A Stroop Stepping Test (SST) using low-cost computer game technology discriminates between older fallers and non-fallers

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Abstract

Background: Impaired stepping and reduced cognitive functioning have both been identified as fall-risk factors in older people. We developed a Stroop Stepping Test (SST) that combines stepping and response inhibition using low-cost computer game technology to provide a functional measure that reflects real-life behaviour and determined whether this test discrimi- nates between older fallers and non-fallers.

Methods: A cross-sectional study, including 103 independent living cognitively intact older people (70–93 years), was conducted. Participants were assessed on the SST and other outcome measures associated with fall-risk. The SST presented arrows on a computer screen with words written within them. Participants were asked to step in the direction indicated by the word and ignore the arrow orientation. Participants also reported whether they had fallen or not in the past 12 months.

Results: Twenty-eight percent of participants reported falling in the past year. SST mean time per trial and SST errors were associated with falls. After adjusting for other fall-risk factors in a multivariate logistic regression analysis, each error made during SST increased the odds of falling by a factor 1.7.

Conclusions: This study shows the SST—a low-cost video game device—is feasible for older people to undertake. The SST was able to distinguish fallers from non-fallers, providing a novel way to explore cognitive mechanisms for fall-risk in older people.

Keywords: accidental falls, assessment, stepping, executive function, inhibition, older people

Introduction

Poor reactive and volitional stepping have been identified as risk factors for falls in older people [1–5] showing that reflexive responses and executive function (EF) are important to maintain balance [6]. An important aspect of EF involves attending selectively to one stimulus while inhibiting other sensory inputs and motor outputs. Studies showing that impaired inhibition is associated with falls have used neuropsychological assessments that are not specific to balance control and therefore might not identify early or small functional impairments resulting in slowed or erroneous motor responses as a consequence of impaired inhibition [4, 7, 8]. Other studies have used sophisticated laboratory equipment making their use in clinical practice questionable [9, 10]. We developed a low-cost Stroop Stepping Test (SST) using dance pads adapted from exercise-based video games. SST involves both stepping and inhibition to provide a measure that reflects complex real-life behaviour. We assessed (i) whether the SST is feasible for older people to undertake, (ii) whether SST performance is associated with validated fall-risk measures and (iii) whether the SST can distinguish fallers from non-fallers.

Methods

Participants were recruited from retirement villages in Sydney, Australia. Inclusion criteria were age over 70 years, independent-living, ambulant with or without a walking aid, able to step unassisted on a step pad. People were excluded if
they were cognitively impaired (MMSE <24), were colour-blind or had visual impairments that could not be corrected, had neurodegenerative disorders or suffered from limiting lower limb pain. Written informed consent was obtained from all participants prior to the study which was approved by the Human Research Ethics Committee at the University of New South Wales.

**SST**

SST was administered using a custom-made dance pad (150 × 90 cm) which was connected to a computer and display screen (1280 × 768 pixels; 60 Hz; 58 cm) (Figure 1). An arrow was presented in the centre of the screen pointing in one of four directions (up, down, left and right) that matched the four possible step directions (forward, backward, left and right). A word indicating a different direction was written inside the arrow. Participants were instructed to ‘Step by the word’ and therefore had to inhibit the response indicated by the arrow’s orientation. Four practice trials, followed by a random sequence of 20 trials in which the directions of word and orientation never matched were administered. The required step size was small (25–30 cm). The average time (ms) to complete a trial (excluding trials with error) and number of errors were recorded.

**Fall-risk assessment**

Sensorimotor function was assessed with visual contrast sensitivity, proprioception, knee extension strength, simple reaction time and postural sway [11]. Choice Stepping Reaction Time was used to measure the ability to perform accurate rapid steps [12]. Functional mobility was assessed with the Timed-Up and Go test [13] and the Alternate Step Test (AST) [14]. Attention and processing speed was assessed using the Digit Symbol Substitution Test [15] and Trail Making Test (TMT) Part A. EF was assessed using the TMT Part B [16] and Stroop test [16]. Delayed recall was taken from the MMSE. The 10-item Iconographical Falls Efficacy Scale was used to measure fear of falling [17].

Participants who reported ≥1 falls in the past 12 months were classified as fallers. A fall was defined as ‘an unexpected event in which the participants come to rest on the ground, floor, or lower level’ [18].

Pearson and Spearman-Rank correlations were used to assess associations between outcome variables. Univariate and multivariate logistic regression analyses were used to calculate odds ratios for the associations between the outcome measures and falls while adjusting for other fall-risk variables (if $P < 0.15$ in univariate analysis). Age, gender, education, delayed recall (dichotomised), lower limb pain and use of walking aids were selected as potential confounders for the relationship between SST performance and falls. Data were analysed with SPSS version 20 for Windows.

**Results**

One hundred and fourteen individuals showed interest in participating in this study, of which 11 were excluded because they did not fulfil the inclusion criteria. All remaining 103 participants (mean age = 79.5 ± 4.8 years, mean MMSE = 28.9 ± 1.1) were able to complete SST in under three minutes. No adverse events were recorded.

Taking longer to complete each SST trial was associated with poorer scores in nearly all other measures (Supplementary data are available in Age and Ageing online, Appendix 1, Table S1). Making more errors on the SST was associated with poorer EF and proprioception but not with any other sensorimotor measures.

Twenty-nine participants (28%) reported falling in the past year. Characteristics of fallers and non-fallers are reported in Table 1. Fallers took longer to complete each SST trial (3.0 ± 1.2 versus 2.6 ± 0.6 s) and made more stepping errors (1.7 ± 2.2 versus 0.6 ± 1.1) than non-fallers. They also scored worse on postural sway, knee extension strength, AST and fear of falling. No difference was observed in any of the cognitive measures except for delayed recall, where participants with better memory scores were more likely to have reported a fall.

After adjusting for sensorimotor and cognitive explanatory variables related to falls in older people, each error made on the SST task increased the odds of having had a fall 1.7 times [OR: 1.65 (1.17–2.34)]. Fear of falling, sway and delayed recall also independently discriminated fallers from non-fallers in the final model when adjusting for potential confounding factors [Supplementary data are available in Age and Ageing online, Appendix 2, Table S2)].

Figure 1. SST: participant stepping according to the word and not the arrow orientation.
The time to complete a SST trial correlated significantly with measures of EF, processing speed, balance and step coordination. This suggests SST time shares characteristics with a range of physical and cognitive functioning measures that are associated with fall-risk. The SST may therefore be considered a composite measure and may provide a more robust estimate of fall-risk compared with clinical tests that assess physical function [20]. The inclusion of this measure suggests that it measures an aspect of fall-risk that is not completely encompassed by balance and stepping measures.

Several studies have found that standard neuropsychological measures of EF predict falls in older people [4, 7, 8]. However, in line with others, we could not confirm this [21, 22]. These discrepancies may be due to differing sample characteristics, faller group classifications and neuropsychological measures used. In contrast, the time and error measures of the SST, which combine EF within a stepping task, showed differences between fallers and non-fallers. This suggests that the composite measurement of inhibition and stepping in a functional context increases discriminative ability for fall-risk. This is in agreement with recent findings showing that the incorporation of Stroop tasks into real-world scenarios improved the ability to detect functional differences in healthy and cognitively impaired people [23, 24]. Finally, we found that older adults with better recall ability were more likely to report falls, most likely reflecting better fall events recall [25].

The SST is portable, easy to set-up and quick to administer. All participants could complete the task including those with previous results showing that inhibition is an important factor in step initiation and that a deficit leads to increased error rates and slowed reaction times [9, 10].
who normally used walking aids. The lack of a floor effect is important as often those people at higher risk are unable to complete assessments due to difficulty of the involved tasks. The low-cost of the equipment also makes it more feasible for translation into clinical practice than highly specialised laboratory equipment.

We acknowledge that this study has certain limitations. The retrospective recording of falls may have underestimated the true prevalence of fall events. However, a history of falls has been shown to be a good predictor of future falls [26] and by including a delayed recall item in the analysis, we tried to control for recall bias. Second, older people with physical frailty or cognitive impairment might not be able to undertake the SST possibly limiting its external validity. Finally, the SST in its current form did not include any cross-over steps, a possible movement strategy for avoiding falls.

Conclusions

The SST, a screening test that combines stepping with response inhibition, was able to distinguish between older fallers and non-fallers. The current study shows the feasibility of using a low-cost video game device for the assessment of older people. Further studies are needed to prospectively validate this test, assess its ability to detect clinically meaningful changes and determine its reliability.

Key points

• A SST that combines executive functioning and rapid stepping using computer game technology was developed.
• In contrast to standard neuropsychological tests, the SST was able to discriminate between fallers and non-fallers.
• By combining both cognitive and physical factors, the SST is a functionally relevant means of assessing fall-risk.

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Conflicts of interest

None declared.

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Supplementary data

Supplementary data mentioned in the text is available to subscribers in Age and Ageing online.

References

C-reactive protein, APOE genotype and longitudinal cognitive change in an older population

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Abstract

Background: circulating measures of inflammatory markers, such as C-reactive protein (CRP) have been associated with an increased risk of future cognitive decline. However, the nature of the relationship among the very old (>75 years) is unclear. Cross-sectional evidence suggests that elevated CRP may even be protective in this age group. This study examines these associations longitudinally.