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Obstacle crossing following stroke improves over one month when the unaffected limb leads, but not when the affected limb leads☆

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ABSTRACT

While it is well established that obstacle crossing is impaired following stroke, it is not known whether obstacle crossing improves as gait improves following stroke. The purpose of this study was to determine whether obstacle crossing changed over a one month time period in people with a recent stroke. Twenty participants receiving rehabilitation following a recent stroke were tested on two occasions one month apart. Participants received usual care rehabilitation, including physiotherapy, between the tests. The main outcome measure was obstacle crossing speed as participants stepped over a 4-cm high obstacle. Secondary measures were spatiotemporal variables. Data were collected via a three dimensional motion analysis system. When leading with the affected limb no changes in obstacle crossing speed or spatiotemporal variables were observed over the one month period. When leading with the unaffected limb, crossing speed significantly increased ($p = .002$), and affected trail limb swing time ($p = .03$) and crossing step double support time reduced ($p = .016$). While not significant, the lead and trail limb pre-obstacle distance increased ($p = .08$), and lead swing time ($p = .052$) reduced. Change in obstacle crossing speed did not correlate with change in level gait speed. Obstacle crossing does not necessarily improve over a one month time period in people receiving rehabilitation following stroke. These findings suggest that there may be a need for more targeted training of obstacle crossing, particularly when leading with the affected limb.

Obstacle crossing is impaired for many people following a stroke [1,2]. Said et al. found over 50% of people able to walk and receiving rehabilitation following stroke either contacted the obstacle or lost balance when attempting to clear a small obstacle [1]. People with stroke also utilised different movement patterns to clear an obstacle compared to unimpaired participants [3,4]. They had significantly slower gait speeds as they crossed the obstacle, which accounted for some differences in the gait pattern such as lead limb placement before the obstacle [3]. However, speed did not account for all gait adjustments. Compared with healthy participants walking at matched speed, people with stroke placed the unaffected lead limb and affected and unaffected trail limb closer to the obstacle after crossing [3]. They also positioned their centre of mass closer to the base of support when leading with the affected limb [4].

Many of these studies assessed people undergoing rehabilitation within six months of stroke, thus some people may not have attained optimal walking recovery [3–5]. While obstacle crossing is more challenging than level ground walking [6–8], it is fundamentally a locomotor task. It is reasonable to expect that if walking ability improves, obstacle crossing may also improve. Gait speed is an important clinical marker of gait improvement [9], and there are valid rationales for anticipating that increased level over-ground gait speed would lead to improvements in obstacle crossing. Some movement deficits during obstacle crossing following stroke were partly speed associated [3,4] and people who fail an obstacle crossing task cross the obstacle more slowly compared with people who pass [10]. Thus if gait speed improves following stroke, aspects of obstacle crossing performance may also normalise. In addition, for some participants, the obstacle crossing task may have been 'novel' following their stroke, as their exposure to complex walking tasks may have been limited at this stage of recovery. With repeated exposure to complex locomotor

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tasks, including obstacle crossing, people with subacute stroke may change their obstacle crossing strategy. We therefore wanted to investigate whether obstacle crossing changes over time in people with subacute stroke.

While many variables have been examined during obstacle crossing, the primary outcome of interest for this study was gait speed during obstacle crossing, as this differentiates between people with stroke and controls [3]. It is also associated with failure on an obstacle crossing task [10]. To explore mechanisms behind observed changes, temporal and sagittal plane spatial variables were examined.

The purpose of this study was to determine whether obstacle crossing gait speed improves over time in people recovering from a recent stroke. It was hypothesised that if level over-ground (unobstructed) walking speed increased following stroke, it would be associated with an increase in obstacle crossing gait speed. It was also anticipated that spatial and temporal variables would change and approach values achieved by unimpaired adults.

1. Method

This was an observational study. Ethics approval was obtained and participants provided informed consent. Obstacle crossing performance and falls, obstacle crossing performance and spatio-temporal characteristics, and variability in spatiotemporal characteristics in these participants have been previously reported [10,11].

1.1. Participants

Data were collected from 20 participants recruited from two hospital physiotherapy departments. A sample of 20 was sufficient to detect a large difference between the two tests ($d = 0.8$), with a power of 70% and a two tailed alpha of 0.05. Participants were receiving ongoing physiotherapy for a gait or balance disorder following a recent stroke, and capable of walking 10 m without a gait aid or physical assistance. Participants were excluded if they had other medical, musculoskeletal or neurological conditions that may have impacted walking. Mean age was 61.1 years ($SD = 15$), mean height 167.9 cm ($SD = 9.23$) and participants were first tested a median of 60.7 days ($SD = 47.2$) post stroke. Participant characteristics are provided in Table 1.

1.2. Apparatus

Data were recorded by a six or eight camera VICON 612 3D motion system[1] and AMTI forceplate.[2] During the obstructed trials a red coloured balsa wood obstacle measuring 40 mm high × 1.5 mm thick × 600 mm long was positioned after the forceplate, approximately 5 m from the start. Data processing utilised Vicon BodyBuilder® Version 3.55 (build 136).[1]

1.3. Procedure

Participants wore loose fitting shorts, walking shoes and any prescription eyewear. Anthropometric measures were obtained (Vicon Plug-in Gait Product Guide[1]) and twenty-one 14 mm passive reflective markers were placed on the lower limbs, [12,13] acromions and obstacle as previously described [3].

Participants performed four unobstructed walking trials at self-selected speed, followed by eight trials with the obstacle. They were instructed to walk at self-selected speed and step over the obstacle without contacting it or losing balance. Participants were accompanied by a therapist, who walked behind and to the side of the subject lightly holding a safety belt. Assistance was only provided if required.

Participants repeated the test procedure one month later (mean 29.5 days, $SD = 5.4$). During this time they received their usual physiotherapy. No attempt was made to standardise or prescribe the type of treatment received; however, as 'receiving physiotherapy for a gait or balance disorder' was a criterion for inclusion, it was assumed that a portion of therapy was directed towards these issues.

1.4. Gait variables: data processing

For each participant, one trial leading with the affected limb and one trial leading with the unaffected limb were analysed for each test. The first trial with adequate data (minimal marker occlusion and clean forceplate strike, if available) was selected. The gait pattern utilised by people with stroke to cross an obstacle was fairly consistent over three attempts within a single session [11], so the selection of one trial for analysis was justified. Trials were excluded from motion analysis if the participant required assistance to maintain balance.

Data were filtered using Woltring filtering routine with a predicted Mean-Squared-Error value of 20. BodyBuilder®[1] was used to create 'virtual markers' on the shoe at the most distal point of the toe and heel. Data were exported to Microsoft Excel to calculate obstacle crossing gait speed (trail heel contact pre-obstacle to trail heel contact post-obstacle), lead and trail limb pre-obstacle horizontal distance (lead or trail heel position before the obstacle to the obstacle), vertical toe clearance (top of the obstacle to the lead or trail toe) and post-obstacle horizontal distance (lead or trail heel position after the obstacle to the obstacle). Foot contact and toe off events were obtained from BodyBuilder® by visual inspection of the position of the virtual markers on the heel and toe. Lead limb swing time was from lead limb toe off pre-obstacle to lead limb foot contact post-obstacle. Trail limb swing time was from trail limb toe off pre-obstacle to foot contact post-obstacle. Crossing double support time was from lead foot contact post-obstacle to trail toe off pre-obstacle. More details on data processing have been previously reported [3].

1.5. Statistical analysis

Statistical analyses were undertaken using IBM SPSS Version 20 for Windows.[3] Paired *t* tests were used to determine whether level over-ground walking speed had changed between the two test sessions.

To determine whether obstacle crossing gait speed or spatiotemporal variables changed over the one month period, data from trials leading with the affected limb and unaffected limb were analysed separately. While most spatial data were normally distributed, temporal data were skewed. Therefore paired *t* tests were used for spatial data and Wilcoxon Signed Rank tests were used for temporal data. Effect sizes were calculated for all data. For parametric tests, effect sizes of 0.8, 0.5 and 0.2 were interpreted as large, medium and small respectively [14]. For nonparametric tests, effect sizes of 0.5, 0.3 and 0.1 were interpreted as large, medium and small respectively [15]. To determine whether changes in obstacle crossing speed were associated with changes in level over-ground walking speed, correlations between the difference scores for the two tests were calculated using Pearson's *r*. As this was an exploratory study and risks associated with a Type I error were low, no corrections for multiple tests were applied.

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[2] Advanced Mechanical Technology, Inc.: Watertown, MA.

[3] IBM SPSS Inc© IBM Corporation.