

If Proprioception Is Relevant to Locomotion, then Why Test It Standing Still?

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Abstract: Traditionally, proprioception research has utilised passive position or movement detection and repositioning tasks. Current evidence suggests proprioception represents a complex synergy of sensory inputs that may be more appropriately assessed during more functional tasks. This study investigated the Minimal Perceptible Difference (MPD) test - a novel assessment of participants' ability to perceive floor height changes whilst hopping. Sixteen healthy volunteers performed multiple hopping trials on a custom-built sleigh apparatus that permitted a floor height change (range 3mm to 48mm). The MPD in floor height was recorded for 8 different hopping conditions (Factors - Technique: alternate / bilateral hopping; Side: dominant / non dominant; Direction of change: up / down) over two separate testing occasions. Within and between-day reliability were assessed using ICC and 95% confidence intervals. Hopping technique was the only factor which significantly influenced participants' sensitivity to detect changes in floor height. The mean MPD was significantly lower ($p < .0001$) for bilateral hopping (15.65mm) when compared to alternate hopping (26.59mm). Bilateral hopping yielded strong ICC for within and between day reliability. We propose the bilateral hopping MPD assessment is a reliable, functional assessment of proprioception sensitivity that may better reflect human gait than established static assessments.

1 INTRODUCTION

Proprioception is defined as “afferent information from proprioceptors located in the proprioceptive fields that contribute to conscious sensations (muscle sense), total posture (postural equilibrium) and segmental posture (joint stability)” (Sherrington, 1906). It is a concept with particular relevance to clinicians and researchers with respect to performance, injury and rehabilitation (Brumagne et al., 2004); (Cameron et al., 2008); (Fu and Hui-Chan, 2007); (Herrington et al., 2008); (Lephart and Jari, 2002); (Vuillerme and Boisgontier, 2008). Most methodologies examine proprioceptive acuity using passive position detection (Down et al., 2007), passive movement detection (Salles et al., 2011) and active repositioning tasks (Ribeiro et al., 2007). However, recent evidence suggests proprioception is a much more complex concept than just joint position sense and kinaesthesia, incorporating the integration of the body schema (Ivanenko et al., 2011) and its continuous refinement being expanded to a concept called “somatoperception” (Longo et

al., 2010). Of particular note is that current testing methods may represent convenient research methods, but may not reflect the dynamic function of the lower limb – to perform repeated Stretch Shortening Cycles (SSC) (Proske et al., 2000).

The authors utilised a sub-maximal sleigh hopping model to replicate the normal function of the limbs via repeated SSC. This model has been applied to develop the Minimal Perceptible Difference (MPD) test – a novel research tool which examines individuals' ability to detect changes in floor surface height during the repeated SSC. This study aimed to investigate the reliability of the MPD test on a within and between day basis. We also aimed to quantify the MPD in floor surface height for a healthy population.

2 METHODS

The MPD test examined the sensitivity of healthy participants to perceive changes in floor surface height whilst hopping on a custom built apparatus

(Figure 1) with an adjustable floor (Figure 2).

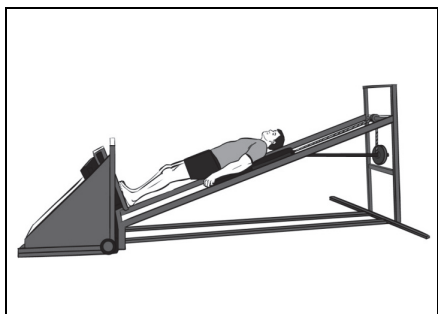


Figure 1: The custom built sleigh apparatus.



Figure 2: The Sliding Floor Mechanism illustrating a 36mm reduction in floor height under the right foot.

Sixteen healthy participants performed multiple trials of 5 consecutive hops on a custom built sleigh apparatus that permitted the testers to change the floor height (range 3mm to 48mm) during each trial, as dictated by a structured searching algorithm.

MPD in floor height was recorded for 8 different hopping conditions (Factors - Technique: alternate / bilateral hopping; Side: dominant / non dominant; Direction of change: up / down) over two testing occasions spaced one week apart. Participants performed a mean of 117 trials on Day 1 and 120 trials on Day2.

3 RESULTS

Intra-class Correlation Coefficients (ICC) and 95% Confidence Intervals (CI) were derived to examine within and between day reliability of the MPD test. All bilateral hopping techniques yielded moderate to high ICC values for both within (0.60 to 0.79) and between day (0.67 to 0.88) reliability.

The only factor which significantly influenced the sensitivity of subjects to detect changes in floor height was the hopping technique (bilateral or

alternate, $p < 0.05$). Comparing across hopping techniques, the mean MPD was significantly lower ($p < .001$) for bilateral hopping than alternate hopping as per table 1:

Table 1: Result of Linear Mixed Model Analysis of Between Days MPD Scores (in mm).

MPDmean Bilateral Hopping	MPDmean Alternate Hopping	Significance
15.65	26.59	$p < .001$

4 DISCUSSION

We propose the MPD test is a novel, reliable and functionally relevant research tool. Furthermore, the MPD represents a change in the research paradigm from testing detection of passive, position matching and force matching of isolated joints (Down et al., 2007); (Jong et al., 2005); (Lowrey et al., 2010); (Matre et al., 2002). Instead we examined proprioception during repeated SSC which may better represent human gait as it considers an expected interaction with a non-homogenous interface between the foot and ground.

For bilateral hopping, ICC values for within and between day comparisons all exceeded proposed ICC of 0.6 that has been recommended for any measure to have clinical utility (Chinn, 1991). This indicates that the MPD test using bilateral hopping may have application in the research setting on single and multiple test occasions.

The increased sensitivity to floor height change detection during bilateral hopping is an interesting observation. Our findings are consistent with previous findings which suggest that gating and utility of sensory information may be strategy dependant (Ivanenko et al., 2000).

It may be hypothesised that the bilateral tasks represent upright stance where we need sensitive and constant feedback to maintain posture and to safely initiate movement. Continuous weight bearing feedback during bipedal stance may be provided via continuous bilateral comparison of both limbs contributing to the postural schema.

Conversely, reduced sensitivity to floor height change detection during alternate hopping suggest that bipedal gait may allow humans progress their centre of mass with sufficient proprioceptive redundancy to overcome large variations in the interface between the foot and the ground surface without cognitive perception of the challenge.

5 FUTURE RESEARCH

We have observed a significant difference in sensitivity to detect floor height changes between alternating and bilateral SSC. An area for future research is to investigate whether this difference in detection is attributable to neurological or biomechanical factors. Furthermore, given these observations more research is required to determine if current “static tests” are valid correlates to dynamic activities such as gait.

6 CONCLUSIONS

The MPD test has been presented and represents a change in research focus towards investigating proprioception using repeated stretch shortening cycle to model normal lower limb dynamic function.

Development of this tool may allow for further investigation of functional proprioceptive ability injured/pathological samples. The MPD test has been demonstrated as reliable over time and is therefore an acceptable research tool for use within and across test occasions.

We observed greater sensitivity of the MPD test in the bilateral hopping technique. This may reflect specific sensory requirements for upright stance, whereas (bipedal) gait may have its own specific redundancies.

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