Effects of reduced plantar cutaneous afferent feedback on locomotor adjustments in dynamic stability during perturbed walking

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Abstract
This study examined the effects of reduced plantar cutaneous afferent feedback on predictive and feedback adaptive locomotor adjustments in dynamic stability during perturbed walking. Twenty-two matched participants divided between an experimental-group and a control-group performed a gait protocol, which included surface alterations to one covered exchangeable gangway-element (hard/soft). In the experimental-group, cutaneous sensation in both foot soles was reduced to the level of sensory peripheral neuropathy by means of intradermal injections of an anaesthetic solution, without affecting foot proprioception or muscles. The gait protocol consisted of baseline trials on a uniformly hard surface and an adaptation phase consisting of nineteen trials incorporating a soft gangway-element, interspersed with three trials using the hard surface-element (2nd, 8th and 19th). Dynamic stability was assessed by quantifying the margin of stability (MS), which was calculated as the difference between the base of support (BS) and the extrapolated centre of mass (CM). The horizontal velocity of the CM and its vertical projection in the anterior–posterior direction and the eigenfrequency of an inverted pendulum determine the extrapolated-CM. Both groups increased the BS at the recovery step in response to the first unexpected perturbation. These feedback corrections were used more extensively in the experimental-group, which led to a higher MS compared to the control-group, i.e. a more stable body-position. In the adaptation phase the MS returned to baseline similarly in both groups. In the trial on the hard surface directly after the first perturbation, both groups increased the MS at touchdown of the disturbed leg compared to baseline trials, indicating rapid predictive adjustments irrespective of plantar cutaneous input. Our findings demonstrate that the locomotor adaptational potential does not decrease due to the loss of plantar sensation.

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1. Introduction

Epidemiological evidence links the lack of peripheral afferent feedback to an increased risk of falling (DeMott et al., 2007). The prevalence of falls in patients who suffer from peripheral neuropathy is up to twice as high compared with an age-matched population (Cavanagh et al., 1992; Stolze et al., 2004). Peripheral neuropathy occurs largely as a consequence of diabetes mellitus and affects small and large-fibre sensory afferents, leading to a regression of nerve function from peripheral to more proximal regions. The resulting deficits in proprioceptive and cutaneous afferent feedback lead to a well-documented increased postural sway in those patients during standing (Cavanagh et al., 1992; Simoneau et al., 1994). However, most of the falls are caused by perturbations during walking, often followed by serious peripheral injury (DeMott et al., 2007; Stolze et al., 2004). Previous studies have observed gait alterations in diabetic neuropathic patients during walking on level and irregular surfaces in terms of walking speed, step length, step time or stride-to-stride variability (Allet et al., 2009; Menz et al., 2004). Dingwell and Cavanagh (2001) and Dingwell et al. (2007) reported that gait alterations are primarily mediated by a decrease in the self-selected walking speed of those patients. It has been suggested that the loss of sensory feedback is not critical for maintaining stable locomotor patterns during undisturbed walking and that the increased risk of falling is more likely due to the inability of neuropathic patients to execute appropriate response strategies when exposed to unexpected perturbations or obstacles during walking (Dingwell and Cavanagh, 2001). Sensory feedback as part...