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Threat-induced changes in attention during tests of static and anticipatory postural control

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ABSTRACT

Postural threat, manipulated through changes in surface height, influences postural control. Evidence suggests changes in attention may contribute to this relationship. However, limited research has explored where and how attention is reallocated when threatened. The primary aim of this study was to describe changes in attention when presented with a postural threat, while a secondary aim was to explore associations between changes in attention and postural control. Eighty-two healthy young adults completed tests of static (quiet standing) and anticipatory (rise to toes) postural control under threatening and non-threatening conditions. Participants completed an open-ended questionnaire after each postural task which asked them to list what they thought about or directed their attention toward. Each item listed was assigned a percentage value reflecting how much attention it occupied. Exit interviews were completed to help confirm where attention was directed. Five attention categories were identified: movement processes, threat-relevant stimuli, self-regulatory strategies, task objectives, and task-irrelevant information. For both postural tasks, the percentage values and number of items listed for movement processes, threat-relevant stimuli, and self-regulatory strategies increased under threatening compared to non-threatening conditions, while the percentage values and number of items listed for task objectives and task-irrelevant information decreased. Changes in attention related to movement processes and self-regulatory strategies were associated with changes in static postural control, while changes in attention related to threat-relevant stimuli were associated with changes in anticipatory postural control. These results suggest that threat-induced changes in attention are multidimensional and contribute to changes in postural control.

1. Introduction

Postural threat has a significant effect on postural control strategies during static and dynamic conditions [1–10]. During normal standing, individuals typically employ a stiffness strategy characterized by highly frequent, low amplitude postural adjustments [1,3,5–7,10], while during more dynamic tasks, such as walking [11] or rising onto toes [2,10], individuals reduce their range and speed of body movement. Less is known concerning the mechanisms underlying this relationship. Physiological changes such as altered autonomic arousal [7,9,12], muscle spindle sensitivity [12,13], and vestibular reflex gain [14,15] occur when threatened and may contribute to threat-induced changes in postural control. Other research suggests changes in attention may contribute to changes in postural control when threatened [9–11,16].

When standing [16] and walking [11] under threatening conditions, individuals have shown poorer dual-task performance, indicating greater overall cognitive demand when threatened. It has been suggested this results from individuals reallocating attention toward the internal mechanics of their movement [11]. Support for this has been provided by research showing that individuals self-report increases in state movement reinvestment, an index of conscious control and monitoring of movement, when threatened [9,10]. Employing this cognitive strategy is less efficient, as it is more attention demanding and may interfere with more automatic processes, potentially contributing to threat-induced stiffening behaviours [17,18]. While research has shown instruction to direct attention toward the internal mechanics of movement leads to increased ankle joint stiffness [19], no

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relationships have been observed between threat-induced changes in movement reinvestment and postural control, other than a shift in mean position (leaning) away from the direction of the threat [9]. However, reallocating attention toward one's movement may not reflect the only change in attention when threatened.

According to attentional control theory (ACT), individuals preferentially process threat-relevant stimuli when anxious [20]. Previous work using a dot probe task has provided support for this theoretical claim as older adults with fear of falling were shown to have an attentional bias toward fall-relevant threat cues [21]. This change in attention has the potential to contribute to threat-induced changes in posture, as directing attention toward threat-relevant stimuli can propagate feelings of anxiety [21,22] and pre-empt attention resources needed to adequately perform the postural task [18,20,23]. ACT hypothesizes that individuals may employ alternative processing strategies or invest additional on-task mental effort to cope with their elevated anxiety levels and compensate for anxiety-related distraction [20]. However, it is unclear the extent to which individuals direct attention toward these sources when posture is threatened.

This study aimed to describe the changes in attention of young adults when maintaining balance under threatening and non-threatening conditions. As little is known about where attention is allocated under either threat condition, an open-ended questionnaire was used to provide an initial description of attention without biasing participants toward specific responses. A secondary aim of this study was to explore associations between threat-induced changes in attention and postural control. Tests of static (quiet standing) and anticipatory (rise to toes) postural control were examined independently as they differ in difficulty and level of conscious motor control [10], and thus may be associated with different changes in attention under threatening conditions.

2. Methods

Data for this study were collected in conjunction with another study [10]. However, the analyses presented here have not been previously reported.

2.1. Participants

Eighty-two healthy young adults (44 males; mean ± standard deviation age = 23.95 ± 4.08 years) volunteered to participate in this study. Participants were free of neurological or musculoskeletal disorders that could influence postural control. No participants self-reported having an extreme fear of heights. All procedures were given ethical clearance by the University of British Columbia and Brock University research ethics boards. Participants provided written informed consent prior to completing the experimental protocol.

2.2. Experimental tasks

Participants stood on a forceplate at the edge of a 2.13 m × 1.52 m hydraulic lift (Penta-lift, Canada) and performed quiet standing and rise to toes tasks under conditions of low and high threat manipulated through changes in surface height. For the low threat conditions, the platform was positioned at its lowest height (0.8 m above ground). As standing away from the platform edge at heights up to 0.8 m has been shown to not influence postural control [5], an additional support surface (0.61 m × 1.52 m) was positioned in front of the platform. The high threat conditions differed for the postural tasks due to differences in task difficulty. The platform was positioned 3.2 m above ground for quiet standing [7,9] and 1.6 m above ground for rise to toes [2].

For quiet standing, participants were told to stand as still as possible with their arms at their sides for 60 s. For rise to toes, participants were told to rise onto their toes as quickly as possible following a verbal cue and to hold that position for 3 s. They were asked to keep their arms at their sides and avoid movement at the knees and hips when rising up [2]. Participants completed five rises onto toes under each threat condition, with any unsuccessful attempts noted and repeated. Foot position was kept consistent across all trials by tracing the borders of participants' feet onto the forceplate. Participants fixated on a visual target positioned at eye level 3.87 m away. Before completing any of the experimental trials, participants completed practice trials for both tasks with the platform positioned at its lowest height [1]. To control for possible order effects, the order of postural tasks and threat conditions were randomized. Throughout all trials, participants wore a harness that was secured to the ceiling.

2.3. Postural measures

For quiet standing, mean position (MPos) of centre of pressure (COP) was calculated along with measures of amplitude (root mean square; RMS) and frequency (mean power frequency; MPF) of COP adjustments. For rise to toes, amplitude and peak velocity of the anticipatory postural adjustment (APA) were calculated (see [10] for specific details).

2.4. Assessment of attention

Attention was assessed using an open-ended questionnaire completed immediately after each postural task condition. Participants were instructed to list what they thought about or directed their attention toward during the task they just completed. To provide an index of how much attention was devoted to each source, participants assigned each item they listed a percentage value reflecting how much of their total attention they devoted to it, with the sum of items needing to equal 100%. This approach was used to provide a comprehensive account of attentional focus without priming participants toward specific sources.

Participants completed an exit interview after completing the experimental tasks to confirm where their attention was directed related to each item they listed on the questionnaire. Participants were guided through each of the items they listed for each postural task condition in the order they were completed. Simple clarification (e.g., "Can you please explain what you meant by [x]?") and elaboration (e.g., "Could you give me a bit more detail related to that point?") questions were used to provide insight into what was meant by each item. Once the experimenter determined enough detail was provided to accurately categorize each item on the questionnaires, the interview was concluded. Interviews lasted between 5–20 min and were audio recorded for use during the data analysis process.

2.5. Data analysis

The lead investigator (MZ) first reviewed all attention questionnaires and interviews to define specific attention categories the data could be divided into. Five categories reflecting different sources of information participants directed their attention toward were identified and operationally defined. These included: movement processes, threat-relevant stimuli, self-regulatory strategies, task objectives, and task-irrelevant information (operational definitions provided in Table 1). These categories were discussed with the research team and further refined to ensure they comprehensively fit the data and were theoretically relevant [18,23,24]. Two investigators (MZ and ALA) then independently categorized data based on written responses and interview recordings for a randomly selected group of 20 participants.