Physical impairment and walking function required for community ambulation in patients with incomplete cervical spinal cord injury

（不全頸髄損傷者の身体機能障害と地域内歩行自立に必要な歩行機能に関する研究）

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Abstract

Study design: Cross-sectional study.

Objective: To identify the physical impairments and walking function required for community ambulation in patients with cervical incomplete spinal cord injury (ISCI).

Setting: Chubu Rosai Hospital, Nagoya, Japan.

Methods: Forty patients with cervical ISCI (mean age: 49.9 years, American Spinal Injury Association Impairment Scale D) were included. The primary outcome measure was community ambulation based on Spinal Cord Independence Measure outdoor scores for a distance of >480 m. We measured the upper and lower extremity motor scores (UEMS and LEMS), sensory and spasticity. The walking tests included 10 m of walking at a comfortable and maximum walking speed (CWS and MWS; m/s), 6 min walking test (6MWT; m), and the Walking Index for Spinal Cord Injury II (WISCI II). Multivariate logistic regression models were used to assess the physical impairments associated with community ambulation. Receiver operating characteristic curves were analyzed to determine the cut-off points for physical impairment and walking function.

Result: The LEMS (β = 0.71) and UEMS (β = 0.41) were independently associated with community ambulation in patients with cervical ISCI. The cut-off points of the LEMS, UEMS, CWS, MWS, 6MWT, and WISCI II were 41.5, 36.5, 1.00 m/s, 1.32 m/s, 472.5 m, and 17.5, respectively, which suggests moderate to high accuracy.

Conclusion: The LEMS and UEMS were the most important factors affecting community ambulation in patients with cervical ISCI. The cut-off points of the walking function tests were highly accurate; therefore, these points can serve as targets for walking training in the future.

要旨

【目的】

近年、不全頸髄損傷患者数が増加傾向にある。不全脊髄損傷者の中でも損傷高位以下に運動機能が残存する者では歩行能力を再獲得する可能性が高く、理学療法の大きな目標の一つとなる。また、歩行は地域社会で生活を営むためには重要な能力である。不全脊髄損傷者の歩行は健常人に比べて歩行速度や持久性が低下するため、屋内歩行は自立するが“地域社会で必要とされる歩行（community ambulation）”が自立に至らない場合がある。これまでに、不全頸髄損傷者の community ambulation に関連する身体機能についての検討は、下肢筋力のみでの報告が多く、上肢筋力、感覚、痙縮などを含む包括的な検討を行った報告は極めて少ない。本研究の目的は、不全頸髄損傷者の community ambulation 自立に関連する身体機能を明らかにすることと、community ambulation 自立となる歩行能力指標のカットオフ値を得ることとした。

【方法】

A 病院に入院中で平地歩行が可能な不全頸髄損傷者(ASIA Impairment Scale：D) 40 名を対象とした。平均年齢は 49.9±13.0 歳、受傷後日数は 7-277 日であった。本研究における community ambulation 自立の定義には、Spinal Cord Independence Measure（SCIM）の屋外移動の項目を用い、得点が 0-3 点を非自立、4-8 点を自立とし、歩行距離の基準は Robinett らの報告を参考に 480m とした。身体機能の評価は、ASIA の評価基準の下肢筋力スコア（LEMS）、上肢筋力スコア（UEMS）、触覚スコア（LTS）、痛覚スコア（PPS）と、膝関節屈曲筋と足関節底屈筋の合計得点である Composite Modified Ashworth Scale（CMAS）を使用した。歩行能力の評価は、10m歩行テストと 6 分間歩行テスト（6MWT）、Walking Index for Spinal Cord Injury Ⅱ（WISCIⅡ）を用いた。10m歩行テストは快適歩行速度（CWS）と最大歩行速度（MWS）を算出した。

各指標間の相関関係には Spearman の順位相関係数を用い、community ambulation 自立群と非自立群の群間比較には対応のない t 検定（性別はカイ 2 乗検定）を用いた。community ambulation 自立に関連する因子の検討には、SCIM 屋外移動を従属変数、年齢・LEMS・UEMS・LTS・PPS・CMAS・を独立変数としたステップワイズ法による多重ロジスティック回帰分析を用いた。community ambulation が自立となる歩行能力のカットオフ値は ROC 曲線を作成し、Youden index により算出した。それぞれ有意水準 5%で検証した。

【結果】

community ambulation 自立群は 22 名（男 21 名、女 1 名）、非自立群は 18 名（男 16

名、女 2 名）であった。群間の比較において、年齢、UEMS、LEMS、CWS、MWS、6MWT、WISCIⅡでは群間に有意な差がみられたが、発症後日数、CMAS、LTS、PPS では有意な差はみられなかった。SCIM の屋外移動と年齢、発症後日数、UEMS、LEMS との間に有意な相関関係がみられたが、CMAS、LTS、PPS の間には有意な相関関係はみられなかった。

多重ロジスティック回帰分析の結果、SCIM 屋外移動の自立に有意に関連する因子として LEMS（オッズ比：2.03、95%信頼区間：1.20-3.43、$p<0.01$）と UEMS（オッズ比：1.51、95%信頼区間：1.08-2.10、$p<0.05$）が抽出された。UEMS のカットオフ値は 36.5、LEMS は 41.5、CWS は 1.00m/s、MWS は 1.32m/s、6MWT は 472.5m、WISCIⅡは 17.5、AUC は 0.85～0.96 であった。また、歩行距離の基準を SCIM の基準である 100m とした場合には、自立群が 29 名となり、実際に近隣のスーパーマーケットで買い物をするような社会参加につながらない例が自立と判断され、CWS は 0.81m/s、MWS は 1.05m/s、6MWT は 343.5m、WISCIⅡは 14、AUC は 0.80～0.94 と 480m の基準よりも低値を示した。

【結論】

不全頚髄損傷者の community ambulation の自立には、下肢筋力だけではなく上肢筋力も有意に関連したが、感覚や痙縮は関連しなかった。さらに、4 つの歩行能力指標のカットオフ値に高い信頼性がみられた。また、自立判定には歩行距離が SCIM 屋外移動の基準である 100m では十分ではないことが推察された。本研究で得られた指標は、今後の理学療法の評価、治療介入、ゴール設定等に具体的な指標として適用できる可能性が示唆された。

Contents

Introduction

Walking is an important human activity that enables us to be productive, participating members of a community. Recent statistics indicate that the proportion of cervical injuries and neurologically incomplete is increasing in patients with spinal cord injury.[1] A large number of patients with initial motor incomplete spinal cord injury (ISCI) regain some form of walking function.[2, 3] Therefore, recovery of walking has become a target of several rehabilitative approaches, and a precise evaluation of walking in these patients has become crucial.[4-6] In recent years, this emphasis has been extended to include the attainment of community ambulation as an important mobility and social outcome.[7]

Community ambulation has been defined as "independent mobility outside the home," which includes the ability to confidently negotiate uneven terrain and curbs, visit a supermarket, a shopping mall, and other public venues.[8] The American Spinal Injury Association Impairment Scale (AIS) D patients have a good prognosis for walking, but not all AIS D patients can achieve community ambulation.[7]

Attempts to evaluate community ambulation are currently underway.

Physical impairment is an important determinant of community ambulation. Previous studies have shown a correlation between walking function and age[9-11], muscle strength[10-12], spasticity[10, 13, 14], sensory[10, 11, 15], and balance[16] in patients with ISCI. However, there are few comprehensive studies on physical impairment required for community ambulation in patients with cervical ISCI.

On the other hand, previous studies have already reported that walking speed and endurance are good indicators of community ambulation in patients with stroke and elderly people.[8, 17, 18] Walking function in patients with ISCI is commonly characterized by slower walking speed and poor efficiency.[7, 19, 20] van Hedel *et al*. suggested that a minimum walking speed of 0.44 m/s using a walking device resulted in independent community ambulation in patients with ISCI.[21] Brotherton *et al.* reported that patients with ISCI who were independent community ambulation used one cane or crutch.[22] However, few studies have examined the cut off point of walking function required for community ambulation comprehensively, including walking endurance and the use of walking devices or braces, in patients with cervical ISCI.

For returning to living in the community after cervical ISCI, achieving community ambulation has significant implications for social participation. Maintenance of independent community ambulation can be integral to quality of life and participate in society.[23] Many different types of physical therapy interventions are routinely provided to patients with cervical ISCI as part of their rehabilitation programs. Physical therapy interventions often target specific impairments such as poor strength, joint mobility, poor sensory, pain or spasticity. However, we have not enough information for decision making which physical impairments are the most debilitating for community ambulation and the cut off point of walking function required for community ambulation in patient with cervical ISCI. Identification of the most debilitating physical impairment required for community ambulation can help guide an effective intervention in patients with cervical ISCI. Furthermore, determination of the cut off point of walking function required for community ambulation can help setting clear clinical goals for these patients.

Therefore, the objectives of this study were as follows: (1) to identify the physical impairments associated with community ambulation, and (2) to determine the cut off points of physical impairments and walking function for community ambulation in patients with cervical ISCI.

Ⅲ. Methods

Patients

Inclusion criteria were inpatients with cervical ISCI who were graded according to the AIS D and were able to walk independently (with or without assistive devices) over 10-m on a level surface. We also included patients who were at the age of 16 to 70 years. Exclusion criteria included severe cognitive impairment, brain injury, and orthopedic or neurological conditions in addition to ISCI. Patients were recruited from April 2010 to December 2012. Forty patients with cervical ISCI were recruited (including 3 women), with a mean age of 49.9 years. The median time since injury was 142 days (range, 7–277 days). All patients had levels ranging from C4 to C8. In accordance with the Declaration of Helsinki, the patients were informed of the experimental procedure, and each provided written informed consent before participation in the study. The experimental procedure was approved by the local ethics committee (Graduate School of Medicine, Nagoya University, approval no. 10-513).

Community ambulation

The ability to community ambulation was the primary functional outcome. The Spinal Cord Independence Measure (SCIM)[24] is the only comprehensive ability rating scale that has been designed specifically for patients with spinal cord injury. We applied a cut off SCIM mobility score to distinguish between individuals who could walk independently and those who could not as previously reported.[11] Scores of 0–3 were grouped and defined as unable to walk or required assistance, whereas grouped scores of 4–8 were defined as able to walk independently. van Hedel *et al.* used SCIM outdoor mobility score to examine community ambulation.[21] This score was assessed by the ability to walk >100 m, although Robinett *et al.* found that distances required to ambulate in the community are often greater than distance benchmarks in clinical measurements, such as the Functional Independence Measure. These authors suggested that individuals may have to ambulate as much as 480 m when visiting supermarkets.[25] Therefore, our study defined community ambulation on the basis of SCIM outdoor scores 4-8, which indicate an ability to walk independently for a distance > 480 m. Because among the public venues at a distance > 480 m there was a supermarket 500 m away from our hospital, we assessed whether it was possible for patients to independently visit the supermarket along a route that included uneven terrain and curbs.

Walking function

Patients were subjected to a 10-m walking test (10MWT)[26] and a 6-min walking test (6MWT; m)[27]. Patients wore sneakers that fitted individually and were used in their daily life, and used whatever assistive and/or orthotic devices they preferred. 10MWT was performed at both a comfortable and maximum walking speed. The test was performed with a dynamic start to allow 2-m acceleration, a timed 10-m distance and 2-m deceleration. Speed is only calculated for the 10-m distance between the "end zones". 6MWT is a measure of distance and represents the maximum distance walked in 6 min. During the test, patients walked up and down a 46 m rectangular walkway. A licensed and well-trained physical therapist assessed all physical performance tests. Walking level also was assessed using the Walking Index for Spinal Cord Injury II (WISCI II)[28].

Physical impairment

Neurological examinations were performed according to the international standards for classification of SCI.[29] A trained examiner assessed the upper and lower extremity motor scores (UEMS and LEMS), light touch scores (LTS) and pin prick scores (PPS). Lower extremity spasticity was measured using the composite Modified Ashworth Scale (CMAS).[30] As published, this is scored 0–4, with a 1+ grade, but for data analyses, the scores were adjusted to give a 0–5 score range (1+ became 2, 2 became 3, and so on). This scale was applied to the knee and ankle flexors. The scores of both sides were added, giving a CMAS from 0 to 20.

Statistical analysis

Descriptive analyses were used to calculate percentages, mean and median values for demographic variables including age, sex, and time since injury. Normality of distribution was tested with the Shapiro-Wilk test. The differences between independent and dependent community ambulation groups were analyzed with Student t-test (for the data with a normal distribution) and with Mann-Whitney U-test (for the data with a non-normal distribution). The relationship between patients' characteristics and SCIM outdoor mobility scores was examined using Spearman's correlation. A linear regression analysis was performed to describe the relationship between LEMS and walking speed, 6MWT. The multivariate logistic regression model using a forward stepwise selection method was used to select the final set of independent factors for community ambulation. Independent variables included age, time since injury, UEMS, LEMS, LTS, PPS and CMAS. A significance level of P less than 0.05 was used for all statistical analysis. Curves for receiver operating characteristics were inspected to determine cut-off points for the UEMS, LEMS, LTS, PPS, CMAS, 6MWT, WISCI II, and comfortable and maximum walking speed that best discriminated between independence and dependence in community ambulation. Cut off points for maximizing the sensitivity and specificity for each test were determined using the Youden index.[31] Data were analyzed using the Statistical Package for the Social Sciences for Windows (version 19.0, Chicago, IL, USA).

Ⅳ. Results

Table 1 shows the demographic and physical factors of 40 patients with cervical ISCI. Thirty-seven patients were men (92.5%). Five walked with one ankle-foot orthosis (AFO); 1 walked with double AFO; 34 walked without lower extremity devices. Thirty-seven of 40 patients were able to stand unsupported, and 3 patients were able to stand with a hand for support.

Table 2 shows the differences in demographic factors, physical impairments and walking function between the independent and dependent community ambulation groups. Twenty-two patients (55%) were independent, and 18 patients (45%) were dependent. Table 3 shows the differences in WISCI II between the independent and dependent community ambulation groups. In the independent group, patients used 1 cane, 1 crutch, or no device.

Figures 1-4 show that there were significant correlations between age, time since injury, UEMS, LEMS, and SCIM outdoor mobility score (age and SCIM outdoor, r = -0.32, *P* = 0.044; time since injury and SCIM outdoor, r = -0.31, *P* = 0.048; UEMS and SCIM outdoor, r = 0.54, *P* < 0.01; LEMS and SCIM outdoor, r = 0.68, *P* < 0.01). There were no significant correlations between sex, LTS, PPS, CMAS, and SCIM outdoor mobility score. The significant correlations existed between LEMS and walking speed and 6MWT (r^2 = 0.57 and 0.63, respectively; P < 0.01).

Logistic regression analyses revealed that LEMS [odds ratio (OR) 2.03; 95% confidence interval (CI) 1.20–3.43; beta coefficient (β) = 0.71; *P* = 0.008] and UEMS (OR 1.51; 95% CI 1.08–2.10; β = 0.41; *P* = 0.015) were independently associated with community ambulation. Age, time since injury, LTS, PPS and CMAS did not show a statistically significant relationship.

The ROC curve analyses are included in Tables 4 and 5. The areas under the curve (AUC) of LEMS, comfortable and maximum walking speed, 6MWT, and WISCI II ranged from 0.90 to 0.96, suggesting high accuracy. The AUC of UEMS was 0.85, which suggests moderate accuracy. The AUC of CMAS, LTS and PPS suggested low accuracy. Figure 5 shows the relationship between dependent and independent community ambulation at different LEMS and UEMS. Our cut off point for LEMS was greater than 41.5, and 20 of 22 subjects achieved independent community ambulation.

V. Table

Table 1 Descriptive statistics of demographic and physical factors

Variables		Range
Age (years)[a]	49.9 (13.0)	23 - 70
Time since injury (days)[a]	139.0 (65.9)	7 - 277
Upper extremity motor score (points)[b]	41.5 (10.5)	29 - 50
Lower extremity motor score (points)[b]	43.0 (8.0)	32 - 50
Composite Modified Ashworth Scale (points)[b]	8.0 (4.0)	0 - 11
Light touch score (points)[b]	79.5 (26.5)	12 - 112
Pin prick score (points)[b]	80.5 (24.5)	30 - 112
Comfortable walking speed (m/s)[a]	1.04 (0.32)	0.51 - 1.74
Maximum walking speed (m/s)[a]	1.43 (0.43)	0.71 - 2.59
6-minute walking test (m)[a]	441.0 (135.5)	189 - 713
Walking index for spinal cord injury II[b]	19.0 (7.0)	9 - 20
SCIM outdoor (points)[b]	6.0 (6.0)	1 - 8
SCIM total (points)[b]	83.0 (18.0)	39 - 100

[a]Values are shown as the mean (standard deviation) for normal distribution.

[b]Values are shown as the median (interquartile range) for non-normal distribution.

Abbreviations: SCIM, spinal cord independence measure.

Table 2 Comparison of demographic factors, physical impairments and walking function between the independent and dependent community ambulation groups

Variables	Group		P-value
	Independent, N = 22	Dependent, N = 18	
Age (years)[a]	45.9 (12.0)	54.7 (12.8)	0.031[c]
Sex			
Men	21	16	
Women	1	2	
Time since injury (days)[a]	122.7 (57.2)	158.8 (71.9)	0.085[c]
Upper extremity motor score (points)[b]	46.0 (7.0)	35.5 (8.0)	<0.001[d]
Lower extremity motor score (points)[b]	47.0 (4.0)	39.5 (5.0)	<0.001[d]
Composite Modified Ashworth Scale (points)[b]	8.0 (4.0)	9.0 (4.0)	0.410[d]
Light touch score (points)[b]	81.0 (23.0)	77.5 (22.0)	0.670[d]
Pin prick score (points)[b]	78.5 (26.0)	80.5 (21.0)	0.947[d]
Comfortable walking speed (m/s)[a]	1.23 (0.25)	0.81 (0.22)	<0.001[c]
Maximum walking speed (m/s)[a]	1.69 (0.36)	1.11 (0.27)	<0.001[c]
6-minute walking test (m)[a]	529.8 (102.8)	332.4 (79.8)	<0.001[c]
Walking index for spinal cord injury II[b]	20.0 (1.0)	13.0 (0.0)	<0.001[d]

[a]Values are shown as the mean (standard deviation) for normal distribution.

[b]Values are shown as the median (interquartile range) for non-normal distribution.

[c]P-value from Student t-test

[d]P-value from Mann–Whitney U-test.

Table 3 Comparison of WISCI II between the independent and dependent community ambulation groups

	Group	
WISCI II	Independent, N = 22	Dependent, N = 18
9		2
12		1
13		11
15	2	
16		2
19	7	2
20	13	

Abbreviations: WISCI II, Walking index for spinal cord injury II.

Table 4 Cut off points of physical impairments for community ambulation

Variables	Cut-off point	Sensitivity	Specificity	AUC
Upper extremity motor score (points)	36.5	0.91	0.67	0.85
Lower extremity motor score (points)	41.5	0.91	0.89	0.92
Composite Modified Ashworth Scale (points)	10.5	0.05	0.94	0.39
Light touch score (points)	77.5	0.44	0.56	0.52
Pin prick score (points)	83.5	0.50	0.67	0.45

Abbreviations: AUC, areas under the curve.

Table 5 Cut off points of walking function for community ambulation

Variables	Cut-off point	Sensitivity	Specificity	AUC
Comfortable walking speed (m/s)	1.00	0.86	0.89	0.90
Maximum walking speed (m/s)	1.32	0.91	0.83	0.91
6-minute walking test (m)	472.5	0.91	0.89	0.94
Walking index for spinal cord injury II	17.5	0.91	0.89	0.96

Abbreviations: AUC, areas under the curve.

VI. Figure

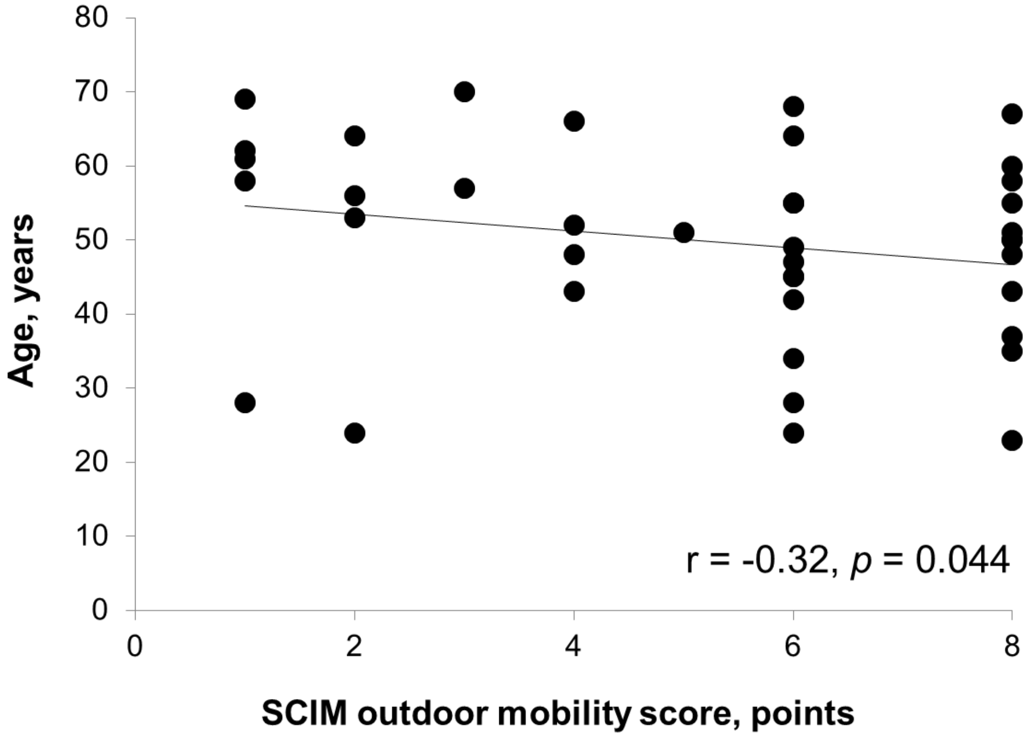

Figure 1 Relationship between SCIM outdoor mobility score and age.

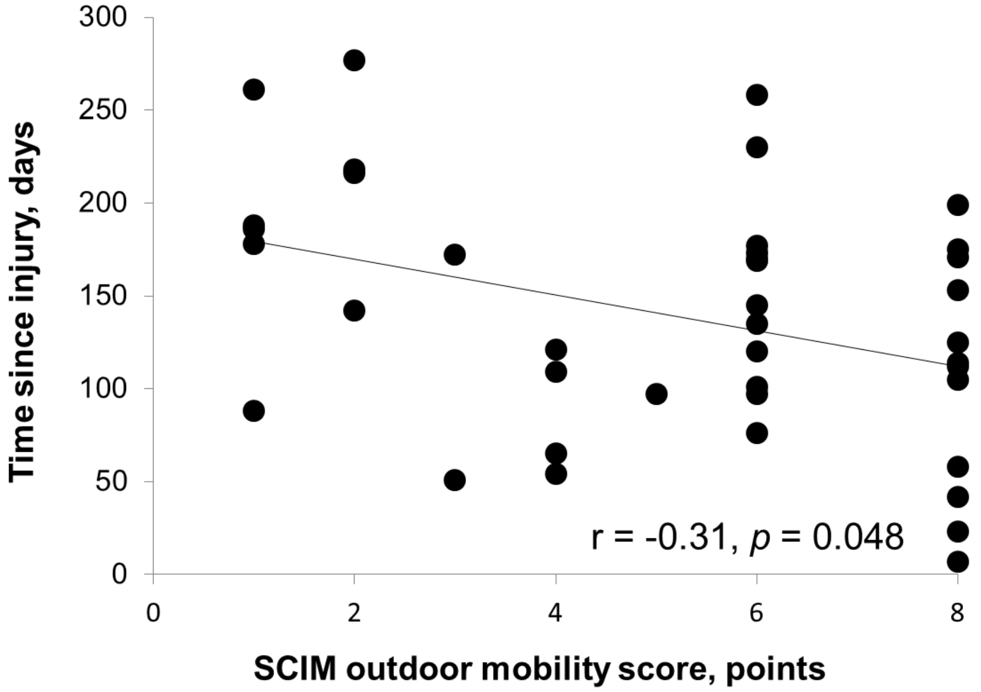

Figure 2 Relationship between SCIM outdoor mobility score and time since injury.

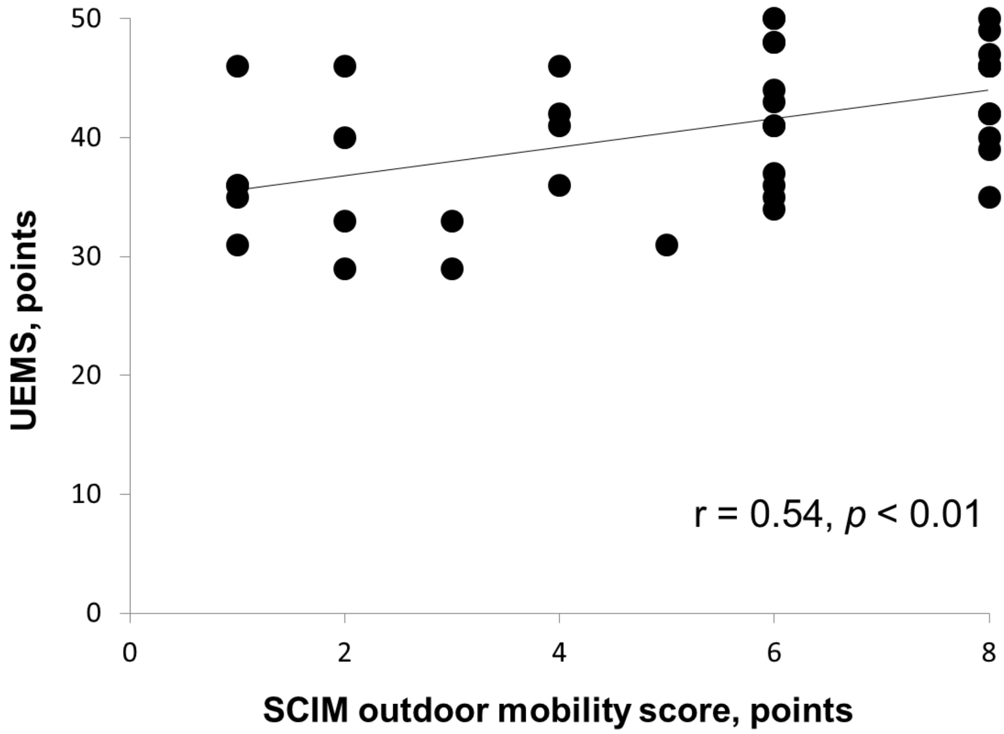

Figure 3 Relationship between SCIM outdoor mobility score and UEMS.

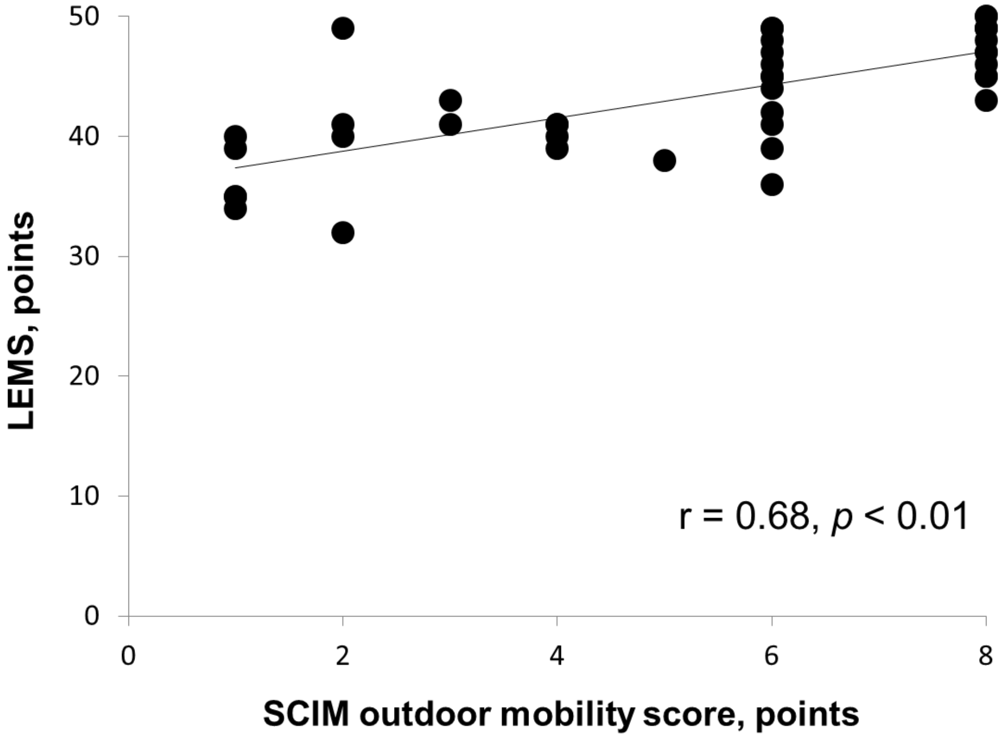

Figure 4 Relationship between SCIM outdoor mobility score and LEMS.

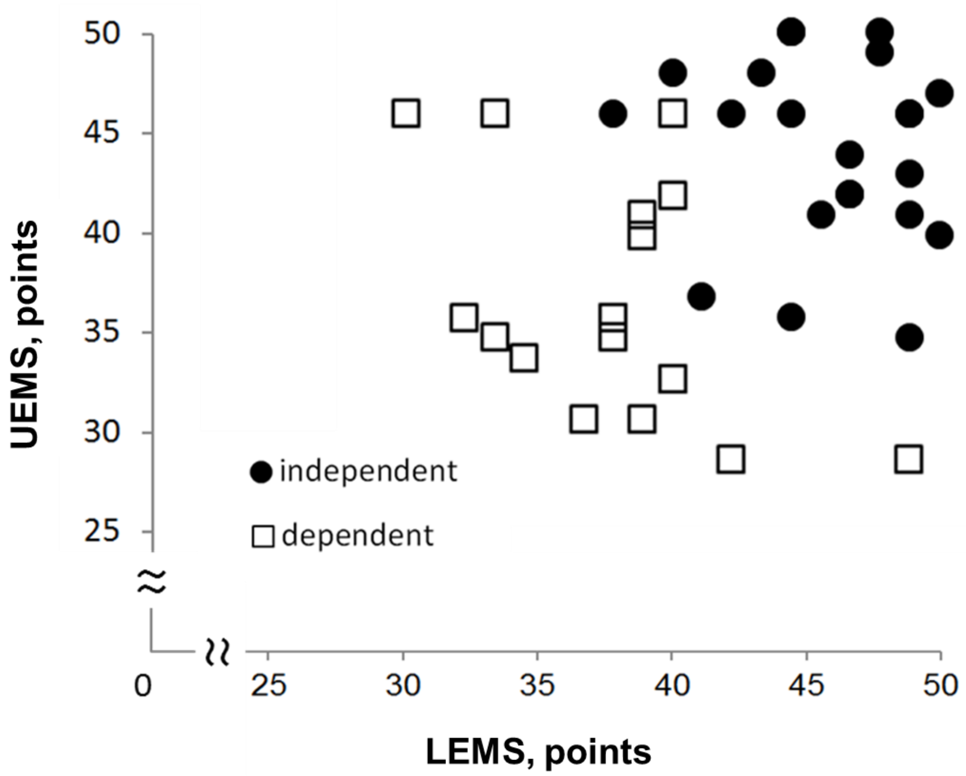

Figure 5

Scatter graph showing the relationship between dependent and independent community ambulation at different LEMS and UEMS.

Ⅶ. Discussion

The main findings were that LEMS and UEMS were independently associated with community ambulation in patients with cervical ISCI, but LTS, PPS and CMAS did not show a statistically significant relationship. Buehner *et al.* suggested that changes in LEMS do not capture the full extent of functional recovery because weak but significant correlations exist between LEMS and walking speed, 6MWT ($r^2 = 0.24$ and 0.25, respectively; $P < 0.05$).[32] However, our study found that moderate but significant correlations existed between LEMS and walking speed, 6MWT ($r^2 = 0.57$ and 0.63, respectively; $P < 0.01$). We suggest that this difference arose from the fact that the patients in our study included only persons capable of walking, whereas the group in the Buehner *et al.* study included patients incapable of walking.

The cut off point of LEMS in this study was 41.5, which is higher than the value of 30 reported in a previous study[33]. This may be because this study included only patients with tetraplegia, whereas in that previous study, 24 of 36 patients had paraplegia. Tetraplegia is difficult compared to paraplegia, and to compensate for LEMS in UEMS, the cut off point of LEMS was higher in this study. In another previous study, patients who achieved community ambulation had LEMS of 36.9 ± 7.6.[34] Twenty-three of 50 patients were able to ambulate in the community in another previous study; of which, 13 walked with lower extremity devices. In contrast, 22 of 40 patients were able to show community ambulation in this study, and only 3 walked with a lower extremity device. Generally, if LEMS is higher, patients do not require lower extremity devices. This may be because patients in this study had higher LEMS than patients in previous study did. Only 1 study reported the relationship between UEMS and community ambulation.[34] The cut off of value UEMS in this study was 36.5, which was higher than that in that previous study (30.3 ± 10.8). This may be because our patients were only graded according to the AIS D, whereas in that previous study, patients were graded according to the AIS C and D. Furthermore, the level of our patients (from C4 to C8) was different from the level of those in that previous study (from C3 to C7).

Our cut off point for LEMS was greater than 41.5, and 20 of 22 subjects achieved independent community ambulation. Two patients could not achieve community ambulation, and had LEMS of 43 and 49, with UEMS of 29 (under our cut off point). However, 2 out of the 18 patients who had LEMS less than 41.5 achieved community ambulation. These 2 patients had UEMS of 46 and 48, which was over our cut off point

(Figure 5). These results suggest that successful community ambulation of patients with cervical ISCI depends on LEMS as well as UEMS. Therefore, both the cut off points for LEMS (41.5) and UEMS (36.5) are important; this provides new information for community ambulation in patients with cervical ISCI who are graded by AIS D.

CMAS did not show a statistically significant relationship with community ambulation in this study. This may be because the degree of spasticity in this study was lower than that in the previous study[35].

The cut off point of comfortable walking speed in this study was 1.00 m/s. This speed was faster than the speed mention by van Hedel *et al.* (minimum 0.44m/s).[21] To us, this difference arose from the difference in walking distance of defined community ambulation. The cut off point for maximum walking speed in this study was 1.32 m/s. One study found that the speed required to cross a street safely was 1.22 m/s.[36] In this study, the cut off point for comfortable walking speed was slower than 1.22 m/s, but the cut off point for maximum walking speed was faster. Therefore, people can increase their walking speed as required, so we can consider that it is possible to live in local communities. The cut off point for WISCI II was 17.5 in this study. Similarly, Brotherton *et al.* also reported that patients who were independent in community ambulation used one cane or crutch in patients with ISCI.[22] Therefore, it is clinically useful to know the cut off point for WISCI II necessary for community ambulation. The cut off points for walking function in this study were highly accurate and should provide useful information.

The median time since injury of this study was 142 days, which was estimated in the sub-acute phase after ISCI when recovery was far from completed. However, Spiess *et al*. reported that approximately 90% of patients with ISCI who were classified within the first 15 days as AIS D did not convert to AIS E at 12 months post-injury.[37] This was one of the reasons we were limited to AIS D patients.

Our findings suggest the importance of upper and lower extremity muscle strength, rather than spasticity and sensory, for community ambulation in patients with cervical ISCI who are graded according to the AIS D. Therefore, resistance training[38] and electrical stimulation training[39] have been identified as successful intervention tools that can load the paralyzed skeletal muscles are recommended for physical therapy intervention to achieve community ambulation in these patients. The cut off points of walking function were also useful in assessing community ambulation. Longitudinal studies are required to assess the applicability of these findings as a motivational tool to achieve community ambulation.

Ⅷ. Conclusion

LEMS and UEMS were the most important factors for community ambulation in patients with cervical ISCI. The cut off points of UEMS, LEMS, 6MWT, WISCI II, and comfortable and maximum walking speed were 36.5, 41.5, 472.5 m, 17.5, 1.00 m/s, and 1.32 m/s, respectively. These cut off points were of moderate to high accuracy, and we will target these points for walking training in the future. In order to make general conclusions, further studies examining a larger sample including other parameters, such as balance and upper extremity spasticity, are warranted.

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