Higher levels of mobility are associated with greater societal participation and better quality-of-life

Article *in* Brain Injury · May 2012

Impact Factor: 1.81 · DOI: 10.3109/02699052.2012.667586 · Source: PubMed

2 authors:

Gavin P Williams
Epworth HealthCare
63 PUBLICATIONS **481** CITATIONS
SEE PROFILE

Catherine Willmott
Monash University (Australia)
19 PUBLICATIONS **1,004** CITATIONS
SEE PROFILE

Brain Injury, August 2012; 26(9): 1065–1071

informa
healthcare

ORIGINAL ARTICLE

Higher levels of mobility are associated with greater societal participation and better quality-of-life

G. WILLIAMS[1] & C. WILLMOTT[2]

[1]*Physiotherapy Department, Epworth Hospital, Richmond, Victoria, Australia, and* [2]*School of Psychology & Psychiatry, Monash University, Victoria, Australia*

(Received 28 June 2011; revised and accepted 9 February 2012)

Abstract

Introduction: Participation rates and quality-of-life (QoL) have been a major focus of rehabilitation programmes and outcome studies following traumatic brain injury (TBI). The extent to which mobility limitations impact on participation rates and QoL has not been thoroughly explored. The main aim of this study was to investigate the relationship between mobility limitations, participation rates and QoL following TBI.

Methods: Thirty-nine people who had sustained an extremely severe TBI were recruited from a major rehabilitation facility. Mobility was quantified using the high-level mobility assessment tool (HiMAT). The Brain Injury Community Rehabilitation Outcome (BICRO-39) and Community Integration Questionnaire (CIQ) were used to measure participation rates and the shorter version of the World Health Organization Quality of Life (WHOQoL-BREF) and Assessment of Quality-of-Life (AQoL-2) were used to measure QoL.

Results: Mobility was most strongly correlated with the total BICRO-39 score ($r = -0.60$, $p < 0.001$) and the mobility domain ($r = -0.59$, $p < 0.001$) of the BICRO-39. Although mobility had a significant relationship with health-related QoL, AQoL-2 ($r = 0.60$, $p < 0.001$), it was most strongly related to the AQoL-2 independent living domain ($r = 0.79$, $p < 0.001$).

Conclusion: Greater capacity to mobilize was associated with higher participation rates and better QoL.

Keywords: *Mobility limitation, activities of daily living, social participation, quality-of-life*

Introduction

The main cause of death and disability for people aged 18–45 years is traumatic brain injury (TBI) [1]. Although the majority of people sustain a mild TBI, mobility limitations are common following moderate–severe TBI. The physical sequelae resulting from TBI have been under-studied relative to cognitive and psychosocial domains [2]. Little is known about the nature of mobility limitations following TBI [3] and the contribution of mobility limitations to participation rates and quality-of-life (QoL) is largely unknown.

Participation rates and QoL have been a major focus of rehabilitation programmes and outcome studies following TBI [4–8]. The term 'participation' relates to the extent to which a person engages in life situations such as household and domestic chores, shopping, social outings, employment and relationships [9]. The diverse nature of TBI may result in restrictions to some, none or all of these domains. To a large extent, the success of a rehabilitation programme relates to the degree to which people with TBI can return to their pre-accident activities. Quality-of-life is a broad ranging concept which includes physical and psychological health, independence, relationships and how these domains interact with the persons own environment. Therefore, the assessment and measurement of QoL often relates to factors associated with participation rates.

Correspondence: Dr Gavin Williams, Physiotherapy Department, Epworth Hospital, 89 Bridge Rd, Richmond, 3121, Victoria, Australia. Tel: +613 9426 8727. Fax: +613 9426 8734. E-mail: gavin.williams@epworth.org.au

ISSN 0269–9052 print/ISSN 1362–301X online © 2012 Informa UK Ltd.
DOI: 10.3109/02699052.2012.667586

Following TBI, the factors associated with higher QoL relate to employment [5, 7,10–12], relationships [8, 10, 13, 14], higher levels of independence and social participation [8, 10, 13, 15] and mental health status [10, 13]. Problems with cognition and psychological and emotional health are prevalent following moderate-to-severe TBI and impact on participation and QoL. However, mobility is also a pre-requisite for independence in many day-to-day activities and higher levels of mobility are important for many of the social, leisure, sporting and employment roles of young people with TBI. Nevertheless, the extent to which mobility limitations impact on participation rates and QoL has not been thoroughly explored.

Very limited data exists on the relationship between physical capacity to mobilize, participation and QoL. Morris et al. [16] conducted an 8-week progressive resistance strength training programme for seven people with very severe TBI. Although all participants made strength gains, no change in mobility (10 metre walk) or participation (Brain Injury Community Rehabilitation Outcome: BICRO-39) was identified. Reavenall and Blake [15] investigated the determinants of physical activity participation for 63 people with TBI. No standardized measure of mobility or participation was used. Participants self-reported physical activity and were coded as active or inactive depending on whether they performed 30 minutes of physical activity for at least 5 days each week. The main finding was self-efficacy (a person's belief in their own ability to achieve an outcome) for exercise was the only significant predictor of participation in physical activity. In the context of this investigation, participation was used to describe involvement in an exercise programme rather than the broader definition used to describe taking part in day-to-day activities. The independent contribution of mobility limitations to participation rates and QoL remains unclear.

The main aim of this study was to investigate the relationship between mobility, participation rates and QoL. The secondary aim was to determine which aspects of participation and QoL higher levels of mobility were most strongly related to. It was hypothesized that there would be a moderately strong relationship between mobility and participation and between mobility and QoL.

Methods

This project was conducted in conjunction with a larger study into gait disorders following TBI. The recruitment and inclusion criteria were patients who: (a) had sustained a TBI; (b) were attending physiotherapy for mobility limitations; (c) were able to walk without assistance of a therapist or gait assistive device over a distance of 20 metres; and (d) provided informed consent. Exclusion criteria were patients who: (a) were unwilling or unable to provide informed consent; (b) presented with a pre-existing central nervous system disorder; and (c) had severe cognitive or behavioural problems that prevented assessment. All subjects who were invited to participate consented to do so. This project was approved by Epworth Hospital's HREC (study number 34006) and the University of Melbourne (Ethics ID: 060496.1).

Mobility

Mobility performance was measured using the high-level mobility assessment tool (HiMAT). The HiMAT was selected as a clinical measure of mobility because it is more responsive to change and less susceptible to a ceiling effect for people with TBI who can walk independently of gait aids [17, 18]. It measures a range of mobility skills, such as walking under various conditions, stair use, running, skipping, hopping and jumping. These abilities may be required for participation in many social, leisure, sporting and employment activities which are important for better QoL. Higher scores indicate better performance (maximum score = 54). It has high inter-rater and re-test reliability [19]. Self-selected 10 metre walk speed was also recorded so the physical capacity of this cohort could be compared to other studies, as self-selected gait speed is one of the more commonly reported measures of mobility. Self-selected gait speed can also be used to predict the functional implications of walking speed [20]. Perry et al. [20] were able to determine whether 147 people recovering from stroke were, for example, limited or unlimited household ambulators or limited or unlimited community ambulators, based on self-selected walking speed.

Participation

Two measures of societal participation were used. The Community Integration Questionnaire (CIQ) [21] is one of the most frequently used measures of societal participation following TBI. The CIQ is comprised of 15 items divided into three sub-scales which quantify home integration, social integration and participation in productive activities. Scores can range from 0–29, with higher scores indicating greater participation. The CIQ can be accurately reported by patients and their family members [22], has good inter-rater reliability, but may be insensitive to change [23].

The Brain Injury Community Rehabilitation Outcome (BICRO-39) [24] comprises 39 items

across six domains (personal care, mobility, self-organization, socializing, productive employment and psychological well-being). The BICRO-39 is scored out of 195, with higher scores indicating worse societal participation. It has good re-test reliability [24] and appears to be sensitive to change, particularly the mobility domain [25]. Although it has been less frequently used to measure participation following TBI than the CIQ, it was selected due to the larger number of items and response categories which may allow greater discriminative ability and responsiveness.

Quality-of-life

Two measures of QoL were also used. The shorter version of the World Health Organization Quality-of-Life (WHOQoL-BREF) [26] was developed as a short form field version of the WHOQoL-100. It comprises 26 questions in four domains (physical health, psychological, social relationships and environment). Raw scores are converted to transformed scores ranging from 0–100, with higher scores indicating better QoL. It has very good re-test reliability and appears to be responsive to change in TBI [27, 28]. The WHOQoL-BREF was selected for this study as it has a domain specifically designated to physical health. The Assessment of Quality-of-Life (AQoL-2) [29] was also selected. The AQoL-2 comprises 20 questions across six domains (independent living, social, mental health, coping, pain and sensory perception). An algorithm is used to convert AQoL raw scores to a scale ranging from −0.04–1.00. Higher scores indicate better QoL. It has recently been validated in TBI [4].

Data analysis

Summary statistics were generated for all of the variables of interest (see Table I). All variables of interest were assessed for distribution normality. Pearson correlation coefficients were calculated to determine the strength of the relationship between mobility and the measures of participation and QoL. Bonferroni corrections were made for the multiple correlations performed between mobility and the participation and QoL domains. Using Cohen's guidelines, a moderate relationship will be interpreted as $r = 0.30$–0.50 and a strong relationship as $r \geq 0.50$ [30].

Results

Participants

This group of 39 people were primarily young (27.7 ± 10.7 years) and male ($n = 29$). The majority had sustained a very severe TBI, the median length of PTA was 40 days (inter-quartile range 18–74 days). The length of time post-injury varied considerably, the median was 9.2 months (inter-quartile range 3.2–24.5). Fourteen of the participants had also sustained lower limb fractures, eight of them bilaterally. Only nine of the 39 participants reported they had returned to work or study (if they were students) to any extent. Thirty-three of the 37 participants who were driving at the time of their accident were still unable to drive at the time of assessment. Thirty-one participants reported they required some level of assistance for day-to-day activities.

Table I. Summary data for mobility, participation and QoL ($n = 39$).

	Mean (SD)	Range
Gait speed ($m\,s^{-1}$)	0.97 (0.38)	0.05–1.42
HiMAT	20.3 (13.3)	1–45
CIQ	12.8 (6.2)	7–20.75
BICRO-39	62.7 (23.2)	24–124
WHOQoL-BREF (Physical Health)	50.8 (13.3)	25–75
AQoL	0.72 (0.22)	0.26–1.00

Mobility

Although several participants had normal or near-normal self-selected gait speeds (Table I), all had mobility limitations when higher levels of mobility were assessed. HiMAT scores obtained in this sample were well below normative values for young adults [31], indicating mobility limitations were likely to restrict participation rates.

All participants in this study were independently mobile, yet capacity to mobilize varied considerably in this sample. According to Perry et al.'s [20] classification of self-selected walking speed, the majority (74.4%) of participants would be classified as 'community walkers' (i.e. self-selected walking speed $> 0.8\,m\,s^{-1}$) (see Table II). However, a smaller number only had capacity for indoor walking with little or no ability to walk in the community.

Participation

Mobility (HiMAT score) had a strong negative relationship ($r = -0.60$, $p < 0.001$) with the total BICRO-39, and its mobility domain ($r = -0.59$, $p < 0.001$), indicating greater capacity to mobilize was associated with higher rates of participation. No significant relationship was identified between mobility and the personal care, self-organization, productive employment, socializing or psychological well-being domains.

Table II. Functional classification of gait speed according to Perry et al. [20].

Gait classification	Gait speed (m s^{-1})	*n*
Physiological walker	0.10	3
Limited household walker	0.23	–
Unlimited household walker	0.27	1
Most-limited community walker	0.40	2
Least-limited community walker	0.58	4
Community walker	0.80	29

A moderate relationship was identified between mobility and the participation in productive activities domain ($r = 0.42$, $p = 0.01$) on the CIQ; however, no significant relationship was identified between mobility and the overall CIQ ($r = 0.33$, $p = 0.06$).

QoL

The mean AQoL-2 scores obtained for this cohort were significantly lower than aged matched population norms [32]. Mobility had a strong relationship with the total AQoL-2 ($r = 0.60$, $p < 0.001$). It also had a strong correlations with the independent living ($r = 0.79$, $p < 0.001$) and social ($r = 0.63$, $p < 0.001$) domains and a moderate correlation with the coping domain ($r = 0.36$, $p = 0.03$). No significant relationships were identified for the mental health, pain or sensory perception domains. In relation to the WHOQoL-BREF, no significant relationship was identified between mobility in any of the domains.

Although this clinical cohort varied considerably in the length of time to testing post-injury, post-hoc testing demonstrated no significant difference between acute (≤1 year) and chronic (>1 years) participants for all measures of mobility, participation and QoL.

Discussion

Although intuitive, this study is the first to find that greater capacity to mobilize was associated with higher rates of participation and better QoL. The relationship between higher rates of participation (employment, greater independence and socialization) and QoL has been well established [10–13]. However, the extent to which mobility contributed to participation rates and subsequent reporting of QoL was unknown. This finding suggests that people with greater ability to mobilize report better QoL. Although employment, mental health, personal independence and relationship status have established links with QoL following TBI, mobility may need to be included in future studies in order to determine whether it improves prediction of participation and QoL outcomes.

The results obtained in this study indicate that higher participation rates in satisfying life roles are facilitated by greater capacity to mobilize. Higher self-selected walking speed has been used as a predictor for community mobility [20]. Recently, Alzahrani et al. [33] found ability to negotiate stairs was the strongest predictor of physical activity in 42 community-dwelling participants with stroke. Higher-levels of mobility, i.e. faster gait speed and ability to negotiate stairs, are required for community access and are directly measured by the HiMAT. Although participation is dependent upon the complex interactions of cognitive, emotional, behavioural and physical domains, it seems that higher levels of mobility are associated with greater participation rates in day-to-day life roles. High-level mobility may be successfully trained for people with acute and chronic TBI [34] and may require greater prioritization in outpatient and community settings where resources tend to be limited.

The positive relationship between greater capacity to mobilize, higher participation rates and better QoL suggests that rehabilitation programmes designed to train advanced or high-level mobility skills may have important wider implications. Physical activity is very important for general health [35]. Reduced cardiovascular fitness, increased susceptibility to fatigue and reduced ability to exercise aerobically following TBI have been well documented and are associated with limited mobility [35–42]. Many methods for improving cardiovascular fitness following TBI based on mobility training have been described. These methods include walking [37, 38, 42, 43] and running [37, 43, 44]. Greater mobility and activity levels following TBI may lead to better cardiovascular health and health-related QoL.

The main finding by Reavenall and Blake [15] was that self-efficacy for exercise was the strongest predictor for physical activity participation. Although self-efficacy for exercise and participation in exercise programmes are important, they differ from the constructs measured in this study. This study measured mobility, which is a measure of capacity or ability, as distinct from activity, which measures how often a person engages in an activity they have the capacity to perform. The results obtained in this study indicate greater capacity to mobilize was associated with higher participation rates and better QoL. Future studies may need to quantify capacity to mobilize, self-efficacy for exercise and actual activity levels using accelerometer-type activity monitors in order to determine which factors are most important for participation, cardiovascular fitness and QoL following TBI.

A further finding of this study was the stronger relationship of mobility to the BICRO-39 rather

than the CIQ as a measure of participation and to the AQoL-2 rather than the WHOQoL-BREF (or its physical health domain) as a measure of QoL. The significance of these relationships may be a reflection of the types of items within the domains on the different measures. For example, one would expect mobility to impact on all items of the Independent Living domain of the AQoL-2, but the Physical Capacity domain of the WHOQoL-BREF includes items such as 'energy and fatigue' and 'sleep and rest' which may not necessarily be influenced by capacity to mobilize. Further, issues related to fatigue, energy levels and sleep are prevalent following TBI and may disproportionately influence 'physical capacity' as measured by the WHOQoL-BREF. Although an alternate version of the AQoL was used, the overall utility score in this TBI cohort (Mean = 0.74, SD = 0.19) was very similar to that reported in another Australian TBI sample (Mean = 0.63, SD = 0.29) [4], supporting the measure as a valid indicator of health-related QoL following TBI.

Limitations

This study has several limitations. First, only a relatively small sample was selected for this study. However, this study is the first to investigate the impact of mobility limitations on participation and QoL. It has identified several significant relationships between mobility and participation and mobility and QoL following TBI. Further, the results assist clinicians and researchers as to which measures may be more appropriate for use in studies related to mobility outcomes following TBI.

Although all the people in this study were independently ambulant, several of the participants were barely able to walk independently whilst others were able to run and jump. The relationship between mobility, participation and QoL identified in this study may have been different if people who required use of gait assistive devices to mobilize, or who were wheelchair-dependent, were included in this study. Although many in this study walked well below the normal walking speeds for healthy adults, the results indicate that, once able to walk independently, there is a strong relationship between mobility and participation and a moderate relationship between mobility and QoL.

Participants in this study were recruited from a rehabilitation facility, yet this is unlikely to have skewed the type of patients recruited. Although receiving therapy for mobility limitations, many had chronic conditions and were not in the acute recovery phase following TBI. However, it may be possible that the nature of this TBI cohort led to insufficient variability on some dimensions. For example, only nine of the 39 participants in this study had returned to work or study, which may impact on the results obtained on domains such as 'Productive Employment' on the BICRO-39. Also, even though the mean gait speed for this cohort of people with TBI (0.97 m s^{-1}) was well below that of healthy young adults (~1.3–1.4 m s^{-1}), it was slightly faster but generally equivalent to that required for community mobility (>0.8 m s^{-1}) [20]. It may be possible that the average gait speed for this sample provided greater a likelihood of engaging in day-to-day community-based activities because many participants walked at a speed above the threshold required for community mobility. Data from this study may be used to inform future projects aimed at comparison of sub-groups within TBI.

Conclusion

Greater capacity to mobilize was associated with higher participation rates and better QoL. Mobility had stronger relationships to the BICRO-39 and the AQoL-2, indicating they may be better suited for measuring participation rates and health-related QoL following TBI.

Declaration of Interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. Thurman D, Alverson C, Browne D, et al. (1999) *Traumatic Brain Injury in the United States: A report to Congress*. DOI: http://www.cdc.gov/ncipc/tbi/tbi_congress/TBI_in_the_US.PDF, accessed 22/03/2011.
2. Walker WC, Pickett TC. Motor impairment after severe traumatic brain injury: A longitudinal multicenter study. Journal of Rehabilitation Research and Development. 2007;44:975–82.
3. Williams G, Galna B, Morris ME, Olver J. Spatiotemporal deficits and kinematic classification of gait following a traumatic brain injury: A systematic review. Journal of Head Trauma Rehabilitation. 2010;25:366–74.
4. Hawthorne G, Gruen RL, Kaye AH. Traumatic brain injury and long-term quality of life: Findings from an Australian study. Journal of Neurotrauma. 2009;26:1623–33.
5. Koskinen S. Quality of life 10 years after a very severe traumatic brain injury (TBI): The perspective of the injured and the closest relative. Brain Injury. 1998;12:631–48.
6. Johnston MV, Goverover Y, Dijkers M. Community activities and individuals' satisfaction with them: Quality of life in the first year after traumatic brain injury. Archives of Physical Medicine and Rehabilitation. 2005;86:735–45.
7. Webb CR, Wrigley M, Yoels W, Fine PR. Explaining quality of life for persons with traumatic brain injuries 2 years after

injury. Archives of Physical Medicine and Rehabilitation. 1995;76:1113–9.
8. Whittle MW. Gait Analysis: An Introduction. 4th ed. 2007, Philadelphia, PA: Butterworth Heinemann Elsevier.
9. World Health Organisation. ICF: International classification of functioning, disability and health. 2001, Geneva: WHO.
10. Steadman-Pare D, Colantonio A, Ratcliff G, Chase S, Vernich L. Factors associated with perceived quality of life many years after traumatic brain injury. Journal of Head Trauma Rehabilitation. 2001;16:330–42.
11. O'Neill J, Hibbard MR, Brown M, Jaffe M, Sliwinski M, Vandergoot D, Weiss M. The effect of employment on quality of life and community integration after traumatic brain injury. Journal of Head Trauma Rehabilitation. 1998;13:68–79.
12. Heinemann AW, Whiteneck GG. Relationships among impairment, disability, handicap, and life satisfaction in persons with traumatic brain injury. Journal of Head Trauma Rehabilitation. 1995;10:54–63.
13. Kreuter M, Sullivan M, Dahllof AG, Siosteen A. Partner relationships, functioning, mood and global quality of life in persons with spinal cord injury and traumatic brain injury. Spinal Cord. 1998;36:252–61.
14. Eriksson G, Tham K, Fugl-Meyer AR. Couples' happiness and its relationship to functioning in everyday life after brain injury. Scandinavian Journal of Occupational Therapy. 2005;12:40–8.
15. Reavenall S, Blake H. Determinants of physical activity participation following traumatic brain injury. International Journal of Therapy & Rehabilitation. 2010;17:360–369.
16. Morris S, Dodd KJ, Morris M, Matyas T. Community-based progressive resistance strength training in traumatic brain injury: A multiple, single-system, trial. Advances in Physiotherapy. 2009;11:218–226.
17. Williams G, Robertson V, Greenwood K, Goldie P, Morris ME. The concurrent validity and responsiveness of the high-level mobility assessment tool for measuring the mobility limitations of people with traumatic brain injury. Archives of Physical Medicine and Rehabilitation. 2006;87:437–42.
18. Williams GP, Robertson V, Greenwood KM, Goldie PA, Morris ME. The high-level mobility assessment tool (HiMAT) for traumatic brain injury. Part 2: Content validity and discriminability. Brain Injury 2005;19:833–43.
19. Williams GP, Greenwood KM, Robertson VJ, Goldie PA, Morris, ME. High-Level Mobility Assessment Tool (HiMAT): Interrater reliability, retest reliability, and internal consistency. Physical Therapy. 2006;86:395–400.
20. Perry J, Garrett M, Gronley JK, Mulroy SJ. Classification of walking handicap in the stroke population. Stroke. 1995;26:982–989.
21. Willer B, Rosenthal M, Kreutzer JS, Gordon WA, Rempel R. Assessment of community integration following rehabilitation for traumatic brain injury. Journal of Head Trauma Rehabilitation. 1993;8:75–87.
22. Sander AM, Seel RT, Kreutzer JS, et al. Agreement between persons with traumatic brain injury and their relatives regarding psychosocial outcome using the Community Integration Questionnaire. Archives of Physical Medicine and Rehabilitation. 1997;78:353–7.
23. van Baalen B, Odding E, van Woensel MPC, Roebroeck ME. Reliability and sensitivity to change of measurement instruments used in a traumatic brain injury population. Clinical Rehabilitation. 2006;20:686–700.
24. Powell JH, Beckers K, Greenwood RJ. Measuring progress and outcome in community rehabilitation after brain injury with a new assessment instrument – the BICRO-39 scales. Brain Injury Community Rehabilitation Outcome. Archives of Physical Medicine and Rehabilitation 1998;79:1213–25.
25. Powell J, Heslin J, Greenwood R. Community based rehabilitation after severe traumatic brain injury: A randomised controlled trial. Journal of Neurology, Neurosurgery & Psychiatry. 2002;72:193–202.
26. Development of the World Health Organization WHOQOL-BREF quality of life assessment. The WHOQOL Group. Psychological Medicine. 1998;28:551–8.
27. Lin MR, Chiu WT, Chen YJ, Yu WY, Huang SJ, Tsai MD. Longitudinal changes in the health-related quality of life during the first year after traumatic brain injury. Archives of Physical Medicine and Rehabilitation. 2010;91:474–80.
28. Chiu W-T, Huang S-J, Hwang H-F, Tsauo JY, Chen CF, Tsai SH, Lin MR. Use of the WHOQOL-BREF for evaluating persons with traumatic brain injury. Journal of Neurotrauma. 2006;23:1609–20.
29. Richardson J, Hawthorne G, Day N, Peacock S (2003) The Assessment of Quality of Life Version 2 (AQoL-2). DOI: http://www.psychiatry.unimelb.edu.au/centres-units/cpro/aqol/index.html. Accessed 17/01/2008.
30. Cohen J, Statistical power analysis for the behavioural sciences. 2nd ed. 1988, Hillsdale, NJ: Lawrence Erlbaum Associates.
31. Williams G, Rosie J, Denisenko S, Taylor D. Normative values for the high-level mobility assessment tool (HiMAT). International Journal of Therapy and Rehabilitation. 2009;16:2–6.
32. Hawthorne G, Osborne R. Population norms and meaningful differences for the Assessment of Quality of Life (AQoL) measure. Australian and New Zealand Journal of Public Health. 2005;29:136–42.
33. Alzahrani MA, Dean CM, Ada L. Ability to negotiate stairs predicts free-living physical activity in community-dwelling people with stroke: An observational study. Australian Journal of Physiotherapy. 2009;55:277–81.
34. Williams GP, Morris ME. High-level mobility outcomes following acquired brain injury: A preliminary evaluation. Brain Injury. 2009;23:307–12.
35. Mossberg KA, Ayala D, Baker T, Heard J, Masel B. Aerobic Capacity After Traumatic Brain Injury: Comparison With a Nondisabled Cohort. Archives of Physical Medicine & Rehabilitation. 2007;88:315–320.
36. Jankowski LW, Sullivan SJ. Aerobic and neuromuscular training: Effect on capacity, efficiency, and fatigability of patients with traumatic brain injuries. Archives of Physical Medicine & Rehabilitation. 1990;71:500–504.
37. Sullivan SJ, Richer E, Laurent F. The role of and possibilities for physical conditioning programmes in the rehabilitation of traumatically brain-injured persons. Brain Injury. 1990;4:407–14.
38. Hunter M, Tomberlin J, Kirkikis C, Kuna ST. Progressive exercise testing in closed head-injured subjects: Comparison of exercise apparatus in assessment of a physical conditioning program. Physical Therapy. 1990;70:363–71.
39. Becker E, Bar-Or O, Mendelson L, Najenson T. Pulmonary functions and responses to exercise of patients following cranio cerebral injury. Scandinavian Journal of Rehabilitation Medicine. 1978;10:47–50.
40. Wolman RL, Cornall C, Fulcher K, Greenwood R. Aerobic training in brain-injured patients. Clinical Rehabilitation. 1994;8:253–7.

41. Bateman A, Culpan FJ, Pickering AD, Powell JH, Scott OM, Greenwood RJ. The effect of aerobic training on rehabilitation outcomes after recent severe brain injury: A randomized controlled evaluation. Archives of Physical Medicine & Rehabilitation. 2001;82:174–82.
42. Mossberg KA, Orlander EE, Norcross JL. Cardiorespiratory capacity after weight-supported treadmill training in patients with traumatic brain injury. Physical Therapy. 2008;88:77–87.
43. Vitale AE, Jankowski LW, Sullivan SJ. Reliability of a walk/run test to estimate aerobic capacity in a brain-injured population. Brain Injury. 1997;11:67–76.
44. Gordon WA, Sliwinski M, Echo J, McLoughlin M, Sheerer MS, Meili TE. The benefits of exercise in individuals with traumatic brain injury: A retrospective study. Journal of Head Trauma Rehabilitation. 1998;13:58–67.