

Incidence and characteristics of physical disabilities in patients with postconcussion syndrome following mTBI

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Abstract

This study aimed to examine the incidence and characteristics of physical disabilities in patients with postconcussion syndrome (PCS) after a mild traumatic brain injury (mTBI).

Of 203 patients diagnosed with PCS after mTBI, 10 patients with definite physical disabilities (worse than moderate disability on the Glasgow outcome scale [GOS], <4 points and inability to walk independently on the Functional Ambulation Category [FAC], <3 points) were enrolled.

Ten of the 203 patients included in the analysis based on prespecified inclusion criteria were further evaluated. Seven patients had moderate disability on the GOS, whereas the remaining 3 showed severe disability. On the Modified Barthel Index, 5 patients were moderately dependent, and 2 patients were severely dependent. By the Motricity Index, 9 patients showed mild quadriplegia, and 1 had mild hemiparesis. All 10 patients could grasp-release their fingers as per the Modified Brunnstrom Classification. By contrast, 7 patients required verbal supervision for independent gait by the FAC, and the remaining 3 patients needed intermittent support from 1 person for independent gait.

Approximately 5% of patients with PCS after mTBI had a definite physical disability, and most of these patients showed mild quadriplegia. These results suggest that a definite physical disability can occur in patients with PCS after mTBI.

Abbreviations: ADL = activities of daily living, CT = computed tomography, DSM-IV-TR = Diagnostic and Statistical Manual of Mental Disorders, fourth edition, text revision, FAC = functional ambulation categories, FLAIR = fluid attenuated inversion recovery, GCS = Glasgow coma scale, GOS = Glasgow outcome scale, MBI = Modified Barthel index, MBC = Modified Brunnstrom classification, MI = motricity index, MMSE = mini-mental state examination, MRI = magnetic resonance imaging, mTBI = mild traumatic brain injury, PCS = postconcussion syndrome, SARA = scale for assessment and rating of ataxia.

Keywords: concussion, disability, mild traumatic brain injury, postconcussion syndrome, traumatic brain injury

1. Introduction

A concussion is defined as a transient, temporary neurological dysfunction resulting from the application of force to the brain. More specifically, a cerebral concussion is an acute trauma-induced change in mental function generally lasting <24 hours and with recovery usually occurring within 2 to 3 weeks.^[1,2] A mild traumatic brain injury (mTBI) is defined as a traumatically induced physiological disruption of brain function as manifested by at least one of the following: any period of loss of consciousness of approximately 30 minutes or less; an initial Glasgow Coma Scale (GCS) score of 13 to 15, after 30 minutes

and posttraumatic amnesia not exceeding 24 hours, as defined by the American Congress of Rehabilitation Medicine Special Interest Group on Mild Traumatic Brain Injury, 1993.^[2,3] Concussion and mTBI are not usually associated with visible lesions that can be detected by conventional computed tomography (CT) or magnetic resonance imaging (MRI).

Concussion and mTBI are used interchangeably, and there have been differing opinions regarding these terms.^[2] In a 2012 review by Rapp and Curley, the authors suggest that due to the heterogeneity of the clinical population and presenting features, the absence of a common etiology of postinjury deficits, and the complex, idiosyncratic time course of the appearance of these deficits in mTBI, it

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may no longer be considered a classical syndrome but may need to be redefined as an event leading up to a diagnosable neurological or psychiatric disorder.^[4] Subsequently, McMahon et al reported that the term “mTBI” is a misnomer because some patients with mTBI show severe neurological sequelae.^[5] In 2015, Sharp and Jenkins concurred that mTBI was not always a benign condition as its name implied, and some patients with mTBI fail to recover.^[6]

Postconcussion syndrome (PCS) is a constellation of cognitive, behavioral, emotional, and physical symptoms persisting for more than 3 months after mTBI.^[7] This syndrome is common in patients with mTBI with a prevalence of up to 82%.^[5] mTBI can affect the quality of life, including the activities of daily living, occupational activities, or other health conditions.^[8] The sequelae of PCS have mainly been reported in cognitive, behavioral, and emotional symptoms.^[7] By contrast, relatively little is known about the sequelae of the physical functions.^[9,10] In particular, regarding physical disability, only a few studies have reported its incidence in PCS.^[5,11] Furthermore, the detailed characteristics of the physical disabilities have not been reported.

Therefore, this study examined the incidence and characteristics of physical disabilities in patients with PCS after mTBI.

2. Methods

2.1. Subjects

A total of 203 patients (70 males and 133 females; mean age of 47.1 ± 12.8 , range, 18–85 years) with a diagnosis of mTBI based on the diagnostic criteria for mTBI by the American Congress of Rehabilitation Medicine Special Interest Group (presenting with loss of consciousness for <30 minutes, posttraumatic amnesia for ≤ 24 hours, and an initial GCS score of 13–15 at the time of TBI) were further evaluated for PCS (Fig. 1). The diagnosis of PCS was made according to the Diagnostic and Statistical Manual of Mental Disorders Text Revision Fourth Edition

(DSM-IV-TR) criteria at the rehabilitation department of a university hospital. Ten patients (1 male and 9 females, mean age 40.8 ± 13.7) were recruited based on the following inclusion criteria^[12]: (1) 18 years or older at the time of TBI; (2) more than 3 months elapsed after head trauma; (3) no specific lesion observed on brain MRI (T1-weighted, T2-weighted, and fluid-attenuated inversion recovery [FLAIR] images); (4) Glasgow Outcome Scale (GOS) <4 points; (5) Functional Ambulation Category (FAC) less than 3 points; (6) Mini-Mental State Exam (MMSE) >25 points; (7) no previous history of head trauma or neurological or psychiatric disease prior to TBI.

The data used in this study were collected retrospectively, and written informed consent was obtained from each participant. This study provided accurate and complete information as stipulated by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement. The Institutional Review Board of a university hospital approved the study protocol.

2.2. Clinical evaluation of the participants for physical disabilities

All the participants were subjected to the following assessments to evaluate the severity of their physical disabilities:

2.2.1. Glasgow outcome scale. GOS is a scale for patients with brain injuries allowing an objective assessment of their recovery. The GOS is subdivided into 5 categories: (1) dead, (2) vegetative state, (3) severe disability (conscious but needs the assistance of another person for some activities of daily living [more than 1 activity]), (4) moderate disability (disabled, but independent in daily life), and (5) good recovery.^[13]

2.2.2. Mini-mental state exam. The MMSE is used for the evaluation of cognitive function (cutoff score < 25, range 1–30; a higher score means better cognition).^[14] The MMSE evaluates

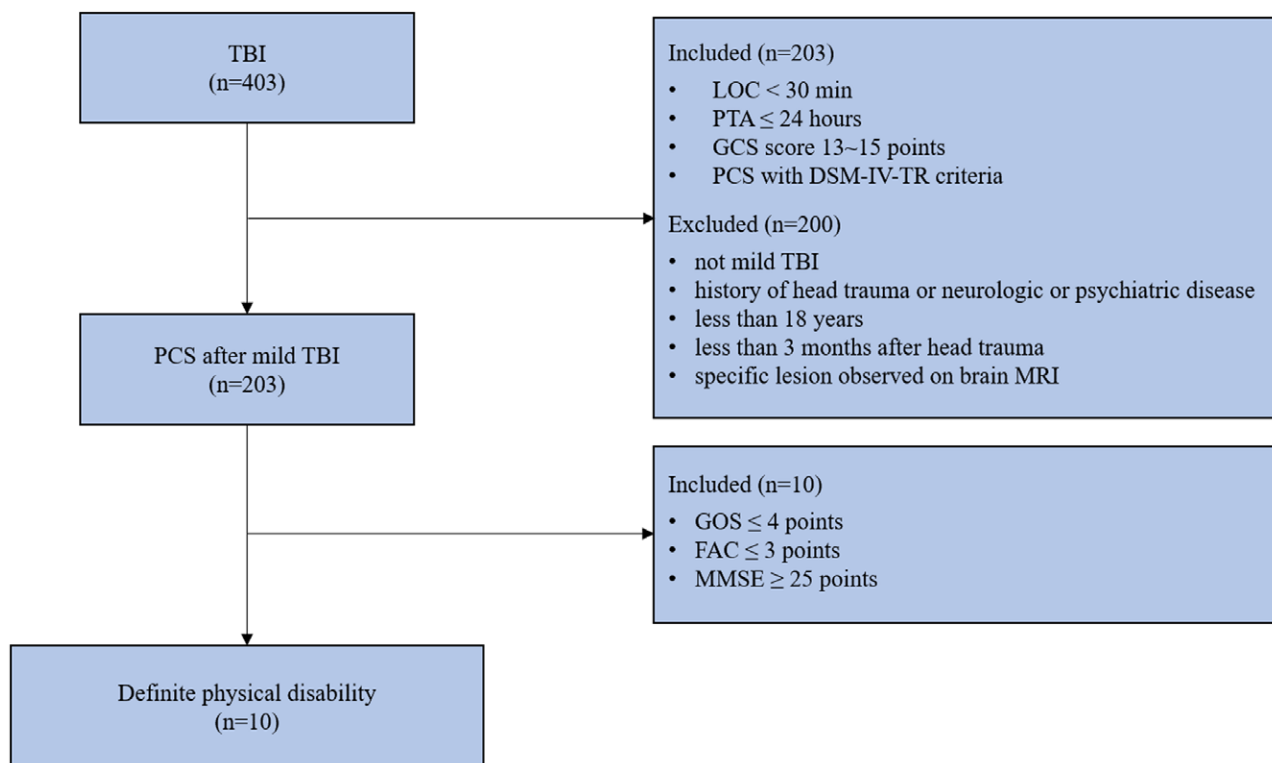


Figure 1. Flow diagram of the inclusion criteria. DSM-IV-TR = Diagnostic and Statistical Manual of Mental Disorders, Text Revision, FAC = functional ambulation category, GCS = Glasgow coma scale, GOS = Glasgow outcome scale, LOC = loss of consciousness, MMSE = mini-mental state examination, MRI = magnetic resonance imaging, PCS = postconcussion syndrome, PTA = posttraumatic amnesia, TBI = traumatic brain injury, .

the subject's orientation, memory, attention, calculation, visuospatial, and language abilities.

2.2.3. Modified Barthel index. The MBI is a measure of activities of daily living (ADL) that shows the degree of independence of a patient from any assistance. It comprises 10 daily living-related activities (range 0–100; a higher score represents a higher degree of independence in performing the basic activities of daily living) and includes feeding, personal hygiene (grooming), bathing, dressing, toilet transfer, bladder control, bowel control, chair/bed transfers, stair climbing, and ambulation. The total MBI score range is divided into 5 daily living activity outcome categories: (1) minimally dependent on others, 91–99; (2) mildly dependent, 75–90, (3) moderately dependent, 50–74; (4) severely dependent, 25– 49; (5) totally dependent on others, 0–24.^[15]

2.2.4. Motricity index. The MI is used to evaluate the motor function of the 4 extremities.^[16] The MI score (range 1–100; a higher score means better motor function) is a modification of the Medical Research Council scoring system.^[16] The total MI score is an average of the upper (shoulder flexor, elbow flexor, and prehension) and lower (hip flexor, knee extensor, and ankle dorsiflexor) MI scores; each joint of the extremities is scored as follows: MI score except for prehension 0 (no contraction), 28 (palpable contraction, but no visible movement), 42 (movement without gravity), 56 (movement against gravity), 74 (movement against a resistance lower than the resistance overcome by the healthy side), and 100 (movement against a resistance equal to the maximum resistance overcome by the healthy side); MI score for prehension 0 (no movement), 33 (beginning of prehension), 56 (prehension of the object without gravity), 65 (prehension of the object against gravity), 77 (prehension against a slight manual resistance applied to the object), and 100 (prehension against a resistance identical to the resistance overcome by the healthy hand).

2.2.5. Modified Brunnstrom classification. The Modified Brunnstrom Classification (MBC) is used to categorize the function of both hands^[17] as follows: 1 (unable to move the fingers voluntarily), 2 (able to move the fingers voluntarily), 3 (able to close the hand voluntarily; unable to open the hand), 4 (able to grasp a card between the thumb and the medial side of the index finger; able to extend the fingers slightly), 5 (able to pick up and hold a glass; able to extend the fingers), and 6 (able to catch and throw a ball in a near-normal fashion; able to button and unbutton a shirt).

2.2.6. Functional ambulation category. The FAC helps determine the gait ability.^[18] The FAC is designed to examine the levels of assistance required during a 15 m walk. Six categories are included in the FAC: 0 (nonambulatory), 1 (needs continuous support from 1 person), 2 (needs intermittent support from 1 person), 3 (needs only verbal supervision), 4 (help is required on stairs and uneven surfaces), and 5 (can walk independently anywhere).

2.2.7. Score of assessment and rating of ataxia. The Score of Assessment and Rating of Ataxia (SARA) is used to evaluate ataxia (range 1–100; a higher score means more severe ataxia). This scale consists of 8 items related to the gait, stance, sitting, speech disturbance, finger-chase test, nose-finger test, fast alternating hand movements, and heel-shin test.^[19]

3. Results

Ten (4.9%) of the 203 patients met the inclusion criteria set for patients with definite physical disabilities (GOS < 4 points and FAC < 3 points). The clinical data were collected from each subject at a mean of 47.2 months (± 34.2; range 13–113 months) after head trauma. Table 1 lists the demographic and clinical

Table 1
Demographic and clinical data of patients.

No	Sex	Age	Data Duration (month)	Cause of Trauma	LOC (min)	PTA (min)	GCS	MMSE	GOS	MBI	MI				MBC			
											Rt. arm	Rt. leg	Lt. arm	Lt. leg	Rt	Lt	FAC	SARA
1	F	50	77	MVA	5	10	15	27	4	40	82.7	74	82.7	74	5	4	3	0
2	F	40	22	Fall	1	1	15	29	4	48	75	74	75	74	6	6	3	23
3	F	52	89	MVA*	17	17	15	25	4	59	75	74	75	74	5	5	3	23
4	F	67	20	Fall	1	0	15	28	3	74	63	56	63	56	6	6	2	27
5	M	38	21	MVA*	0	0	15	27	3	67	100	100	82.7	56	6	6	2	0
6	F	43	113	MVA*	0	0	15	26	4	77	63	56	75	74	6	6	3	0
7	F	28	13	MVA*	3	3	15	28	3	63	69	74	69	74	5	5	2	18
8	F	23	36	MVA*	0	0	15	29	4	84	82.7	74	82.7	74	6	6	3	8
9	F	24	48	MVA*	2	2	15	29	4	56	63	56	75	74	5	5	3	0
10	F	43	33	MVA*	2	0	15	28	4	79	58.3	56	58.3	56	4	4	3	0
Mean ± SD		40.8 ± 13.7	47.2 ± 34.2		3.1 ± 5.1	3.3 ± 5.7	15 ± 0.0	27.6 ± 1.3	3.7 ± 0.5	64.7 ± 14.2	73.2 ± 12.7	69.4 ± 14.0	73.8 ± 8.3	68.6 ± 8.7	5.4 ± 0.7	5.3 ± 0.8	2.7 ± 0.5	9.9 ± 11.5

FAC = functional ambulation category, GCS = Glasgow coma scale, GOS = Glasgow outcome scale, LOC = loss of consciousness, LT = left, MBI = modified Barthel index, MBC = modified Brunnstrom classification, MI = Motricity Index, MMSE = mini-mental state examination, MVA = Motor vehicle accident, PTA = posttraumatic amnesia, RT = right, SARA = scale for assessment and rating of ataxia.
*Whiplash.

data of the patients. Nine out of 10 patients were female, and the mean age was 40.8 years (range: 23–67 years). According to the age groups, twenty and forty were the most common age groups comprising 3 patients each. 2 patients were in their fifties. Regarding the cause of head trauma, 8 of the 10 patients sustained their head trauma from a motor vehicle accident, and 2 patients were injured by a fall. Among the 8 patients who had met with a motor vehicle accident, the trauma of 7 patients was associated with whiplash.

According to the GOS, 7 patients were categorized as having a moderate disability (disabled, but independent in daily life), whereas the condition of 3 patients corresponded to severe disability (conscious but disabled with the patient being dependent for daily support). The MBI scores of the patients ranged from 40 (severe dependence) to 84 (mild dependence), with a mean score of 64.7 (\pm 14.2). Five of the 10 patients were classified as moderately dependent (MBI: 50–74), and 2 patients were severely dependent (MBI: 25 - 49).

The MI scores showed that 9 patients had quadriplegia, and 1 patient (patient 5) showed left hemiparesis. The mean MIs of the arms (Rt: 73.2 \pm 12.7, Lt: 73.8 \pm 8.3) were mildly higher than those of the legs (Rt: 69.4 \pm 14.0, Lt: 68.6 \pm 8.7). The mean total MIs of the right and left extremities were 71.3 \pm 12.5 and 71.2 \pm 7.0, respectively. The mean MBC scores of the right and left hands were 5.4 (\pm 0.7, range 4–6) and 5.3 (\pm 0.8, range 4–6), respectively. By contrast, the mean FAC score was 2.7 (\pm 0.5); 7 patients required verbal supervision for independent gait (FAC: 3), and 3 needed intermittent support from 1 person for independent gait (FAC: 2). Ataxia was observed in 5 patients with a mean SARA of 19.8 (\pm 7.3).

4. Discussion

This study enrolled patients with PCS who showed definite physical disabilities after mTBI. Thus, patients who scored less than 4 points on the GOS (moderate disability: disabled, but independent in daily life) were recruited. Another inclusion criterion using FAC (<3 points: the patients who could not walk completely independently) was added to recruit patients who had definite physical disabilities because of the possibility that the GOS could be ambiguous in some cases.^[20] After filtering the patients as per the above criteria, 10 (4.9%) out of 203 patients met the inclusion criteria.

The characteristics of the 10 patients are summarized as follows. (1) Nine patients were female. The mean age was 40.8 years; twenty and forty were the most common age groups with 3 patients each. (2) Motor vehicle accidents were the most common cause of head trauma involving 8 patients, and 7 patients were associated with whiplash. (3) Seven patients showed moderate disability and 3 patients had severe disability on the GOS. (4) Five patients were moderately dependent, and 2 patients were severely dependent on MBI. (5) Nine patients showed quadriplegia, and 1 patient had hemiparesis. The severity of motor weakness was mild as reflected by the total MI score of approximately 70 points (out of a total score of 100 points). (6) All patients could at least grasp-release their fingers on the MBC (mean 5.4, range 4–6). (7) On the FAC, 7 patients required verbal supervision for independent gait (FAC: 3), and 3 patients needed intermittent support from 1 person for independent gait (FAC: 2). (8) Five patients showed mild ataxia with a mean SARA score of 19.8 (total score of 100).

Sex and age have been reported to be critical demographic factors related to the severity of the clinical features and outcome in concussion or mTBI.^[21–23] Many studies have reported that the female sex and younger age are associated with severe clinical symptoms and poorer outcomes.^[21–23] A recent multicenter prospective cohort study of 2000 patients with mTBI reported more severe cognitive and somatic symptoms in females compared to males, whereas there was no difference in

symptoms based on the sex of the control patients with orthopedic trauma.^[22] Within the female patients, the symptoms of those aged 35 to 49 years were worse than those aged 17 to 34 years or older than 50 years. As a result, the authors concluded that females were more vulnerable to persistent mTBI-related cognitive and somatic symptoms than males. Moreover, women aged 35 to 49 years had worse postconcussion symptoms than both younger and older women. Although there is some controversy regarding age, a direct comparison between previous studies is difficult because the age of the patients and age grouping were different in each study.^[21] The results of the present study (9 patients were female, and twenty and forty were the most common age groups with 3 patients each) appeared to concur with the results mentioned above.^[21–23]

Whiplash is a bony or soft tissue injury resulting from acceleration-deceleration energy transfers in the neck.^[24] Whiplash has been suggested to be a pathophysiological mechanism of concussion or mTBI.^[25,26] Previous studies reported that mTBI due to whiplash was associated with more severe clinical features than mTBI from other causes.^[27] The introduction of diffusion tensor imaging has revealed several pathophysiological mechanisms of brain injury by whiplash including traumatic axonal injury.^[24,25] Furthermore, a few studies have reported that whiplash was associated with poorer outcomes or more severe traumatic axonal injury than other causes of head trauma.^[28] Thus, the result showing that 7 out of 10 patients were associated with whiplash suggests that this may be a factor leading to the physical disability of patients with PCS after mTBI.

In this study, 4.9% of the 203 patients with PCS after mTBI had a definite physical disability. Seven of these patients had a moderate disability (disabled, but independent in daily life), and 3 patients had a severe disability (conscious but disabled with the patient being dependent on daily support). Consequently, these results indicate that 30% of such patients required a caregiver's help for their daily living activities. This physical disability presented by our patients appears to correspond to an actual physical disability and not a cognitive or mental disability because the cognition of all our patients was within the normal range on the MMSE. Also, similar results were observed on the MBI, wherein 5 patients were moderately dependent (MBI: 50–74), and 2 patients were severely dependent (MBI: 25 - 49).

Several case studies have reported patients with a physical disability following mTBI or PCS.^[29,30] On the other hand, only a few clinical trials have reported the incidence of physical disabilities in patients with mTBI or PCS following mTBI.^[5,11] In 2008, Smits et al examined the incidence of physical disabilities in a prospective study that followed up 237 patients with minor head injuries.^[11] At 15 months after a minor head injury, there was full recovery (GOS: 5) in 63% of patients, moderate disability (GOS: 4) in 30% of patients, severe disability (GOS: 3) in 3.0% of patients, and death in 4.2% of patients. More than 70% of the patients had intracranial lesions on the brain CT, even though the authors had recruited patients with a GCS of 13 to 15. In 2014, McMahon et al reported the incidence of physical disabilities in 375 patients with mTBI (GCS score of 13–15). They found that 22.4% of patients had still not returned to their full preinjury functional status (worse than GOS-extended 6: upper-moderate disability, in other words, a patient with some disability, who can potentially return to some form of employment) at 12 months after mTBI.^[5] On the other hand, approximately 44% of patients showed positive findings on brain CTs. The variation in physical disabilities in our study compared to the above studies can be attributed to the following reasons: First, our study recruited patients with more severe physical disabilities than the above studies. The 2 studies above were classified using GOS or GOS-extended. By contrast, our study recruited patients who could not walk completely independently on FAC and patients with a disability on GOS (worse than GOS 4: moderate disability). Second, the 2 studies above included patients with brain lesions

on brain CTs, whereas our study included only patients who did not show any brain lesions on brain MRIs.

The physical disabilities of the patients in our study were as follows: Nine patients showed mild quadriparesis, and 1 patient had hemiparesis with a mean MI score of approximately 70.0 (total score of 100). Regarding hand functions, all patients could at least grasp-release their fingers on the MBC (mean 5.4, range 4–6). By contrast, the gait function tests showed that 3 patients could not walk without intermittent support from 1 person (FAC 2). As a result, the gait function appeared to be mildly worse than the hand function in these patients. On the other hand, mild ataxia was observed in 5 patients (mean SARA: 19.8, range: 8–23, total score 100). Consequently, ataxia appeared to be a factor in the physical disabilities of these patients. To the best of the authors' knowledge, this study is the first to investigate the characteristics of definite physical disabilities in patients with PCS after mTBI.

This study had some limitations. First, the number of subjects was small. Second, there was a paucity of detailed clinical data on the physical disabilities of the patients. Third, the patients in this study may have had more severe clinical features than those in a general population of patients because the study specifically included patients who visited the rehabilitation department of a university hospital. Further prospective multicenter studies involving a larger number of subjects will be needed to overcome the above limitations.

In conclusion, approximately 5% of patients with PCS after mTBI had definite physical disabilities, and the majority of these patients presented with mild quadriparesis. These results suggest that definite physical disabilities can occur even in mTBI patients. Therefore, patients with mTBI can develop sequelae of physical disabilities at the chronic stage. Hence, early detection and comprehensive rehabilitation are necessary in the early stages of TBI.

Author contributions

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