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Validation of an environmentally-friendly and affordable cardboard 9-hole peg test

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ABSTRACT

Background: In multiple sclerosis (MS) upper limb neurological impairments, are an important driver of disability and handicap. The gold standard for assessing upper limb function is the 9-hole peg test (9HPT). One disadvantage of the current plastic version is its price, which prevents its widespread use as a self-monitoring tool by the MS community.

Objective: To develop and validate an affordable cardboard version of 9HPT for patients to self-monitor upper limb function at home. The aim is not to replace the plastic version, which would stay the gold standard in MS centers.

Methods: We enrolled 177 volunteers, 68 healthy controls and 109 people with MS (pwMS) at varying stages of their disease. Volunteers performed two trials of the 9HPT with their dominant hand and two with their non-dominant hand using both plastic 9HPT and cardboard 9HPT. The primary comparison parameter was the time needed to perform the task.

Results: The mean score for the cardboard 9HPT was 24.58 (SEM 1.54 s) seconds compared to 26.03 (SEM 1.44 s) seconds for the plastic 9HPT ($p = 0.007$). However, the two versions of the tests correlated very strongly, $r = 0.96$ ($p < 0.001$). The coefficient of variation, repeat-repeat testing, showed less variability with the cardboard version than in the plastic one with 10% and 14%, respectively. Two-thirds of pwMS preferred using the cardboard version.

Conclusion: This study demonstrates that the cardboard version is at least equivalent to the plastic version of the test with arguably better design attributes making it the preferred option for self-monitoring.

1. Introduction

Multiple sclerosis (MS) is a chronic immune-mediated and degenerative disease of the central nervous system (Barnett and Prineas, 2004; Compston and Coles, 2008).

Among the symptoms observed in PwMS, upper limb (UL) dysfunction are of particular importance. Together with difficulties walking, fatigue, and cognitive deficits, UL dysfunction is among the most common neurological problem in pwMS (Kister et al., 2013).

In MS, the 9-hole peg test (9HPT) has been standardised and validated (Schwid et al., 1997). Changes in the 9HPT scores have been found to be closely related to disabilities that impact on activities of daily living (Kragt et al., 2006). Importantly the 9HPT interrogates the functioning of several neurological systems, i.e. Power, visual attention, depth perception, sensory perception and coordination. The 9HPT has become de facto the gold standard outcome measure for assessing, and monitoring, UL function in MS.

The current 9HPT plastic version is expensive, not environmentally friendly and the plastic pegs are slippery. The current commercial test kit is only available as a "plastic" version to allow disinfection between subjects, costing approximately $55 online (Amazon, last accessed 14/03/2017).

As part of a PPI (patient public involvement) programme, with the aim of empowering people to monitor their disease using validated outcome measures, we designed a cheap and environmentally friendly version of the 9HPT using cardboard and commercially available

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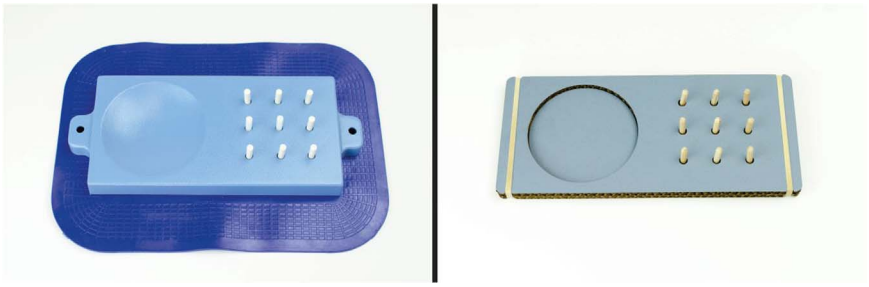

Fig. 1. Cardboard and plastic 9HPT. The original plastic 9HPT on the left and our new cardboard 9HPT on the right. See http://www.clinicspeak.com/9-hole-peg-test/ for more information on how to order or manufacture a cardboard 9HPT, how to replace lost pegs, an instruction video and how to record your times.

wooden dowel pegs (Fig. 1) and mass-produced it. In this study, we validated our 9HPT version by comparison of the scores collected using the cardboard version with the scores collected using the 'plastic version'.

2. Methods

2.1. Volunteers

Between August and September 2016, 177 male and female subjects, of which 68 were normal controls, and 109 pwMS, mean age 46 years [range = 20–84]), volunteered to validate the 9HPT. Volunteers were recruited in day care unit, clinics, research day and conferences. The only inclusion criteria was being diagnosed with MS. The 9HPT validation did not meet the NHS definition of research hence IRB approval was not required. Volunteers performed two trials of the 9HPT with their dominant hand and two with their non-dominant hand using both the plastic 9HPT and the cardboard 9HPT. In the MS group, 4 patients did not manage to use their dominant hand because of pain, hence these volunteers were excluded from the study. The 9HPT was first performed with the dominant hand and subsequently with the non-dominant hand, according to the standardised instructions given as part of the MSFC (MS functional composite)(Ontaneda et al., 2012). Cardboard and plastic tests were performed strictly one after the other. We consecutively alternated the starting test, according to the patient's arrival order in the 9HPT stand, to prevent a systematic learning effect affecting the performance of the second test.

The primary comparison parameter was the time needed to perform the task. Each task being composed of two attempts, with an average calculated for each volunteer. Once the tests were completed, 87 of the 106 pwMS, were asked which version of the 9HPT they preferred using the most (cardboard or the plastic).

2.2. Statistical analysis

Excel 2016 was used to perform all the statistics. A Q-Q plot tested whether the sample population was normally distributed. The overall distribution of the 9HPT times were positively skewed by some very slow times. Therefore, the continuous variables were converted to log scale. Results are reported as mean ± standard deviation of the mean (SD) and were represented in the form of a box-and-whisker plot (see Table 1). Paired *t*-Test p values < 0.05 were performed to explore whether the two groups (cardboard and plastic) are equivalent. The two-tailed p-value are indicated to confirm the significance of the results. Spearman's rank correlation was used to estimate correlations between the cardboard and plastic user groups in order to confirm the equivalence of the two 9HPT versions. Finally, the coefficient of variation (CV) of both group was assessed to explore differences between them.

3. Results

A total of 177 people participated in the study, 121 females (68%) and 56 males (32%).

Volunteers were allocated into (see Table 2) Group 1 that contained 68 healthy control (HC) people, while Group 2 was composed of 109 pwMS, 71 females (65%). The pwMS were at varying stages of their disease. Results from 4 volunteers from Group 2 were excluded as they could not use their dominant hand because of pain.

We focused exclusively on the scores obtained with the dominant hand (173 patients).

When all the volunteers were considered together, the mean score for the cardboard 9HPT (c9HPT) was 24.58 s (SEM 1.54 s) compared to 26.03 s (SEM 1.44 s) for the plastic 9HPT (p9HPT) ($p = 0.007$).

In the HC the mean results were 18.35 ± 0.9 s for the c9HPT versus 19.19 ± 0.9 for the p9HPT ($p < 0.001$). In the pwMS group mean for the c9HPT was 28.61 ± 2.38 versus 30.47 ± 2.19 s for the p9HPT ($p = 0.03$).

The Q-Q plot test showed that the population distribution was not normal. In the Cardboard group patients perform the test with a minimum at 12.66 s, the median was 19.39 s and a maximum of 229 s. The IQR was 9 s. In the Plastic group the minimum was 12.85 s, the median was 20.78 s and the maximum was 177.58 s with an IQR = 8.5 s.

Although the performance of the c9HPT was slightly quicker than the p9HPT the results of the two tests correlated very strongly. Overall the correlation (r) taken with a logarithmic conversion of the mean was 0.96 ($p < 0.001$), 0.94 for the HCs ($p < 0.001$) and 0.95 for the pwMS ($p < 0.001$) (Fig. 2).

The coefficient of variation within each group was assessed to explore differences between the two 9HPT versions. The CV is the result of the intra-subject variation between the first and the second attempt. In this specific comparison, 8 volunteers from Group 2 were excluded because they were unable to perform two attempts in a row.

When HC and pwMS were considered together, the c9HPT group performed both attempts with a CV of 10% compared to the p9HPT group where the CV was 14%.

This difference is probably due to fewer slower times from dropping

Table 1
Summary results of the cardboard (c9HPT) and plastic 9HPT (p9HPT).

	Combined c9HPT	Combined p9HPT	Dominant c9HPT	Dominant p9HPT	Non-dominant c9HPT	Non-Dominant p9HPT
Overall group	23.13 (n = 109)	24.88 (n = 108)	24.58 (n = 173)	26.03 (n = 173)	23.83 (n = 112)	25.22 (n = 111)
Heath Controls	19.52 (n = 43)	20.39 (n = 43)	18.35 (n = 68)	19.19 (n = 68)	20.23 (n = 43)	20.76 (n = 43)
People with MS	25.48 (n = 66)	27.85 (n = 65)	28.61 (n = 105)	30.47 (n = 105)	26.08 (n = 69)	28.04 (n = 68)