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RESEARCH ARTICLE

The relationship between cognitive reserve, cognitive performance, and outcomes of return to work and life satisfaction after brain injury: a retrospective cohort study

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ABSTRACT

Purpose: Cognitive reserve and neuropsychological test results are linked to outcomes after acquired brain injury (ABI), but their interaction and their impact on different types of outcomes remains to be explored. This study aimed to explore how cognitive reserve, measured by education, is related to neuropsychological outcomes, return-to-work and life satisfaction after ABI.

Methods: Long term follow-up of 83 patients with ABI, 5–15 years after specialized brain injury rehabilitation. Logistic regression was used to analyze the relationship between independent variables and outcomes (return-to-work and life satisfaction).

Results: Return-to-work was associated with cognitive reserve (OR = 1.31, $p = 0.024$), age (OR = 0.95, $p = 0.042$), general fatigue (OR = 0.77, $p = 0.034$), and Cognitive Profiency Index (measures of working memory and processing speed, OR = 1.06, $p = 0.037$). Verbal and spatial abilities were related to education, but not to return-to-work. General fatigue was related to satisfaction with mental health in both univariate (OR = 0.78, $p = 0.008$) and multivariate analyses (OR = 0.8, $p = 0.037$), but no other variables were significantly associated with life satisfaction in multivariate analyses.

Conclusion: Patients with lower cognitive reserve paired with slower processing speed and poor working memory may need additional support for successful return-to-work, while life satisfaction appears to depend more on other factors.

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Brain injuries; stroke; educational status; return-to-work; neuropsychological tests

IMPLICATIONS FOR REHABILITATION

- Patients with low educational level, slow processing speed and poor working memory need extra support for successful return-to-work after acquired brain injury (ABI).
- Neuropsychological assessments aimed at helping people with ABI back to work should include tests of working memory and processing speed as these are more related to return to work than tests of verbal and spatial ability.
- Successful rehabilitation after ABI requires a broad approach and tailored interventions to address both life satisfaction and return-to-work effectively.

Introduction

Stroke and traumatic brain injury are the two most common causes of acquired brain injury [1]. Although their causes and initial treatments are quite different, the rehabilitation process becomes similar in the later stages of recovery [1,2]. A considerable proportion of patients with stroke or traumatic brain injury (TBI) do not make a full recovery but live with permanent cognitive, physical, and/or emotional impairments [3,4]. For persons of working age, return-to-work is an important rehabilitation outcome, which meta-analytic data suggests is achieved by only 40% after two years [5]. However, the return-to-work rate varies considerably between studies, likely due to the large discrepancies in the definition of return-to-work [5]. Furthermore, life satisfaction has repeatedly been found to be significantly lower after an acquired brain injury compared to the general population [6].

Earlier studies have found that the long-term outcomes following both TBI and stroke are influenced by a complex combination of pre-injury, injury-related, and post-injury factors [7,8]. Regarding long-term outcomes, there is a growing consensus that premorbid psychosocial factors are, in some cases, more decisive for outcomes such as return-to-work and life satisfaction than factors such as age and ratings of injury severity [9,10]. Other variables, such as results on neuropsychological tests, have also been associated with outcomes after brain injury [11]. In general, better results on neuropsychological tests are linked to better or more stable rates of employment [12]. When looking at specific subtests, better results on tests of processing speed and working memory are associated with higher odds of returning to work in both stroke and TBI [13–16]. For other outcomes, such as life satisfaction, the relationship with neuropsychological test results appears to be weaker [11].

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A factor often found to be related to both better functional and emotional outcomes after brain injury is a higher level of cognitive reserve [17–19]. Cognitive reserve refers to the capacity to enhance performance by selectively engaging various brain networks, and according to the theory of cognitive reserve, a higher premorbid cognitive reserve provides the brain with increased resistance to injury [20]. This protective effect of cognitive reserve has been observed in many neurological conditions, including Alzheimer's disease. The level of education before injury is often used as a proxy measure of cognitive reserve [19,20]. Some studies also suggest that a higher cognitive reserve is linked to faster recovery after brain injury, while other studies have found no such relationship [21,22]. In brain injury research, cognitive reserve has been primarily investigated in the context of TBI, but evidence suggests it is equally relevant for stroke [23,24].

Education is not only associated with outcomes after brain injury but also influences scores on neuropsychological tests [25]. For instance, a low test score could reflect an individual's cognitive deficit due to a brain injury, but it could also be attributed to a low level of education or cognitive reserve [11]. It is recognized that certain neuropsychological test results are more resilient to the effects of brain injury, and that these tests reflect premorbid educational levels to a greater extent. For instance, tests of vocabulary are less affected than other tests more sensitive to the effects of brain injury, such as tests of processing speed and working memory [26,27].

Whereas it is well established that educational level, and to a certain degree, results on neuropsychological tests, are linked to outcomes after brain injury, there is still a need for a deeper understanding of which cognitive domains are more strongly associated with functional outcomes, such as return-to-work. This is particularly important for patients undergoing specialized rehabilitation, as the interventions often aim to improve functional outcomes. Further investigation is also required to explore the interaction between education, neuropsychological test results, and other variables related to long-term outcomes after stroke and TBI. The present study aimed to explore the factors that contribute to return-to-work after stroke and TBI, with a focus on cognitive reserve and neuropsychological variables, in a patient group referred to specialized rehabilitation. A secondary aim was to investigate whether the same variables contribute to life satisfaction.

Method

Study setting

The study is a retrospective cohort study following patients for 5–15 years after stroke or TBI. Ethics approval was obtained from the Regional Ethical Review Board in Uppsala, diary no: 2018/242, 2020-05887, 2021-02002.

A specialized outpatient brain injury rehabilitation team at a Rehabilitation Medicine Clinic, in a rural area of Sweden, offers specialized rehabilitation services for adults with an acquired brain injury of working age and provides support to both patients and significant others regarding everyday life and work rehabilitation.

The Brain Injury Rehabilitation Team provides multidisciplinary team rehabilitation, consisting of contact with a physician specialist in rehabilitation medicine, an occupational therapist, a social worker, and a psychologist. The contact commences with an assessment of the patient's current medical, psychosocial, activity, and cognitive status. Goals for the rehabilitation period are established based on this assessment, such as facilitating return-to-work and developing coping strategies for cognitive deficits. Rehabilitation interventions are tailored to the patient's individual goals and may include workplace visits to help adapt the environment and discuss suitable tasks, psychological treatment targeting anxiety and depression, and coping strategies for managing fatigue. Education regarding brain injuries for significant others is also provided. The average duration of intervention for participants in the study was 2.5 years, with the frequency of contact varying between every week and every three months.

Participants

Former patients at the Brain Injury Rehabilitation Team, who had suffered a stroke or a TBI between the years 2003—2016, were invited by mail to participate in the study. The inclusion criteria were: (1) Stroke or TBI between the years 2003–2016, (2) Previous or ongoing contact with the outpatient brain injury rehabilitation team in a rural healthcare service area in Sweden, (3) Currently living in the specific healthcare service area. Patients with an intellectual disability (IQ below 70) or who had acquired a new brain injury were excluded. For more details about patient selection, see Figure 1. Out of the 237 patients that fulfilled the inclusion criteria, 87 accepted. However, only 83 were interviewed, as 4 of them were unreachable, despite repeated efforts to contact them. There were no significant statistical differences in gender, diagnosis, or the time since injury between participants and non-participants, as determined by χ^2-tests and t-test. The participants ($M = 45$ years, $SD = 12$ years) were significantly older at time of injury than the non-participants ($M = 40$ years, $SD = 13$ years), $t(235) = 2.79$, $p = 0.006$.

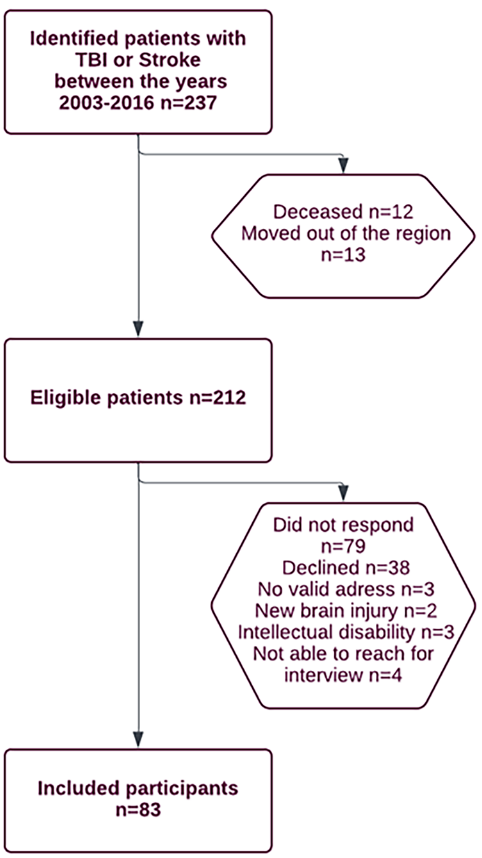


Figure 1. Participant flow chart describing reasons for exclusions and number of excluded patients.

Procedure

After receiving written consent, a structured telephone interview was booked with the patient. The interview was conducted on average 9 years after brain injury (ranging from 5 years to 15 years) during the period from 2 November 2018 to 30 March 2022. The follow-up time was chosen to ensure that patients were in a stable phase after their brain injury, with a minimum of ongoing rehabilitation efforts. However, it was limited to no more than 15 years to avoid significant discrepancies in the care received by the patients over time. The interview followed standardized manual including questions about employment, fatigue, life satisfaction according to the Life Satisfaction Questionnaire (LiSat-11 [28]), anxiety and depression according to the Hospital Depression and Anxiety Scale (HADS [29]) and general outcome according to the Glasgow Outcome Scale-Extended (GOSE [30]). The interview took approximately 30 min and was carried out by a social worker, psychologist, or a psychology student with no previous relation to the patient. Educational level served as a proxy indicator of cognitive reserve, as employed in prior studies, and was obtained *via* interviews and chart reviews [20]. Level of consciousness according to the Glasgow Coma Scale (GCS [31]) or Reaction Level Scale (RLS [32]) at the time of injury was collected from patient medical charts. Neuropsychological variables from the Wechsler scales [33,34] as well as results on HADS and LiSat-11 at the time of admittance to the Brain Injury Rehabilitation Team were also collected from patient charts through retrospective chart review. Information from patient charts was collected during November 2018 and November 2021. Participants were coded and only the first author had access to the coding key in order to identify patient charts during the retrospective chart review.

Main outcome measures

Return-to-work

Return-to-work was assessed during the interview. Some patients had reached retirement age at the time of the interview, and in those instances, return-to-work was considered as the level of employment maintained prior to retirement. Return-to-work was dichotomized as 1 representing successful return-to-work and 0 representing not return-to-work. By successful return-to-work, we refer to engaging in paid employment for at least 10 h a week, with or without workplace adaptations. This criterion for successful return-to-work is based on the Swedish social security system's determination that working at least 10 h a week is the minimum requirement for having the ability to work. If you do not meet this threshold, you are eligible for a full-time disability pension.

Life satisfaction

Life satisfaction was assessed through the LiSat-11. This instrument consists of 11 questions and assesses overall satisfaction with life with one question as well as domain-specific satisfaction within ten domains with one question each [28]. In the current study, only the 3 questions concerning satisfaction with life in general, physical health, and mental health, were analyzed, as they represent different areas considered important for rehabilitation outcomes. The first question, satisfaction with life in general, has also been found to represent a global measure of satisfaction with life [35]. The response options extend over six levels from "Very dissatisfied" to "Very satisfied." LiSat-11 has been found to be valid for the general population as well as for people with acquired brain injury [36,37]. Previous research has indicated that responses can be dichotomized into two groups: the top two options, "Satisfied (5)" and "Very satisfied (6)," indicate satisfaction with the area of interest, while the remaining four options indicate dissatisfaction [1–4,28]. The dichotomized version of the answers was used in the current study as the distribution of scores was non-normal, violating assumptions for linear regression.

Predictor variables

To estimate cognitive reserve, years of education were used as a continuous variable, as employed in prior studies [19,38]. Verbal, spatial, and cognitive efficiency were assessed by the Wechsler Adult Intelligence Scale (WAIS). WAIS is an internationally used instrument for measuring cognitive function and is translated and standardized for a Swedish population [33,34]. Assessments conducted between 2003 and 2010 used the WAIS-III, while those from 2011 onward used the WAIS-IV. The raw scores were converted to scaled scores as to make the two tests comparable. Subtests from the subcategory processing speed (Symbol Search and Coding) and from the subcategory working memory (Digit Span and Arithmetic) have previously been found to be more sensitive to the effects of brain injury [39]. Hence, these measures were combined into the cognitive profiency index (CPI) to reflect possible impact of the brain injury on cognition. This variable is considered to reflect cognitive efficiency and is available as an index score in WAIS-IV, but not in earlier versions [40,41]. However, as we used the same subtests to derive the index from the older version of the WAIS, we conclude that this usage reflects CPI well enough to use the same name, despite not being able to use the index score. The CPI variable was calculated by summarizing the WAIS index score from the processing speed and working memory index, divided by two. In many cases a complete index scores were not available for the WAIS Perceptual Reasoning Index and the WAIS Verbal Comprehension Index. Therefore, the spatial and verbal indexes were calculated by summarizing the scale score, incorporating available tests from the Perceptual Reasoning category (Block Design and Matrix Reasoning) and the Verbal Comprehension category (Similarities, Vocabulary, and Information) respectively, and dividing by the number of tests. If only one test had been performed, the scale score from that test was directly used. The Perceptual Reasoning Index and the Verbal Comprehension Index can be combined into a General Ability Index, reflecting global intellectual functioning [34]. As many of the patients had one-sided brain injuries, which strongly affected one of these indexes while leaving the other intact, we chose not to combine the verbal and performance indexes. We felt that combining them would not accurately represent global intellectual functioning in this patient group.

General fatigue was assessed by asking patients the following question: "*How much are you bothered by mental fatigue/brain fatigue after your brain injury on a scale from 1 to 10, where 1 is not at all and 10 is the worst imaginable fatigue?*"

Descriptive measures

To assess anxiety and depression symptoms, the HADS, which has been widely used to assess symptoms of anxiety and depression following TBI, was used [42]. The HADS comprises two separate scales for anxiety and depression. Scores range from 0 to 21, with scores above 7 considered to be clinically relevant [43].

To assess overall outcome after brain injury, the GOSE was used. The GOSE is a frequently used measure of outcome, targeting disability and social participation, after brain injury [30]. Scores range from 1 (dead) to 8 (upper good recovery), where higher scores indicate better recovery. The scale can be dichotomized into unfavorable outcome [1–4] and favorable outcome [5–8].

GCS and RLS were used as a measure of injury severity. RLS scores were transformed into GCS scores to facilitate description and comparisons of the patients [44,45]. GCS scores were categorized by injury severity: mild TBI [13–15], moderate TBI [9–12], and severe TBI [3–8,46].

Statistical analysis

All data analysis was conducted using RStudio, version 4.2.2, and the packages dplyr, tidyr, ggplot, gridExtra, ggpubr, MASS, logistf, brant, and car [47]. A threshold significance level of 0.05 was used for all statistical tests. In cases of missing data, these were excluded from the analysis. Descriptive statistics to depict patient characteristics and analyzing differences between subgroups were calculated using Student's t-test, Chi-squared test, Wilcoxon rank sum test, and Fischer's exact test, according to the properties of the data. As the outcome variables were dichotomized and the sample relatively small, logistic regression with Firth's bias reduction, including theoretically relevant variables, was used to model the chance of returning to work as well as life satisfaction. Univariate analyses were performed for all variables included in the multivariate model to understand each variable's individual effect on the outcome variables. The return-to-work model was tested without diagnosis as an exploratory analysis to assess its impact on model stability, since it was the only variable not significantly related to return-to-work in the multivariate model. Since results from neuropsychological testing are known to correlate with educational level, correlations between cognitive variables and years of education were calculated (Spearman's rho). Only cognitive variables not correlating significantly with education were included in the logistic regression model. One extreme outlier in CPI was excluded from the logistic regression due to violating logistic regression assumptions. Assumptions were checked with plots and descriptives, and the Hosmer–Lemeshow goodness-of-fit test. Multicollinearity between variables was low.

Results

For a description of the included patients, see Table 1.

The stroke patients were significantly older than the TBI patients and tended to have slightly worse outcomes according to GOSE. The stroke patients also had significantly higher scores on GCS and the verbal index. There were several points of missing data in the CPI variable. An analysis of missing data revealed that the patients who had not performed tests of working memory and processing speed were more likely to have suffered a stroke (17 stroke patients compared to 4 TBI, $p=0.008$). A total of 37 participants scored above the cutoff (above 7) for depression or anxiety according to HADS at the time of cognitive testing. There was no significant difference in CPI between the participants with scores indicating anxiety or depression and the participants who scored below the cutoff according to HADS, $t(56)=0.27$, $p=0.79$. Concerning gender differences, the women reported higher general fatigue scores ($m=6.2$) compared to men ($m=4.7$), $t\ (79)=-2.99$, $p=0.004$, but no other significant differences were found.

The relationship between different neuropsychological tests and years of education

CPI, unlike verbal and spatial index, did not correlate significantly with years of education, $r=0.04$, $p=0.74$. There was a moderate

Table 1. Description of patient characteristics.

	Stroke, n[a] = 47	TBI, n[a] = 36	Total, n = 83	p-Value[b]
Work status				0.3
Not working	28 (60%)	17 (47%)	45 (54%)	
Working at least 25%	19 (40%)	19 (53%)	38 (46%)	
Gender				0.8
Male	29 (62%)	21 (58%)	50 (60%)	
Female	18 (38%)	15 (42%)	33 (40%)	
Age at time of injury, years	*50 (9)*	*39 (14)*	*45 (12)*	<0.001
Age at time of interview, years	*58 (10)*	*49 (14)*	*54 (13)*	0.001
Present levels general fatigue	5.0 (3.5, 7.0)	5.0 (4.0, 7.0)	5.0 (4.0, 7.0)	0.7
Education, years	12.0 (10.0, 13.0)	12.0 (11.0, 12.1)	12.0 (10.0, 13.0)	>0.9
CPI	86 (79, 94)	90 (82, 97)	88 (80, 97)	0.4
Missing	17	4	21	
Verbal index	9 (7, 10)	7 (6, 9)	8 (6, 9.5)	0.036
Missing	5	1	6	
Spatial index	9.5 (7, 11.5)	10 (8.5, 12)	10 (8, 12)	0.5
Missing	6	2	8	
GOSE				0.094
Unfavorable outcome (1–5)	27 (57%)	14 (39%)	41 (49%)	
Favorable outcome (6–8)	20 (43%)	22 (61%)	42 (51%)	
GCS	3–8: 3 (7%)	3–8: 13 (38%)	3–8: 16 (21%)	*<0.001*
Missing	9–12: 6 (13%)	9–12: 9 (26%)	9–12: 15 (19%)	
	13–15: 35 (80%)	13–15: 12 (35%)	13–15: 47 (60%)	
	3	2	5	
Life in general	Not satisfied (1–4): 26 (55%) Satisfied (5–6): 21 (45%)	Not satisfied (1–4): 20 (56%) Satisfied (5–6): 16 (44%)	Not satisfied (1–4): 46 (55%) Satisfied (5–6): 37 (45%)	>0.9
Physical health	Not satisfied (1–4): 32 (68%) Satisfied (5–6): 15 (32%)	Not satisfied (1–4): 24 (67%) Satisfied (5–6): 12 (33%)	Not satisfied (1–4): 56 (67%) Satisfied (5–6): 27 (33%)	0.9
Mental health	Not satisfied (1–4): 18 (38%) Satisfied (5–6): 29 (62%)	Not satisfied (1–4): 19 (53%) Satisfied (5–6): 17 (47%)	Not satisfied (1–4): 37 (45%) Satisfied (5–6): 46 (55%)	0.2

[a]*n* (%); Median (IQR) except for Age where Mean (SD) is displayed.
[b]Pearson's Chi-squared test; Wilcoxon rank sum test; Fisher's exact test, Student's *t*-test.
TBI: Traumatic brain injury; CPI: Cognitive profiency index based on Wechsler index score (M(SD): 100 (15); Verbal and Spatial Index are based on Wechsler scale points (M(SD): 10 (3); GOSE: Glasgow outcome scale; GCS = Glasgow Coma Scale.

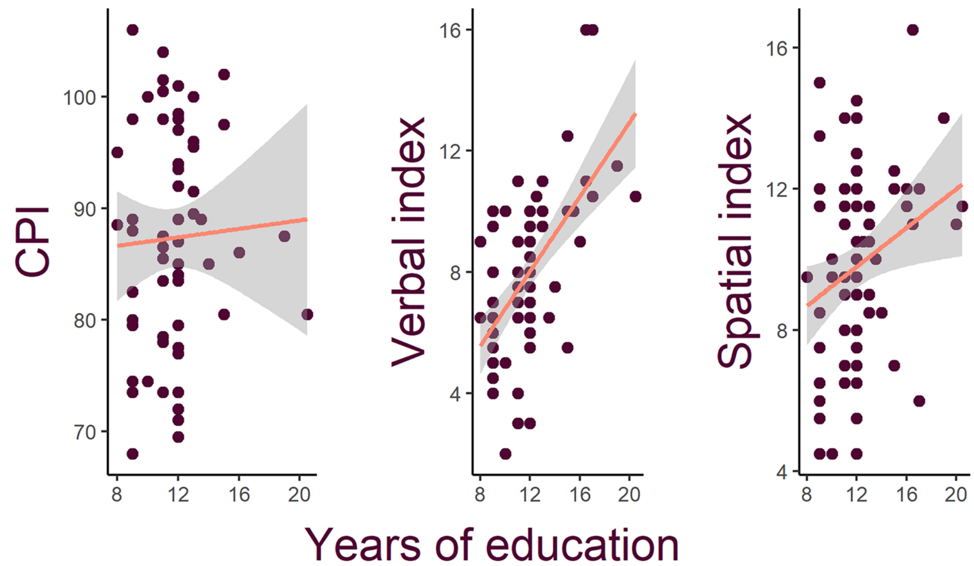


Figure 2. The figures show the linear relationship between cognitive variables and years of education. CPI: cognitive profiency index.

correlation between verbal index and years of education, $r = 0.62$, $p < 0.001$ and also a small correlation for the spatial index, $r = 0.27$, $p = 0.019$. See Figure 2.

The relationship between return-to-work and education and cognitive variables

As described in Table 2 the group that returned to work was significantly younger than the group that did not returned to work at the time of injury.

No other variables differed significantly when comparing them separately. As the GCS is intended for use within the TBI group rather than the stroke group, a separate analysis was conducted specifically for TBI patients. However, this analysis still revealed no significant difference between the injury severity groups in GCS, t (34)=0.21, $p = 0.848$. One patient was excluded due to being an extreme outlier in CPI (126.5) and violating assumptions for logistic regression, thus only 44 patients remained in the not return-to-work group.

Multivariate analysis

A logistic regression model was fitted to examine the relationship between return-to-work and CPI as well as education, controlling for age, general fatigue, and diagnosis in the 61 patients with complete CPI-data.

All included variables except diagnosis had a significant impact on return-to-work. Removing diagnosis as a controlling variable did not markedly affect the model, the remaining included variables were still significant. The model correctly classified 75% of the participants as returned to work or not and the Wald test was significant, W(5) = 11.80, $p = 0.038$, indicating that the model was a better fit than the null hypothesis. As shown in Figure 3, CPI, education, age at time of injury, and levels of fatigue all had a significant impact on return-to-work, higher CPI and education increased the odds of returning to work, while higher age and levels of general fatigue decreased the odds. For a visualization of how the continuous variables relate to return-to-work across different values see Figure 4.

Table 2. Description of differences in patient characteristics between return-to-work and not return-to-work groups, respectively.

	Not working, $N = 44$[a]	Return-to-work min 25 %, $N = 38$[a]	*p*-Value[b]
Gender			0.7
Male	26 (59%)	24 (63%)	
Female	18 (41%)	14 (37%)	
Diagnosis			0.3
Stroke	27 (61%)	19 (50%)	
TBI	17 (39%)	19 (50%)	
Age in years at time of injury	48 (12)	42 (12)	0.019
Age in years at time of interview	57 (12)	50 (12)	0.055
Present levels of general fatigue	6.00 (4.00, 8.00)	5.00 (3.00, 6.00)	0.081
Years of education	11.00 (9.00, 12.00)	12.00 (11.00, 13.00)	0.065
CPI	86 (78, 94)	92 (83, 98)	0.056
Missing	10	11	
Verbal index	8 (6–9.5)	9 (5.5–11)	0.4
Missing	3	3	
Spatial index	9.5 (7–11.5)	10.5 (8.5–12)	0.2
Missing	3	5	
GCS	3–8: 6 (15%)	3–8: 9 (24%)	0.5
Missing	9–12: 8 (20%)	9–12: 8 (22%)	
	13–15: 26 (65%)	13–15: 20 (54%)	
	4	1	

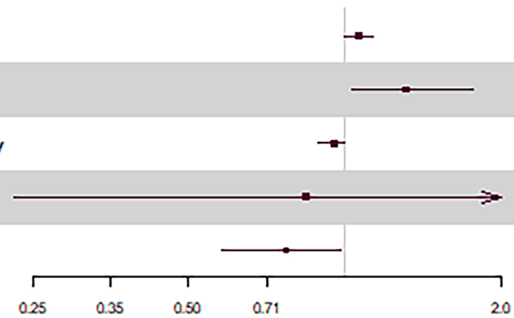
One outlier in CPI was excluded from the not working group.
[a]*n* (%); Median (IQR) except for Age where Mean (*SD*) is displayed.
[b]Pearson's Chi-squared test; Wilcoxon rank sum test, Two sample *t*-test.
TBI: Traumatic brain injury; CPI: Cognitive profiency index based on Wechsler index score (*M*(*SD*)=100 (15); Verbal and Spatial Index are based on Wechsler scale points (*M*(*SD*)=10 (3); GOSE = Glasgow outcome scale; GCS = Glasgow Coma Scale.

Univariate analysis

None of the variables were significantly related to return-to-work in univariate analysis. CPI showed a trend toward significance ($p = 0.050$).

Life satisfaction

The influence of CPI and education, controlling for age, present general fatigue, and diagnosis, on life satisfaction was also modeled using logistic regression (see Figures 5 and 6).



Variable	Multivariate OR	Multivariate 95% CI	Univariate OR	Univariate 95% CI
CPI	1.06	1.00, 1.13	1.05	1.00, 1.11
Years of education	1.31	1.03, 1.77	1.16	0.97, 1.40
Age at time of injury	0.95	0.89, 1.00	0.97	0.93, 1.00
TBI vs Stroke	0.84	0.23, 2.90	1.57	0.66, 3.78
Present fatigue	0.77	0.58, 0.98	0.85	0.70, 1.02

Figure 3. Forest plot showing or and 95% CI from a penalized logistic regression model assessing the relationship between each variable and the likelihood of return-to-work. Each horizontal line represents the CI for a predictor variable, with the point estimate shown as a square. Odds ratios greater than 1 indicate an increased likelihood of return to work, values less than 1 indicate a decreased likelihood. Confidence intervals that do not cross the vertical reference line at or = 1 indicate statistically significant associations. OR and 95% CI from the univariate analyses are also added as reference. OR: Odds ratio; CI: Confidence interval; CPI: Cognitive profiency index; TBI: Traumatic brain injury.

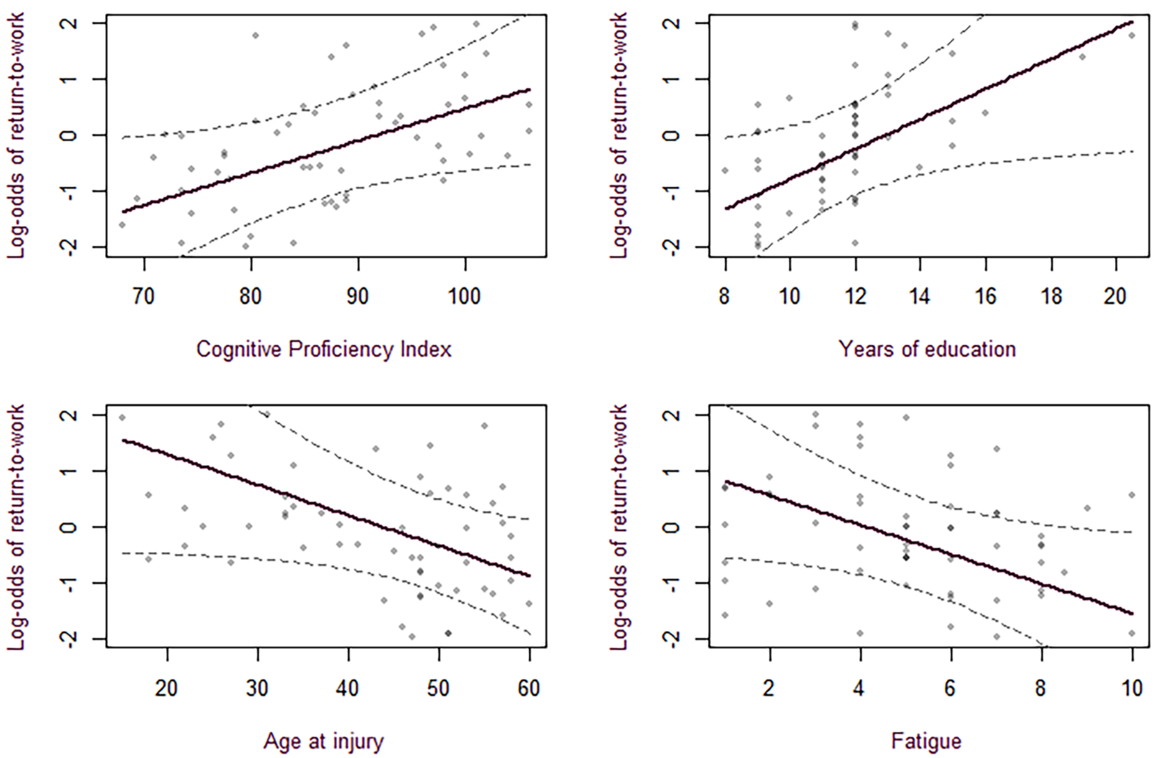


Figure 4. Partial effect plots illustrating the relationship between continuous variables and the log-odds of returning to work. Each plot displays the estimated log-odds (solid line) as a function of the continuous variable, with the area between the dashed lines representing the 95% confidence intervals. An upward trend in the line indicates that higher values of the continuous variable correspond to an increased likelihood of returning to work, whereas a downward trend indicates a decreased likelihood.

Multivariate analysis

None of the variables showed a significant relationship with satisfaction levels for physical health, nor for satisfaction with life in general in the multivariate model. However, levels of fatigue were found to be significantly associated with satisfaction with mental health. Furthermore, only the model for satisfaction with physical health had a significant Wald test W(5)=11.43, p=0.043, indicating the models for satisfaction with life in general and satisfaction with mental health did not explain the outcome better than a null model.

Univariate analysis

In univariate analyses, general fatigue was significantly correlated with satisfaction with mental health (OR = 0.78 [0.63–0.94], p=0.008), and age showed a significant positive association with satisfaction with mental health as well (OR = 1.05 [1.01–1.09], p=0.011). Additionally, there was a trend to significance for the relationship between CPI and satisfaction with physical health (OR = 1.06 [0.89–1.00], p=0.05). None of the explanatory variables showed a significant relationship with overall life satisfaction in univariate analysis.

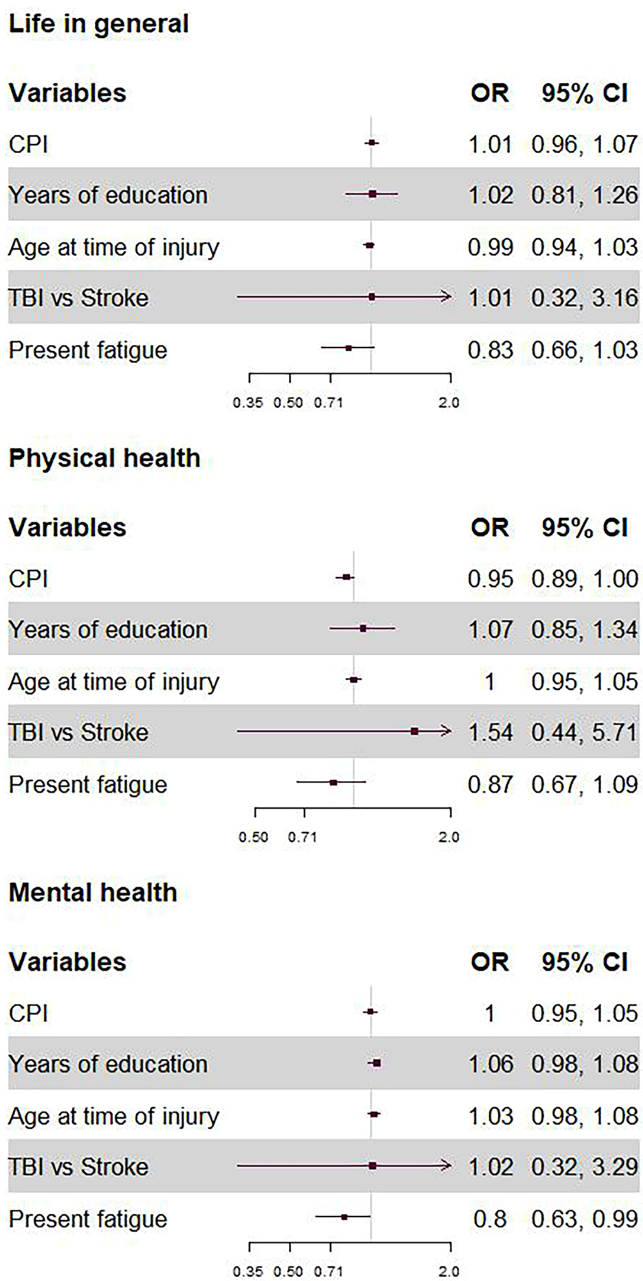


Figure 5. Forest plot showing or and 95% CI from a penalized logistic regression model assessing the association between each variable with the likelihood of feeling satisfied with life in general, physical health and mental health respectively. Each horizontal line represents the CI for a predictor variable, with the point estimate shown as a square. Odds ratios greater than 1 indicate an increased likelihood of feeling satisfied, values less than 1 indicate a decreased likelihood. Confidence intervals that do not cross the vertical reference line at or = 1 indicate statistically significant associations. OR: Odds ratio; CI: Confidence interval; CPI: Cognitive profiency index; TBI: Traumatic brain injury.

Discussion

The present study aimed to explore how cognitive reserve and neuropsychological variables contribute to return-to-work after stroke and TBI. Patients were more likely to have returned to work if they were younger, had lower levels of general fatigue, had higher education, and better working memory and processing speed. We also investigated if the same variables contributed to life satisfaction and found that life satisfaction may be determined by other factors, although present levels of fatigue were found to be related to satisfaction with mental health.

In our study, cognitive efficiency (working memory and processing speed) was independently, and when controlled for other variables, associated with the likelihood of returning to work. Working memory is an aspect of attention, and together with processing speed, they are both known to be sensitive to brain injury [39]. In contrast, measures of verbal and spatial ability primarily appeared to reflect educational levels. This finding is consistent with a recent paper by Ayton and coworkers that also found a relationship between measures of processing speed and working memory and years in working life after brain injury, while other cognitive tests were related to education [48]. Nevertheless, other studies have found significant differences in results based on verbal and spatial tests respectively, between groups based on employment status [12,13]. However, these studies did not consider education, which may have a confounding effect by enhancing scores on verbal and spatial ability tests as well as increasing the likelihood of returning to work.

Cognitive reserve, as measured by levels of education, was not independently associated with return-to-work in our study. This is somewhat surprising given that education has been found to positively affect return-to-work in previous studies [19,49,50]. However, the lack of a direct relationship between return-to-work and education in our study might be due to individuals with higher education also being older, thereby negating some of the positive effect of education, as higher age had a negative impact on return-to-work. This interpretation aligns with the fact that cognitive reserve was significant when controlling for CPI, age at the time of injury, and levels of general fatigue. In previous research the mechanism of cognitive reserve has been proposed to be related to innate characteristics of the highly educated brain, such as more efficient networks [38]. However, other explanations are possible for the protective effect of higher education, for instance, the positive correlation between education and health literacy or more education translating into more job opportunities and more possibilities for workplace adaptations, such as remote work [51–53]. In general, return-to-work is a complex outcome influenced by multiple factors, and no single variable alone is likely to explain the variance in return-to-work [54]. Regarding the concept of cognitive reserve, it is important to note that most studies investigating cognitive reserve are cross-sectional [38,55,56]. This makes it challenging to determine whether the positive effects of education are due to an innate higher cognitive ability, which makes individuals more likely to pursue higher education, or if they result from changes in the brain due to education directly or indirectly through factors such as higher socioeconomic status. Longitudinal studies in dementia research suggests that cognitive ability in young adulthood is more important than educational level for later-life cognitive functioning, indicating that for cognitive functioning the first alternative is more likely [57].

Concerning life satisfaction, present levels of general fatigue influenced satisfaction with mental health. These results align with previous research underscoring the importance of fatigue for life satisfaction and mental health after brain injury [58]. Higher age was also associated with more satisfaction with mental health in univariate analysis, consistent with previous studies on stroke patients indicating that satisfaction with mental health is not negatively affected by higher age after stroke, unlike other areas of life satisfaction [59]. However, this relationship was no longer significant when controlling for other variables. Higher satisfaction with physical health trended to be significantly related to CPI in

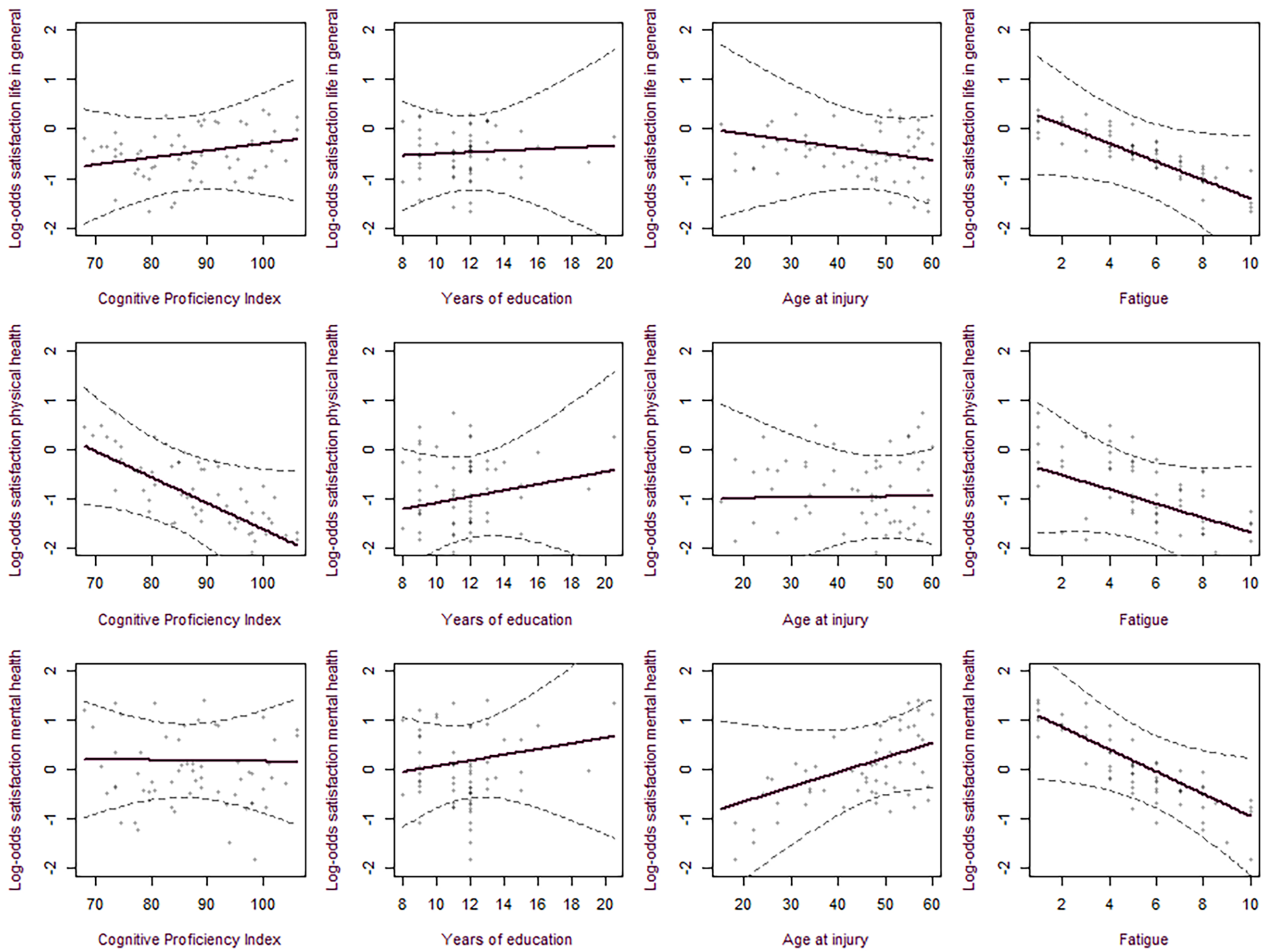


Figure 6. Partial effect plots illustrating the relationship between continuous variables and the log-odds of being satisfied with life in general (top row), physical health (middle row) and mental health (bottom row). Each plot displays the estimated log-odds (solid line) as a function of the continuous variable, with the area between the dashed lines representing the 95% confidence intervals. An upward trend in the line indicates that higher values of the continuous variable correspond to an increased likelihood of returning to work, whereas a downward trend indicates a decreased likelihood.

univariate models, although this relationship became weaker when controlling for other variables. It is possible that persons with lower function according to CPI also have more severe brain injuries, thereby suffering from more physical health problems. Satisfaction with life in general did not significantly relate to any of the variables included. Our results align with previous research, where various factors, many unrelated to brain injury, appeared more important for life satisfaction, for instance, sense of coherence [9,60]. Interventions primarily aimed at returning to work might therefore not be successful in improving life satisfaction as they seem determined by different factors.

A strength of the study is the long-term follow-up. Many studies typically track patients for only 6 months to a year, which probably is inadequate given the lifelong consequences of brain injury [61,62]. Another strength is the study's setting and patient selection. It was conducted in a rural part of Sweden, with a lower average educational level than in the university cities, thus encompassing patients not usually included in similar studies [61,63]. However, the geographical area also introduces selection bias, making these results less applicable to urban areas.

A limitation of the study was the retrospective design resulting in some missing data, most prominently in the CPI measures. Older stroke patients, who often face additional medical issues and hemiparesis affecting rehabilitation and test performance, appeared to be excluded from these tests. One participant with a very high CPI was excluded due to violating the logistic regression assumptions. Participants with very low CPI were also likely to be excluded, as IQ below 70 was an exclusion criterion, making the model invalid for patients with a very high or very low CPI. No patients with aphasia participated, as they could not complete the interview, also limiting generalizability. The study also lacked a good measure of injury severity for the stroke patients, as the GCS is not being intended to measure injury severity in patients suffering from a stroke. Moreover, many patients were initially assessed using the RLS, with the RLS scores being transformed into GCS scores. The response rate was low among younger patients, limiting conclusions for this group. Additionally, the study lacked data on physical disabilities, though patients referred to the brain injury rehabilitation team typically had mild physical disabilities, as physical rehabilitation is undertaken elsewhere. The time span for the follow-up was long, ranging from 5 to 15 years. Still, analysis revealed no significant differences in follow-up times for return-to-work rates or life satisfaction levels, suggesting that time variability did not impact the outcomes. The interviewer was aware of the participant's education level during the interview, which might have influenced the conduct of the interview. However, the interview followed a standardized protocol for all patients, and the interviewers had, in all but one case, no knowledge of the study's hypothesis. One factor that may limit the generalizability of the study is the inclusion criteria. Specifically, the study only enrolled patients who had participated in outpatient rehabilitation. While some of these individuals had previously undergone inpatient rehabilitation, those with the most severe brain injuries, who are typically unable to engage in outpatient programs, were excluded. As a result, the findings may not be representative of the broader population of patients with severe brain injuries.

Conclusions and future research

Patients with lower cognitive reserve paired with slower processing speed and poor working memory functions might need additional support for successful return-to-work. While neuropsychological tests are valuable for assessing factors relevant to return-to-work, our findings emphasize the value of measuring working memory and processing speed. However, outcomes related to life satisfaction seem to be primarily determined by other factors than those influencing return-to-work.

To validate these results, a prospective study measuring working memory and processing speed at baseline, with follow-ups at fixed intervals, is needed. Additionally, the current study focused on cognitive tests related to intelligence. It would be beneficial to include measures of other cognitive functions, such as executive function and memory, and to explore their relationship to outcomes.

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