Discriminative ability of the three functional tests in independent ambulatory patients with spinal cord injury who walked with and without ambulatory assistive devices

**Wilairat Saensook^{1,2,3}, Puttipong Poncumhak^{2,4}, Jiamjit Saengsuwan^{2,5},
Lugkana Mato^{1,2}, Worawan Kamruecha^{1,2}, Sugalya Amatachaya^{1,2}**

¹School of Physical Therapy, Faculty of Associated Medical Sciences, Khon Kaen University, Khon Kaen, Thailand,

²Improvement of Physical Performance and Quality of Life (IPQ) Research Group, Khon Kaen University, Khon Kaen, Thailand, ³Department of Rehabilitation Medicine, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand, ⁴Department of Physical Therapy, School of Allied Health Sciences, University of Phayao, Phayao, Thailand, ⁵Faculty of Public Health, Khon Kaen University, Khon Kaen, Thailand

Background/objectives: Many persons with spinal cord injury (SCI) require an ambulatory assistive device (AAD). An effective monitoring method enables the use of an appropriate AAD and promotes levels of independence for patients. This study investigated the discriminative ability of the three-functional tools relating to walking ability, including the 10-meter walk test (10MWT), the five times sit-to-stand test (FTSST), and the timed up and go test (TUGT), in independent ambulatory persons with SCI who walked with walker, crutches, cane, and non-AAD.

Methods: Eighty-five persons with SCI who could perform sit-to-stand and walk independently at least 50 m were cross-sectionally assessed for their functional ability using the 10MWT, FTSST, and TUGT.

Results: The findings for persons not using AADs were significantly better than the other groups for every test ($P < 0.001$). In addition, persons who walked with cane were significantly different from those who used walkers ($P < 0.001$) but there were no significant differences between persons who used walker and crutches for every test ($P > 0.05$).

Conclusion: The findings supported the discriminative validity of the tools, allowing them to indicate functional changes in persons with SCI who walk with different AADs. However, the non-significant differences between subjects who used a walker and crutches may relate to the method of subject arrangement and inclusion criteria that recruit subjects with rather good walking capability and lower limb function. The findings may also suggest the use of the sit-to-stand maneuver as a simple screening tool for walking advancement of walker users, pending further investigation.

Keywords: Balance, Functional assessment, Muscle strength, Walking, Walking device

Introduction

Approximately 70% of patients with incomplete spinal cord injury (iSCI) retain or regain ambulatory ability after rehabilitation.^{1,2} However, the quality and degree of their ambulation may be affected by sensorimotor dysfunctions such as spasticity, diminished or absent

sensation, muscle weakness, and difficulty with timing and sequencing of muscle activation.^{3,4} Therefore, the ambulatory ability of these patients is likely to be limited to a certain location such as within the house, over a short distance, and requiring lower-extremity braces or an ambulatory assistive device (AAD) such as canes, crutches, and walkers.³⁻⁵

An AAD is commonly prescribed in order to reduce lower-limb loading which helps to alleviate joint pain

Correspondence to: Sugalya Amatachaya, School of Physical Therapy, Faculty of Associated Medical Sciences, Khon Kaen University, Khon Kaen 40002, Thailand. Email: samata@kku.ac.th

or compensate for lower extremity muscle weakness.⁵ In addition, an AAD provides mechanical advantages as well as somatosensory feedback, and increases the body base of support (BOS) which improves balance control and permits independent ambulation.^{6,7} Therefore, using an AAD enables a chance to activate the neuromuscular system below the level of the lesion via task-specific experience of walking training. However, walking with an AAD increases attention, neuromotor, musculoskeletal, physiological, and metabolic demands depending on the supporting ability of the device.^{4,7,8} Some studies also found the association between using an AAD, and musculoskeletal pain and level of functional decline in other groups of subjects.^{9,10} Smidt and Mommens¹¹ report that, when one or two AADs are added, the number of contact points on the floor is greater than two which increases the complexity of the sequencing and timing of floor contact. With several advantages and disadvantages of an AAD, ambulation with a suitable walking device can offer patients the most efficient means of locomotion and locomotor advancement.⁸ The recent evidence also emphasizes that rehabilitation professionals need to closely monitor the ambulatory ability and make appropriate choices for an AAD to promote a level of independence for the patients.⁴

Nowadays, there is a trend toward patients with spinal cord injury (SCI) having a shorter length of stay in a hospital.¹² It is likely that the patients cannot achieve an optimal level of ability at the time of discharge and this increases the requirements of an AAD for daily activities. Waters *et al.*^{13,14} reported that 76% of individuals with incomplete paraplegia and 46% of those with incomplete tetraplegia achieve community ambulation, and the majority of them require an AAD for daily walking. Recent evidence from our colleagues^{15,16} also suggests that more than half of 110 independent ambulatory subjects with iSCI ($n = 65$ or 59%) needed an AAD for daily walking. Among these, 41 subjects used a walker, 9 subjects walked with crutches, and 15 subjects walked with canes. Therefore, using a quantitative standardized assessment relating to the requirement of an AAD would offer useful information to monitor functional changes and promote levels of independence of the patients.

The 10-meter walk test (10MWT) quantifies walking speed that associates with motor function and overall quality of walking.¹⁷ The five times sit-to-stand test (FTSST) correlates with lower extremity muscle strength (LEMS), multiple sensorimotor processes, and balance control while changing postures.^{18,19} The timed up and go test (TUGT) measures balance control during

upright and walking activities.²⁰ Poncumhak *et al.*²¹ report that these tests are practical, valid, and reliable to assess functional ability in patients with SCI who walk with and without an AAD. However, the findings were derived from a group of subjects who used various types of an AAD. A further investigation on the use of these tools to discriminate ability of the patients who walk with walkers, crutches, canes, and non-AAD may adequately direct the use of these tools during inpatient rehabilitation and after discharge. Therefore, this study compared the ability of independent ambulatory patients with SCI who walked with walkers, crutches, canes, and non-AAD using the 10MWT, FTSST, and TUGT.

Methods

Subjects

Independent ambulatory patients with SCI who walked with walkers, crutches, canes, and non-AAD were invited to participate in the study based on the proportion reported previously (4.6:1:1.67:7.2 for walker, crutches, cane, and non-AAD, respectively).^{15,16} The inclusion criteria were the ability of independent walking with and without AAD over at least 50 m continuously (Functional Independence Measure Locomotor scores 6–7). In addition, subjects needed the ability of independent standing up without the use of hands. Any patients with signs and symptoms that might affect participation in the study, i.e. leg length discrepancy and pain in the musculoskeletal system with a pain score of more than 5 out of 10 on a visual analog scale, were excluded. According to the criteria, 125 independent ambulatory patients with SCI agreed to participate in the study. However, 40 of them were excluded because of inability to rise from a chair or bed independently ($n = 39$) and having severe musculoskeletal pain ($n = 1$). Hence, 85 subjects completed the study in which 30 subjects customarily walked with a walker, 7 subjects preferred to use crutches, 11 subjects needed a cane, and 37 subjects did not require any walking devices (non-AAD) (Fig. 1). None of these subjects used multiple AADs. Table 1 presents baseline demographics and SCI characteristics of the subjects. All of them had to sign an informed consent document approved by the local ethics committee prior to taking part in this study.

Procedure

Subjects participated in the study for 2 consecutive days. On the first day, subjects were interviewed and assessed for their baseline demographics (including age, sex, weight, and height), SCI characteristics (including

Figure 1 Subjects participation flow chart.

Table 1 Baseline demographics and spinal cord injury characteristics of the subjects

Variable	Groups of subjects				P value
	Walker (n = 30)	Crutches (n = 7)	Cane (n = 11)	Non-AAD (n = 37)	
Age (years)*	54.00 (37.75–61.25)	39.00 (36.00–51.00)	57 (50.00–63.00)	53.5 (38.75–61.00)	0.65
Body mass index (kg/m ²)*	23.09 (19.64–26.64)	21.30 (19.10–23.14)	25.32 (21.30–26.84)	22.06 (20.46–23.99)	0.565
Post-injury time (months)*	31.50 (11.25–72.00)	28.00 (22.00–60.00)	72 (36.00–108.00)	27.00 (12.00–48.00)	0.053
Sex: Male (n (%))†	20 (67)	7 (100)	4 (36)	28 (76)	0.023‡
Severity of injury: AIS C (n (%))†	14 (47)	3 (43)	3 (27)	2 (5)	0.001‡
Level of injury: Paraplegia (n (%))†	19 (63)	5 (71)	9 (82)	26 (70)	0.718

*The data are presented using median and interquartile ranges (Q1–Q3), and the differences among the groups were analyzed using the Kruskal–Wallis *H* test. †These variables were categorized according to the following criteria: Sex: Male/female, Severity of injury: AIS C/D, Level of injury: Paraplegia/tetraplegia, and the comparisons among the groups were executed using the χ^2 test. ‡Indicated significant differences among the groups ($P < 0.05$).

AAD, Ambulatory assistive device; AIS, American Spinal Injury Association (ASIA) Impairment Scale.

causes, level and severity of injury, and post-injury time) and baseline walking ability (types of AAD and ability of independent walking over at least 50 m). On the second day, subjects were assessed for their functional ability using the 10MWT, FTSST, and TUGT in a random order to minimize carrying-over effects that might occur due to sequences of the tests such as fatigue and learning effects. Details of the tests are as follows.

10-Meter walk test

The 10MWT measures ambulatory status in terms of gait speed.^{17,22} Subjects walked at a comfortable pace with or without an AAD according to their usual walking along a 10-m walkway. In order to minimize acceleration and deceleration effects, the test recorded the time required over the middle 4 m of the walkway.²¹ Then the finding was converted to walking speed using the formula $v = s/t$.

Five times sit-to-stand test

The FTSST quantifies functional LEMS during changing from sitting to standing.²³ Subjects sat on a standard armless chair with their arms to their sides, back upright, hip flexion 90°, and feet flat on the floor at 10 cm behind the knees. Then they were instructed to stand up with the hips and knees in full extension, and sit down five times at a safe fastest speed without using hands. This test recorded the time from the command “Go” until the subject’s back touched the backrest of the chair on the fifth repetition.^{19,21,24}

Timed up and go test

The TUGT assesses dynamic balance control while performing basic mobility tasks, i.e. changing from sitting to standing, walking, and turning around, in which the time taken to complete the test is strongly correlated with level of functional mobility.²⁰ Subjects stood up from a standard armchair, walked around a traffic

cone that was located 3 m away from the chair, and returned to sit down on the chair at a maximum and safe speed with or without an AAD according to their customary walking. The test recorded the time taken from the command “Go” until the subject’s back against the backrest of the chair.^{20,21}

Subjects had to perform three trials per test and the average findings were used for data analyses. During the tests, subjects wore a lightweight safety belt with a physical therapist being or walking alongside the subjects to ensure their safety. They were able to take a period of rest between the tests as required (at least 5 minutes or until their heart rates returned to the baseline level).

Data analyses

Data were analyzed using the SPSS for Windows program (SPSS Statistics for Windows, Version 17.0, SPSS Inc., Chicago, IL, USA). Findings of the study were explained using the non-parametric statistics (median and interquartile range). The Kruskal–Wallis *H* test was used to compare the continuous data among the groups. Then, the Mann–Whitney *U* test was utilized to identify the differences of every pairwise condition. For the categorical data, the findings among the groups were compared using the χ^2 test. The level of significant differences was set at $P < 0.05$.

Results

Table 2 presents findings of the study as measured using the 10MWT, FTSST, and TUGT, respectively. The data demonstrated that the non-AAD subjects walked at the fastest speed and required the shortest time to complete the FTSST and TUGT, followed by those who used cane, crutches, and walkers, respectively. The functional ability of the non-AAD subjects was significantly better than the other groups for every test ($P < 0.001$). The 10MWT and FTSST of subjects who walked with canes were also significantly different from those who used walkers ($P < 0.001$) whereas the TUGT data of

these subjects were significantly better than those who walked with walkers ($P < 0.001$) and crutches ($P < 0.05$). However, functional ability of subjects who used walker and crutches showed no significant difference for all tests ($P > 0.05$).

Discussion

This study investigated the discriminative ability of the three functional tests, including the 10MWT, FTSST, and TUGT, in independent ambulatory subjects with SCI who walked with a walker, crutches, a cane, and non-AAD. The findings demonstrated that the tools could clearly discriminate functional ability of non-AAD subjects and those who walked with a walker, crutches, and a cane ($P < 0.001$, Table 2). In addition, significant differences were found between subjects who walked with cane and walker ($P < 0.05$) but no significant differences were found between those who used walker and crutches ($P > 0.05$, Table 2). Among the three tests, the TUGT showed the best discriminative ability for ambulatory subjects with SCI who used different types of walking devices (Table 2).

A walker is commonly used to greatly enlarge the body BOS. The device also aids stability by allowing large stabilizing hand-reaction forces and moments to be generated bilaterally for up to 100% of the body weight, which maximizes safety for the patients.^{7,25,26} In patients with iSCI, the peak vertical loads exerted on a walker range between 39 and 48% of the body weight.^{13,26} As a result, a walker is likely prescribed in patients with good upper limb functions to compensate for the significant reduction of the trunk and LEMS to permit independent ambulation.^{5,8} For crutches, the peak axial loads are reported to be slightly lower (22 to 35% of body weight).^{13,26} Furthermore, crutches are less cumbersome with less appearance of disability than a walker; therefore they allow the patients to easily maneuver small spaces.⁵ These devices can be advanced during a double-limb support phase, therefore

Table 2 Functional ability of the subjects who walked with walker, crutches, cane, and non-AAD

Variables	Groups of subjects				P value
	Walker (n = 30)	Crutches (n = 7)	Cane (n = 11)	Non-AAD (n = 37)	
10-Meter walk test (m/second)	0.31 (0.20–0.39)	0.45 (0.21–0.63)	0.69 ^W (0.52–0.78)	0.86 ^{W,Cr,Ca} (0.69–1.05)	<0.001
Five times sit-to-stand test (seconds)	19.47 (16.71–25.95)	15.67 (13.74–21.20)	16.25 ^W (12.25–18.93)	10.58 ^{W,Cr,Ca} (9.10–12.42)	<0.001
Timed up and go test (seconds)	31.03 (28.12–48.22)	30.69 (18.78–52.45)	15.80 ^{W,Cr} (13.52–24.00)	10.86 ^{W,Cr,Ca} (9.15–14.25)	<0.001

The data are presented using median and interquartile range (Q1–Q3). The differences among the four groups were analyzed using the Kruskal–Wallis *H* test and every pairwise comparison was analyzed using the Mann–Whitney *U* test. Superscripts indicate the group(s) with significant differences from the indicated groups where W = walker, Cr = crutches, Ca = cane.

AAD, Ambulatory assistive device.

it eliminates the challenge of balancing solely on one leg.⁷ Cane users rarely place more than 15–20% of body weight on the device, therefore a cane is commonly utilized to compensate for the reduction of balance control, generating stabilizing reaction forces from the hand, and assisting with propulsion and braking by generating horizontal ground reaction forces.^{7,27} As a result, patients with SCI are likely started their walking using a walker. When the patients improve their lower limb functions and balance control, they will be advanced to use a less support device, i.e. crutches, cane, and non-ADD.^{5,7}

The 10MWT reflects walking speed that the result associates with motor function, walking endurance, and overall quality of gait.¹⁹ The FTSST is likely used to assess proximal muscle strength of the lower extremities and balance control while changing postures from sitting to standing.^{18,19,28} The TUGT incorporates many sequential locomotor tasks, i.e. sitting-to-standing, walking and turning activities, that the results correlate with functional mobility, balance and postural control, walking ability, and the risk of falls.²⁰ Therefore, these tools showed good discriminate ability for subjects who used different types of AAD, particularly the TUGT. The test incorporates a turning activity which considerably influences the walking speed of patients with neurological disorders.²⁹ Moreover, when using an AAD, the number of contact points on the floor is increased according to the number of legs of the device. This increases the complexity of the sequencing and timing of floor contact particularly while changing the direction of walking (turning).¹¹ Thus, the TUGT showed better discriminative ability than the 10MWT and the FTSST (Table 2). Nevertheless, the non-significant differences between subjects who used a walker and crutches may reflect the inclusion criteria of the study. Subjects were arranged into the groups according to their customary AAD, not their highest ability. In addition, the eligible subjects needed ability of independent sitting-to-standing without the use of hands and walking over at least 50 m continuously in order to minimize effects of other confounding factors such as fatigue and levels of external assistance on the outcomes. However, using such criteria may recruit only subjects with rather good balance control, walking ability, and lower extremity function; even those who used walkers. Wretenberg and Aborelius³⁰ found that the knee extensors need to contribute 72% of the concentric force at the hip and the knee joint during sit-to-stand. Bohannon²³ also reports that ability of independent sitting-to-standing correlates with walking speed,

independent ambulation, and stair climbing. Therefore, the non-significant differences between subjects who used a walker and crutches may alternatively suggest the use of ability of independent sitting-to-standing as a simple screening tool for walking advancement of walker users. However, this assumption still needs to be confirmed by a further investigation which is still being carried out in our laboratory.

Clinically, physical therapists likely evaluate the patients for abnormalities and identify the form of an AAD to be used from their clinical experience in dealing with manifestations of disorders.¹¹ However, the result of such assessments is subjective and highly dependent on the experience of the assessors.³¹ Moreover, the decision about clinically relevant changes can be difficult when time intervals between visits are long or with changes in the assessors.³² A quantitative standard measure is easier to be standardized and provides objective data that allows efficient data comparison among testers and test intervals. The findings of this study further support clinical utility of the 10MWT, FTSST, and TUGT for screening and monitoring functional changes of patients with SCI who used different types of an AAD. However, the results may not indicate systems with disorders. A further assessment to determine the impairments relating to the requirements of an AAD (e.g. trunk and pelvic control, upper and lower extremity motor strength, and the reduction of sensation) is still needed.

Nonetheless, there are some limitations of the study. First, as indicated above, subjects were arranged into the groups according to their preferred AAD, not their highest ability which may affect the findings. Moreover, the eligible subjects needed ability of independent sit-to-stand without using hands and walking over at least 50 m continuously in order to increase the number of subjects who could complete the FTSST and minimize effects of other confounding factors such as fatigue and levels of external assistance on the outcomes. As a result, a large number of patients were excluded (Fig. 1) and the utility of the findings may be limited to only patients with rather good walking ability. Second, it is difficult to distinguish whether the findings are the effects of demands related to use of an AAD or the disability due to the SCI. Third, there were no existing data of these tools in patients with SCI who used different types of an AAD. Therefore, the number of subjects in each group was recruited based on the proportion found in the previous reports and the findings of these tests showed acceptable to high power of test (60–95%).^{15,16} The significant differences among the groups support the use of these tools to

monitor levels of ability in these subjects. Nevertheless, a further investigation that properly reduces effects of these factors with offering a cutoff score for ability of independent ambulation without an AAD will enhance the utility of these tools.

Conclusion

This study investigated the discriminative ability of three functional tools including the 10MWT, FTSST, and TUGT in independent ambulatory subjects with SCI who walked with walkers, crutches, canes, and non-AAD. The findings supported the discriminative validity of the tools. However, the non-significant differences between subjects who used a walker and crutches may relate to the method of subject arrangement and inclusion criteria that recruited subjects with rather good walking capability and lower limb function. Alternatively, the findings may suggest the use of the sit-to-stand maneuver as a simple screening tool for the walking advancement of walker users. However, this assumption still needs to be supported by a further investigation.

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