Signal conditioner/amplifier) prior to A/D conversion at a sampling frequency of 31 Hz (930 data samples per trial; one sample every .033 sec). The digital signal was processed in an IBM compatible computer system using the Computer Automated Stabilograph software (AMTI, CAS). The centre of pressure of ground reaction force (CP) was calculated for both the (A-P) and (LAT) planes using the following approximations:

$$Y = Mx/Fz \qquad\qquad X = My/Fz$$

where, Y = y co-ordinate of the centre of pressure (A-P)

X = x co-ordinate of the centre of pressure (LAT)

(Starkes & Riach, 1990)

The x-y fluctuations of the CP over the 30-second test trial period were plotted. An amplitude analysis of CP excursion served to quantify the extent of spontaneous postural sway. Root Mean Square values of centre of pressure excursion (RMSx and RMSy) relative to the mean position provided the amplitude measures. The RMS value of a signal is equivalent to the standard deviation of the signal about the mean position (Riach, 1985). Thus, the RMS values of sway amplitude provided an estimate of the variance of CP excursion about the mean position. RMS represents a suitable measure of sway magnitude over a certain period and allows for an easy comparison to be made between the effects of different experimental conditions (Bles, Kapteyn, Brandt, & Arnold, 1980).

The amplitude measures (RMSx and RMSy) were expressed relative to base of support (BOS) dimensions (length and width) obtained from foot tracings. This method of normalizing allowed for expression of the amplitude measures as a percentage of the maximum possible CP displacement and permitted comparison of relative stability between subjects of different body dimensions (Maki et al., 1990). RMS/BOS reflected the degree to which the limits of stability were approached during quiet standing.

4.4 Design and Analysis

Three independent variables were manipulated in the present study as follows: age; gender; and visual test condition. A comparison between older and younger adults investigated the effect of age on postural control. Comparison between sexes examined the effect of gender on the ability to control posture. Manipulation of the visual environment tested the influence of vision on postural control.

Two dependent variables were measured and each of these variables were normalized to base of support dimensions. Each dependent variable was measured for the lateral (x) and for the antero-posterior (y) planes of sway, producing a total of four dependent measures. Independent and dependent variables are listed in Tables 1 and 2 respectively.

A separate 2 X 2 X 3 (age x gender x visual test condition) repeated measures analysis of variance was performed on each dependent variable to test for statistically significant differences between independent variables. Where statistically significant effects were found, post hoc analysis by the procedure of Tukey's HSD (Honestly Significant Difference) was used to determine where differences between experimental conditions existed. Statistically significant differences were accepted at the probability level of alpha = .05.

4.5 Hypotheses

The following null hypotheses associated with the specified manipulations of the independent variables in the present study were tested. Each hypothesis relates to postural sway in each of two planes (lateral and antero-posterior) for the four dependent variables defining postural control (RMSx; RMSx/BOSx; RMSy; and RMSy/BOSy). The main effect null hypotheses were as follows:

Ho(1) There would be no statistically significant differences in postural control between younger and older adults.

Ho(2) There would be no statistically significant differences in postural control between males and females.

Ho(3) There would be no statistically significant differences in postural control between the three visual environments.

The null hypotheses for interactions between independent variables were as follows:

Ho(4) There would be no statistically significant interactions between age and gender.

Ho(5) There would be no statistically significant interactions between age and visual test condition.

Ho(6) There would be no statistically significant interactions between gender and visual test condition.

Ho(7) There would be no statistically significant interactions between age x gender x visual test condition.

Table 1. Independent Variables

VARIABLE	LEVEL	DESCRIPTION
AGE	(a) young adult (b) older adult	
GENDER	(a) males (b) females	
VISUAL TEST CONDITION	(a) EC	eyes closed
	(b) EOFC	eyes open - constant visual fixation
	(c) EOFR	eyes open - random intermittent visual fixation

Table 2. Dependent Variables

VARIABLE	LEVEL	DESCRIPTION
RMS (cm)	(a) RMSx	standard deviation of lateral CP excursion about the mean position
	(b) RMSy	standard deviation of antero-posterior CP excursion about the mean position
RMS/BOS (%)	(a) RMSx/BOSx	lateral sway magnitude relative to support base width
	(b) RMSy/BOSy	antero-posterior sway magnitude relative to support base length

CHAPTER V

RESULTS

Summary statistics for age and base of support dimensions are provided in Tables 3 and 4 respectively. The mean age for the younger adults was 24.41 ± 1.5 years. The mean age for the older adults was 70.97 ± 4.1 years. The mean base of support width for males was 20.46 ± .96 cm and for females was 18.83 ± 1.15 cm. The mean base of support length for males was 27.42 ± 1.31 cm and for females was 24.71 ± .66 cm.

Table 3. Age Statistics

MEAN ± STANDARD DEVIATION (years)			
YOUNG MALE	YOUNG FEMALE	OLDER MALE	OLDER FEMALE
24.73 ± 1.6	24.08 ± 1.5	73.05 ± 3.9	68.91 ± 3.5
YOUNG ADULTS		OLDER ADULTS	
24.41 ± 1.5		70.97 ± 4.1	

There was a statistically significant difference in base of support dimensions between sexes. Male subjects had significantly larger support base length ($F(1,22) = 40.95$, $p < .05$) and width ($F(1,22) = 14.00$, $p < .05$) dimensions than females (Table 4).

Table 4a. Base of Support Dimensions: WIDTH

MEAN ± STANDARD DEVIATION (cm)			
YOUNG MALE	YOUNG FEMALE	OLDER MALE	OLDER FEMALE
19.92 ± 1.0	18.33 ± 1.1	21.00 ± .41	19.33 ± .80
FEMALES		MALES	
18.83 ± 1.15		20.46 ± .96**	

** p<.01

Table 4b. Base of Support Dimensions: LENGTH

MEAN ± STANDARD DEVIATION (cm)			
YOUNG MALE	YOUNG FEMALE	OLDER MALE	OLDER FEMALE
26.75 ± .95	24.58 ± .34	28.08 ± 1.17	24.83 ± .80
FEMALES		MALES	
24.71 ± .66		27.42 ± 1.31***	

*** p<.001

Descriptive statistics for dependent variables defining the analysis of CP excursion in each visual condition are provided in Tables 5a & b, 6a & b, and 7a & b.

Repeated measures analyses of variance showed no statistically significant interactions between levels of the independent variables for each of four dependent variables. F-ratios for three-way interactions (age x gender x visual test condition) were as follows:

RMSx ($F(2,40) = 1.52$, $p > .05$)

RMSx/BOSx ($F(2,40) = 1.65$, $p > .05$)

RMSy ($F(2,40) = 1.44$, $p > .05$)

RMSy/BOSy ($F(2,40) = 1.63$, $p > .05$)

F-ratios for two-way interactions between age and gender were as follows:

RMSx ($F(1,20) = 1.11$, $p > .05$)

RMSx/BOSx ($F(1,20) = 0.68$, $p > .05$)

RMSy ($F(1,20) = 0.66$, $p > .05$)

RMSy/BOSy ($F(1,20) = 0.37$, $p > .05$)

F-ratios for two-way interactions between age and visual test condition were as follows:

RMSx ($F(2,40) = 0.05$, $p > .05$)

RMSx/BOSx ($F(2,40) = 0.04$, $p > .05$)

RMSy ($F(2,40) = 1.08$, $p > .05$)

RMSy/BOSy ($F(2,40) = 1.18$, $p > .05$)

Table 5a. Descriptive Statistics by Group.
Condition: EC

	MEAN ± STANDARD DEVIATION			
VARIABLE	YM	YF	OM	OF
RMSx (cm)	.576 ± .06	.497 ± .12	.802 ± .15	.580 ± .12
RMSx/BOSx (%)	2.897 ± .37	2.748 ± .78	3.818 ± .72	2.988 ± .58
RMSy (cm)	.528 ± .16	.433 ± .14	.680 ± .26	.522 ± .14
RMSy/BOSy (%)	1.982 ± .62	1.768 ± .55	2.447 ± .99	2.093 ± .51

Table 5b. Descriptive Statistics by Age and Gender.
Condition: EC

MEAN ± STANDARD DEVIATION		
	YOUNG ADULTS	OLDER ADULTS
RMSx (cm)	.536 ± .10	.691 ± .18
RMSx/BOSx (%)	2.823 ± .61	3.403 ± .78
RMSy (cm)	.481 ± .16	.601 ± .22
RMSy/BOSy (%)	1.875 ± .59	2.270 ± .81
	MALES	FEMALES
RMSx (cm)	.688 ± .16	.538 ± .13
RMSx/BOSx (%)	3.358 ± .73	2.868 ± .70
RMSy (cm)	.604 ± .23	.478 ± .14
RMSy/BOSy (%)	2.214 ± .85	1.931 ± .56

Table 6a. Descriptive Statistics by Group.
Condition: EOFC

MEAN ± STANDARD DEVIATION				
VARIABLE	YM	YF	OM	OF
RMSx (cm)	.402 ± .06	.388 ± .13	.618 ± .18	.467 ± .06
RMSx/BOSx (%)	2.022 ± .31	2.127 ± .71	2.942 ± .84	2.415 ± .34
RMSy (cm)	.488 ± .12	.457 ± .09	.652 ± .22	.413 ± .09
RMSy/BOSy (%)	1.838 ± .49	1.870 ± .38	2.343 ± .82	1.660 ± .36

Table 6b. Descriptive Statistics by Age and Gender.
Condition: EOFC

MEAN ± STANDARD DEVIATION		
	YOUNG ADULTS	OLDER ADULTS
RMSx (cm)	.395 ± .15	.543 ± .09
RMSx/BOSx (%)	2.074 ± .55	2.678 ± .69
RMSy (cm)	.473 ± .11	.533 ± .21
RMSy/BOSy (%)	1.854 ± .44	2.002 ± .72
	MALES	FEMALES
RMSx (cm)	.510 ± .17	.428 ± .11
RMSx/BOSx (%)	2.482 ± .78	2.271 ± .57
RMSy (cm)	.570 ± .19	.435 ± .10
RMSy/BOSy (%)	2.091 ± .72	1.765 ± .38

Table 7a. Descriptive Statistics by Group.
Condition: EOFR

	MEAN ± STANDARD DEVIATION			
VARIABLE	YM	YF	OM	OF
RMSx (cm)	.578 ± .16	.432 ± .07	.710 ± .09	.577 ± .11
RMSx/BOSx (%)	2.938 ± .97	2.358 ± .42	3.382 ± .41	2.980 ± .54
RMSy (cm)	.500 ± .23	.393 ± .09	.655 ± .17	.490 ± .16
RMSy/BOSy (%)	1.892 ± .91	1.608 ± .34	2.348 ± .64	1.970 ± .61

Table 7b. Descriptive Statistics by Age and Gender.
Condition: EOFR

MEAN ± STANDARD DEVIATION		
	YOUNG ADULTS	OLDER ADULTS
RMSx (cm)	.505 ± .15	.643 ± .12
RMSx/BOSx (%)	2.648 ± .80	3.181 ± .52
RMSy (cm)	.447 ± .18	.573 ± .18
RMSy/BOSy (%)	1.750 ± .70	2.159 ± .65
	MALES	FEMALES
RMSx (cm)	.644 ± .15	.504 ± .12
RMSx/BOSx (%)	3.160 ± .78	2.669 ± .57
RMSy (cm)	.578 ± .22	.442 ± .14
RMSy/BOSy (%)	2.120 ± .82	1.789 ± .53

F-ratios for two-way interactions between gender and visual test condition were as follows:

RMSx ($F(2,40) = 1.02$, $p > .05$)

RMSx/BOSx ($F(2,40) = 0.74$, $p > .05$)

RMSy ($F(2,40) = 0.02$, $p > .05$)

RMSy/BOSy ($F(2,40) = 0.04$, $p > .05$)

Significant main effects for each independent variable are addressed separately.

5.1 Age

A statistically significant effect for age was revealed for lateral sway magnitude (RMSx) ($F(1,20) = 12.004$, $p < .05$) (Table 8). A statistically significant age difference was also noted when lateral CP sway magnitude was expressed relative to support base width (RMSx/BOSx) ($F(1,20) = 6.233$, $p < .05$) (Table 9). These findings are summarized and illustrated in Figures 1 & 2, where it can be seen that older adults demonstrated a significantly greater magnitude of lateral sway (RMSx) under all conditions than younger adults.

No statistically significant age-related differences were found for antero-posterior sway magnitude (RMSy) ($F(1,20) = 2.28$, $p > .05$). Similarly, no age differences were noted for the dependent variable defining anterior-posterior sway magnitude relative to support base length (RMSy/BOSy) ($F(1,20) = 1.48$, $p > .05$). Figures 3 & 4 illustrate these results.

5.2 *Gender*

A statistically significant effect for gender was noted for lateral sway (RMSx) ($F(1,20) = 8.57$, $p < .05$) (Table 8). It can be seen in Figure 5 that males demonstrated higher mean RMSx values than females. An examination of Figure 6 reveals that this gender-based difference was not seen when magnitude of lateral sway was expressed relative to support base width (RMSx/BOSx) ($F(1,20) = 2.99$, $p > .05$) (Table 9). In the antero-posterior plane, no sex-related differences were noted for RMSy ($F(1,20) = 3.84$, $p > .05$) or RMSy/BOSy ($F(1,20) = 1.44$ $p > .05$). Figures 7 & 8 illustrate these results.

5.3 *Visual Test Condition*

A statistically significant effect for visual test condition was found for both dependent variables defining lateral sway magnitude as follows: RMSx ($F(2,40) = 17.134$, $P < .051$) (Table 8); and RMSx/BOSx ($F(2,40) = 16.447$, $p < .05$) (Table 9). A Post hoc comparison (Tukey's HSD) revealed a statistically significant difference between conditions EC and EOFC ($p < .05$), and between conditions EOFC and EOFR ($p < .05$). No statistically significant difference was noted between conditions EC and EOFR. Tukey's HSD post hoc procedure revealed the same statistically significant differences when data were normalized for base of support width (RMSx/BOSx).

Data are summarized in Figure 9 to illustrate that higher mean RMSx values occurred in the EC condition than in the EOFC condition for all groups. The mean RMSx score is lower in the EOFC condition than in the EOFR condition for all groups. Similar results for the dependent variable defining lateral sway magnitude relative to base of support width (RMSx/BOSx) are illustrated in Figure 10.

No statistically significant differences among visual test conditions were noted for either of the variables used to define antero-posterior sway (i.e. RMSy ($F(2,40) = 1.35$, $p > .10$) and RMSy/BOSy ($F(2,40) = 1.29$, $p > .10$)). Tables 10 and 11, and Figures 11 and 12 summarize and illustrate these findings.

Table 8. Source Table for Repeated Measures Analysis of Variance: RMSx

VARIABLE A = AGE (younger adult / older adult)
VARIABLE B = GENDER (male / female)
VARIABLE C = VISUAL TEST CONDITION (EC / EOFC / EOFR)+

SOURCE	SS	df	MS	F
BETWEEN SUBJ:	1.35	23		
VARIABLE A:	.39	1	.39	12.01**
VARIABLE B:	.28	1	.28	8.57**
A X B:	3.60	1	3.60	1.11
ERROR:	.65	20	3.24	
WITHIN SUBJ:	.62	48		
VARIABLE C:	.27	2	.13	17.13**
A X C:	.001	2	.001	.05
B X C:	.002	2	.01	1.02
A X B X C:	.02	2	.01	1.52
ERROR:	.31	40	.01	
TOTAL:	1.97	71		

** $p < .01$

+ Repeated Measure

Table 9. Source Table for Repeated Measures Analysis of Variance: RMSx/BOSx

VARIABLE A = AGE (younger adult / older adult)
VARIABLE B = GENDER (male / female)
VARIABLE C = VISUAL TEST CONDITION (EC / EOFC / EOFR)+

SOURCE	SS	df	MS	F
BETWEEN SUBJ:	28.31	23		
VARIABLE A:	5.90	1	5.90	6.23*
VARIABLE B:	2.84	1	2.84	2.99
A X B:	.64	1	.64	.68
ERROR:	18.93	20	.95	
WITHIN SUBJ:	16.48	48		
VARIABLE C:	6.97	2	3.48	16.44**
A X C:	.02	2	.04	.04
B X C:	.31	2	.16	.74
A X B X C:	.70	2	.35	1.65
ERROR:	8.48	40	.21	
TOTAL:	49.79	71		

** $p < .01$ * $p < .05$

+ Repeated Measure

Table 10. Source Table for Repeated Measures Analysis of Variance: RMSy

VARIABLE A = AGE (younger adult / older adult)
VARIABLE B = GENDER (male / female)
VARIABLE C = VISUAL TEST CONDITION (EC / EOFC / EOFR)+

SOURCE	SS	df	MS	F
BETWEEN SUBJ:	2.20	23		
VARIABLE A:	.19	1	.19	2.28
VARIABLE B:	.31	1	.32	3.84
A X B:	.05	1	.05	.66
ERROR:	1.65	20	.08	
WITHIN SUBJ:	.35	48		
VARIABLE C:	.02	2	.01	1.35
A X C:	.02	2	.01	1.08
B X C:	.001	2	.001	.02
A X B X C:	.02	2	.01	1.44
ERROR:	.30	40	.001	
TOTAL:	2.56	71		

+ Repeated Measure

Table 11. Source Table for Repeated Measures Analysis of Variance: RMSy/BOSy

VARIABLE A = AGE (younger adult / older adult)
VARIABLE B = GENDER (male / female)
VARIABLE C = VISUAL TEST CONDITION (EC / EOFC / EOFR)+

SOURCE	SS	df	MS	F
BETWEEN SUBJ:	28.56	23		
VARIABLE A:	1.81	1	1.81	1.48
VARIABLE B:	1.77	1	1.77	1.44
A X B:	.45	1	.45	.37
ERROR:	24.53	20	1.23	
WITHIN SUBJ:	5.31	48		
VARIABLE C:	.28	2	.14	1.29
A X C:	.26	2	.13	1.18
B X C:	.01	2	.004	.04
A X B X C:	.36	2	.18	1.63
ERROR:	4.40	40	.11	
TOTAL:	33.87	71		

+ Repeated Measure

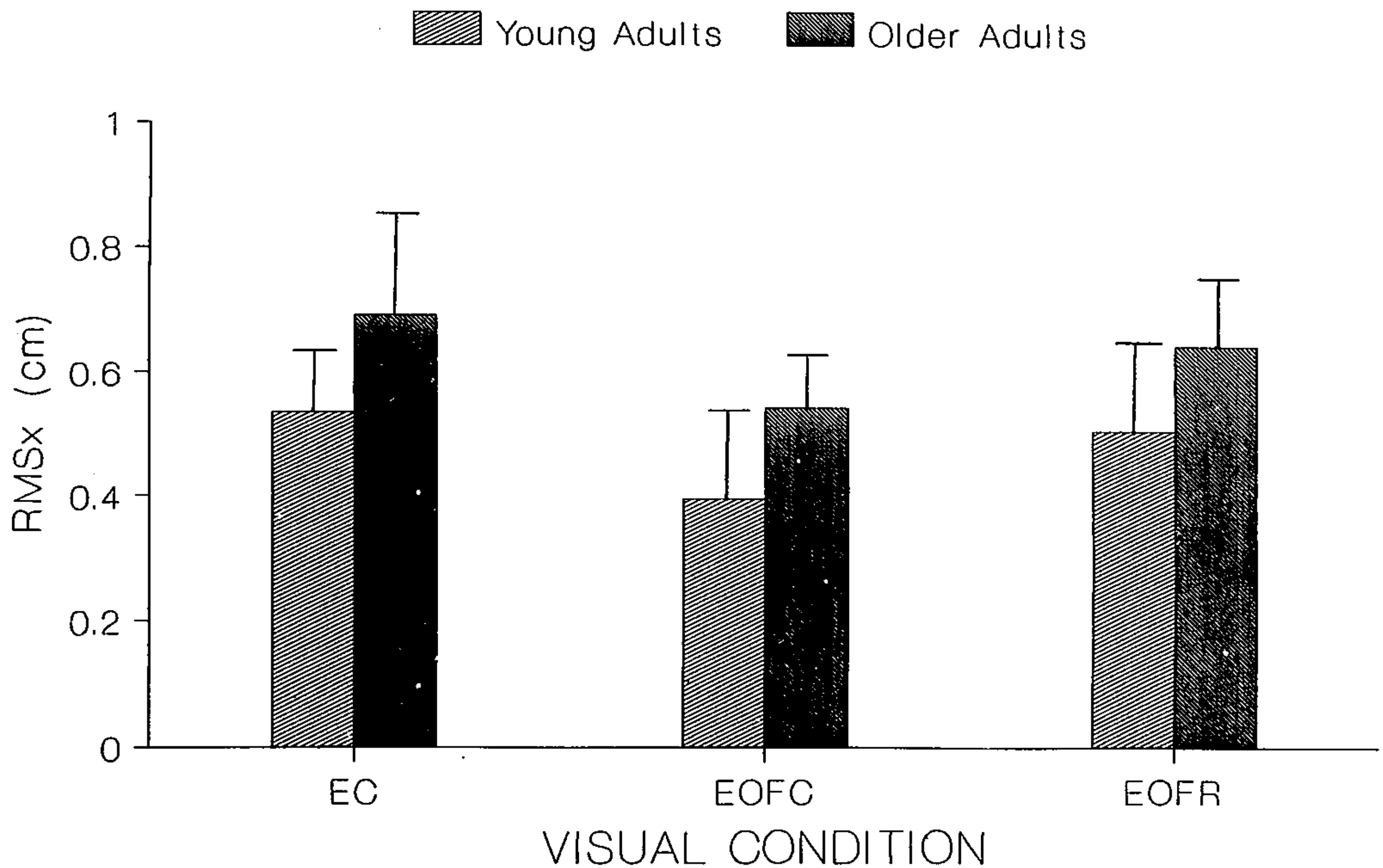

Figure 1. Mean Lateral Sway for Younger and Older Adults in each Visual Condition.

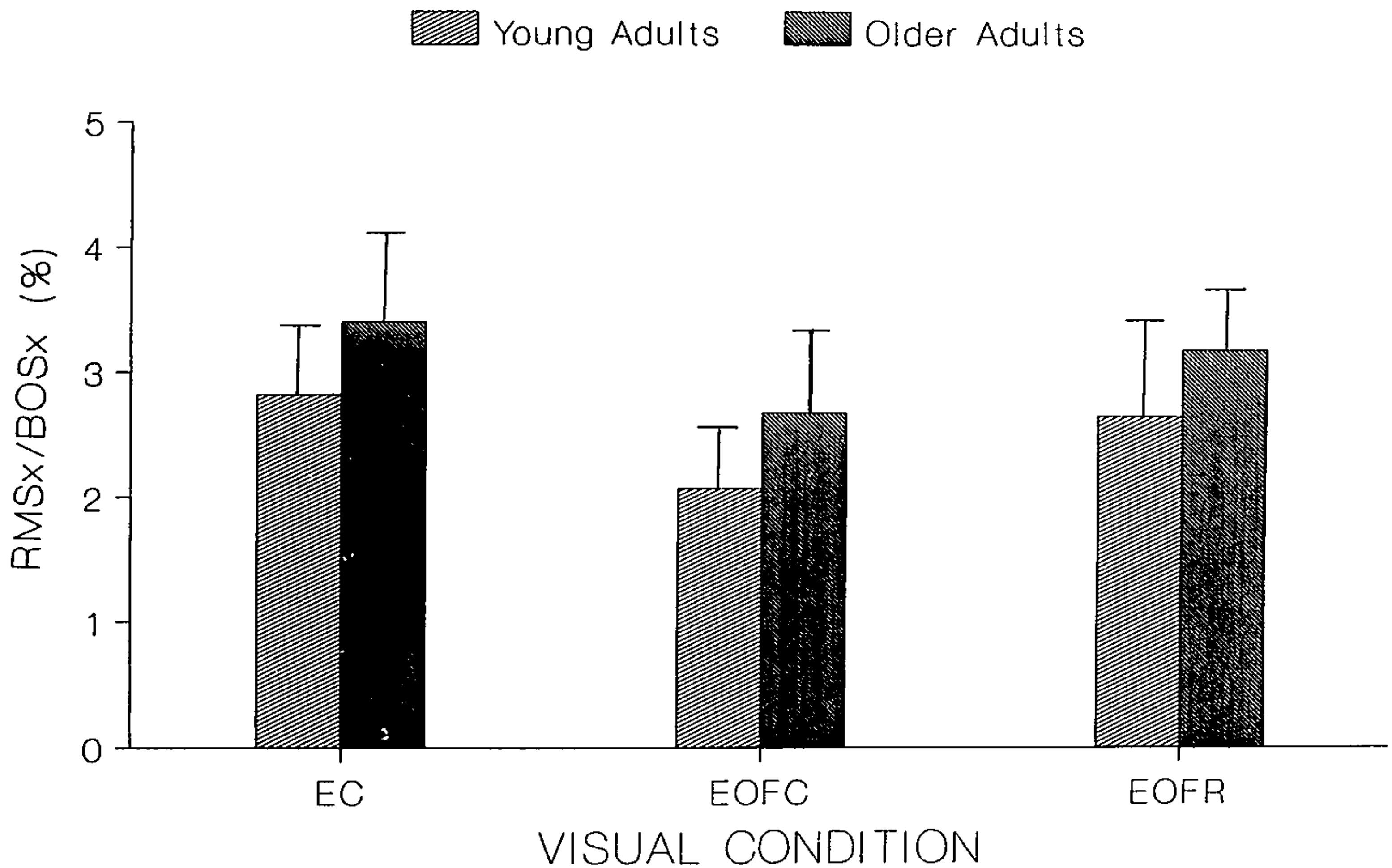

Figure 2. Mean Lateral Sway Expressed Relative to Support Base Width for Younger and Older Adults in each Visual Condition.

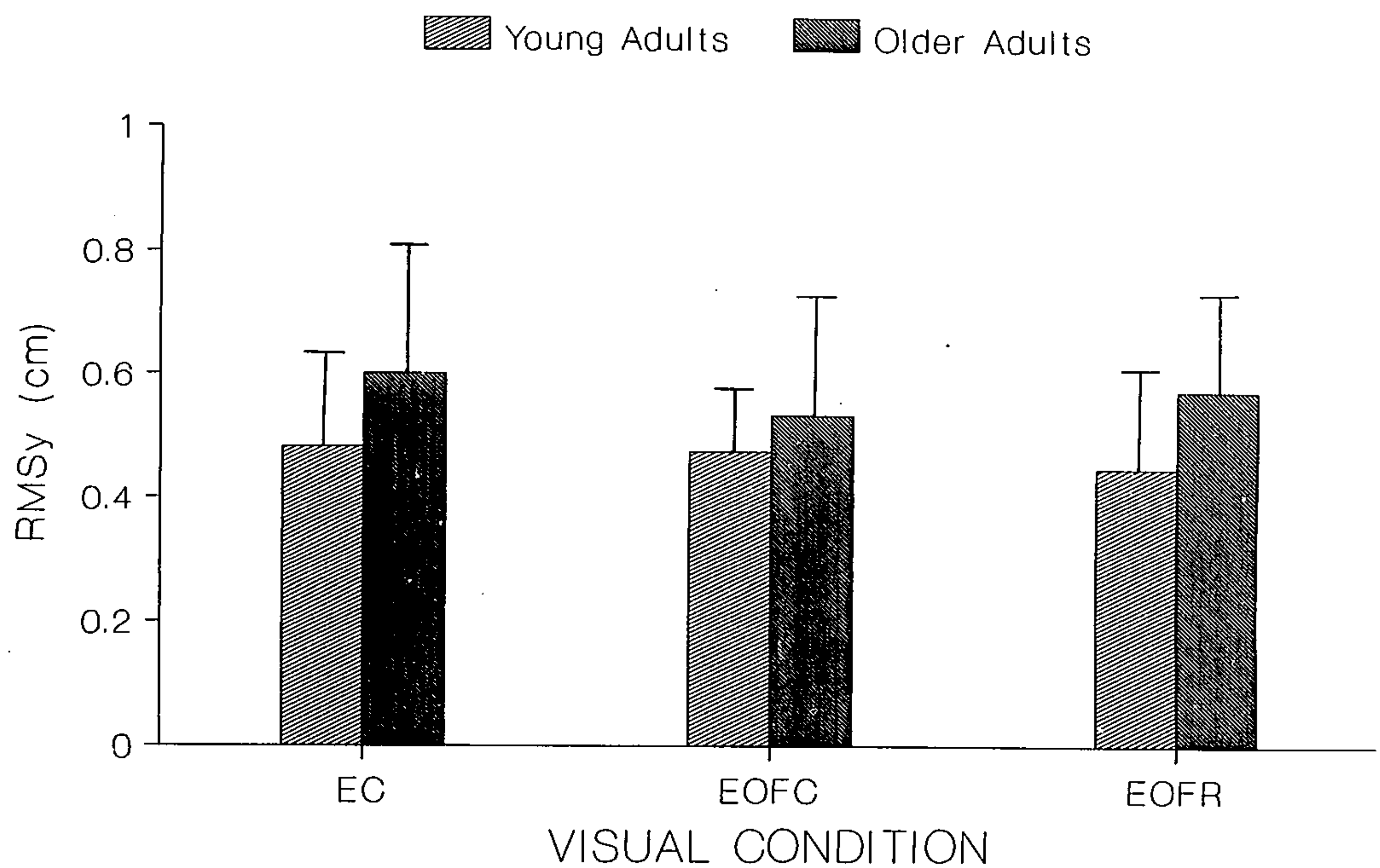

Figure 3. Mean A-P Sway for Younger and Older Adults in each Visual Condition.

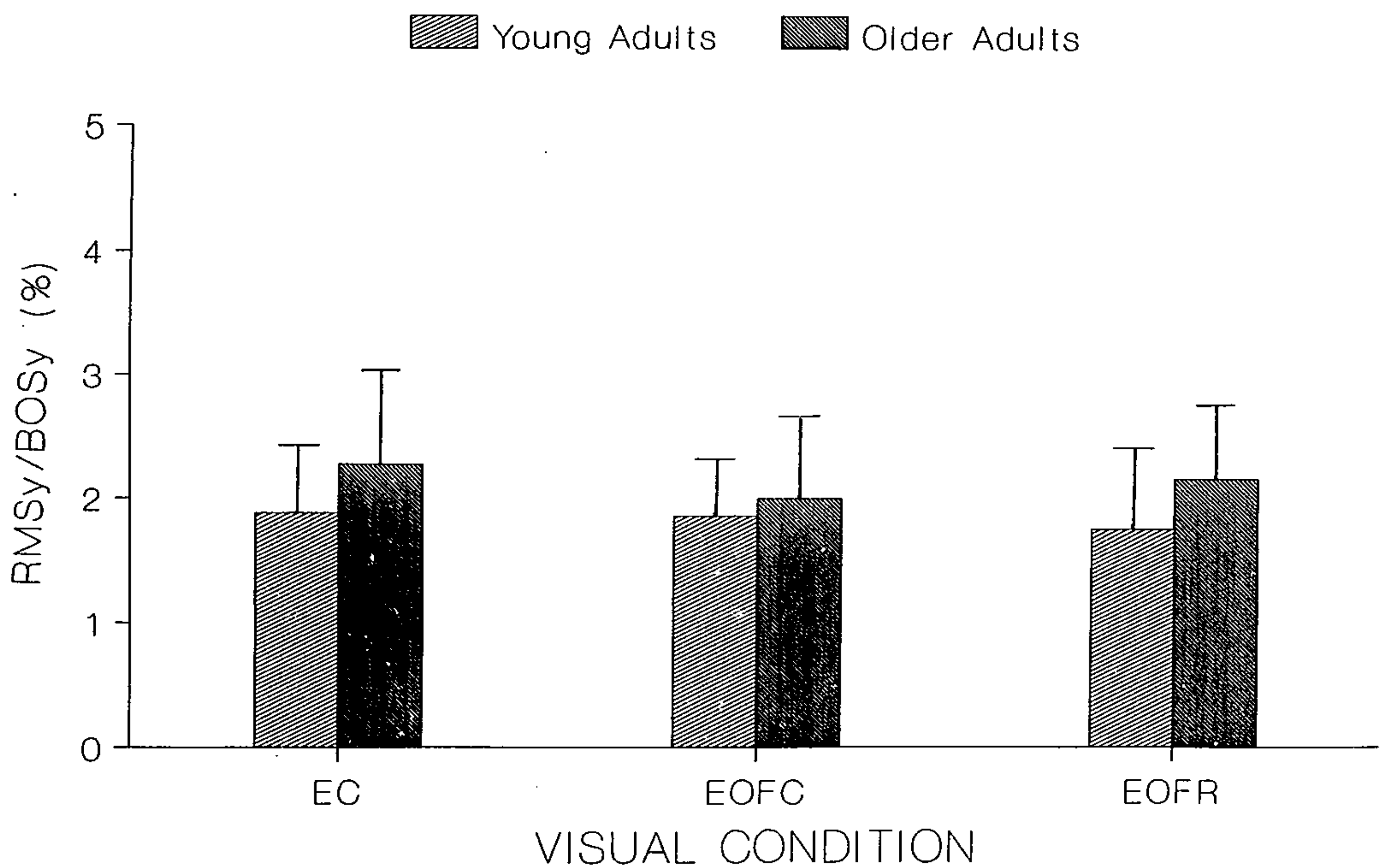

Figure 4. Mean A-P Sway Expressed Relative to Support Base Length for Younger and Older Adults in each Visual Condition.

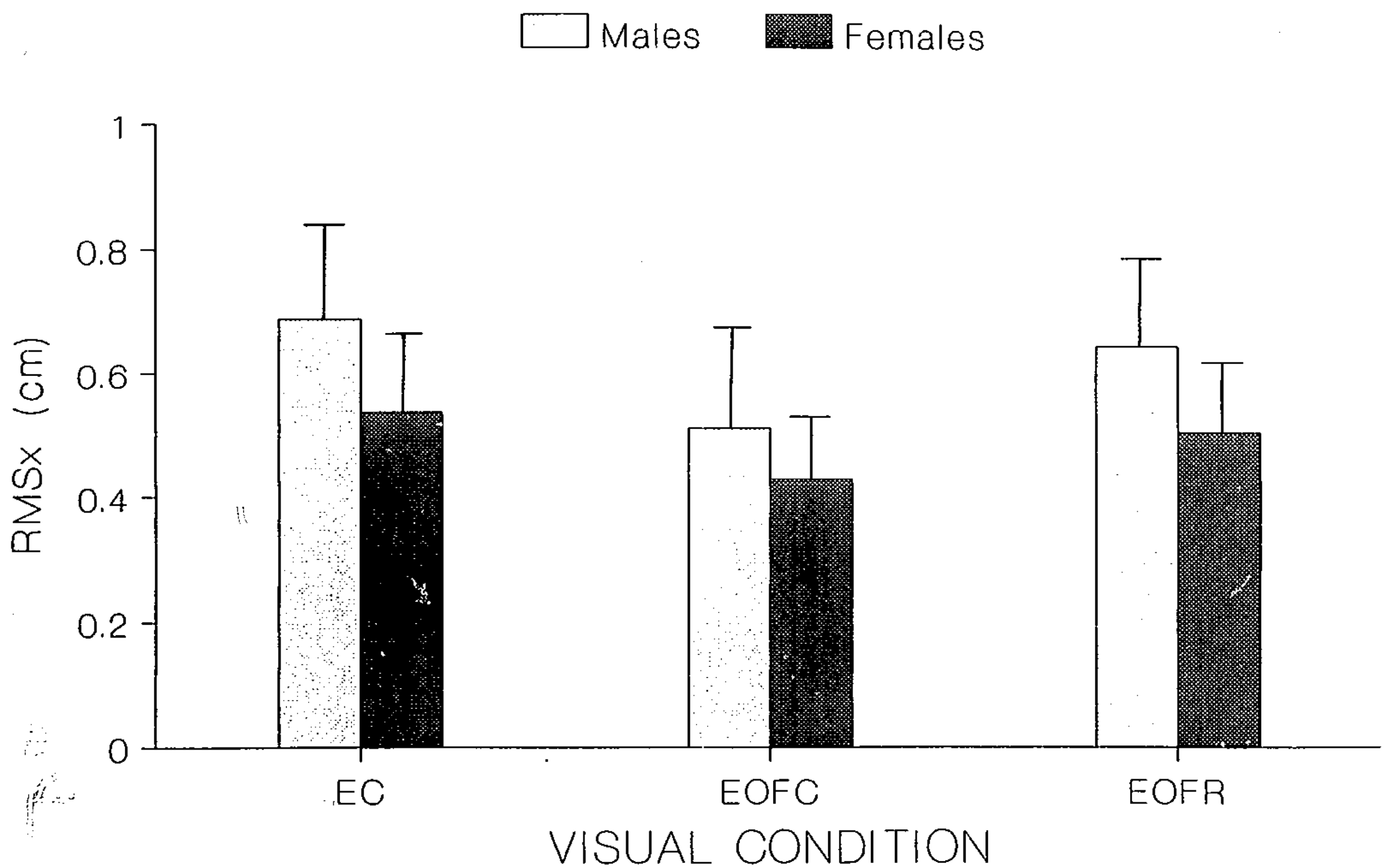

Figure 5. Mean Lateral Sway for Males and Females in each Visual Condition.

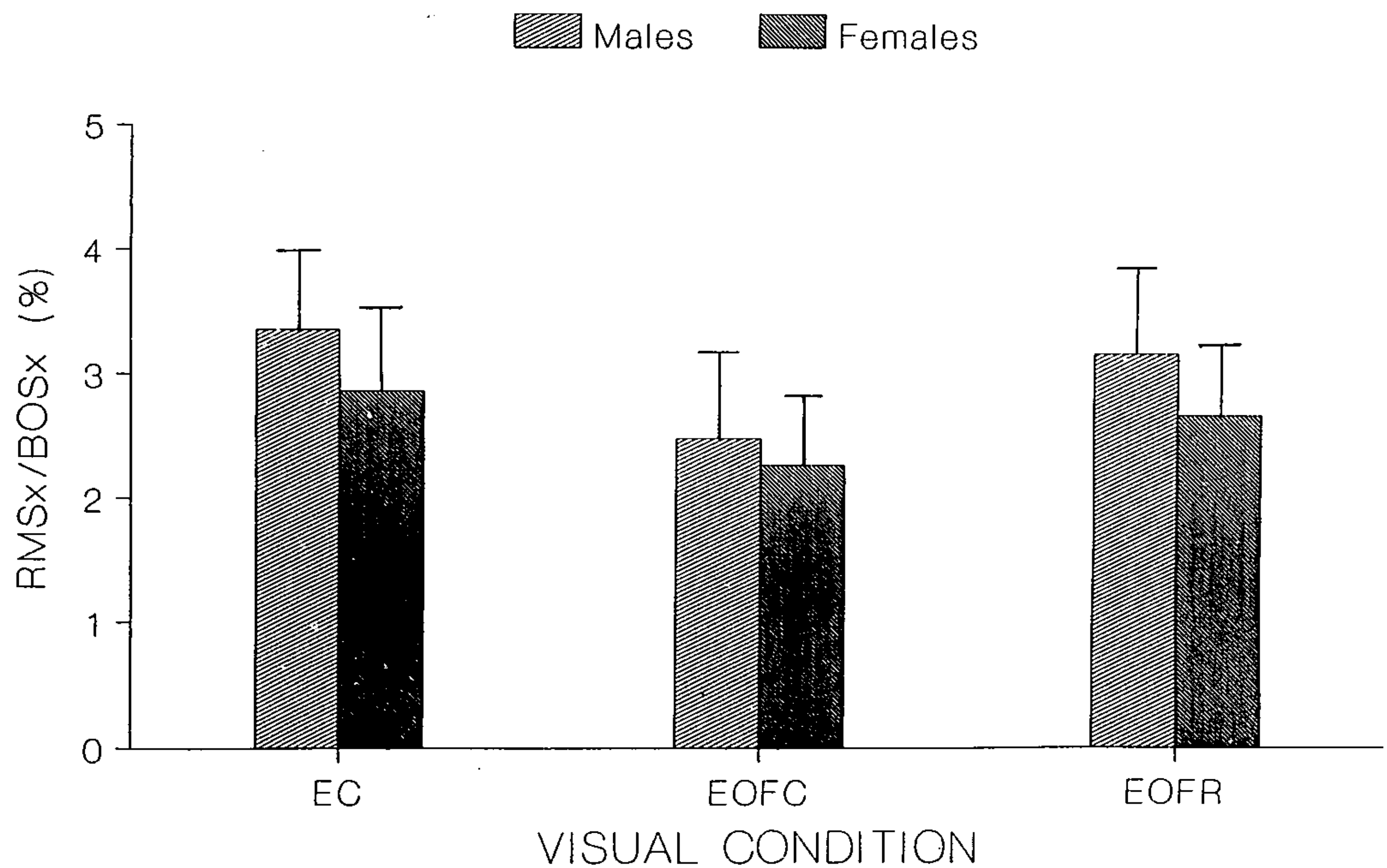

Figure 6. Mean Lateral Sway Expressed Relative to Support Base Width for Males and Females in each Visual Condition.

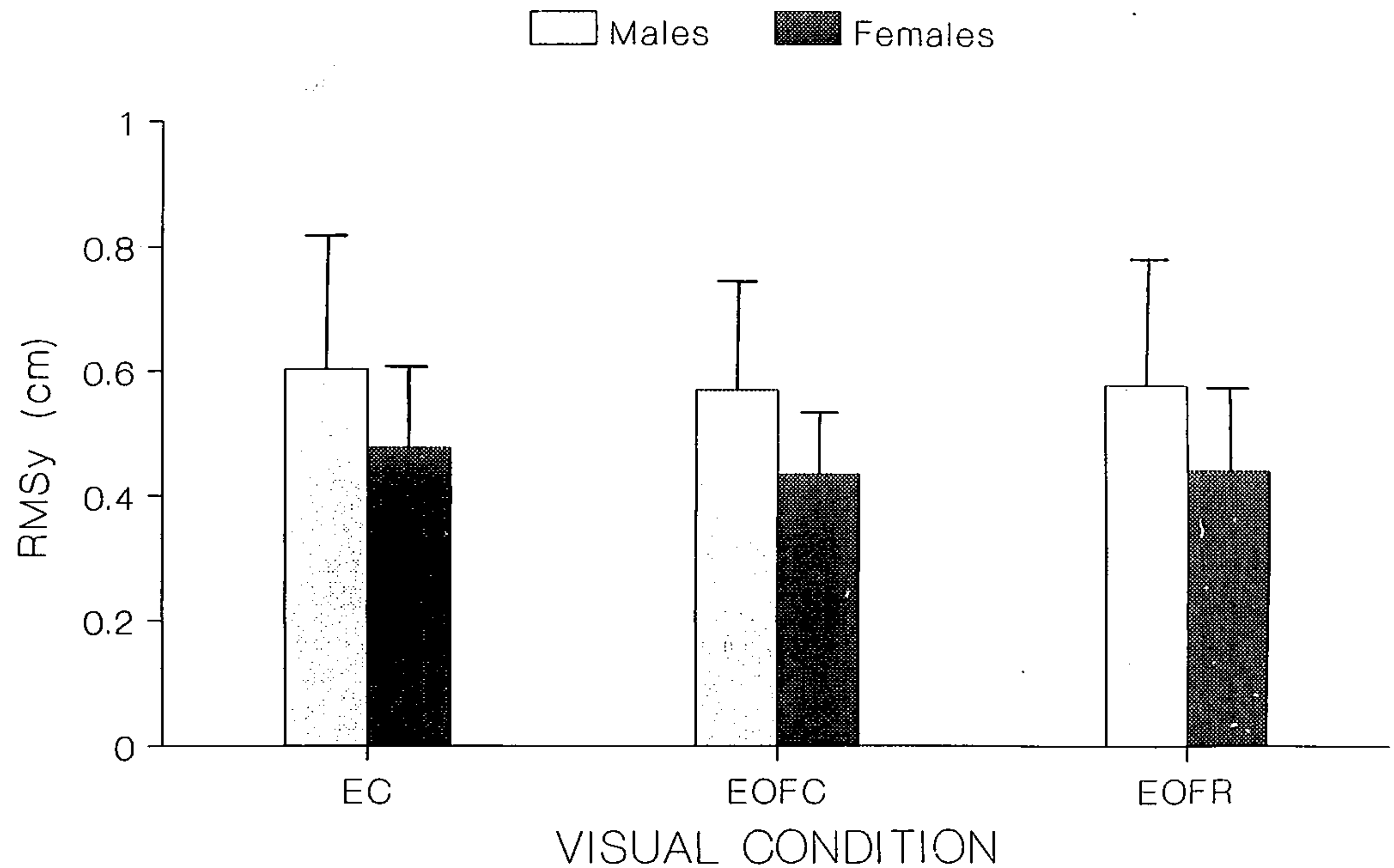

Figure 7. Mean A-P Sway for Males and Females in each Visual Condition.

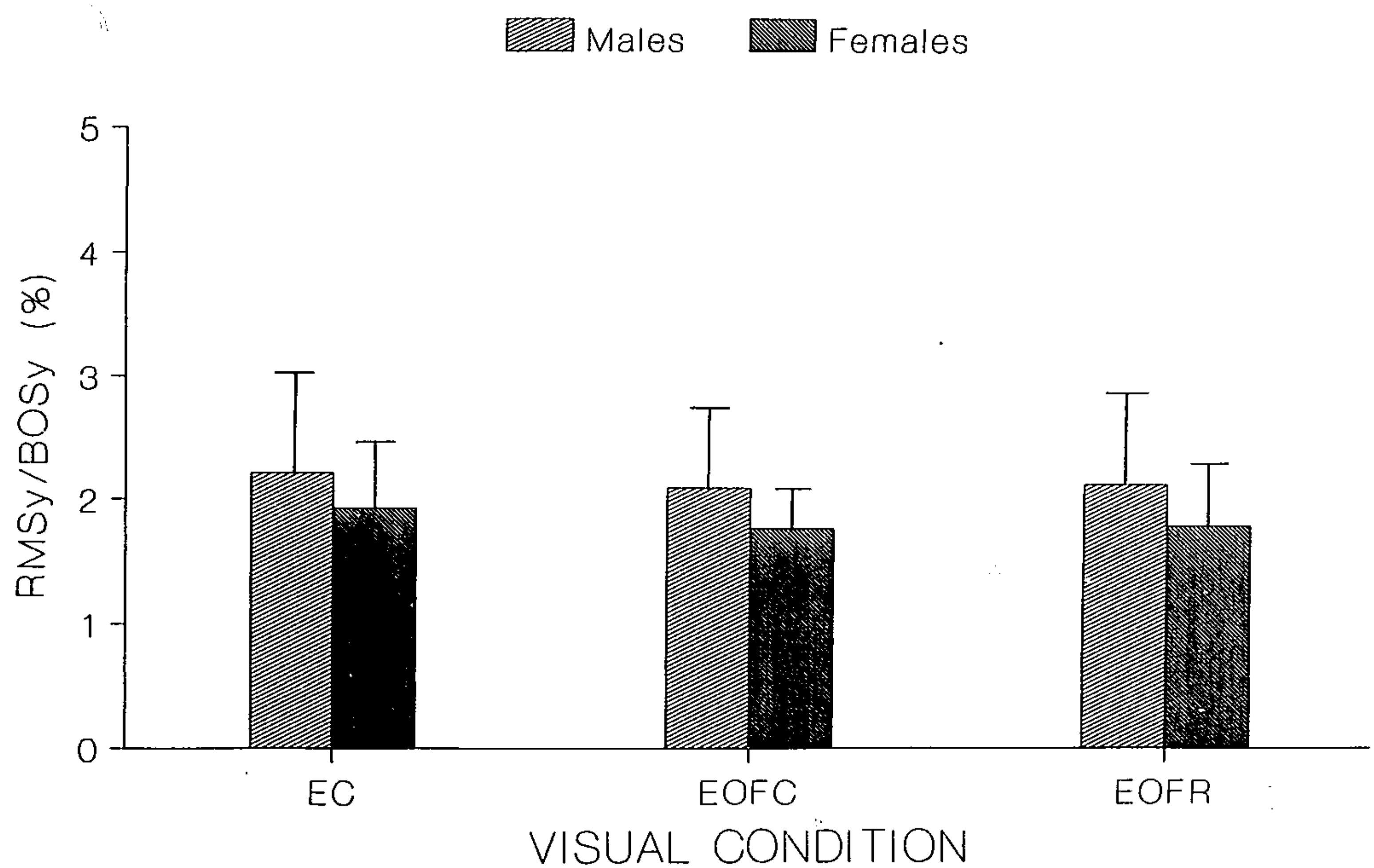

Figure 8. Mean A-P Sway Expressed Relative to Support Base Length for Males and Females in each Visual Condition.

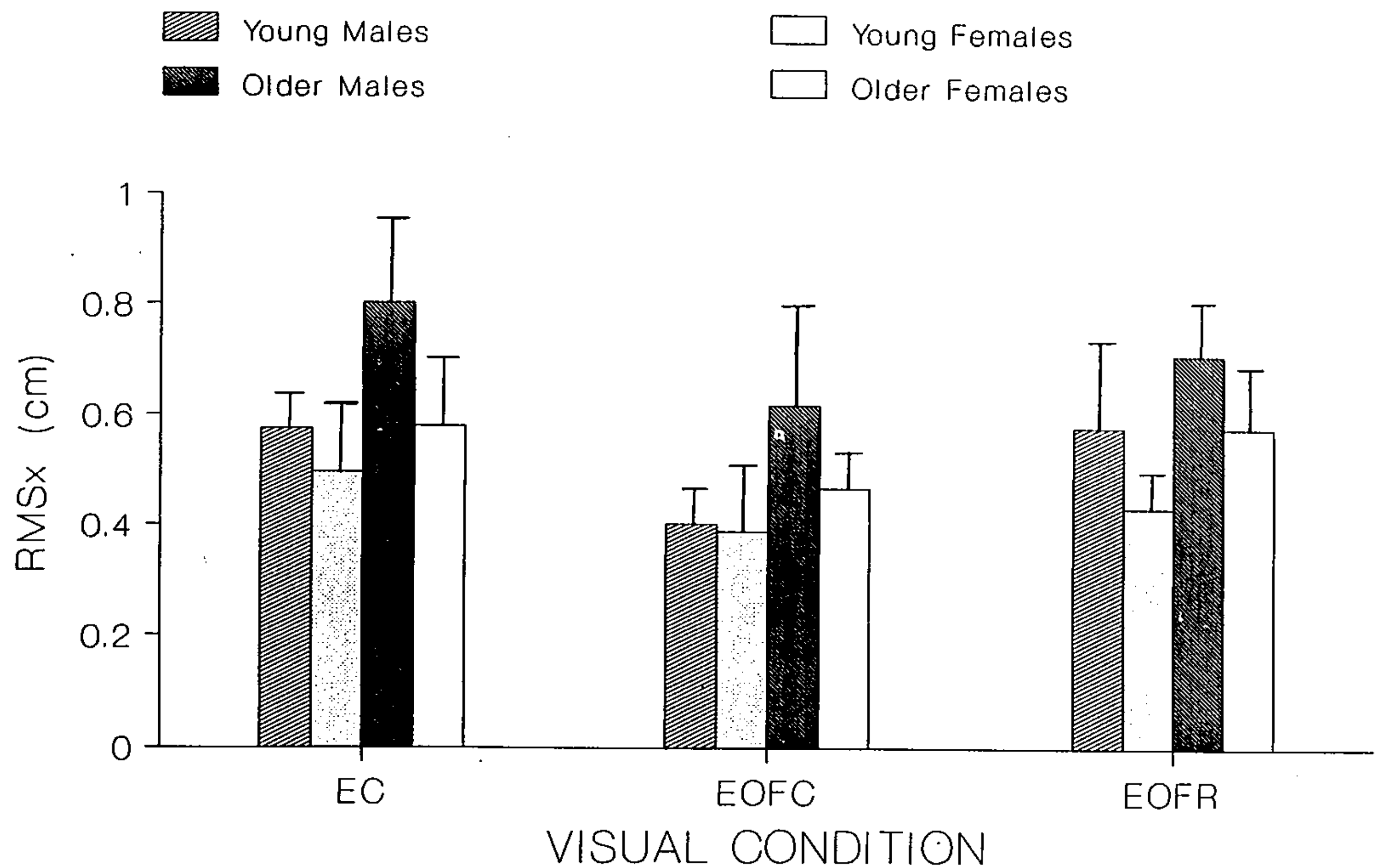

Figure 9. Mean Lateral Sway for All Groups in each Visual Condition.

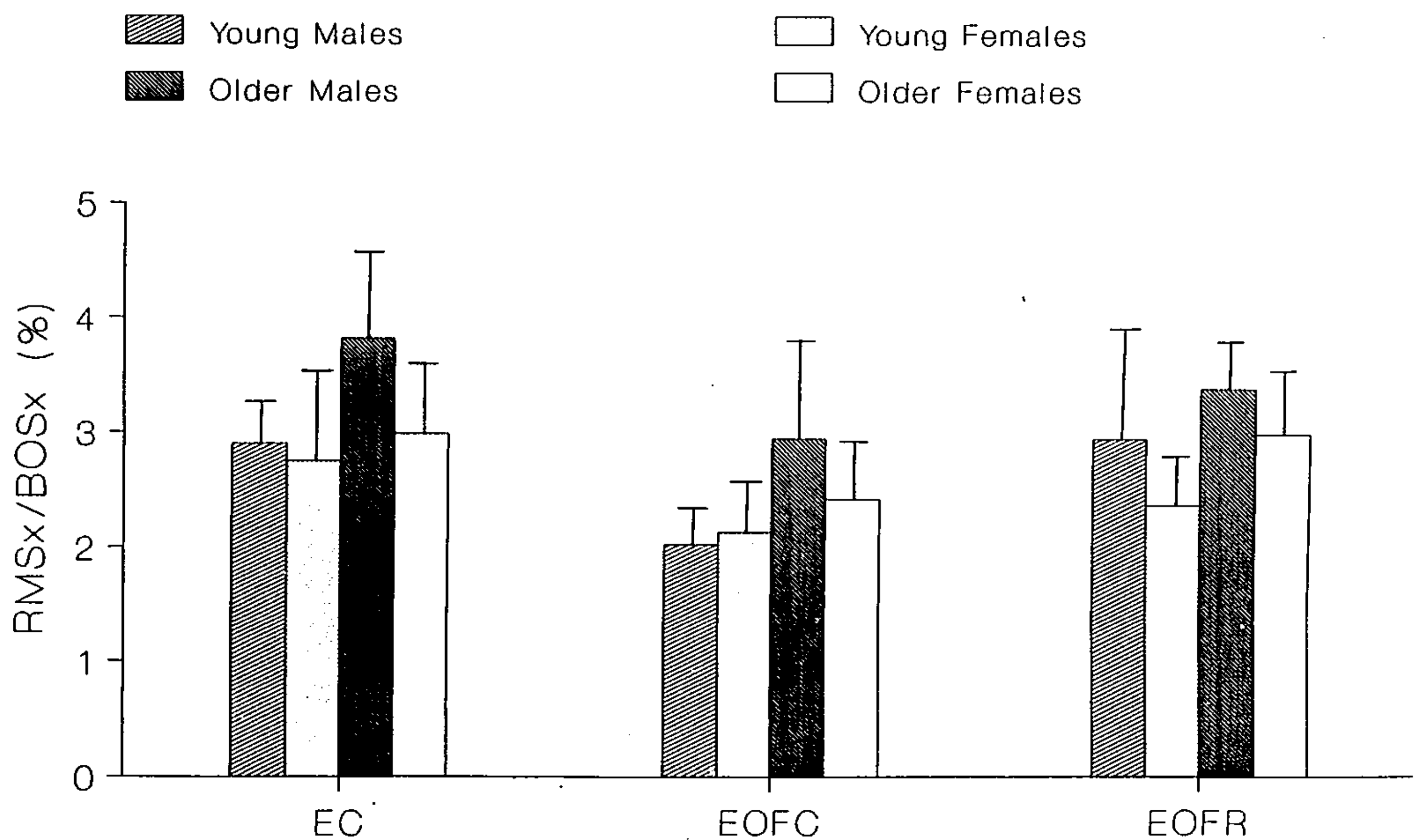

Figure 10. Mean Lateral Sway Expressed Relative to Support Base Width for All Groups in each Visual Condition.

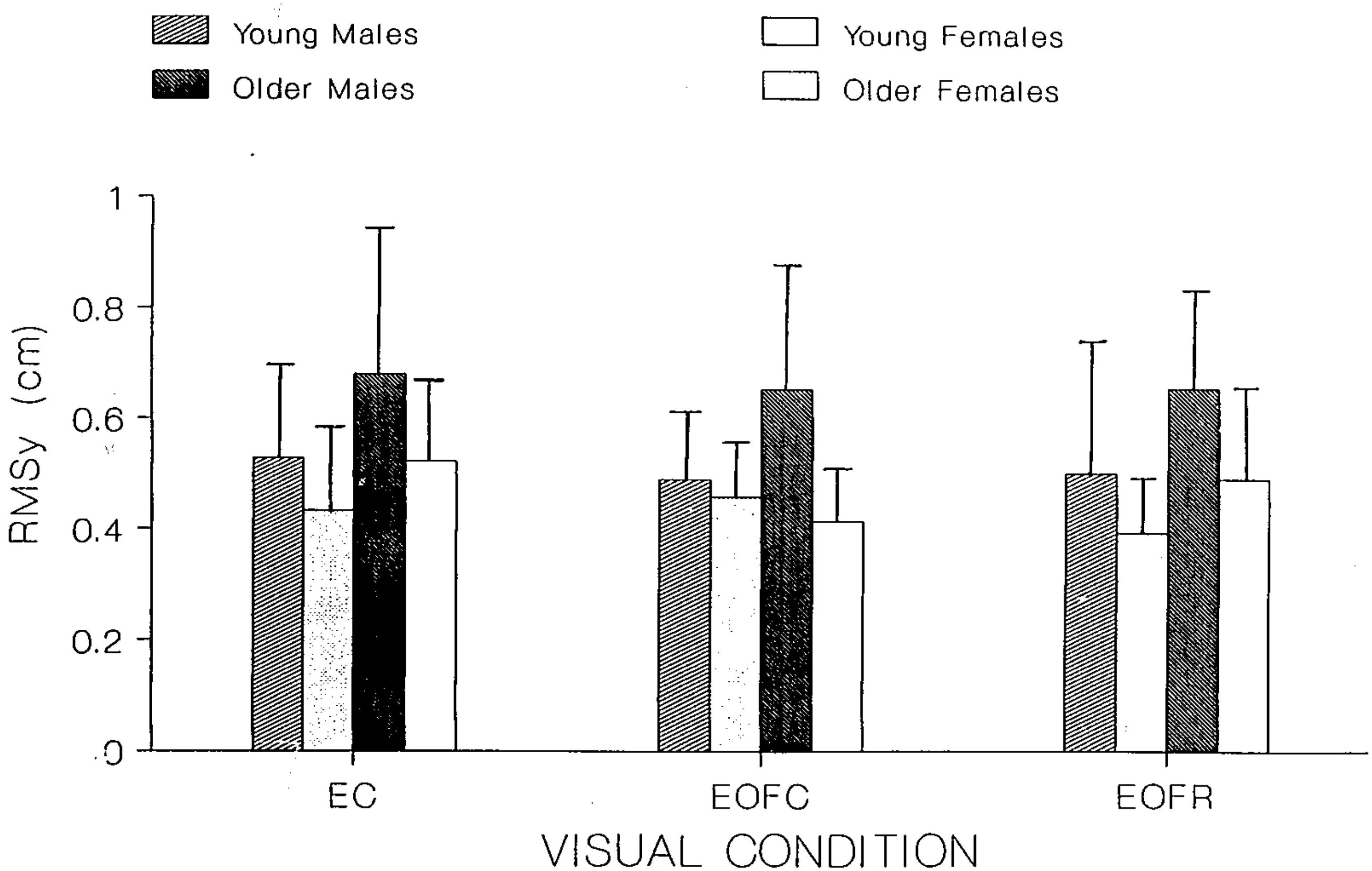

Figure 11. Mean A-P Sway for All Groups in each Visual Condition.

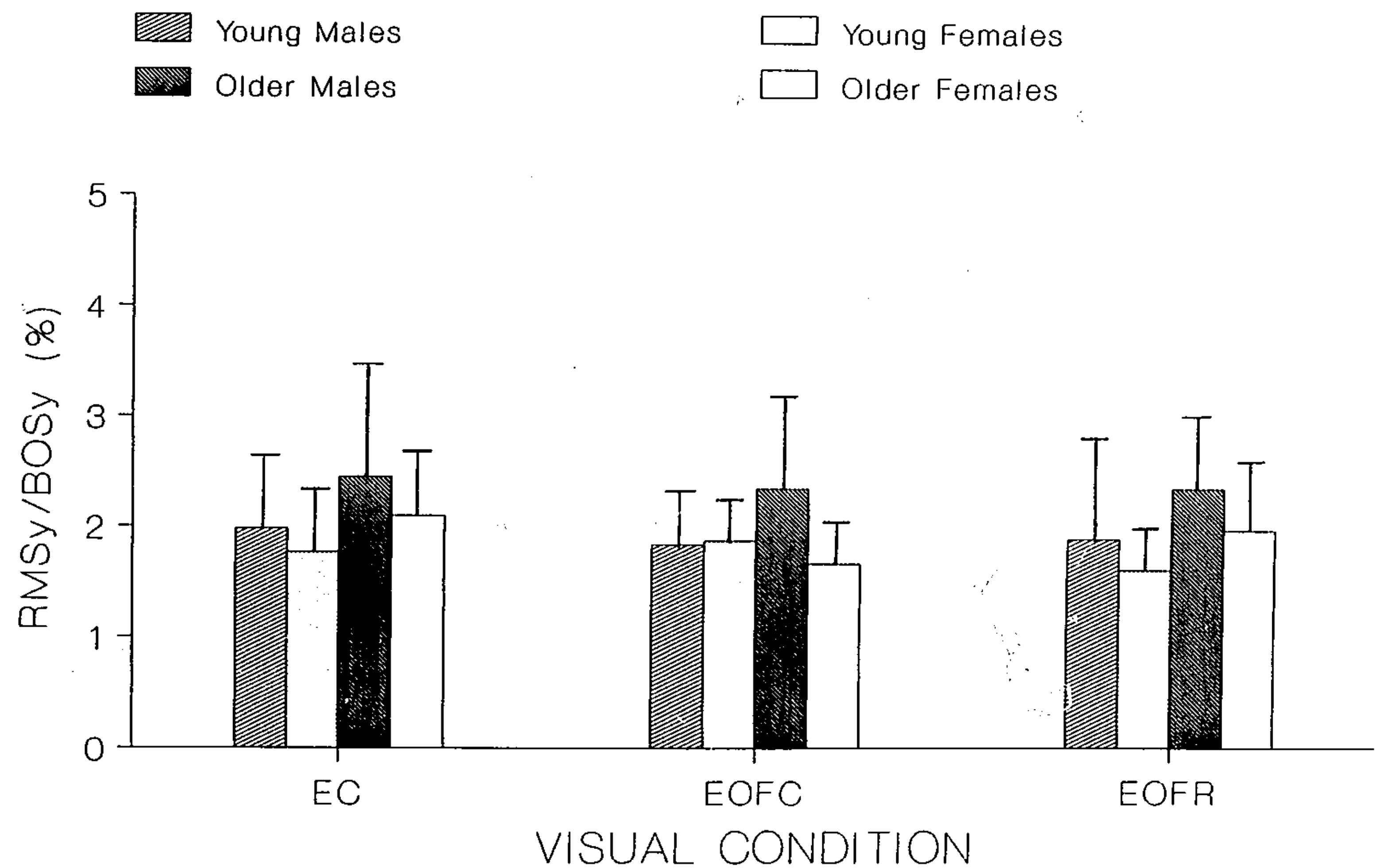

Figure 12. Mean A-P Sway Expressed Relative to Support Base Length for All Groups in each Visual Condition.

CHAPTER VI

DISCUSSION

It has been well established that vision contributes to the control of upright stance. Vision provides information in parallel with vestibular and proprioceptive afferents, and may attenuate body sway by as much as 50% in normal adults (Paulus et al., 1988).

Classically, standard protocol for assessing the contribution of vision to postural control has compared body sway during constant visual fixation with body sway during conditions absent of visual information (i.e. eyes closed). Criticism regarding the ecological validity of such testing protocol has lead to investigations on the influence of voluntary eye movements on postural control.

The results of the present study provide insight into the role of vision as a stabilizing factor in postural control by comparing the effects of three separate visual conditions on postural control between younger and older adults and between males and females.

6.1 Age

It has been well documented that the extent of postural sway during quiet stance increases with advancing age (Era & Heikkinen, 1985; Hayes et al., 1984; Maki et al., 1990; Pyykko et al., 1988; Sheldon, 1963; Walt et al., 1990; Woollacott et al., 1986). The results of the present study were in agreement with these findings and substantiate an age-related deterioration of the mechanisms underlying postural control. Older adults in this study consistently demonstrated significantly greater lateral sway magnitudes (RMSx, RMSx/BOSx) than younger adults for all visual conditions tested.

No statistically significant age-related differences were found for variables defining antero-posterior sway magnitude (RMSy, RMSy/BOSy). Similar results have been reported elsewhere (Maki et al., 1990).

6.2 Gender

A statistically significant gender-related difference was found for lateral sway magnitude (RMSx). Male participants in this study demonstrated higher RMSx values than female participants. These results seem to suggest a greater tendency toward instability for males than for females. This gender-based difference in lateral sway magnitude may reflect biomechanical and anthropometric features distinguishing the sexes. The distinguishing features may be the differences in the vertical position of the centre of gravity and in the dimensions of the base of support between males and females. The position of the centre of gravity for males is higher than that of females, suggesting a greater propensity toward instability for males. For the stance requirements in this study, the size of the base of support was determined by foot dimensions. Differences in support base dimensions between sexes define the limits of stability. As postural adjustments require displacement of the CP, instability will result when the CP cannot be displaced to compensate for a postural adjustment (i.e. when the CP reaches the perimeter of the base of support (Maki et al., 1990)). The male subjects in this study had significantly larger base of support dimensions than the female subjects. This difference afforded male subjects greater limits of stability and the potential for a greater magnitude of postural sway without destabilizing consequences.

No statistically significant gender-related difference in lateral sway magnitude was noted when sway magnitude was expressed relative to support base width (RMSx/BOSx), which suggests that any differences due to gender may be attributed to anthropometric and/or biomechanical differences.

No statistically significant differences were noted for magnitude of antero-posterior sway (RMSy) between males and females. Consideration of anthropometric differences through expression of sway magnitude relative to support base length (RMSy/BOSy) also failed to show any statistically significant differences between sexes.

The absence of any gender effects is a common finding in most postural sway studies (Amblard, Cremieux, Marchand, & Carblanc, 1985; Maki et al., 1990). As indicated previously, gender is not a contributing factor predisposing an individual to instability.

6.3 Visual Test Condition

Based on the results of the present study, the contribution of vision to postural control was the same for younger and older adults and for males and females.

Both variables defining lateral sway magnitude (RMSx, RMSx/BOSx) were statistically significant among the three visual conditions for all groups. Further analysis revealed constant visual fixation (EOFC) to be the most stabilizing condition for all groups. Lateral sway magnitude was significantly greater for all groups in the conditions defined by random visual fixation (EOFR) and no visual information (EC). A lack of a statistically significant difference between these conditions (EOFR & EC) suggests random visual fixation to be as destabilizing as no vision (EC).

It has been established that constant visual fixation provides a stabilizing influence to postural control. As noted by Lee & Lishman (1975), the presence of a visual target served to reduce postural sway for adults during quiet stance. Pyykko et al (1988) have demonstrated similar results in older adults. In these subjects, the presence of a visual target served to reduce spontaneous postural sway by as much as 50% (relative to the nonvisual condition). The results of the present study are in agreement with these findings and support the contribution of constant visual fixation as a stabilizing factor in postural control. In all groups, lateral sway magnitude was significantly smaller during constant visual fixation.

Constant visual fixation aids perceptual interpretation of self-motion. Spontaneous postural adjustments accompanying quiet stance demand retinal accommodation and may contribute to the visually induced perception of self-motion. As suggested by Gibson (1966), the "optic flow pattern" of the surrounding visual field provides proprioceptive information about the amount and direction of sway. Postural adjustments in response to movements of the visual image may serve to reduce postural sway.

The results of the present study indicate that alternating visual saccades with random periods of visual fixation increases lateral body sway (relative to constant visual fixation) for all groups tested. This finding is distinct from the trend of research findings surrounding the influences of saccadic eye movements on body sway. Uchida et al (1979), in an analysis of the influence of periodic saccades induced by alternately flashing lights noted a decrease in postural sway in adults. Similar results have been reported elsewhere (Iwase, Uchida, Hashimoto, Suzuki, Takegami, & Yamamoto, 1979). Riach and Starkes (1989) noted that young children, while demonstrating significantly greater postural sway than adults, also demonstrated more spontaneous visual saccades. From these results it was postulated that the high number of visual saccades characteristic of young children may reflect an attempt at improving stability, providing further substantiation for the stabilizing effects of visual saccades.

Various explanations for the stabilizing effects of visual saccades have been proposed. Riach and Starkes (1989) suggested that visual saccades may increase visual information, substantiating the stabilizing effects noted for young children. Eye movements themselves, when performed in darkness without vision, have been shown to decrease body sway (Oblak, Michelin, & Gregoric, 1976), suggesting a beneficial effect of eye movements on postural control. Uchida and colleagues (1979) proposed that information related to the execution of visual saccades may influence the spinal motor system causing an increase in postural stability through activation of lower leg muscles.

The expected stabilizing effect for saccadic eye movements was not supported by the results of this study. Explanation for this finding may be associated with discrepancy between standard experimental protocol and the methodologies utilized in the present study. Standard protocol for assessing the effects of retinal dislocation on body sway conventionally demands alternating visual fixation at a constant frequency (Riach & Starkes, 1989; Uchida et al., 1979; White et al., 1980). Such an environment affords a constant focal time between saccadic shifts. The protocol used in the present study was more complex than standard methodologies and defined a random period of visual fixation between saccadic shifts. It is possible that the complexity of this visual condition contributed to the destabilizing results.

An important feature of consistent eye movements is prediction. It has been found that when responding to a periodic visual target, the eyes can follow without delay and can even lead the target (Raphan & Cohen, 1978). It is suggested that the consequences of prediction contribute to the stabilizing effects for visual saccades prominent in the literature.

The complexity of the random nature of visual fixation in the methodology of the present study was not conducive to such predictive behaviour. The result of this visual fixation protocol may have required increased attention and concentration and may have affected the anxiety levels of the participants. In addition, a cognitive task (counting backwards) was imposed in all test conditions to distract conscious control of posture. Increased complexity compounded by distraction of conscious postural control, may provide explanation for the destabilizing effects for the visual saccades noted in this study.

No statistically significant differences in the magnitude of antero-posterior (a-p) body sway were demonstrated among visual conditions for all subjects. Apparently, visual proprioception did not play a beneficial role in reducing a-p body sway for the subjects in this study. Although similar results have been reported for young children (Zernicke, Gregor, & Cratty, 1982), the results of the present study contradict the majority of research findings regarding the use of visual information in reducing a-p body sway. Lee & Lishman (1975) demonstrated that visual proprioception improved postural control in adults. Pyykko and colleagues (1988) noted a decrease in postural control (lat and a-p sway) for both young and older adults in the absence of visual consequences. Riach and Starkes (1989) demonstrated that the absence of visual information produced more a-p sway than occurred in the presence of a visual target.

Both the proximity and size of the visual target are critical factors to the visual stabilization of posture, affecting the magnitude of change on the retinal surface caused by spontaneous sway. For this reason, a nearby target is most beneficial in reducing postural sway (Paulus et al., 1988). Similarly, a larger visual target is most conducive to a reduction in postural sway (Paulus, Straube, Krafczyk, & Brandt, 1989). In addition, the changes in the retinal image during lateral sway are greater than those during a-p sway. It is for this reason that the effectiveness of a visual target may be greater in lateral sway (Riach & Starkes, 1989).

From the results of the present study it appears that the eye-target distance of one metre was adequate to decrease lateral sway, yet ineffective in reducing a-p sway. Also, the size of the visual target (light-emitting diode) was acceptable for reducing lateral sway, but inadequate (too small) to contribute to an a-p sway reduction. In addition to external limitations, the absence of a visual contribution to a-p sway may possibly be attributed to interference between potential visual benefits and the cognitive demands imposed to distract conscious control of posture in each test trial. It may be that the demands of the cognitive task made it impossible to take advantage of (limited) visual information. The results of the present study suggest that the lack of a visual contribution to a-p sway may be attributed to external limitations (experimental set-up) and/or distraction of conscious postural control, and not and inability to utilize visual proprioception.

The results of the present study suggest that the visual contribution to (lateral) postural control was not affected by age or gender. Constant visual fixation was the most stabilizing condition for all groups. The destabilizing effects of the non-visual condition (EC) and the condition defined by a variable visual fixation (EOFC) was consistently demonstrated by all groups.

A lack of statistical significance for the visual contribution to postural control between sexes confirmed that gender is not a contributing factor predisposing an individual to instability.

A lack of statistical significance for the influence of vision between age groups suggested that the contribution of vision to postural control is the same for older adults as younger adults, and eliminated the possibility that differences between age groups can be attributed to the perception or integration of afferent visual information.

Performance differences for the control of upright stance separating the age groups must be related to factors other than visual contributions. Whether these influences are peripheral in nature (i.e. exclusively proprioceptive or vestibular degeneration, or a combined result of visual and/or proprioceptive and/or vestibular inputs), related to central integration of postural control information, or to motor output of the integrated signal/message remains to be determined.

Based on the results of the present study, the following conclusions are warranted:

Deterioration in postural control accompanies advancing age; gender is not a contributing factor predisposing an individual to a deterioration in postural control.

The visual contribution to postural control is the same between younger and older adults, and between males and females.

Apparently, age-related differences in postural control cannot be attributed exclusively to deterioration in the perception or integration of afferent visual information.

6.4 Application and Suggestions for Future Study

Based on the findings of the present study, there is equivalent potential for instability for both younger and older adults in response to complex visual environments. As a result of the noted age-related deterioration in (lateral) postural control, the consequences of potential instability may be more severe for older individuals.

From the results of the present study, the following directions for future study are suggested:

An investigation regarding age-related changes in antero-posterior sway would confirm the validity of results from the present study. An increased sample size and a broader age range of older subjects may provide an experimental design conducive to distinguishing possible age-related differences.

Future investigations into the visual contribution to antero-posterior postural sway are recommended to utilize an increased target size and a decreased eye-target distance.

Further study comparing the postural response between conditions of conscious control and conditions of cognitive demand (i.e. by imposing adequate cognitive demand to distract conscious control of posture) is suggested. Comparison between young and older adults may provide insight into possible age-related differences in the conscious demands of posture.

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APPENDIX A

Information and Consent Form

McMASTER UNIVERSITY
Department of Physical Education
1280 Main Street West, Hamilton, Ontario L8S 4K1
Telephone: (416) 525-9140
Fax: (416) 527-0100

Information and Consent Form

Project Title:

Postural Control in Younger and Older Adults: The Role of Vision as a Stabilizing Factor.

Project Outline:

Subjects will be required to stand at attention and as still as possible for three 30-second test conditions. During this time excursions of the body's natural sway pattern will be recorded. Data will be collected using an Advanced Mechanical Technologies Inc. (A.M.T.I.) Force Plate as is available at the Biomechanics Research Laboratory, McMaster University.

A measure of each subject's height and weight will be obtained prior to testing.

Participation and Confidentiality:

Participation in these tests is voluntary and subjects are free to withdraw at any point during the testing session. Information collected on each subject will be kept confidential and any data published or otherwise disseminated will be grouped so as to protect the identity of the participants.

Lesley Brown, B.P.E.

Cindy Riach, Ph.D.

McMASTER UNIVERSITY
Department of Physical Education
1280 Main Street West, Hamilton, Ontario L8S 4K1
Telephone: (416) 525-9140
Fax: (416) 527-0100

Date: ______________________________

Subject Consent:

I, ____:

- have willingly volunteered to participate in this experiment which measures my balance over a thirty second duration.
- know that the experiment will cause me no physical harm.
- have had the experimental regime explained to me.
- know that I may leave at any time.
- know that my identity and results will remain in confidence and will not be discussed.

Signed: ______________________________

Signature of Researcher: ______________________________

VITA AUCTORIS

NAME: LESLEY-ANNE BROWN

DATE OF BIRTH: April 12, 1966.

PLACE OF BIRTH: Glasgow, Scotland.

EDUCATION:

Ontario Secondary School Honours Graduation Diploma (1985)
Clarkson Secondary School
Mississauga, Ontario

Bachelor of Physical Education (1989)
McMaster University
Hamilton, Ontario

Master of Human Kinetics (October, 1991)
University of Windsor
Windsor, Ontario