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Research article

Is perception of vertical impaired in individuals with chronic stroke with a history of 'pushing'?

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HIGHLIGHTS

- 'Pushing' is a sign of stroke where the patient leans on the paretic side.
- Pushing behaviour is caused by a misperception of vertical in the roll plane.
- Our work suggests that misperception of postural vertical resolves with recovery of pushing behaviour.
- Impaired perception of visual vertical can persist after pushing symptoms resolve.

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Abbreviations:
BBS, Berg Balance Scale
HP, history of pushing (group)
NIH-SS, National Institutes of Health Stroke Scale
HP, no history of pushing (group)
SCP, Scale for Contraversive Pushing
SNAP, Sunnybrook Neglect Assessment Procedure
SPV, subjective postural vertical
SVV, subjective visual vertical

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ABSTRACT

Post-stroke 'pushing' behaviour appears to be caused by impaired perception of vertical in the roll plane. While pushing behaviour typically resolves with stroke recovery, it is not known if misperception of vertical persists. The purpose of this study was to determine if perception of vertical is impaired amongst stroke survivors with a history of pushing behaviour. Fourteen individuals with chronic stroke (7 with history of pushing) and 10 age-matched healthy controls participated. Participants sat upright on a chair surrounded by a curved projection screen in a laboratory mounted on a motion base. Subjective visual vertical (SVV) was assessed using a 30 trial, forced-choice protocol. For each trial participants viewed a line projected on the screen and indicated if the line was tilted to the right or the left. For the subjective postural vertical (SPV), participants wore a blindfold and the motion base was tilted to the left or right by 10–20°. Participants were asked to adjust the angular movements of the motion base until they felt upright. SPV was not different between groups. SVV was significantly more biased towards the contralesional side for participants with history of pushing ($-3.6 \pm 4.1°$) than those without ($-0.1 \pm 1.4°$). Two individuals with history of pushing had SVV or SPV outside the maximum for healthy controls. Impaired vertical perception may persist in some individuals with prior post-stroke pushing, despite resolution of pushing behaviours, which could have consequences for functional mobility and falls.

1. Introduction

'Pushing' is a sign of stroke whereby the individual leans towards the contralesional side and actively resists attempts to correct to a symmetrical posture [1]. Pushing behaviour affects up to 63% of

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acute [2] and 46% of sub-acute [3] patients with stroke, and can be so severe that the individual cannot sit and/or stand independently, preventing participation in physical rehabilitation [1] and activities of daily living [4]. Prognosis for those with post-stroke pushing is poor; compared to those without pushing, individuals with pushing behaviour have delayed admission to rehabilitation [5], longer lengths of stay [2,5,6] or lower functional outcomes on discharge [6,7], and are less likely to be discharged home [5–7].

It is thought that pushing behaviour arises from misperception of vertical in the roll plane [8,9]. Previously, investigators have measured subjective visual vertical (SVV; i.e. aligning a luminous line with perceived earth vertical) and subjective postural vertical (SPV; i.e. aligning one's body with perceived earth vertical) post-stroke. Findings show that individuals exhibiting pushing behaviours have a contralesional tilt of the SPV [8] and SVV [8,10]. Despite the fact that pushing behaviour appears to resolve within 3–6 months post-stroke [1,2] it is not known if an underlying misperception of vertical persists, even after obvious pushing behaviours resolve. Thus, the purpose of this study was to determine if misperception of vertical persists after pushing behaviour resolves. We expected that recovery of pushing behaviour occurs due to compensatory mechanisms rather than recovery of the underlying perceptual problem; that is, that perception of vertical would be resistant to improvement with recovery from stroke. Therefore, we hypothesized that individuals with prior history of pushing behaviour would show a contralesional tilt of SPV and SVV.

2. Materials and methods

Fourteen individuals with chronic stroke (>6 months post-stroke) were recruited from two sources: (1) former participants in a longitudinal study of stroke recovery; and (2) a database of former stroke patients at the investigators' institution who agreed to be contacted for future research. Participants from the longitudinal study ($n = 6$) completed the Scale for Contraversive Pushing (SCP) early post-stroke and were included if they either: (1) scored ≥ 1 on item C (resists correction) of the SCP early in stroke recovery (e.g. admission to rehabilitation; history of pushing (HP) group); or (2) scored 0 on the SCP early post-stroke (no history of pushing (NHP) group). Participants recruited from the investigators' institution ($n = 8$) were included if they either: (1) had a clear history of "pushing" or "lateropulsion" noted in their hospital charts during acute care (HP group); or (2) no evidence of pushing behaviour noted on their hospital charts (NHP group). All HP and NHP participants had experienced a single stroke event. Ten healthy community-dwelling age-matched (50–85 years old) participants were also recruited (controls). All participants were excluded if, at the time of enrolment, they: (1) had SCP > 0; (2) had any neurological conditions (besides stroke for HP or NHP participants) or musculoskeletal conditions that were likely to affect balance; (3) were unable to communicate in English; and/or (4) had visual acuity worse than 20/50 as tested using a Snellen eye chart. Additionally, participants were excluded if they had prior history of vestibular disorders (e.g. vertigo or dizziness). Controls were excluded if they had Berg Balance Scale (BBS) scores outside the 'normal' range for their age and sex [11]. Past medical history was obtained by hospital chart review (HP and NHP participants) and self-report. The study was approved by the institution's Research Ethics Board and participants provided written informed consent prior to participation.

Data collection occurred during two sessions separated by 1–4 weeks. In the first session, the BBS [12], SCP and Snellen visual acuity tests were conducted for screening purposes. Additionally, the following measures were obtained: age, sex, National Institutes of Health Stroke Scale (NIH-SS [13]; a measure of stroke severity), the Lateropulsion Scale [14], and the Sunnybrook Neglect Assessment Procedure (SNAP; [15]). The Lateropulsion Scale evaluates postural orientation and resistance to correction in lying, sitting, standing, transfers, and walking [14]. Thus, while the SCP is more frequently used in research on pushing behaviour [16], the Lateropulsion Scale provides an additional measure that may be more sensitive to detecting mild pushing behaviour [17]. The SNAP was used to categorize participants according to severity of visuo-spatial neglect; a score <5 indicated no neglect, 5–40 indicated mild-moderate neglect, and >40 indicated severe neglect [15]. Assessments were performed and scored by a physiotherapist. For participants with stroke, time post-stroke and lesion location were obtained from hospital charts.

SPV and SVV were assessed in the second test session; participants were seated restrained in a cushioned chair placed inside a virtual reality motion platform (Fig. 1). Head motion was limited with cushioning and leg motion was limited by footrests [18]. For the SPV, participants were seated in the dark and blindfolded. The motion platform rolled left or right by 10°, 15°, or 20° in the roll plane. One trial was completed for each starting angle in each direction (i.e. 6 trials total); trials were presented in an unpredictable order, alternating between left and right rolls. Once the starting angle had been reached, participants verbally directed the experimenter to tilt the motion base until they felt upright and the final roll angle was recorded. Motion base angular velocity was 0.5°/s and peak acceleration/deceleration was 0.2°/s^2. SPV was the mean of the final roll angle across all 6 trials. For the SVV, participants were seated upright in the chair with eyes open. A white line subtending 3° of visual angle was projected on the screen. Participants were asked to judge if the line would topple to the left or right. A psychometric function was generated from 30 trials using the adaptive staircase procedure QUEST [19,20]. The SVV error was calculated by subtracting the point of subjective equality (i.e. angular bias) of the resulting function from true gravitational upright.

Demographic characteristics and functional balance were compared between the three groups using analysis of variance (ANOVA; age and BBS) or chi-square (sex) tests. Clinical and stroke characteristics were compared between the two stroke groups with ANOVA (time post-stroke, NIH-SS, and SNAP) or chi-square (side of lesion and stroke type) tests. Negative SPV or SVV values are associated with contralesional biases (HP and NHP groups) or leftward biases (controls). To test the primary hypothesis, SPV and SVV were compared between groups with ANOVA. Pre-planned contrasts compared participants with stroke to controls and HP to NHP participants. Additionally, the maximum absolute SPV and SVV values were calculated for controls. Individual stroke participants were considered to have impaired perception if their SPVs or SVVs were outside the maximum for healthy controls. All continuous or ordinal variables were rank-transformed prior to ANOVA. Alpha was 0.05. Values in text are presented as mean [95% confidence interval] for interval data or median [quartiles] for ordinal data.

3. Results

Participant characteristics are shown in Table 1. The three groups did not differ in terms of age ($F_{2,21} = 1.17$, $p = 0.33$) or sex ($\chi^2 = 5.26$, $p = 0.072$). Participants with stroke had worse functional balance than controls (i.e. lower BBS scores; $F_{1,21} = 21.51$, $p = 0.0001$). HP and NHP participants did not differ on lesion side or type of stroke ($\chi^2 < 1.41$, $p > 0.23$). On average, HP participants were recruited later post-stroke (HP: 29.9 [12.3, 47.6] months; NHP: 12.4 [9.0, 15.9] months; $F_{1,12} = 6.23$, $p = 0.028$), had higher SNAP scores (HP: 5 [2,33]; NHP: 0 [0,2]; $F_{1,12} = 7.09$, $p = 0.021$) and had lower BBS scores (HP: 35.6 [20.6, 50.6]; NHP: 53.7 [51.1, 56]; $F_{1,21} = 15.44$, $p = 0.0008$) than NHP participants. There was a trend