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ORIGINAL REPORT

GAIT IMPROVEMENT IN ADULTS WITH HEMIPARESIS USING A ROLLING CANE: A CROSS-OVER TRIAL

Thierry DELTOMBE, MD[1], Mie LEEUWERCK, PT[1], Jacques JAMART, MD[2], Anne FREDERICK, MD[3] and Geoffroy DELLICOUR, PT[3,4]

From the [1]Physical Medicine & Rehabilitation Department, [2]Biostatistics Department, CHU UCL Namur site Godinne, Yvoir, [3]Centre Hospitalier Neurologique William-Lennox and [4]Innorehab, B-1340 Ottignies, Belgium

Objective: To assess the changes in gait parameters in adults with hemiparesis using a rolling cane (quadripod cane with small wheels; Wheeleo®) compared with a classical quadripod cane.

Design: A prospective, multicentric, cross-over randomized trial.

Participants: Thirty-two ambulatory adults with hemiparesis.

Methods: Participants were assessed using a quadripod cane and a rolling cane. Outcome measures were changes in: walking speed during a 10-m walk test and a 6-min walk test; frequency of 2-step gait; physiological cost index; number of therapist interventions to control the balance; perceived exertion; and participant satisfaction.

Results: The following outcomes were improved with the use of a rolling cane: walking speed during a 10-m walk test at comfortable (+22%: $p<0.001$) and maximal (+30%: $p<0.001$) speeds; walking speed (+50%: $p<0.001$) and distance (+49%: $p<0.001$) during a 6-min walk test; and the frequency of 2-step gait. The physiological cost index, perceived exertion, and number of therapist interventions to control the balance remained unchanged. Participant satisfaction improved.

Conclusion: A rolling cane, Wheeleo®, increases walking speed in adults with hemiparesis without additional risk of falls.

Key words: hemiplegia; fall, assistive device; walking speed.

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Correspondence address: Thierry Deltombe, Physical Medicine & Rehabilitation Department, CHU UCL Namur site Godinne, Yvoir, Belgium. E-mail: thierry.deltombe@uclouvain.be

LAY ABSTRACT

Stroke patients frequently require a quadripod cane for walking. The Wheeleo® rolling cane has small wheels, allowing the patient to roll the cane instead of lifting it. Compared with a quadripod cane, this study found that the rolling cane improved walking speed and distance without additional risk of falls. Patient satisfaction was increased. The rolling cane can therefore be used as a rehabilitation device for these patients.

Stroke is the major cause of severe disability in industrialized countries. While the overall goal of rehabilitation after a stroke is to maximize the individual functional independence at home and in the community, the treatment goal most often stated is to improve walking function (1). Approximately 80% of hemiparetic patients after stroke regain walking function with decreased walking speed, asymmetrical gait pattern and increased risk of falls (2-4). Consequently, adults with hemiparesis frequently require walking aids, such as a single-point cane, crutch, 4-point cane, hemi-walker or rollator. Individuals who do not load more than 40% of their body weight on their paretic lower limb could benefit from the use of a cane (5). The choice of a specific walking aid depends on multiple factors, including the degree of balance impairment, the sensorimotor deficits of both upper and lower extremities, cognitive ability, environmental constraints and individual preferences (1). The quadripod cane, with a greater base of support, leading to reduced sway and increased stability during the stance phase, is frequently mandatory for individuals with poor balance (6, 7). However, the cane has to be lifted and advanced. This pattern induces a 3-step gait, which limits walking speed. Similarly, in the elderly patient, the use of a fixed-frame walker leads to a major increase in gait physiological cost index in comparison with a walker with front wheels (8). In order to construct a rolling cane that can be used with one hand, we added small wheels to a quadripod cane. The patient rolls the cane instead of lifting it. However, there was concern that the wheels could disturb the user's balance and increase falls.

The aim of the present study was to prospectively assess efficacy (gait speed, endurance, energy cost), safety and patient satisfaction when using a Wheeleo® rolling cane in comparison with a quadripod cane in adults with hemiparesis. The study hypothesis was that removing the induced 3-step gait pattern on a 2-step gait, by means of a rolling cane may increase walking speed and decrease energy cost without additional risk of falls.

METHODS

Design

The study followed a multicentre, prospective, randomized, crossover design. It was conducted in agreement with the CONSORT statement (http://www.consort-statement.org) and was registered at ClinicalTrial.gov number NCT02279069.

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Participants

Adults with hemiparesis due to stroke or traumatic brain injury were recruited in the rehabilitation departments of Godinne (CHU UCL Namur) and Ottignies (Centre Hospitalier Neurologique William Lennox) in Belgium. Inclusion criteria were: age over 18 years; a history of hemiparesis as a consequence of a stroke or traumatic brain injury; use of a quadripod cane for walking; the ability to walk independently without additional help or support; and the capability to use the rolling cane for a few steps. Exclusion criteria were: severe cognitive deficits and the need for an external support or therapist assistance to combat imbalance. The CHU UCL Namur site Godinne ethics committee approved the study, and informed consent was obtained from all participants before starting the study.

Between January 2016 and March 2017, 45 adults with hemiparesis necessitating a quadripod cane for walking were screened for eligibility and 32 met the inclusion and agreed to participate. Three participants refused to participate because they were afraid of using the rolling cane. Each participant completed 2 experimental sessions with either a quadripod cane or Wheeleo® rolling cane at 1–7 days interval. No patient dropped out during the study. A CONSORT flow diagram of the protocol is provided in Fig 1.

Randomization

The 2 experiments were randomly performed. Constrained randomization was performed by means of sealed envelopes.

Intervention

All of the participants benefited from a short (few minutes) training session performed by the physical therapist involved in the study to familiarize themselves with the rolling cane. The rolling cane Wheeleo® is a new device. It weighs 2.7 kg and the height can be adapted from 74 to 98 cm. Before starting the experiment, the global neurological impairments were assessed using the Stroke Impairment Assessment Set (SIAS) (9). The resting heart rate (RHR), in beats per min (bpm), and the presence of beta-blocker medication were also monitored. During each session (with the quadripod cane (Fig. 2) or rolling cane (Fig. 3)),

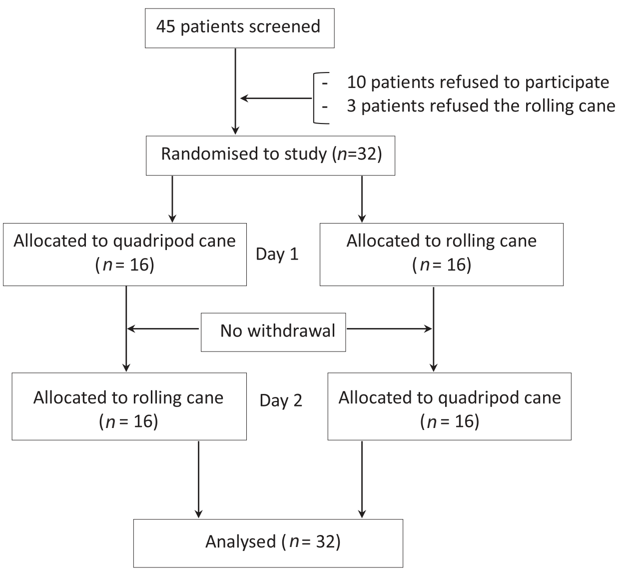

Fig. 1. CONSORT (Consolidated Standards of Reporting Trials) flow chart.

Fig. 2 Quadripod cane.

Fig. 3 Rolling cane.

the participants were assessed by the same physical therapist who did not provide any encouragement or distract the participants. Participants performed, in the following order: a 10-m walk test (10MWT) at spontaneous speed, a 10MWT at maximal speed, and a 6-min walk test (6MWT) at spontaneous speed. The 6MWT was performed over a 30-m distance with half-turns. Between each test, the participants were invited to rest in order to return to their baseline heart rate. The primary outcome was the change in walking speed (WS), in m/s, during a 10MWT at spontaneous speed using a rolling cane compared with a quadripod cane. The secondary outcomes were the change in walking speed during a 10MWT at maximal speed, and during a 6MWT, in cadence (steps/min), in the type of gait (2-step or 3-step) and in the physiological cost index (PCI) during a 6MWT. A 2-step gait was clinically defined as the ability to move the cane while moving a leg. A 3-step gait was defined as the necessity for the participant to stop moving their legs when moving the cane. The first step is to move the quadripod cane with the non-paretic hand, the second step is to move the paretic leg and the third and last step is to move the non-paretic leg. The maximal heart rate (MHR), in bpm, was monitored during each test. The physiological cost index (PCI), in beats per metre, was calculated for each test in participants who did not take beta-blocker medication as follows: PCI = MHR – RHR/WS (10). The heart rate was monitored with a sports watch (Polar, Kempele, Finland). During each test, the therapist was requested to stay close to the participant to prevent falls. Each time the therapist was confronted with an imbalance (even without a fall), they were allowed to touch the participant to reinforce the sense of security and was asked to note the number of participants who necessitated a contact. After each experiment (quadripod cane or rolling cane), the perceived exertion was assessed with the modified Borg scale graded 0 to 10 and the global participant satisfaction related to the device (as an answer to the question "What is your satisfaction level with regards to

Table I. Demographic and clinical characteristics of participants at baseline

Characteristics	
Participants, *n*	32
Age, years, median (IQR)	63 [55:71]
Height, cm, median (IQR)	166 [160:172]
Weight, kg, median (IQR)	68 [59:80]
Right/left affected side, *n* (%)	19 (59.4)/13 (37.5)
SIAS, median (IQR)	45 [38:51]
Delay, months, median (IQR)	4 [2:7]
Aetiology, *n* (%)	
Ischaemic	19 (59.4)
Haemorrhagic	12 (37.5)
Traumatic	1 (3.1)
Beta-blockers, *n* (%)	8 (25)

SIAS: Stroke Impairment Assessment Set; IQR: Interquartile range.

ease of use and sense of safety") was recorded by means of a VAS graded 0–10.

Statistical analysis

A clinically relevant difference was defined as 0.22 m/s for a 10-m walk test at spontaneous speed. The estimation of standard error of the mean (SEM) of 0.04 m/s on 100 subjects (11) allowed us to estimate an effect size of 0.55. A sample size of 30 subjects was thus required in a cross-over trial for detecting such an effect size with an alpha error level of 0.05 and a power of 0.80 by a 2-tailed Wilcoxon-signed rank test. Computation was performed by G*Power 3.1.9.2 software (12). Numerical variables are expressed as medians with first and third quartiles in parentheses, and were compared between the 2 situations by Wilcoxon signed-rank test. Categorical variables were compared by McNemar test. All tests are 2-tailed and were performed by SPSS 18.0 software (SPSS Inc., Chicago, IL, USA).

RESULTS

Participant's characteristics are found in Table I. Data were obtained from all participants who received experiments in the order allocated.

Table II shows the results obtained with the quadripod cane and the rolling cane (Table II). When using a rolling cane, the walking speed assessed during a 10MWT at spontaneous speed (primary outcome) increased from 0.36 to 0.44 m/s (+22%, $p<0.001$) in relation to a decrease in time spent to walk 10 m from 27.8 to 22.5 s (–19%, $p=0.001$). This was associated with an increase in cadence (+19%, $p=0.002$). The period when each cane was used (order effect) was not relevant, as walking speed was 0.36 m/s whatever the period with quadripod cane (NS, $p>0.50$) and 0.43 m/s and 0.47 m/s (NS, $p>0.50$) during the first and second period, respectively, with the rolling cane. The walking speed also increased during a 10MWT at maximal speed, from 0.44 to 0.57 m/s (+30%, $p<0.001$) and during a 6MWT from 0.36 to 0.54 m/s (+50%, $p<0.001$). As a consequence, the median distance during the 6MWT increased from 131 to 195 m (+49%, $p<0.001$). The number of participants walking with a 2-step gait increased during the 10MWT at comfortable speed from 22/32 to 29/32 (+22%, $p=0.016$), and maximal speed from 24/32 to 30/32 (+25%, $p=0.031$). The PCI during the 6MWT and the global perceived exertion on the Borg scale stayed unchanged. The number of contacts with the therapist remained unchanged as only one participant in each experimental group needed a contact with the therapist due to imbalance during the 10MWT at spontaneous speed. Finally, the participants' median satisfaction increased significantly from 6 [IQR 4: 8] with the quadripod cane to 8 [IQR 7: 10] with the rolling cane ($p=0.006$).

DISCUSSION

The use of a cane or crutch in adults with hemiparesis is known to increase gait symmetry and gait speed in both comfortable and fast walking conditions, especially when the baseline speed ranges from 0.4 to

Table II. Medians with first and third quartiles into brackets of walking speed (m/s), time (s), cadence, distance (m), frequency of 2-step gait, physiological cost index and number of contact with the therapist during a 10-m walk test (10 MWT) at spontaneous and maximal gait speed and during a 6-min walk test (6 MWT) at spontaneous gait speed with a quadripod cane and a rolling cane. The number of participants who necessitated a contact with therapists is expressed as a percentage

	10MWT						6MWT		
	Comfortable speed			Maximal speed			Comfortable speed		
	Quadripod	Rolling cane	Comparison % change	Quadripod	Rolling cane	Comparison % change	Quadripod	Rolling cane	Comparison % change
Walking speed, m/s, median (IQR)	0.36 [0.27:0.49]	0.44 [0.33:0.58]	$p<0.001$ 22%	0.44 [0.32:0.62]	0.57 [0.42:0.76]	$p<0.001$ 30%	0.36 [0.25:0.58]	0.54 [0.34:0.70]	$p<0.001$ 50%
Cadence/min, median (IQR)	63 [50:82]	75 [61:90]	$p=0.002$ 19%	77 [57:94]	83 [67:98]	$p<0.001$ 8%	NA	NA	
2-step frequency, *n* (%)	22 (69)	29 (91)	$p=0.016$ 22%	24 (75%	30 (94)	$p=0.031$ 25%	24 (75)	29 (91)	NS
PCI, beats/m, median (IQR)	NA	NA		NA	NA		1.09 [0.69:2.36]	1.25 [0.73:1.92]	NS
Number of participants in contact with therapists, *n* (%)	1 (3)	1 (3)	NS	1 (3)	2 (6)	NS	7 (22)	9 (28)	NS

NA:not applicable; NS: not significant; IQR: interquartile range.

0.8 m/s (13–15). When an individual is not stabilized with a single-point cane and is unable to use walker due to upper extremity impairments (or does not have enough space), a quadripod cane is recommended (1). However, the gait symmetry, gait velocity and gait endurance achieved with a quadripod cane are significantly lower than with a single-point cane, and the energy cost is significantly higher (6, 13, 16).

This study found that adults with hemiparesis using a rolling cane walked faster at comfortable and maximal walking speeds, allowing them to walk a longer distance. The walking speed obtained when using a rolling cane at comfortable speed is the same as when using a quadripod cane at maximal speed. This increase in walking speed was due to a step cadence increase obtained by a more frequent 2-step gait and potentially by facilitation in half-turns during the 6MWT. It has been shown that the balance and gait speed are correlated with the quality of life in adults with hemiparesis (17). Therefore, improving balance and gait speed are frequent goals of the rehabilitation process. Jeong et al. (16) and Allet et al. (17) demonstrated that the adults with hemiparesis walked for a longer distance on the 6MWT with a simple cane (mean 115.5 (SD 55) and 135 (SD 36) m, respectively) than with a quadripod cane (mean 101.4 (SD 54) and 92.6 (SD 22) m, respectively) (6, 17). The improvement obtained in the current study when using a rolling cane is equivalent to these results. We postulate that the increase in walking speed and distance obtained with a rolling cane is equivalent to the results obtained with a single-point cane (6). An important distinction, in contrast with these studies, is that our participants were not stable enough with a single-point cane, and therefore required the use of a quadripod cane. Therefore, the rolling cane allowed individuals who were unable to use a single-point cane to walk as fast as if they were using one.

Secondly, adults with hemiparesis using a rolling cane more frequently walked with a 2-step gait, leading to an increase in cadence and walking speed. Indeed, individuals who require a quadripod cane frequently use a 3-step gait, which reduces walking speed. Fortunately, some patients using a quadripod cane are able to move the cane and the paretic leg simultaneously to produce a 2-step gait. When using a rolling cane all, but 3 participants walked with a 2-step gait. This is the most likely explanation of the walking speed improvement, as the participants did not need to stop moving the foot to move the cane.

Thirdly, the energy consumption, as measured by the PCI, and the perceived exertion, measured by the modified Borg scale, stayed unchanged. The physiological cost index (PCI) is based on the parallel evolution between the oxygen energy consumption (VO_2) and heart rate (HR) during a walking test (16). The PCI reflects the heart rate function, and thus indirectly the O_2 consumption. The best PCI is obtained when the subject walks at a spontaneous comfortable speed (10). While gait asymmetry is known to be correlated with an increase in metabolic cost, the reduction in gait asymmetry observed with the rolling cane was not correlated with a reduction in energy consumption or a reduction in perceived exertion (18).

Fourthly, the risk of falling, measured by the number of participants who needed contact with the therapist to improve stability or increase the sense of security, was unchanged in all conditions, supporting the fact that the rolling cane does not increase the risk of falling when used under therapist supervision. This is important, as individuals using a quadripod cane are usually severely affected, with a high risk of falls. The addition of wheels to the cane allows it to move laterally. Thus, at first, use of the rolling cane may produce a fear of falls and a decreased sense of security, as the cane may roll laterally instead of anteriorly.

Finally, the improved participant satisfaction associated with an increased walking speed could contribute to a better autonomy, and therefore an increase in social participation. Indeed, it has been demonstrated that adults with hemiparesis walking with slow gait speed and using a cane had less social participation than their age-matched counterparts who walked unaided (19, 20).

Limitations

This study and the device have several limitations. First, the rolling cane was only tested during a supervised activity under the assistance of a specialized therapist, which does not mimic real life use. It cannot be used on irregular ground, thus it is limited to indoor use. Further studies in real-life conditions are necessary, in particular to assess the risk of falls in daily activities. Secondly, the type of gait (2- or 3-step) has been evaluated clinically, without an instrumented gait laboratory analysis, while the energy consumption has been extrapolated with PCI. Finally, this study mainly focused on the body function and activity level of the International Classification of Functioning (ICF) and did not investigate the participation domain.

Conclusion

This study demonstrates that, in adults with hemiparesis who needed a quadripod cane for walking, use of the Wheeleo® rolling cane increased the walking speed, cadence, distance and the number of participants walking with a 2-step gait without additional risk of falls, resulting in greater participant satisfaction. The rolling cane could be considered as an option and a rehabilitation tool for adults with hemiparesis who are unable to use a single-point cane, in order to improve their independence. Further studies are requested to confirm its safety in daily activities and to better understand the mechanisms underlying these results.

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Conflicts of interest. G. Dellicour is the founder of Innorehab Company, which commercialized the Wheeleo® cane. None of the other authors has any conflicts of interest to declare. No funding was provided to support the study.

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