Factors Related to Obstacle Crossing in Independent Ambulatory Patients With Spinal Cord Injury

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Abstract

Background/Objectives: To evaluate factors related to the ability of ambulatory patients with spinal cord injury (SCI) to walk over small obstacles.

Study Design: Cross-sectional study.

Methods: Thirty-four patients with SCI (ASIA impairment scale [AIS] D) who were able to walk independently at least 10 m with or without walking devices were recruited for the study. Participants were required to walk over small obstacles (1, 4, and 8 cm in height or width; total of 6 conditions). A “fail” was recorded when either the lower limbs or the walking device contacted the obstacle. Multiple logistic regression models were applied to determine the effects of walking devices (presence or absence), SCI levels (tetraparesis or paraparesis), and SCI stages (acute or chronic) on the ability of obstacle crossing.

Results: Fifteen participants (44%) failed to adequately clear the foot or walking device over obstacles in at least one condition (range 1–3 conditions). After adjusting for covariates, the chance of failure on obstacle crossing was greatly increased with the use of walking devices (odds ratio = 8.50; 95% CI = 0.85–75.03).

Conclusions: Gait safety in independent ambulatory participants with SCI remains threatened. Participants who walked with walking devices encountered a greater chance of failing to walk over obstacles as a result of inefficiently moving the foot or walking device over small obstacles. Thus, instead of training in an empty/quiet room, rehabilitation procedures should incorporate contextual conditions that patients encounter at home and in the community in order to minimize risk of injury and prepare patients to be more independent after discharge.

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Key Words: Spinal cord injuries; Walking; Obstacle crossing; Walking devices; Rehabilitation

INTRODUCTION

Walking is an ultimate goal that patients with spinal cord injury (SCI) want to achieve (1,2). Although 80% of patients with motor-incomplete SCI can regain locomotor function, only a few of them will become functional walkers (3,4). This may relate to the methods of gait rehabilitation that normally take place in an empty room for the purpose of helping the patient gain confidence while practicing walking (5). However, this contextual condition is different from what patients encounter at home and in the community. In an everyday environment, obstacle crossing is one of many complex tasks associated with ambulation (6).

Said et al (6) reported that obstacles likely found in homes vary in height and width from <1 cm to 8 cm. Although these sizes do not represent all obstacles that may be found in the community, using larger obstacles in an experimental setup may expose patients to an unacceptable risk of injury. Furthermore, in the community, patients may choose to negotiate larger obstacles by walking around them (7).

A critical measure in obstacle crossing is the ability to complete the task by both limbs and walking devices (6). Inadequate clearance may lead to a trip and subsequent fall (7). To successfully walk over a high obstacle, patients must use a flexor strategy to increase foot clearance, whereas a wide obstacle requires them to lengthen their step length (7,8). In addition, to effectively walk over obstacles, patients must be able to balance themselves on double limb support when lifting the walking devices off the ground. Epidemiology of fall risk in the elderly has indicated that 50% of falls occur during some form of locomotion (9).

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Factors influencing ambulatory potential in SCI include levels of injury (tetraparesis or paraparesis), severity of injury (ASIA impairment scale [AIS] C or D), motivation, and medical conditions (10). In addition, movement patterns of patients with chronic SCI become very rigid or less adaptable and therefore are likely to be described as hard wired, stereotyped, or obligatory. Little information is known about the deficits in obstacle crossing in independent ambulatory patients. The present study identified crucial information for risk prevention and treatment modification for patients in this group. This study investigated the ability of independent ambulatory patients with SCI to walk over obstacles of sizes commonly found in homes and communities. Moreover, the study also explored certain characteristics that may relate to a failure during obstacle crossing, including the use of a walking device (presence or absence), SCI levels (tetraparesis or paraparesis), and stages of injury (acute or chronic).

METHODS

The study recruited patients with SCI (AIS D) from traumatic injuries or nonprogressive diseases from a rehabilitation center in Thailand. Eligible patients were required to be able to walk at least 10 m independently with or without assistive devices. Patients were excluded if they had any other orthopedic, neurologic, or medical conditions that might have affected their ambulation. Patients who were legally blind or had a history of visual deficits were excluded.

The test was conducted in a rehabilitation room with a wooden floor. Wooden obstacles (0.5 cm wide $\times$ 60 cm long) were in 3 heights (1 cm, 4 cm, and 8 cm) to represent obstacles likely found in homes and communities (6) (Figure 1a and b). Every obstacle was painted to provide contrast with the floor color. To provide a high obstacle, each obstacle was placed vertically (Figure 1a); to present a wide obstacle, each obstacle was placed flat on the floor (Figure 1b). To ensure safety, each participant wore a lightweight safety belt around the waist; a physiotherapist walked alongside the participant throughout the test. If an obstacle was contacted by a foot or walking device, it fell flat to the floor, thus minimizing the risk of tripping or injury.

Before taking part in this study, participants were required to sign an informed consent document approved by the ethics committee based on the Declaration of Helsinki. Participants were asked to participate in the study on 2 consecutive days. On the first day, the participants' neurologic functions were evaluated, including the motor and sensory systems to confirm the level and severity of injury, as well as walking ability with their preferred devices. On the second day, participants' walking ability over obstacles was tested without shoes. During the test, each obstacle was placed at the middle of a 10-m walkway. Every participant negotiated 3 obstacle heights (1 cm, 4 cm, and 8 cm) and 3 obstacle

(a)

(b)

Figure 1. Obstacles used in the study: (a) high obstacles and (b) wide obstacles.

widths (1 cm, 4 cm, and 8 cm) for a total of 6 conditions (1 trial for each condition). To avoid crossover effects (fatigue and/or learning effects), orders of presentation of obstacle sizes were counterbalanced across participants. During testing, participants used walking devices, orthoses (eg, ankle-foot orthoses), and the glasses or corrective lenses that they normally wore during walking. All participants were advised not to attempt to walk over an obstacle that they felt posed a risk to their safety. The instructions given to participants were as follows: "The purpose of the study is to see how safely you can step over an obstacle. Walk from the start of the walkway to the end at a comfortable speed, and step either limb over

(a)

(b)

Figure 2. Subject walks over obstacles: (a) over an 8-cm wide obstacle and (b) over an 8-cm high obstacle.

the obstacle in the middle without touching it. If you think that any obstacle is too difficult for you, I want you to stop. Do you have any questions?” Participants were allowed to rest as long as they needed before starting the

next trial. Figure 2 shows examples of a participant walking over an obstacle.

The ability to walk over an obstacle was recorded as “pass” or “fail.” A “pass” was recorded if participants were able to walk over an obstacle without contact with the obstacle by the feet and walking device. A “fail” was recorded if the participant’s feet or device contacted with the obstacle.

Statistical Analysis

All analyses were obtained by using SPSS for Windows version 12.0. Descriptive statistics were applied to explain the ability of walking over obstacles. Multiple logistic regression models were applied to determine the effects of independent variables, including walking device (presence or absence), SCI levels (tetraparesis or paraparesis), and SCI stages (acute or chronic) on the ability to walk over obstacles (pass or fail). The results were reported in the forms of unadjusted and adjusted odds ratios with corresponding 95% CIs. The unadjusted odds ratio indicates the chance that participants would fail if they had a certain characteristic (walking with walking device, having tetraparesis, or having chronic stage of injury) relative to the chance of fail if they did not have that characteristic. Adjusted odd ratios provide information about the increase or decrease in odds that a failure would happen given that the other independent variables had simultaneously occurred (11). The significance level was set at $P < 0.05$.

RESULTS

Thirty-four independent ambulatory patients (AIS D) agreed to participate in the study (Table 1). There were 27 men and 7 women. Average age and postinjury time were 48 ± 15.04 years (range = 19–75 years) and 19.68 ± 28.88 months (range = 3–120 months), respectively. Sixteen participants had an acute stage of injury (<6 months), whereas 18 participants had a chronic stage of injury (≥ 6 months). Most of them (27 participants) required walking devices for routine walking (24 participants used walkers, 2 participants used crutches, and 1 participant used a 3-point cane). One participant could walk >10 m but <50 m, whereas the rest were able to walk >50 m at one time (Table 1).

Nineteen (56%) of the 34 participants were able to successfully walk over obstacles, whereas 15 participants (44%) failed to walk over an obstacle during at least 1

Table 1. Participant Demographics

Variable	Result
Gender (male/female) (n)	27/7
Age: mean $\pm$ SD (years)	48 ± 15.04 (range = 19–75)
Postinjury time: mean $\pm$ SD (months)	19.68 ± 28.88 (range = 3–120)
Stage: acute/chronic (n)	16/18
Level: tetraparesis (C4–C8)/paraparesis (T4–T12) (n)	11/23

Table 2. Results of Walking Over Obstacles: Unadjusted (uOR) and Adjusted (aOR) Odds Ratios

Variable	Total (n)	No. of Fail (%)	uOR	aOR	95% CI	P value
Device					0.85–75.03	0.07
Nondevice	7	1 (14)	1	1		
Device	27	14 (52)	6.46	8.50		
Level					0.31–8.43	0.58
Paraparesis	23	10 (44)	1	1		
Tetraparesis	11	5 (46)	1.08	1.61		
Stage					0.42–8.04	0.42
Acute	18	7 (47)	1	1		
Chronic	16	8 (50)	1.57	1.84		

Multiple logistic regression equation: $y = -2.46 + 2.14\text{device} + 0.47\text{level} + 0.61\text{stage}$

condition. Of the 15 participants, 7 participants failed 1 condition, whereas the other 8 participants failed 2 to 3 conditions (including obstacles measuring 1 cm in height or width).

Table 2 presents the unadjusted and adjusted odds ratios of the effects of walking devices, injury levels, and injury stages on ability of obstacle crossing. Walking with walking devices, having tetraparesis, and having chronic stage of injury increased the likelihood of a failure to walk over obstacles (Table 1). After adjustment, these 3 factors posed a greater risk of failure, particularly the requirement of walking devices (Table 2).

Table 3 demonstrates further analysis on types of walking devices and failure. Most fails occurred in participants who required walking devices, particularly a walker (39 conditions: some participants failed 1 or more conditions). These fails were mostly due to leg contact (Table 3).

DISCUSSION

The data demonstrated that 44% of independent ambulatory participants with SCI failed to walk over an obstacle of sizes that are commonly found in homes and communities. Use of a walking device, having tetraparesis, or having a chronic stage of injury increased risk of failure on obstacle crossing. The adjusted odds ratios of fails caused by the requirement of walking devices

showed a trend toward being significant ($P = 0.07$) and was clearly higher than the unadjusted odds. In other words, when controlling for the effects of levels and stages of SCI, it appeared that participants who walked with walking devices were 8.50 times more likely to fail on obstacle crossing than those who walked without the devices.

Fails in participants who required walking devices were mostly due to leg contact with obstacles. This may imply that participants who needed a walking device still had difficulty modifying their leg movements according to environmental demands. Thus, they may encounter a high risk of a trip and subsequent fall when walking over small obstacles. Bateni and Maki (12) reported that walking devices are prescribed for individuals who have a moderate level of impairment, generalized weakness, extreme inability for lower-limb weight bearing, debilitating conditions, or poor balance control. Using walking aids enhances confidence and feelings of safety, which, in turn, can raise levels of activity and independence (13). However, several studies reported that the use of a walking aid is a prospective predictor of increased risk of falling in older adults (14,15) or is associated with falls and related injuries (16). This may relate to the difficulty of modifying their leg movements to accommodate contextual demands, which could potentially lead to injury when walking.

Table 3. Effect of Walking Devices on Obstacle Crossing

Type of Walking Devices	Total no. of Participants	Total no. of Fail	No. and Cause of Fail (Conditions ^a)	
			Leg Contact	Device Contact
None	7	1	1	–
Walker	24	12	39	3
Crutches	2	2	3	–
3-point cane	1	1	1	–

^a Each participant failed 1 or more conditions.

Results of this study suggest that although participants were able to walk overground independently, they may still have trouble controlling/altering their movements to successfully walk over an obstacle, even an obstacle of 1 cm in height or width. This was evident when tested with participants with mild severity SCI (AIS D). The tests were executed under the best possible conditions because participants did not wear shoes or slippers, as they normally wore at home, except for one participant who required a plastic ankle-foot orthosis to correct her foot drop (she passed every condition). All of them were aware of the positions and sizes of the obstacles that were painted to provide contrasting color with the floor. The testing process was carried out in an empty, quiet room; thus, distractions were at a minimum. The results suggest that independent ambulatory participants with SCI still possess an even higher risk of injury when they walk over an obstacle in the home and community.

Brotherton et al (17) reported that independent ambulatory patients with SCI had a high risk of falls (75%). Falls occurred in homes, offices, and communities. The incidence of falls in SCI patients is higher than that in frail elderly patients (40–50%) (18) and patients with other neurologic disorders, such as Parkinson disease (38–62%) (19,20) and peripheral neuropathy (50%) (21). The relationship between fall risk and obstacle-crossing failure, however, is as yet unknown.

The findings provide an important contribution to rehabilitation programs designed to improve walking control and injury prevention after discharge. In addition to training to walk in an empty/quiet room, physiotherapists should incorporate contextual conditions that patients encounter at home and in the community. Such training conditions will constrain them to modify their movements to successfully carry out the tasks while in a safe environment and may help to minimize risk of injury after discharge.

Limitations

There are some noteworthy limitations in this study. Participants who had AIS D from traumatic injuries or nonprogressive diseases were recruited from a tertiary rehabilitation center. Thus, the study captured a small sample size with a variety of participant characteristics, which resulted in a very wide range of 95% CI that encompassed the number 1. The increase in odds ratio in participants who walked with walking devices, had tetraparesis, or had a chronic stage of injury may occur by chance. A larger sample size may increase statistical power, narrow the confidence interval, and clearly show that results are not simply due to chance. Information on the relationship of fall on obstacle crossing and fall history may provide important information for fall prevention. Moreover, investigation of other factors related to obstacle-crossing ability will be useful, such as age, severity of injury, levels of spasticity, muscle strength, and sensation. A more mechanistic description

of a cause of failure or success, including common gait variables (eg, toe clearance, step length) would also provide crucial information for injury prevention and increased levels of independence.

CONCLUSIONS

Forty-four percent of independent ambulatory participants failed to walk over small obstacles that are commonly found in homes and communities. The results suggest that participants who required walking devices still had trouble altering their leg movement according to environmental demand. Thus, their gait safety may remain threatened. Physiotherapists need to incorporate contextual conditions that patients encounter at home and in the community in order to minimize the risk of injury and increase patient safety after discharge.

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