Effect of Age at Injury on Walking Ability Following Incomplete Cervical Spinal Cord Injury: A Retrospective Cohort Study

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Abstract:

Introduction: Recently, the cases of elderly individuals with spinal cord injuries are increasing in Japan. For individuals with spinal cord injury, regaining the ability to walk independently after an injury is one of the most important aspects of rehabilitation. Nevertheless, instead of age-optimized programs, uniform rehabilitation programs are currently provided to all patients because there is no information available for predicting prognosis based on age at the time of injury. This study aimed to elucidate the effect of age at the time of injury on the walking ability of patients with incomplete cervical spinal cord injury.

Methods: Of the 1,195 patients registered in the Japan single-center study for spinal cord injury database, those hospitalized within 28 days after injury, followed up for >180 days, had a cervical spinal cord injury, and had a lower extremity motor score of ≥42 points were examined. Patients were stratified into three groups according to the age at the time of injury (≤59, 60-69, or ≥70 years). The walking ability scores and independence levels of mobility were compared; these data were evaluated based on indoor mobility (item 12) and outdoor mobility (item 14) in the Spinal Cord Independence Measure III and Walking Index for Spinal Cord Injury II. All comparisons used data at discharge.

Results: The walking ability scores and independence levels of mobility were significantly lower in the group aged ≥70 years than those in the remaining two groups.

Conclusions: In patients with cervical spinal cord injuries with the same limb function, if the age at the time of injury was ≥70 years, the decline in physical function due to aging exerted a substantial effect on walking ability.

Keywords:
age, rehabilitation, spinal cord injury, walking ability

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Introduction

Recently, individuals with spinal cord injuries are increasingly aging in Japan. Previous surveys demonstrated a patient distribution pattern with bimodal peaks at a young age and an advanced age[1]; nevertheless, the current patient distribution follows a unimodal pattern with the peak at an advanced age (60s)[2,3]. Additionally, the rate of cervical spinal cord injury and that of incomplete injury are increasing as the population ages[4]. The Japan single-center study for spinal cord injury database (JSSCI-DB) used in this study was constructed, is operated by the Spinal Injuries Center of Japan (SIC-J), and has accumulated 134 items of data since 2005, including age at the time of injury, extremity muscle strength scores, and walking ability scores of patients with traumatic spinal cord injuries. The data were collected at 13 time points between hospitalization and discharge. In the SIC-J, patients with cervical spinal cord injury can be hospitalized for approximately 1 year and provided with stable long-term follow-up during data collection.

Functional recovery after spinal cord injuries can occur in several patients at different levels[5-7]. Furthermore, recovery in walking ability is one of the most important aspects in rehabilitation after spinal cord injuries and is a major factor

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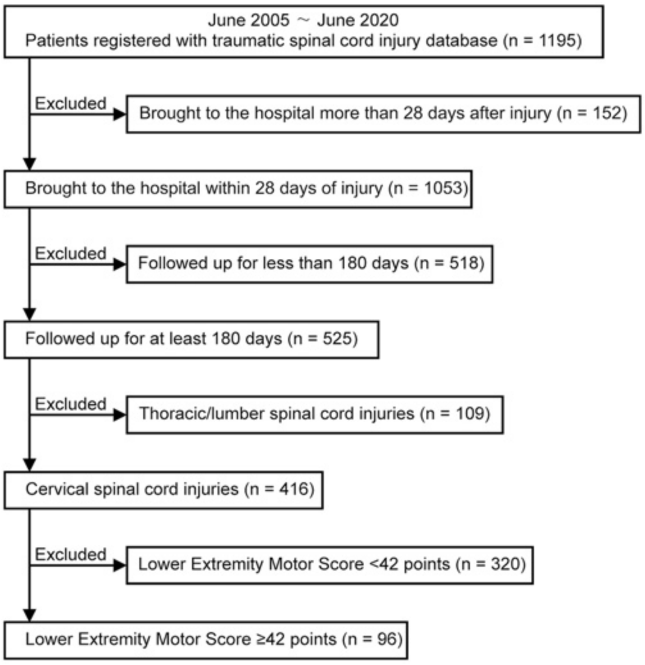

Figure 1. Flowchart representation of the final samples of 96 participants of the study.

affecting return to society. Thus, it is important to set goals early after injury and provide each patient with an appropriate rehabilitation program to realize independent walking ability. Nevertheless, uniform rehabilitation programs rather than age-optimized programs are currently provided to all patients because there is no information available for prognosis prediction based on age at injury.

Several reports have described an association between age and walking. Scivoletto et al. reported that the level of recovery in walking ability differs between those above and below 50 years of age[8]. However, they assessed a mixture of patients with traumatic and nontraumatic cervical spinal cord injuries and thoracolumbar cord injuries. Additionally, Cifu et al. compared the Functional Independence Measure (FIM) motor score among three groups of patients with spinal cord injuries (18-34, 35-64, and ≥65 years of age) and reported that the score of the ≥65-year age group was lower than that of the other two groups[9]. Nevertheless, the FIM motor score is not an absolute measure of walking ability because it includes transfers and self-care. To the best of our knowledge, no previous studies have evaluated walking ability in individuals with cervical spinal cord injuries who have similar levels of function in the upper and lower extremities.

Hence, we hypothesized that walking ability in individuals with cervical spinal cord injuries decreases with age as long as their upper/lower extremity motor scores (UEMS/LEMS) do not differ significantly and strictly selected participants and functional assessment from the JSSCI-DB. This study aimed to examine the effect of age at the time of injury on the walking ability of patients with incomplete cervical spinal cord injury.

Materials and Methods

Participants

In total, 1,195 patients with traumatic spinal cord injuries were registered with the JSSCI-DB between June 2005 and June 2020. Of these patients, those with cervical spinal cord injuries who were admitted to the SIC-J within 4 weeks after injury and followed up for at least 180 days after injury were selected. Of these patients, those who scored at least 42 points (considered a threshold for independent walking) in LEMS at discharge were included in this study (Fig. 1)[10].

Because the age distribution of patients with spinal cord injuries in Japan has a single peak in the age group of 60s, participants were divided into three groups based on this peak age: ≤59, 60-69, and ≥70 years of age. The criterion of lower extremity muscle strength was set according to that reported by Hasegawa et al., which stated that LEMS was the factor with the greatest impact on walking ability[10]. If a participant has severe paralysis and extremely weakened lower extremities, the reason for the reduced walking ability could be the reduced lower extremity muscle strength. Based on a previous study that concluded that at least 41.5 LEMS points are required for patients with incomplete cervical cord injury to achieve a practical level of walking ability and considering the effects of deteriorated lower extremity muscle strength[10], we set 42 points as the threshold for inclusion in this study.

All the participants provided informed consent after receiving an adequate explanation. This study was conducted with the approval of the Ethics Committee of our hospital.

Data analysis

This study was a retrospective cohort study analyzing the JSSCI-DB. Data were extracted for LEMS, UEMS, indoor mobility (item 12), and outdoor mobility (item 14) of Spinal Cord Independence Measure III (SCIM)[11], Walking Index for Spinal Cord Injury II (WISCI)[12], Modified Ashworth Scale (MAS), and total length of stay (LoS). All data used were the values at the time of discharge.

The extracted data were used to compare the walking ability scores (indoor mobility, outdoor mobility, and WISCI) and independence levels of indoor and outdoor mobility among the three groups. Dunn's multiple comparison test was used to compare the walking ability scores. The χ^2 test was used to compare the independence levels and surgical intervention. For the independence levels, those with a score of ≥4 points were considered independent and those with a score of ≤3 points were considered nonindependent, referring to a previous study[13]. Odds ratios were calculated using Fisher's exact test, and Kruskal-Wallis test was used to compare the total LoS and MAS. Spasticity was analyzed separately for upper limb and lower limb MAS, considering the effect on gait. The JSSCI-DB collected MAS data for elbow and wrist joints flexion and extension; hip joints flexion, extension, adduction, and abduction; knee joints flexion and extension; and ankle joints dorsiflexion and plantarflexion. Statistical analysis was performed using Stat Flex ver. 6.0. The significance level was set at ≤5%.

Clinical and functional assessment

LEMS

The LEMS is a standard assessment determined using the American Spinal Injury Association (ASIA) and involves the evaluation of five key muscles of the L2-S1 segments in both lower extremities[14]. The muscle strength is rated 0-5 points (0=no muscle contraction, 5=can hold even when maximum resistance is applied), and the cumulative score ranges 0-50 points.

UEMS

The UEMS is also a standard assessment determined using the ASIA and involves the evaluation of five key muscles in the C5-T1 segments in both upper extremities. The cumulative score ranges from 0 to 50 points.

SCIM III

The SCIM is one of the most important assessment tools for evaluating the activity of daily living (e.g., management of urination and defecation, transfer to bed, toilet seat, and car) in patients with spinal cord injury[15]. The scores for both indoor and outdoor mobility range from 0 to 8 points.

WISCI

The WISCI assesses the ability to walk 10 m. Unlike the 10 m walk test, the WISCI is scored 0-20 points, depending on the orthoses and physical assistance required to walk 10 m. This method is a reliable clinical measure to quantify the walking ability of people with spinal cord injury[16,17].

Results

We retrospectively analyzed 1,195 patients with traumatic spinal cord injuries registered with the JSSCI-DB and identified 96 patients who met the inclusion criteria (81 men, 15 women; mean age [standard deviation, SD], 62.1 [11.4]; total LoS [SD], 287.1 [99.2]) (Table 1). The remaining 1,101 patients did not meet the inclusion criteria (Fig. 1). All participants included in this study were ASIA Impairment Scale (AIS) grade-D patients with incomplete cervical spinal cord injury. In total, 32, 43, and 21 participants were classified into the ≤59, 60-69, and ≥70-year subgroups of age at injury, respectively (Table 1).

A comparison of LEMS (Kruskal-Wallis test) was performed among the three groups, and no significant difference was found. As the upper extremity function can affect the walking ability when using a cane, etc., a comparison of UEMS indicating the upper extremity function (Kruskal-Wallis test) was also performed; no significant difference was found. These results demonstrated that the three groups have equivalent levels of extremity function.

Walking ability scores

In terms of the indoor mobility score, the ≥70-year age group (median: 4 points) was significantly inferior to the ≤59-year age group (median: 8 points) and the 60-69-year age group (median: 8 points). With respect to the outdoor mobility score, the ≥70-year age group (median: 2 points) was significantly inferior to the ≤59-year age group (median: 6 points) and the 60-69-year age group (median: 6 points). The WISCI score of the ≥70-year age group (median: 17 points) was significantly lower than that of the ≤59-year age group (median: 20 points) and the 60-69-year age group (median: 20 points). These results indicate that walking ability scores of the ≥70-year age group were significantly lower than those of the other two groups in all evaluations (Table 2).

Independence levels of walking

In terms of the independence level of indoor mobility, although 29 of 32 (91%) participants in the ≤59-year age group and 38 of 43 (88%) participants in the 60-69-year age group were independent, only 13 of 21 (62%) participants in the ≥70-year age group were independent, indicating a significantly lower level of independence in the ≥70-year age group than the ≤59-year and 60-69-year age groups (Table 3). Indoor independent walking acquisition rate (odds ratio) was as low as 1/6 (95% confidence interval [CI], 1.4-26.1) of the ≤59-year age group for the ≥70-year age group and 1/5 (95% CI, 1.3-16.9) of the 60-69-year age group. Additionally, regarding the independence level of outdoor mobility, although 28 of 32 (88%) participants and 35 of 43 (81%) participants were independent in the ≤59-year age group and 60-69-year age group, respectively, only 10 of 21 (48%) participants in the ≥70-year age group were independent, indicating a significantly lower level of independence in the ≥70-year age group than the ≤59-year and 60-69-year age groups. The rate of acquisition (odds ratio) of outdoor independent walking was similarly low in the ≥70-year age group, 1/8 (95% CI, 2.0-29.8) of the ≤59-year age group, and 1/5 (95% CI, 1.5-15.2) of the 60-69-year age group.

Discussion

Presently, the most common age group at the time of injury for patients with spinal cord injury in Japan is 60s. For this reason, three groups were created in this study based on this age group. The results of this study demonstrated that walking ability scores and independence levels of mobility decreased significantly when the age at injury was ≥70 years, even if measures of extremity function exceeded levels enough for independent walking (LEMS: ≥41.5 points, UEMS: ≥36.5 points)[10]. Moreover, compared with mobility independence, Cramer's coefficient V, which indicates an association between two factors in an m×n contingency table, was 0.36 for the independence level of outdoor mobility, whereas it was 0.31 for the independence level of indoor

Table 1. Characteristics of Participants of the Study.

	Total Sample n=96	≤59 years n=32	60–69 years n=43	≥70 years n=21	P-value
Age (years)	62.1±11.4	49.6±8.6	64.5±2.7	76.4±4.0	
Sex					
Men	81 (84.4)	29 (90.6)	35 (81.4)	17 (81.0)	
Women	15 (15.6)	3 (9.4)	8 (18.6)	4 (19.0)	
Cause of trauma					
Street accidents[a]		12	10	5	
Fall down		7	11	6	
Falls		9	18	9	
Other		4	4	1	
Surgical intervention	21/96	8/32	10/43	3/21	n.s.
LEMS	48.0±2.5	48.4±2.3	48.0±2.4	47.2±2.6	n.s.
UEMS	41.2±7.4	42.2±7.3	41.6±5.5	39.1±9.9	n.s.
MAS (LE)	0.51±0.52	0.50±0.52	0.54±0.54	0.48±0.47	n.s.
MAS (UE)	0.50±0.57	0.51±0.53	0.48±0.56	0.54±0.64	n.s.
Total LoS (days)	287.1±99.2	291.4±119.1	286.2±83.6	282.2±94.8	n.s.

NOTE. Values were mean±SD or n (%).
[a]Street accidents: car, motorcycle, and bicycle accidents
LEMS, lower extremity motor score; UEMS, upper extremity motor score
MAS, modified Ashworth scale; LE, lower extremity; UE, upper extremity
LoS, length of stay; n.s., not significant

Table 2. Summary of Walking Ability Score Results.

	≤59 years	60–69 years	≥70 years	P-value	Dunn's multiple comparison test
Indoor mobility	8 (5–8)	8 (5.5–8)	4 (2–6)	0.0031	≤59 years†, 60–69 years† vs. ≥70 years
Outdoor mobility	6 (5–8)	6 (4–8)	2 (2–5)	0.0008	≤59 years‡, 60–69 years† vs. ≥70 years
WISCI	20 (18.5–20)	20 (18–20)	17 (13–20)	0.0053	≤59 years†, 60–69 years* vs. ≥70 years

NOTE. Values were given as median (interquartile range).
WISCI, Walking Index for Spinal Cord Injury II
* P<0.05, † P<0.01, ‡ P<0.001
≤59 years vs. 60–69 years: No significant differences in all evaluations.

mobility. This result suggests that outdoor mobility is more strongly affected by age at the time of injury compared with that of indoor mobility. This is because outdoor mobility involves walking on irregular terrain and thus requires the ability to balance and a greater walking speed. The effects of age on balance ability and walking speed have been investigated previously[18-20], and aging reduces the balance ability and walking speed. This is likely the reason why the levels of independence decreased significantly with age at injury in patients with cervical spinal cord injury even though their UEMS/LEMS did not exhibit a significant difference. Cifu et al. examined FIM cognitive scores in patients with spinal cord injuries and reported that cognitive function deteriorated as age increased[9]. Deteriorated cognitive function can be a contributing factor to the present results because cognitive function is essential for understanding fall risks and improving walking proficiency. Nevertheless, it has been suggested that individuals in their 60s can achieve walking ability comparable with that of individuals aged <59 years.

As an effect of rehabilitation due to exercise, active walking training that begins early after an injury has been reported to improve indices, such as LEMS, WISCI, and the 10 m walk test[21,22]. Also, reportedly, exercise effects did not differ by age[22-24]. Thus, we believe that active gait training started early in the rehabilitation of elderly individuals is useful for achieving independent walking. For individuals with spinal cord injuries, regaining their walking ability is the most important task in rehabilitation. Our findings are expected to assist in the development of age-optimized rehabilitation programs and allow for more accurate goal setting.

This study had some limitations. First, currently, the age distribution at the time of spinal cord injury in Japan showed a unimodal pattern with a peak in the age group of 60s; however, distribution patterns in other countries may not be the same. Second, the lower extremity muscle strength and walking ability were measured at discharge, which occurred on different days after injury for each case; these data were used for analysis because functional recovery in patients with spinal cord injuries reaches a plateau approximately 6 months after injury[5]. The total LoS did not differ to a statistically significant degree among the three groups, and the mean LoS was longer than the time to reach

Table 3. Comparison of Independence Levels of Walking.

Indoor mobility	≤59 years n=32	60–69 years n=43	≥70 years n=21
Independent (n)	29	38	13
Nonindependent (n)	3	5	8
Independence level (%)	91	88	62
P-value		0.0114	
Cramer's coefficient V		0.31	
OR (95% CI)			
≤59 vs. ≥70		6.0 (1.4–26.1)	
60–69 vs. ≥70		4.7 (1.3–16.9)	
≤59 vs. 60–69		1.3 (0.3–5.8)	
Outdoor mobility	**≤59 years n=32**	**60–69 years n=43**	**≥70 years n=21**
Independent (n)	28	35	10
Nonindependent (n)	4	8	11
Independence level (%)	88	81	48
P-value		0.0021	
Cramer's coefficient V		0.36	
OR (95% CI)			
≤59 vs. ≥70		7.7 (2.0–29.8)	
60–69 vs. ≥70		4.8 (1.5–15.2)	
≤59 vs. 60–69		1.6 (0.4–5.9)	

OR, odds ratio; CI, confidence interval

the plateau, i.e., 6 months. Nonetheless, different lengths of time from injury to evaluation may impact accuracy. Third, the total number of patients with traumatic spinal cord injury who were registered in the JSSCI-DB was 1,195. However, there were more than 500 patients who were transferred or discharged from the hospital before the completion of 180 days of follow-up, which resulted in a small number of patient inclusion in this study. Fourth, although all patients in this study had AIS grade-D, the LoS in the hospital was long, approximately 300 days. This is because some patients were not AIS grade-D at the time of injury, but recovered gradually after the injury and could become AIS grade-D at the time of discharge evaluation. This may be a reason for the long hospital stay. Finally, all participants in this study were able to walk independently before the trauma. However, detailed complications (e.g., cerebral infarction, knee osteoarthritis, and spinal canal stenosis) and balance could not be compared between the groups due to insufficient data in the JSSCI-DB. Complications may have a significant impact not only on walking ability but also on the cause of injury. Since balance is a factor that affects walking ability, expanding the scope of data collection, such as the Berg Balance Scale, should be considered in the future.

Our study elucidated that age at the time of injury affected walking ability scores and independent walking ability. We believe that this finding complements conventional rehabilitation. It is important to set goals early after injury based on predicted prognosis and hence provide an age-optimized rehabilitation program.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Author Contributions: Tomoki Naka was the principal investigator of this paper, wrote the summary of the study, conducted the statistical analysis, and wrote the manuscript.

Tetsuo Hayashi and Atsushi Sugyo critiqued the manuscript, made revisions, and assisted in writing the final draft of this paper.

Fumihiro Towatari and Takeshi Maeda provided feedback on the paper. All authors approved the final draft.

Ethical Approval: This study was approved by the Institutional Review Board of our hospital.

The name of the institution: Japan Organization of Occupational Health and Safety, Spinal Injuries Center

Approval code: 15-2

Informed Consent: Both written and oral explanations of the contents of this study were provided to the participants, and their consent was obtained.

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