CROSSTALK

Crosstalk opposing view: Fear of falling does not influence vestibular-evoked balance responses

Raymond F. Reynolds[1], Callum J. Osler[2], M. C. A. Tersteeg[3] and Ian D. Loram[3]

[1] *School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham, UK*

[2] *Sport, Outdoor and Exercise Science, Department of Life Sciences, University of Derby, UK*

[3] *Cognitive Motor Function Research Group, School of Healthcare Science, Manchester Metropolitan University, Manchester, UK*

Email: r.f.reynolds@bham.ac.uk

Fear of falling becomes more common as we age and increases following a fall (Murphy & Isaacs, 1982). Fear of falling itself may also increase the likelihood of future falls. Delbaere *et al.* (2010) found that risk of a future fall is determined not only by physiological predictors (e.g. weakness, poor vision) and by past fall history, but also independently by the perceived risk of falling itself. This raises the possibility that perception of risk coupled with motivation to prevent a fall can induce deleterious changes in the sensorimotor control of balance (Young & Mark, 2015). Understanding these changes is important if we are to reveal the mechanisms leading to a fall. A recent paper in *The Journal of Physiology* by Horslen *et al.* (2014) suggested that fear of falling increases postural responsiveness to vestibular input and that this may underlie altered balance control in the fearful state. However, our own research suggests that the balance response to vestibular stimulation is largely unaffected by fear (Osler *et al.* 2013). Here we discuss the apparent discrepancy.

Horslen *et al.* (2014) described the influence of postural threat upon vestibular responses when healthy adults stood on the edge of a platform elevated by 3.2m. A continuous stochastically varying current was applied to the ears to modulate vestibular nerve activity (2–25Hz; 1.1mA root mean square), and the ongoing postural response was recorded using a force platform. The stimulus–response relationship was quantified by cross-correlation and cross-spectral analysis. At height, cross-correlation magnitude increased compared with the ground. Frequency analysis also revealed an increase in response gain, mainly at high frequencies (>5 Hz). The authors concluded that altered processing of vestibular information may underlie changes in balance behaviour at height. Osler *et al.* (2013) adopted a similar approach, exposing healthy adults to a height of 3.85m while standing on a plank 22cm wide. Instead of a stochastic vestibular stimulus (SVS), however, 'galvanic' vestibular stimulation was applied, consisting of a square-wave current (2s; 1mA). In these circumstances, the early component of the stimulus-evoked body sway response (<800 ms) was indistinguishable between height and ground. Beyond this time, height caused a large reduction in the sway response. The extent of this reduction was correlated with skin conductance, a measure of sympathetic arousal that is correlated with fear. Our interpretation is that the feedforward coupling of vestibular input to a motor balance response was unaffected by fear, as reflected in the unchanged early component. Only when sensory feedback of the body sway response became available from other sources (e.g. proprioception) was sway suppressed, as reflected by the smaller late component. Thus, while the control of balance was undoubtedly affected at height, we do not attribute this to changes in processing of vestibular information *per se*. Why the discrepancy between the two papers? We believe it is due to differences in stimulus characteristics and outcome measures, as well as differing interpretations.

Relevance of stimulus to balance

The SVS stimulus used by Horslen *et al.* (2014) was deliberately engineered to produce minimal body sway. Application of a time-varying current that oscillates around zero and removing stimulus frequencies below 2Hz precludes the development of any significant body sway (Dakin *et al.* 2010). Thus, while significant differences were observed in the ground reaction forces, the stimulus does not challenge balance by evoking sustained sway in any direction. Furthermore, the reported differences were mainly in the high-frequency component of the response. Whatever effects are demonstrated, their relevance to balance is uncertain.

To investigate control of balance, we believe it is important to use a stimulus that challenges the balance system. We therefore used a 2 s constant-current stimulus, which evoked a sustained sway towards the edge of the narrow plank, thus directly challenging balance. The sway response contained substantial power at the low frequencies within the bandwidth of human movement. Whatever effects are demonstrated, we can be sure they are relevant to balance.

Raymond Reynolds is a Senior Lecturer in the School of Sport, Exercise & Rehabilitation Sciences at The University of Birmingham. He has a BSc in Physiology, MSc in Neuroscience, and received his PhD in postural control from Imperial College London in 2004. He obtained a BBSRC New Investigator Award in 2010, and is currently funded by the BBSRC to investigate the effects of ageing upon postural control. **Callum Osler** obtained his BSc PhD from The School of Sport, Exercise & Rehabilitation Sciences at The University of Birmingham. His research concerns context-specific changes in the use of vestibular information for balance. He is currently a Lecturer in Physiology at The University of Derby. **Linda Tersteeg** obtained her master's degree from the Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam in 2007. She completed her PhD at the Manchester Metropolitan University in 2012. Her PhD research focused on the effects of height on stance and locomotion. **Ian Loram** obtained his Ph.D. degree in applied physiology from The University of Birmingham. He worked as a Leverhulme Early Career Research Fellow and is currently Professor in Neuromuscular Control of Human Movement at MMU. His work focuses on the application of neuromuscular physiology, control theory, biomechanics, motion analysis and ultrasound/EMG analysis to understand muscle action in the control of posture, movement and human performance.

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Outcome measures

The SVS approach, combined with spectral analysis, maximizes the statistical sensitivity for detecting small changes in gain between stimulus and response, which was ground reaction force in the case of Horslen *et al.* (2014). However, given the multisegmental nature of the human body, ground reaction forces alone do not identify the location of the vestibular-evoked muscle force generation. The uncertain kinematic location, coupled with the frequency range (strongest effect above 5 Hz), makes it uncertain whether the evoked muscle forces have any consequence for the control of balance.

For balance, the outcome measure of primary importance is location of the centre of mass in relation to the base of support. To assess the effect of vestibular-evoked responses on balance control, we measured body movement in the direction of the 'dangerous' edge. The key result is that during the early phase, prior to integration of proprioceptive information, body position and velocity were indistinguishable between ground and height. We agree with Horslen *et al.* (2014) that our methods are less sensitive for identifying changes in the early, high-frequency component. With sufficient participants, small differences in velocity between height and ground conditions may be statistically detectable. However, the key point is any such difference is small and the effect on centre-of-mass position even smaller.

While we observed little change in the early body sway response, we identified considerable suppression of the late component. Therefore, if there are any changes in the early component they are extremely subtle and, crucially, have minimal relevance for the control of body sway. Thus, while we do not dispute the veracity of the results presented by Horslen *et al.* (2014), we do question their relevance.

Interpretation of results

What are the implications for the effect of risk perception and motivation to prevent a fall upon vestibular control of balance? The answer requires comparative analysis of the early effect, attributed to altered vestibular processing, and the later effect involving integration of all sensory modalities.

In the paper by Osler *et al.* (2013), elevated skin conductance confirmed that subjects were in a physiologically fearful state. Despite this, and despite the changes described by Horslen *et al.* (2014), we observed no difference in the early sway response to galvanic vestibular stimulation. We conclude that any changes in vestibular control caused by fear are subtle at best and have unproven relevance for balance. Does this mean that fear of falling has no effect upon balance? Quite the contrary! The later suppression that we observed at height suggests that sway is minimized in the fearful state. At this late stage, sensory feedback from non-vestibular sources has time to exert an effect, effectively arresting the response to the vestibular stimulus. It is therefore likely that fear affects multisensory integration for posture.

Given the strength of motivation to prevent a fall, it is unsurprising that there is some effect on vestibular processes. More surprising is the extent to which the balance response is unaltered. We contend that Horslen *et al.* (2014) have confused statistical significance with functional significance. Compared with the effect of fear of falling, the more accurate point is the extent to which vestibular balance responses are impervious to the perception of risk and motivation to prevent a fall. Fear of falling appears not to influence vestibular-evoked balance responses in any functionally significant manner.

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Additional information

Competing interests

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