**Locomotor Stability Control and Vestibular Function among Older Adults: Implications for Falls Prevention and Research**

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**Introduction**

Approximately one third of older adults fall each year (Berg, Alessio, Mills and Tong, 1997). The ability to respond appropriately to unexpected disturbances during gait is important for preventing a fall (Maki & McIlroy, 2006). However, assessment of such reactive stability control is not common in clinical settings. Additionally, declined vestibular function is often associated with falls (Tuunainen, Rasku, Jäntti & Pyykkö, 2014). In the following studies, we explored the relationships between age, vestibulopathy and stability control, in order to determine the age and vestibulopathy-related effects on stability control, and to establish if a relationship existed between static and dynamic stability task performance.

**Methods**

**Study 1** (McCrum et al., 2014): 17 middle-aged adults with vestibulopathy (mean(SD): 49(9)y) and 17 healthy middle-aged adults (51(8)y) walked on a treadmill at 1.4m/s and were subjected to eight unexpected trip perturbations to the right leg. A resistance of 2.1kg was delivered via a Teflon cable and ankle strap, using an electronically driven magnet system. For each perturbation, the margin of stability (MoS; state of the centre of mass in relation to the base of support (BoS); Hof et al., 2005) was determined at touchdown (TD) of the perturbed leg and the following six recovery steps. A 3-way ANOVA with group, step and trial (1 or 8) was conducted.

**Study 2** (McCrum, Epro, Meijer, Zijlstra, Brüggemann & Karamanidis, 2016): 11 young (25.5(2.1)y), 11 middle-aged (50.6(6.4)y) and 14 older (69.0(4.7)y) women walked on a treadmill at 1.4m/s. The same resistance perturbation perturbed the subjects’ gait for one swing phase. After a wash-out period, the resistance was applied again, this time for 18 consecutive steps of the right leg, after which the resistance was removed without notice. Aftereffects were analyzed in the BoS. The MoS was calculated for all perturbed steps. A 2-way ANOVA with age group and step was conducted.

**Study 3:** We assessed if gait stability was associated with standing balance. To achieve this, we pooled data from Study 1 (McCrum et al., 2014) and a prior study of stance stability with the same patients (Eysel-Gosepath, McCrum, Epro, Brüggemann & Karamanidis, 2016). 12 patients were included. Change in MoS and BoS relative to non-perturbed gait (MoS\_change and BoS\_change respectively) were calculated for the perturbed and first recovery steps from Study 1. The centre of pressure (COP) path during 30s stance with eyes open and closed, and the distance between the most anterior point of the COP and the anterior BoS boundary during forward leaning (A\_Dist) were assessed using a force plate. Pearson correlations were conducted between all static and dynamic stability variables.
Results

Study 1: The first perturbation resulted in a reduced MoS at TD of the perturbed step in both groups to a similar degree ($p < .05$). However, while controls returned to baseline MoS level in five steps, the patients with vestibulopathy did not return to baseline MoS level within the six analysed steps. By the eighth perturbation, controls needed two steps and patients needed three steps to recover to baseline MoS. MoS at TD of the perturbed leg increased ($p < .05$) after repeated trips for controls, indicating feedback-driven locomotor adaptation, but the patients’ MoS at TD of the perturbed step did not improve.

Study 2: During the first perturbation, no group differences were found in MoS of the perturbed step. During the 18-step sustained perturbation period, the older group demonstrated significantly lower MoS in the first six steps ($p < .05$) compared with the two younger groups. There were no differences for the last five steps (steps 14-18; $p > .05$). After removing the resistance, all three groups showed comparable aftereffects (increased BoS).

Study 3: The correlation analysis of the static and dynamic stability task parameters revealed one (out of 12) significant correlation (MoS change at the perturbed step and ADist; $r = -.595$, $p = .041$; non-significant correlations: $.068 \leq p \leq .995$).

Discussion

These results show that vestibulopathy is related to a diminished ability to control and recover gait stability after an unexpected perturbation, and to a deficient reactive adaptation potential. With ageing, the ability to recalibrate locomotor commands to control stability is preserved, although this recalibration may be slower in old age compared to middle and young age. Given that a decline in vestibular function is seen with increasing age, we suggest that assessment of vestibular function may be necessary when investigating locomotor stability and falls risk in both research and clinical settings. Finally, despite static balance tasks and parameters being commonly used in clinical settings, we did not find a consistent relationship between static and dynamic stability task performance, indicating the importance of dynamic stability tests when assessing falls risk in clinical settings.

References


