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ORIGINAL PAPER

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Fear of heights: cognitive performance and postural control

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Abstract *Introduction* Fear of heights, or acrophobia, is one of the most frequent subtypes of specific phobia frequently associated to depression and other anxiety disorders. Previous evidence suggests a correlation between acrophobia and abnormalities in balance control, particularly involving the use of visual information to keep postural stability. This study investigates the hypotheses that (1) abnormalities in balance control are more frequent in individuals with acrophobia even when not exposed to heights, that (2) acrophobic symptoms are associated to abnormalities in visual perception of movement; and that (3) individuals with acrophobia are more sensitive to balance-cognition interactions. *Method* Thirty-one individuals with specific phobia of heights and thirty one non-phobic controls were compared using dynamic posturography and a manual tracking task. *Results* Acrophobics had poorer performance in both tasks, especially when carried out simultaneously. Previously described interference between posture control and cognitive activity seems to play a major role in these individuals. *Discussion* The presence of physiologic abnormalities is compatible with the hypothesis of a non-associative acquisition of fear of heights, i.e., not associated to previous traumatic events or other learning experiences. Clinically, this preliminary study corroborates the hypothesis that vestibular physical therapy can be particularly useful in treating individuals with fear of heights.

Key words heights · fear · acrophobia · balance · vision

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Introduction

Fear of heights or acrophobia is one of the most frequent subtypes of specific phobia [8] with high co-morbidity rates with other anxiety disorders and depression [6]. Differently from other phobias, there is evidence that fear of heights is not acquired by conditioning or other learning processes but arises through a non-associative pathway [21, 25, 26, 28]. For example, a prospective study by Poulton et al. [24] did not find significant correlation between falls resulting in serious injury before age 5 and the presence of fear of heights at age 11 to 18. Poulton et al. [25–27] also reported that individuals with height fears and phobias had significantly less exposure to height stimuli, suggesting that phobic symptoms are not the consequence of negative or traumatic experience. Although fear of heights can be considered normal in different situations or developmental periods, for unknown reasons, a group of individuals becomes phobic independently of learning experiences.

In this article we investigated the hypotheses that fear of heights is associated to abnormalities in balance control. Accordingly, avoidance of high places would be a behavioral consequence of an underlying physiologic abnormality. This hypothesis comes from the pioneering works of Bles et al. [4] and Brandt et al. [5], who proposed the concept of "height vertigo", a condition where fear of heights results from a reduction of effectiveness of visual inputs in providing appropriate information to postural control [4, 5].

Adequate upright posture control is obtained by integrated processing of vestibular, visual, and proprioceptive inputs. The strategy involving the use of these modalities of sensory information can change in some clinical conditions. The presence of vestibular dysfunction can lead to an increased dependence from visual (visual dependence) or proprioceptive (surface dependence) information to keep balance. Besides vestibular diseases, increased visual and surface dependence have been described in individuals with panic disorder and agoraphobia [15, 16]. Jacob et al. [17] suggest that the frequent association between dizziness, anxiety, and other symptoms linked to postural control abnormalities can be better explained by the concept of "Space and Motion Discomfort" (SMD). Space and Motion Discomfort is a condition in which anxiety and stress are elicited in situations where adequate visual or kinesthetic information for normal orientation is not available. The authors suggested that individuals with SMD have some degree of vestibular impairment and are therefore more dependent on visual or kinesthetic inputs for spatial orientation. Higher levels of SMD are found in individuals with both vestibular and anxiety disorders and fear of heights is one of the most important SMD symptoms. In fact, fear of heights is one of the two most prevalent fears in patients with balance disorders [7] and also one of the most common fears in agoraphobia [15].

Even in non-phobic individuals, exposure to high places disturbs balance control by changing the magnitude and timing of postural adjustments, associated with increased anxiety and physiological arousal [2]. These balance changes increase progressively with the level of postural threat [1, 13]. There is evidence that proactive mechanisms of balance control are modulated mainly by visual information and involve activation of postural adjustments prior to the occurrence of destabilizing changes [14]. Nakahara et al. [23] reported that, when exposed to high places, non-acrophobic subjects had less body sway if their eyes were uncovered and open, whereas acrophobic subjects showed the opposite response.

Another characteristic of postural control mechanisms, not yet associated to acrophobia, is their interference with the performance in cognitive tasks. Several studies have explored the balance-cognition interaction using a dual-task paradigm where measures of postural stability are taken simultaneously with performance in different cognitive tasks. These tasks included verbal reaction time to visual stimuli [35], auditory choice reaction time [33], sentence completion [34], math tasks [29], spatial and nonspatial versions of the memory test of Brook [19], working memory [9], postural and nonspatial memory [19], and the Stroop test [10]. These studies found a strong interaction between posture control and higher level cognition suggesting that these activities share common resource requirements. However, a consistent pattern of prioritization between tasks has not been found and the mechanisms involved in this phenomenon are still under discussion [12].

If individuals with acrophobia have abnormalities in vestibular function, it is expected that they become more sensitive to balance-cognition interactions similarly to what is seen in balance-impaired individuals [30, 31, 33]. In order to test this hypothesis, we developed a task involving visual perception of movement, because it is a kind of cognitive activity not yet explored trough dual-task paradigm, in spite of its ubiquitous presence in everyday life. Such interaction can have a negative impact in cognitive performance of acrophobics during common daily activities (walking or driving, for example) and even impose additional difficulties to the learning during exposure therapy.

The present work investigates the following hypotheses: (1) individuals with acrophobia differ from controls in relation to the occurrence of abnormalities in balance control even when not exposed to high places; (2) acrophobic symptoms are associated to abnormalities in performing tasks that involve visual perception of movement; and (3) the presence of balance control abnormalities make individuals with fear of heights are more sensitive to balance-cognition interactions. For testing those hypotheses, measures of postural stability were taken with and without simultaneous execution of a task involving the manual tracking of a moving target. This relatively complex cognitive task combines demands on sustained attention, visual perception of movement, control of eye movements, and visuomanual coordination. This task was chosen due to the exploratory character of our investigation and the intention to increase the probability of detecting differences between acrophobics and controls in the laboratory setting, i.e., when phobic individuals are not exposed to high places.

Methods

Individuals with fear of heights (acrophobics) were recruited from staff, students and the public attending the University of Sao Paulo Hospital. After a brief telephone screening, 52 individuals were invited to come to the laboratory to possibly participate in the study. Eight individuals did not come to the lab after the first telephone contact for unknown reasons, and the diagnosis of specific fear of heights could not be confirmed. Eight acrophobic candidates did not enter in the study due to presence of major depressive symptoms or due to being under clinical investigation for dizziness or balance related symptoms ($n = 5$). At end of the selective process, thirty-one subjects (23 females; age = 36.4 ± 13.5 years) fulfilled DSM-IV criteria for specific phobia of heights and agreed to participate of the experiment.

Thirty-nine non-phobic controls (22 females; age = 32.4 ± 12.0 years) were recruited from the university and by outdoors advertisement. Exclusion criteria were the presence or past history of any mental or vestibular disorders (evaluated by clinical interview). The groups were comparable in relation to gender distribution (Fisher's Exact Test $P = 0.140$) and age ($t = -1.642$; $df = 68$; $P = 0.105$).

The study was approved by the Hospital Ethical Committee of the University of Sao Paulo Medical School. All participants provided signed informed consent.

Posturography

Balance was evaluated with a dynamic platform (Pro Balance Master, Neurocom, Inc.) that provided rotation of the floor about the ankle. The variables studied were: (1) Area delimited by the center of pressure (CoP) in cm^2 (AREA); (2) maximum displacement of CoP in X-axis or latero-lateral direction (CoPx) in cm; (3) maximum displacement of CoP in Y-axis or antero-posterior direction (CoPy) in cm; (4) mean velocity of displacement of CoP in X-axis (VMx) in cm/s; (5) mean velocity of displacement of COP in Y-axis (VMy) in cm/s; (6) root mean square of CoP displacement in X-axis (RMSx) in cm; and (7) root mean square of CoP displacement in Y-axis (RMSy) in cm.

Scores were obtained with stable platform and in the "sway referencing" condition, where the platform rotates in direct proportion to the individual's sway in the antero-posterior direction. By controlling the usefulness of the proprioceptive information through sway referencing conditions, useful support surface information are eliminated and a sensory conflict situation is induced. These conditions isolate vestibular balance control mechanisms, as well as stress the adaptive responses of the central nervous system.

Individuals were evaluated in two conditions: fixed platform with open eyes (FIX) and sway referencing platform with eyes open (SWR). Data from all conditions were acquired in three periods of 20 s separated by intervals of 20 s between measures. The first trial of 20 s was not considered for analysis and the final score was the mean of the second and third periods of data acquisition. Including an initial 20 s period without data acquisition, the test duration was 120 s.

After these procedures, the same equilibrium tasks (FIX and SWR) were repeated, then including the simultaneous execution of the manual tracking test with fixed (FIXtrack) and sway-referenced (SWRtrack) platform.

Manual tracking task

The manual tracking task was presented in a computer screen. Target consisted in a 3° width yellow square in unpredictable horizontal movement (maximum range of 35°, maximum speed of 16°/s). The instruction was to move a 0.7° diameter white circle using a joystick trying to keep it inside the square. In order to avoid the effect of learning, two minutes training sections were repeated until individuals had achieved their best performance. Performances were evaluated by the percentage of time-on-target (TOT).

The computer screen was positioned in front of the platform, distant 70 cm from eyes. Individuals were instructed to hold a joystick with both hands keeping elbows close to the body and arms forming a 90° angle. The joystick was grasped with both hands, without contact on any fixed part of the platform, in order to avoid haptic cues. The performance was evaluated during 120 s trials, with rejection of the initial 3 s.

Data analysis

Performance in postural test and manual tracking task was evaluated by a 2-way repeated measures ANOVA with platform condition (FIX and SWR) and task (FIXtrack and SWRtrack) as within-subjects factor and group as between-subjects factor.

Results

Significant differences between groups were found in measures of AREA ($F = 4.34$; $P = 0.041$), CoPx ($F = 5{,}962$; $P = 0.017$), RMSx ($F = 9.245$; $P = 0.03$, and RMSy ($F = 4.092$; $P = 0.047$) measures and no differences were found in C0Py ($F = 3.161$; 0.08), MVx ($F = 3.112$; P = 0.083), and MVy ($F = 0.121$; $P = 0.729$) (Fig. 1).

The effect of cognitive task over postural stability was evaluated by Bonferroni post-hoc comparisons between FIX versus FIX track and SWR versus SWRtrack scores. In fixed platform condition, the addition of manual tracking task decreased postural stability in CoPx ($P < 0.001$); CoPy ($P < 0.001$); MVx ($P < 0.001$); MVy ($P < 0.001$); and RMSx ($P = 0.05$) measures. Similarly, in sway referencing condition, the addition of manual tracking task decreased postural stability in CoPx ($P < 0.001$); CoPy ($P < 0.001$); MVx ($P = 0.05$); and MVy ($P = 0.014$) (Fig. 1).

In the manual tracking task, individuals with acrophobia had lower scores than controls in both platform conditions (group effect $F = 21.509$; $P < 0.001$). The performance in manual tracking task showed no differences in FIX versus FIXtrack and SWR versus SWRtrack comparisons for both groups (platform effect $F = 0.326$; $P = 0.570$) (Fig. 2).

Discussion

Individuals with specific phobia of heights had lower scores in balance stability measures in fixed and sway referenced platform conditions. To our knowledge, this is the first empirical demonstration of increased surface dependence in this group of individuals. This finding corroborates the hypothesis of Jacob et al. that SMD has a key role in the pathophysiology of acrophobia [15]. Although it is conceivable that such postural changes can be mediated by anxiety and fear [1, 13], we evaluated individuals at floor level and wearing a safety belt that prevented falls. Anxiety and fear were not directly accessed before and during the tests but all participants reported to feel comfortable in the experimental setting, suggesting that acute emotional stress had not major influence on the results. Thus, in relation to the first hypothesis, acrophobic individuals showed a postural control abnormality, surface dependence, even when not exposed to heights.

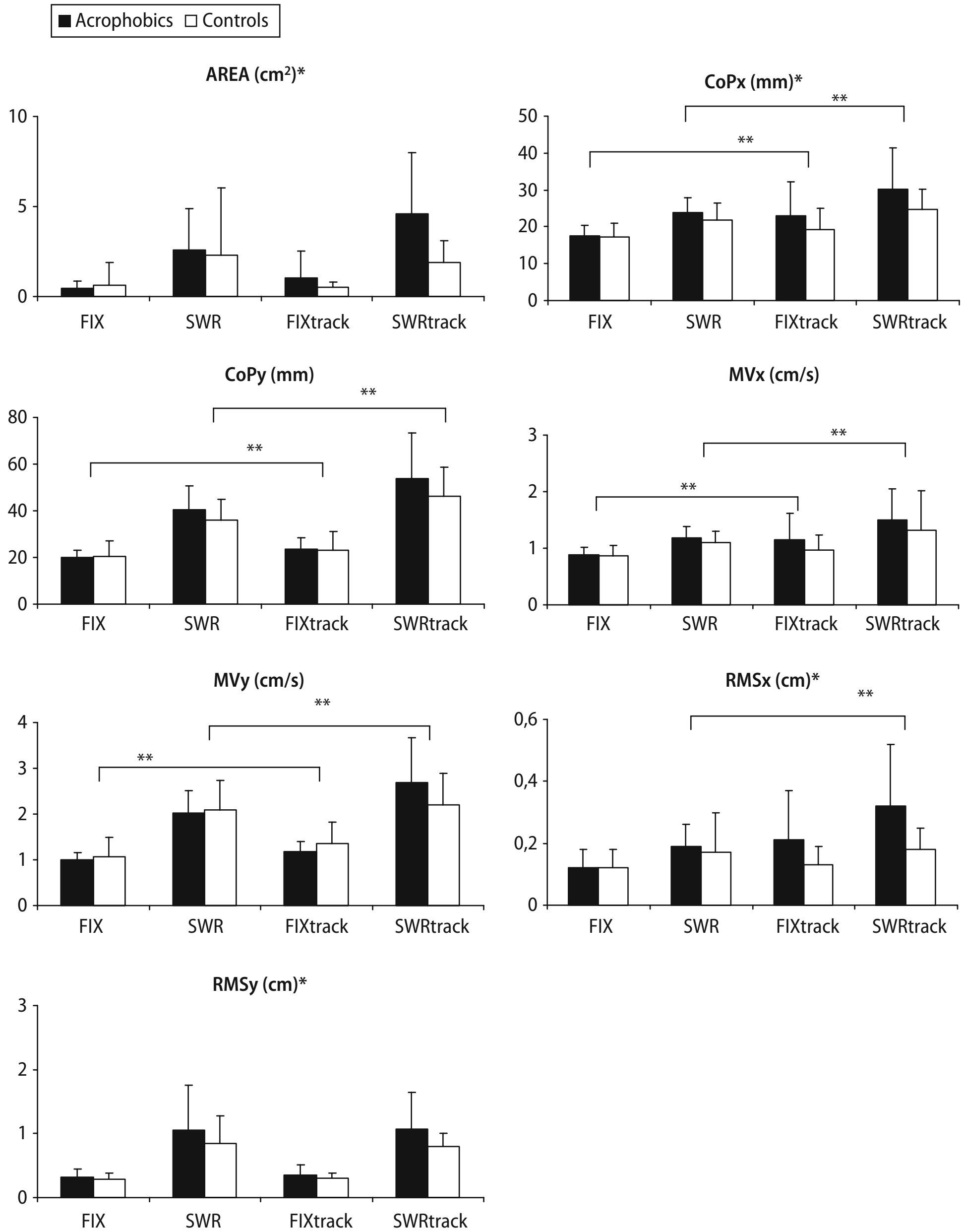

Fig. 1 Comparison between acrophobics and controls with respect to (**1**) area delimited by the center of pressure (CoP) in cm^2 (AREA); **2** maximum displacement of CoP in *X*-axis or latero-lateral direction (CoPx) in cm; **3** maximum displacement of CoP in *Y*-axis or antero-posterior direction (CoPy) in cm; **4** mean velocity of displacement of CoP in *X*-axis (VMx) in cm/s; **5** mean velocity of displacement of COP in *Y*-axis (VMy) in cm/s; **6** root mean square of CoP displacement in *X*-axis (RMSx) in cm; and **7** root mean square of CoP displacement in *Y*-axis (RMSy) in cm. Error bars = SD. Conditions: FIX fixed platform with open eyes, SWR sway referencing platform with eyes open, FIXtrack performing manual tracking task with fixed platform, and SWRtrack performing manual tracking task with sway referencing platform. *significant differences between groups ($P \leq 0.005$). **significant differences in post-hoc comparisons between platform conditions: FIX versus FIXtrack and SWR and SWRtrack ($P \leq 0.005$)

Lower scores in the manual tracking found in individuals with acrophobia, even when standing over a stable support, suggest abnormalities in the visual perception of movement, corroborating the second hypothesis of this study. However, since the apparatus to control visual surround in the Equitest^{TM} platform was not available, it was not possible to determine the occurrence of visual dependence in our sample following standard clinical procedures.

Once we observed these differences between groups, our third objective was to evaluate the interference between postural control and cognitive activity. Our results suggest that the increase of postural demand did not affect the performance of the manual task, but the addition of this task impaired postural stability. This pattern of interference can be interpreted as a prioritization of the cognitive over the

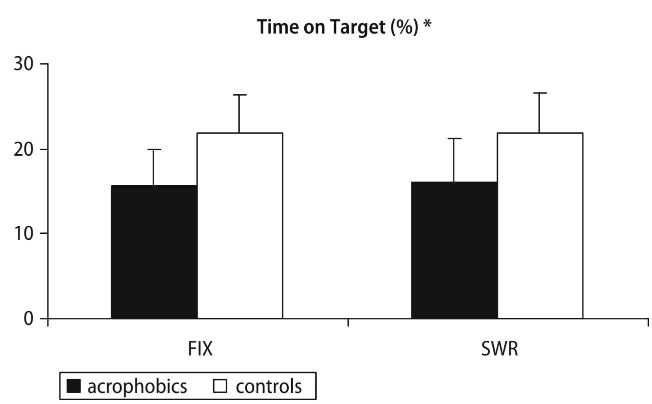

Fig. 2 Comparison between groups in the manual tracking task. Conditions: FIX fixed platform with open eyes, SWR sway referencing platform with eyes open. *significant differences between groups ($P \leq 0.005$)

postural task but such interactions may be complex and demand caution [22]. In a recent review, Fraizer and Mitra [12] found evidence for impairment of cognitive task performance when stance was mechanically or visually perturbed, particularly in older and balance-impaired adults. On the other hand, task manipulations have produced a mixed set of results, variously resulting in increased or decreased postural sway. The authors pointed out that "although dual-task investigations strongly suggest that posture control and higher level cognition have common resource requirements, inconsistencies in the data and differences in experimental design make it difficult to distill a fuller understanding of the specific mechanisms behind posture-cognition dual tasking".

Tracking a moving target is a complex task and interference with equilibrium control may occur at different levels. Briefly, the manual tracking of a target in the visual field, moving in an unpredictable way, requires sustained visual attention, adequate control of smooth pursuit eye movements (SPEM), eye-head movement compensation, and adequate eye-hand coordination. Smooth pursuit eye movements in a head-restrained condition involve a cortico-ponto-cerebellar pathway arising from the medial superior temporal sulcus of the extrastriate cortex, that accesses the brain stem via inhibitory projections from the cerebellar flocculus and ventral paraflocculus [18, 32]. The coordinated movements of eyes and head with unrestrained head appear to involve cerebellar and vestibular structures [3, 20]. Roy and Cullen [32] suggest that eye-head (EH) neurons within the medial vestibular nuclei are the primary input to the extra-ocular motoneurons during smooth pursuit and that such EH neurons carry vestibular and gaze-related information to the motoneurons during gaze pursuit. Finally, the close parallelism between ocular and manual behavior in the eye-hand coordination during pursuit suggest the existence of a central controller, since the inertia of the eye is considerably less than the inertia of the arm [11].

The differences between individuals with acrophobia and controls found in this study suggest the existence of physiological mechanisms capable to trigger phobic behaviors in the absence of learning experience, in accordance with the hypothesis of a non-associative mode of acquisition in acrophobia. We did not evaluate individuals with other anxiety or phobic disorders and, therefore, it is not possible to speculate whether such mechanisms are specific to acrophobia. Further investigations are needed, but these preliminary results may help us understand the mechanisms involved in the positive effects of physical therapy in individuals with fear of heights [36].

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References

1. Adkin AL, Frank JS, Carpenter MG, Peysar GW (2000) Postural control is scaled to level of postural threat. Gait Posture 12:87–93
2. Adkin AL, Frank JS, Carpenter MG, Peysar GW (2002) Fear of falling modifies anticipatory postural control. Exp Brain Res 143:160–170
3. Belton T, McCrea R (2000) Role of the cerebellar flocculus region in the coordination of eye and head movements during gaze pursuit. J Neurophysiol 84:1614–1626
4. Bles W, Kapteyn TS, Brandt T, Arnold F (1980) The mechanism of physiological height vertigo. II. Posturography. Acta Otolaryngol 89:534–540
5. Brandt T, Arnold F, Bles W, Kapteyn TS (1980) The mechanism of physiological height vertigo. I. Theoretical approach and psychophysics. Acta Otolaryngol 89:513–523
6. Choy Y, Fyer AJ, Lipsitz JD (2007) Treatment of specific phobia in adults. Clin Psychol Rev 27:266–286
7. Clark DB, Leslie M, Jacob RG (1992) Balance complaints and panic disorder: a clinical study of panic symptoms on members of a self-help group for balance disorders. J Anxiety Dis 6:47–53
8. Curtis GC, Magee WJ, Eaton WW, Wittchen HU, Kessler RC (1998) Specific fears and phobias. Epidemiology and classification. Br J Psychiatry 173:212–217
9. Dault MC, Frank JS, Allard F (2001) Influence of a visuo-spatial, verbal and central executive working memory task on postural control. Gait Posture 14:110–116
10. Dault MC, Geurts ACH, Mulder TW, Duysens J (2001) Postural control and cognitive task performance in healthy participants while balancing on different support-surface configurations. Gait Posture 14:248–255
11. Engel KC, Anderson JH, Soechting JF (2000) Similarity in the response of smooth pursuit and manual tracking to a change in the direction of target motion. J Neurophysiol 84:1149–1156
12. Fraizer EV, Mitra S (2008) Methodological and interpretive issues in posture-cognition dual-tasking in upright stance. Gait Posture 27:271–279
13. Hauck LJ, Carpenter MG, Frank JS (2007) Task-specific measures of balance efficacy, anxiety, and stability and their relationship to clinical balance performance. Gait and Posture. doi:10.1016/j.gaitpost.2007.09.002
14. Hsiao H, Simeonov P (2001) Preventing falls from roofs: a critical review. Ergonomics 44:537–561
15. Jacob RG, Furman JM, Durrant JD, Turner SM (1997) Surface dependence: a balance control strategy in panic disorder with agoraphobia. Psychosom Med 59:323–30
16. Jacob RG, Redfern MS, Furman JM (1995) Optic flow-induced sway in anxiety disorders associated with space and motion discomfort. J Anxiety Disord 9:411–425
17. Jacob RG, Woody SR, Clark D., Lilienfeld S, Hirsch BE, Kucera G, Furman JM, Durrant JD (1993) Discomfort with space and motion: a possible marker of vestibular dysfunction assessed by the situational characteristics questionnaire. J Psychopathol Behav Assess 15:299–324
18. Keller EL, Heinen SJ (1991) Generation of smooth-pursuit eye movements: neuronal mechanisms and pathways. Neurosci Res 11:79–107
19. Maylor EA, Allison S, Wing AM (2001) Effects of spatial and nonspatial cognitive activity on postural stability. Br J Psychol 92:319–338
20. Miall RC, Reckess GZ, Imamizu H (2001) The cerebellum coordinates eye and hand tracking movements. Nat Neurosci 4:638–644
21. Mineka S, Ohman A (2002) Born to fear: non-associative vs associative factors in the etiology of phobias. Behav Res Ther 40:173–184
22. Muller ML, Redfern MS, Jennings JR (2007) Postural prioritization defines the interaction between a reaction time task and postural perturbations. Exp Brain Res 183:447–456

23. Nakahara H, Takemori S, Tsuruoka H (2000) Influence of height on the spatial orientation and equilibrium of the body. Otolaryngol Head Neck Surg 123:501–504
24. Poulton R, Davies S, Menzies RG, Langley JD, Silva PA (1998) Evidence for a non-associative model of the acquisition of a fear of heights. Behav Res Ther 36:537–544
25. Poulton R, Menzies RG (2002) Fears born and bred: toward a more inclusive theory of fear acquisition. Behav Res Ther 40:197–208
26. Poulton R, Menzies RG (2002) Non-associative fear acquisition: a review of the evidence from retrospective and longitudinal research. Behav Res Ther 40:127–149
27. Poulton R, Waldie KE, Menzies RG, Craske MG, Silva PA (2001) Failure to overcome 'innate' fear: a developmental test of the non- associative model of fear acquisition. Behav Res Ther 39:29–43
28. Rachman S (2002) Fears born and bred: non-associative fear acquisition? Behav Res Ther 40:121–126
29. Rankin JK, Woollacott MH, Shumway-Cook A, Brown LA (2000) Cognitive influence on postural stability: a neuromuscular analysis in young and older adults. J Gerontol A Biol Sci Med Sci 55:M112–M119
30. Rapp MA, Krampe RT, Baltes PB (2006) Adaptive task prioritization in aging: selective resource allocation to postural control is preserved in Alzheimer disease. Am J Geriat Psychiat 14:52–61
31. Redfern MS, Talkowski ME, Jennings JR, Furman JM (2004) Cognitiveinfluences in postural control of patients with unilateral vestibular loss. Gait Posture 19:105–114
32. Roy JE, Cullen KE (2003) Brain stem pursuit pathways: dissociating visual, vestibular, and proprioceptive inputs during combined eye-head gaze tracking. J Neurophysiol 90:271–290
33. Shumway-Cook A, Woollacott M (2000) Attentional demands and postural control: the effect of sensory context. J Gerontol A Biol Sci Med Sci 55:M10–M16
34. Shumway-Cook A, Woollacott M, Kerns KA, Baldwin M (1997) The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. J Gerontol A Biol Sci Med Sci 52:M232–M240
35. Vuillerme N, Nougier V, Teasdale N (2000) Effects of a reaction time task on postural control in humans. Neurosci Lett 291:77–80
36. Whitney SL, Jacob RG, Sparto PJ, Olshansky EF, Detweiler-Shostak G, Brown EL, Furman JM (2005) Acrophobia and pathological height vertigo: indications for vestibular physical therapy? Phys Ther 85:443–458