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Original article

Effect of traumatic upper-limb injury on cognitive functions: A cross-sectional observational study

Effet des lésions traumatiques des membres supérieurs sur les fonctions cognitives: étude observationnelle transversale

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A B S T R A C T

Objectives: There is growing evidence of cognitive impairment after traumatic peripheral lesions. The purpose of this study was to explore the association between cognitive function and traumatic upper-limb injury. We assessed difference in cognitive function between participants with and without upper-limb injury, and explored the association between cognitive function and certain variables in injured individuals: gender, age, body mass index (BMI), educational level, and occupation. We sought to identify the factors associated with cognitive function in injured subjects: time since injury, injury side, nerve injury, hand function, pain, and finger sensation.
Material and methods: A cross-sectional observational study was conducted, with 2 groups: observational group (with traumatic upper-limb injury) and control group (uninjured). The 2 groups were matched for age, gender, BMI, educational level and occupation. Short-term memory and executive functions were assessed using the Rey Auditory and Verbal Learning Test (RAVLT) and Stroop Color and Word Test (SCWT), respectively.
Results: 104 participants with traumatic upper-limb injury and 104 uninjured control subjects were included. There was a significant inter-group difference only in RAVLT ($p < 0.01$; Cohen d, of 0.38). Regression analysis demonstrated an association of pain on VAS (beta = -0.16, $p < 0.01$) and touch-test (beta = 1.09, $p < 0.05$) with total RAVLT score (short-term memory) in injured subjects ($R^2 = 0.19$, $F(2, 82) = 9.54$, $p < 0.001$).
Conclusion: Traumatic upper-limb injury can impact short-term memory, which should be kept in mind during rehabilitation.

Mots-clés:
Fonctions cognitives
Mémoire
Fonction exécutive
Traumatisme de la main
Traumatisme du membre supérieur

R É S U M É

Objectifs. – Un nombre croissant d'études suggère que les individus peuvent développer des troubles cognitifs après des lésions traumatiques des extrémités. L'objectif de ce travail était d'explorer l'association entre la fonction cognitive et les traumatismes des membres supérieurs. Nous avons examiné les différences de fonction cognitive entre les participants avec et sans traumatismes des membres supérieurs et exploré l'association entre la fonction cognitive et certaines variables chez les individus blessés, par exemple le sexe, l'âge, l'indice de masse corporelle (IMC), l'éducation et la profession. De plus, nous avons détecté comment les caractéristiques traumatiques prédisent les

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fonctions cognitives des individus blessés, par exemple la durée depuis le traumatisme, le côté blessé, les lésions nerveuses, la fonction globale de la main, la douleur et la sensibilité digitale.
Matériels et méthodes. – Une étude observationnelle transversale a été menée avec deux groupes: le groupe d'observation (participants avec des traumatismes aux membres supérieurs) et le groupe témoin (participants non blessés). Les participants des deux groupes ont été appariés selon l'âge, le sexe, l'IMC, l'éducation et la profession. La mémoire à court terme et les fonctions exécutives ont été évaluées à l'aide du test d'apprentissage auditif et verbal de Rey (RAVLT) et du test de Stroop couleur et mot (SCWT), respectivement.
Résultats. – Cette étude a inclus 104 participants avec des traumatismes aux membres supérieurs et 104 participants non blessés. Une différence significative a été observée entre les participants blessés et non blessés dans le RAVLT ($p < 0{,}01$) seulement avec un d de Cohen de 0,38. L'analyse de régression a montré une association de VAS (bêta = –0,16, $p < 0{,}01$) et SWM (bêta = 1,09, $p < 0{,}05$) avec les scores totaux de RAVLT et avec la fonction de mémoire à court terme chez les individus blessés (R 2 = 0,19, F (2, 82) = 9,54, $p < 0{,}001$).
Conclusion. – Les traumatismes aux membres supérieurs peuvent avoir un impact sur l'altération de la mémoire à court terme, ce qui devrait être pris en compte lors de la rééducation.

Introduction

The upper limbs are the distal part of the body and play a crucial role in daily life [1]. Upper limb injury is commonly encountered in contexts such as sport, work and other activities [2]. Traumatic upper-limb injury affecting the fingers, wrist, arm, elbow and shoulder are highly prevalent, accounting for approximately 30% of all emergency care cases [3]. Patients recover only gradually, with function improving over several months. Some patients experience enduring loss of hand function, necessitating temporary or permanent sick leave.

As well as the above sequelae, cognitive functions may be impaired after traumatic upper-limb injury, which is one sort of traumatic peripheral injury [4]. A growing number of findings suggest that patients may develop cognitive impairment in a broad variety of cognitive domains, such as attention, memory, visuospatial skills and executive function, following traumatic peripheral injury [5–7]. Compared with non-injured subjects, patients showed impaired performance on cognitive tasks such as the Trail Making Test, Stroop Test, etc. [4]. Numerous predictive factors contribute to this association between cognitive impairment and traumatic peripheral lesions: pain [6], poor sensory recovery [7] and insomnia [5]. Such contributing factors overlap and are difficult to analyze in isolation. Associations between cognitive impairment and traumatic injury specifically to the upper limbs, on the other hand, is less well documented in humans.

It is important to identify the association between cognitive impairment and traumatic upper-limb injury, as impaired cognitive function increases the risk of further musculoskeletal injury [8]. If there is an association between cognitive impairment and traumatic upper-limb injury, the specific cognitive impairments should be identified and addressed, as these patients may be at risk of additional injury when they return to work or resume other activities of daily living. Also, awareness of potential cognitive impairment is crucial for tasks that require patients with such injury to acquire new information or new skills. Thus, assessment of cognitive impairment in patients with traumatic upper-limb injury should have a significant impact on treatment and rehabilitation.

This study aimed to assess (1) differences in cognitive function between individuals with and without traumatic upper-limb injury, and (2) associations between cognitive functions and trauma characteristics: time since injury, injury side, nerve injury, pain, sensation, and hand function. It is hoped that the study will provide further insights into the relationship between trauma and cognitive function and will influence the management of traumatic injuries and minimize the risk of additional injury and learning challenges after rehabilitation.

Participants and methods

Participants

Patients with unilateral traumatic upper-limb injury admitted to the outpatient or inpatient department of Guangdong Work Injury Rehabilitation Hospital (Guangzhou, China) were invited to participate in the study between December 17, 2021, and August 30, 2022. The inclusion criteria were: 18–64 years old; medically stable; Mini-Mental State Examination ≥26 points; able to speak Chinese; and providing informed consent. The exclusion criteria were: history of brain or central nervous system trauma or disease (e.g., stroke, epilepsy, brain injury, or dementia); congenital or developmental disease; history of cognitive impairment (e.g., due to substance addiction); damage to sight, hearing, smell or taste; pregnancy; history of traumatic events or previous surgery; chronic metabolic disease (e.g., hypertension, diabetes, hyperlipidemia); participation in an interventional trial in the past 6 months; and identification of psychological problems during admission screening by the department of psychotherapy.

Uninjured control participants were recruited from the local community: patients' family members, residents of the nearby community, and factory workers in the city. Control participants were volunteers and received no monetary compensation. Inclusion criteria comprised normal mental status, 18–64 years old, Chinese-proficient, and able to provide informed consent. Exclusion criteria were as in the injured group.

Methods

Study design

A cross-sectional observational study was conducted, with 2 groups: observational (group 1) and control (group 2). Group 1 included adult patients with unilateral upper-limb trauma, and group 2 comprised uninjured individuals matched with group 1 for age, gender, BMI, educational background and occupation. A printed questionnaire with basic information (age, gender, BMI, occupation, education, medical history) was distributed to both groups, for primary inclusion criteria assessment before a step of face-to-face assessment in Group 2.

Assessments

Age, gender, BMI, educational background and occupation were recorded. Data were extracted from medical records in Group 1, and face-to-face interviews were conducted with participants in Group 2. Occupations were categorized according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO) [9]: level 1, 'Managers', and 'Professionals' (e.g., arts and media professionals, educational professionals, health professionals); level 2, 'Technicians and Trade Workers', 'Machinery Operators and Drivers', and 'Laborers'; level 3, 'Community and Personal Service Workers', 'Clerical and Administrative Workers', and 'Sales Workers'; and level 4, other, such as students, housewives or unemployed.

Educational background was categorized based on completed years of schooling according to the local division of educational stages [10]: secondary school or below, high school or polytechnic school, and higher education.

Cognitive functions were assessed on the Chinese version of the Rey Auditory and Verbal Learning Test (RAVLT) [11] and Stroop Color and Word Test (SCWT) [12]. To optimize performance, participants were allowed to take breaks as needed.

The RAVLT [13] is frequently used to measure aspects of short-term memory [14] The Chinese version was demonstrated to have good reliability and validity [11]. The test involves reading 12 words aloud to participants, who are then instructed to recall the words three times. After a 5-minute interference test, they have to freely recall the 12 words for a fourth time: delayed free recall. The fifth free recall is conducted after another 20 min: long delayed free recall. The score is determined as the number of correct words out of 60, higher score indicating better memory performance.

The SCWT is a classic test for evaluating executive function [15]. The Chinese version has good reliability and validity [12]. Each reader had to complete tasks A, B, and C on separate A4 sheets: reading words in black, recognizing colors of dots, and recognizing a word's ink color. Each sheet includes 50 words or colored dots. If the colors and words in task C conflict, such as the word "blue" written in red ink, the brain must make an effort to filter out competing signals, which can suggest cognitive interference [16]. Respondents must complete the 3 tasks as fast as possible. The score is based on both Stroop interference-effect consumed time (SIECT = time consumed in task C minus time consumed in task B) and Stroop interference-effect correct number (SIECN = - correct number in task B minus correct number in task C). Higher scores indicate poorer executive function performance.

In addition to basic information and cognitive functions, various trauma characteristics were recorded in injured participants: time since injury (days), affected side (left or right), presence or absence of nerve injury, hand function, pain level, and sensation. The 4-part Action Research Arm Test (ARAT) was used for hand motion: grasping (6 items), holding (4 items), pinching (6 items), and coarse motion (3 items), [17], each scored 0–3 (0, no corresponding action within 60 s; 3, completing action in normal position within 5 s). A visual analogue scale (VAS) was used for pain, self-rated from 0 to 10 [18]. A Semmes-Weinstein monofilament [19] was used for sensation assessment on the 6-piece foot-kit Touch-Test [20]; results were classified on 5 levels: normal, diminished light touch, diminished protective sensation, loss of protective sensation, and deep pressure sensation only.

Statistical analysis

Statistical analyses used IBM SPSS Statistics software for Windows, version 22 (IBM Corp., Armonk, New York, USA). To assess intergroup differences, an independent *t*-test or Mann–Whitney *U* test was performed as appropriate. Cohen's d effect-size was used to measure the strength of relationship. Chi-square tests were used for categorical variables: gender, educational background, and occupation. Finally, univariate and multiple linear regression analyses were used to investigate the relationships between the independent (age, gender, BMI, educational background, occupation, SIECT and SIECN) and dependent variables in the 2 groups, and independent (time since injury, injury side, nerve injury, hand function, pain, sensation) and dependent variables in the observational group. All tests were two-tailed and considered significant at $p < 0.05$.

Results

Demographics and descriptive information

One hundred and four patients with traumatic upper-limb injury (group 1) and 104 uninjured controls (group 2) were included, with 70 males and 34 females in each group. Median age in both group 1 (range, 19–64 years) and group 2 (range, 18–64 years) was 37.00 years. Median BMI was 22.31 and 22.85 kg/m^2, respectively. There were no significant intergroup differences in age, gender, BMI, education or occupation (Table 1).

Table 1
Participant characteristics and cognitive function by group.

	Unilateral traumatic upper-limb injury patients (N = 104)	Uninjured participants (N = 104)	*p* Value
Gender, N (%)			1
Female	34 (33%)	34 (33%)	
Male	70 (67%)	70 (67%)	
Age (years), median (IQR)	37.00 (28.25, 46.00)	37.00 (30.00, 45.50)	0.96
BMI, median (IQR)	22.31 (20.22, 25.95)	22.85 (20.61, 24.98)	0.76
Education, N (%)			0.89
Secondary school or below	40 (39%)	37 (36%)	
High school or polytechnic school	19 (18%)	21 (20%)	
Bachelor's or higher	45 (43%)	46 (44%)	
Occupations, N (%)			0.99
Level 1	32 (31%)	31 (30%)	
Level 2	48 (46%)	48 (46%)	
Level 3	17 (16%)	17 (16%)	
Level 4	7 (7%)	8 (8%)	
RAVLT, mean (SD)	28.53 (9.11)	31.73 (7.55)	0.006
SCWT, median (IQR)			
SIECT	20.60 (16.33, 29.60)	20.10 (15.05, 27.10)	0.33
SIECN	1 (0, 3)	1 (0, 3)	0.90

IQR: Interquartile range; N: number; SD: standard deviation; BMI: body mass index; SIECT: Stroop Interference-Effect Consumed Time; SIECN: Stroop Interference-Effect Correct Number.

Table 2
Trauma characteristics in group 1.

	Category	N	%	Mean (SD)/Median (IQR)
Time since injury (days)				51 (11, 138.75)
Injury side	left	42	40%	–
	right	62	60%	–
Nerve injury	With	51	49%	–
	Without	53	51%	–
ARAT				43.50 (21, 56)
Pain on VAS				14 (0, 30)
SWM	Normal	39	37%	–
	Diminished Light Touch	18	17%	–
	Diminished Protective Sensation	10	10%	–
	Loss of Protective Sensation	3	3%	–
	Deep Pressure Sensation Only	11	11%	–
	Not available	23	22%	–

Regarding trauma characteristics in group 1, median time since injury was 51 days. 40% (n = 42) were left-side and 60% (n = 62) right-side injury. 49% (n = 51) of patients had nerve injury and 51% (53) not. Median ARAT score was 43.5, and median pain rating on VAS was 14/100. 37% of patients (n = 39) had normal SWM, 17% (n = 18) diminished light touch, 10% (n = 10) diminished protective sensation, 3% (n = 3) had lost protective sensation, and 11% (n = 11) had deep pressure sensation only. For 22% of patients (n = 23) SWM data were not available because of acute post-operative bandaging or fixation (Table 2).

Cognitive functions

The present findings showed a significant intergroup difference in mean RAVLT score, lower in group 1 (M = 31.7, SD = 7.6) than group 2 (M = 28.5, SD = 9). Effect size ranged between small and medium, with Cohen's d 0.38. In contrast, no significant differences were observed in executive function on SCWT between groups 1 and 2 (median SIECT 20.6 and 20.1, respectively; U = 4988.50, $p = 0.33$), and median SIECN was1.0 for both groups (U = 5355.00, $p = 0.90$) (Table 1).

When a statistical association was observed between variables on univariate regression analysis, stepwise multiple linear regression analysis was conducted to confirm the final model. As shown in Table 2, total RAVLT score (F (4203) = 30.61, $p < 0.001$, $R^2 = 0.38$) was associated with group (beta = −2.89, $p < 0.01$), gender (beta = −3.08, $p < 0.01$), education (beta = −8.54, $p < 0.01$), and SIECN (beta = −0.72, $p < 0.01$). No significant interaction was observed in RAVLT scores ($p > 0.05$), suggesting that the homogeneity of the regression slopes was the same for the variables gender, education and SIECN [13] (Table 3).

To assess the association between cognitive functions and trauma characteristics (time since injury, injury side, nerve injury, hand function, pain, sensation) in group 1, multiple linear regression was implemented. VAS pain rating and SWM explained a variance (R^2) of 0.19 (F (2, 82) = 9.54, $p < 0.001$) for RAVLT in group 1, with VAS (beta = −0.16, $p < 0.01$) and SWM (beta = 1.09, $p < 0.05$) significantly associated with total RAVLT score (Table 4).

Table 3
Results of univariate and multiple linear regression analysis of RAVLT in the two groups.

Variables	Univariate regression coefficient (95% CI)	Multiple linear regression coefficient (95% CI)
Group (Group 1)	−3.20 (−5.59, −0.92)**	−2.86 (−4.70, −1.01)**
Gender (Male)	−4.85 (−7.25, −2.46)**	−3.08 (−5.09, −1.06)**
Age - years	−0.19 (−0.29, 0.09)**	
BMI - kg/m^2	−0.40 (−0.73, −0.07)*	
Education		
Secondary or below vs Bachelor's or higher	−9.81 (−12.03, −7.59)**	−8.54 (−10.65, −6.43)**
Highschool diploma vs Bachelor's or higher	−3.02 (−5.74, −0.29)**	−2.27 (−4.82, 0.27)
Occupation		
Level 2 vs Level 1	−8.20 (5.78, 10.61)**	
Level 3 vs Level 1	−0.12 (−3.29, 3.05)	
Level 4 vs Level 1	3.48 (−0.81, 7.76)	
SIECT	−0.21 (−0.31, −0.11)**	
SIECN	−1.15 (−1.60, −0.70)**	−0.72 (−1.11, −0.33)**

CI: confidence interval; *: $p < 0.05$; **: $p < 0.01$; SD: standard deviation; BMI: body mass index; SIECT: Stroop Interference-Effect Consumed Time; SIECN: Stroop Interference-Effect Correct Number.

Table 4
Results of univariate and multiple linear regression analysis of RAVLT in group 1.

	Univariate regression coefficient (95% CI)	Multiple linear regression coefficient (95% CI)
Time since injury	0.10 (−0.01, 0.02)	
Injury side	0.08 (−2.09, 5.14)	
Nerve injury	4.50 (1.05, 7.95)*	
ARAT	0.22 (0.01, 0.18)*	
VAS	−0.39 (−0.26, −0.09)**	−0.10 (−0.19, −0.01)*
SWM	0.28 (0.35, 1.73)**	0.99 (0.15, 1.83)*

CI: confidence interval; *: p <0.05; **: p <0.01; BMI: body mass index; SIECT: Stroop Interference-Effect Consumed Time; SIECN: Stroop Interference-Effect Correct Number.

No significant VAS* SWM interaction was observed for RAVLT, showing homogeneity of the regression slopes.

Discussion

The main purpose of the present study was to determine differences in cognitive functions between individuals with and without traumatic upper-limb injury. The secondary aim was to investigate the association between cognitive function and trauma characteristics in injured individuals: time since injury, injury side, nerve injury, pain, sensation, hand function. The findings showed that patients had significantly poorer short-term memory than controls. However, there was no significant difference in executive function between the two groups. Additionally, patients showed a correlation between cognitive functions and trauma characteristics (pain, SWM). This is an important discovery, as little previous research examined the impact of traumatic upper-limb injury on short-term memory. Apart from intrinsic importance of cognitive function, the findings have practical implications for how to support patients in managing cognitive challenges after traumatic upper-limb injury.

Short-term memory was poorer in patients, despite excluding brain or central nervous system trauma or disease: i.e., individuals with traumatic upper-limb injury had more severe short-term memory impairment than uninjured individuals. This is an important discovery to identify the risk of traumatic upper-limb injury. Based on these results, there are two possible hypotheses. The first possibility is that the injured individuals may have had pre-existing short-term memory problems, making them more likely to get hurt than others, with poor neurocognitive performance inducing elevated risk of musculoskeletal injury [21] and musculoskeletal limb pain [22]. In this case, we should identify individuals with declining short-term memory in jobs with high risk of trauma with strong cognitive requirements, to decrease the incidence of trauma. Another hypothesis is that the injured individuals might show impaired short-memory specifically after their injury, and that traumatic upper-limb injury has a negative impact on short-term memory: i.e., that short-term memory impairment may be a post-traumatic complication. To determine which hypothesis is closer to the truth, change in short-term memory after traumatic upper-limb injury should be monitored without regular cognitive treatment.

Regarding factors associated with short-term memory in injured individuals, trauma characteristics were assessed for clinical significance, as baseline variables such as gender and educational status were discussed as significant risk factors in previous studies [23–26]. The present results revealed that pain and SWM were associated with short-term memory function.

Pain is widely believed to be a possible cause of cognitive impairment [27]. As shown in a previous review, a significant correlation was found between pain and memory decline [28]. At the root of this relation, pain functions as one of the body's most effective warning systems, buit can lead to stress. Painful stressors increase cortisol levels [29], which are associated with memory impairment [30]. Thus, pain starts a sequence of events that ultimately results in short- memory loss, according to this hormonal interpretation. Another explanation involves higher cerebral activity stimulated by pain [31]. Pain was found to induce functional brain reorganization after peripheral injury [32], increasing central nervous system pain transmission excitability, including in the hippocampus, which is primarily in charge of short-term memory storage [33]. Consequently, hippocampal neurosensitization limits short-term memory performance. Thus, pain may have contributed to the decline of short-term memory through the conduction pathway; this requires further investigation to determine the relationship between pain and cognitive impairment in traumatic upper-limb injury.

Upper-limb sensation as assessed by SWM was a proximal contributing factor for short-term memory decline. Sensation is a significant superficial sensory input to the brain involved in a variety of upper-limb tasks. It can elicit corresponding postural and motor responses [34] that rely on cognitive information processing, such as central multisensory integration and voluntary control [34,35]. In other words, the brain processes fewer signals when there is less sensory input from the upper limbs. After traumatic upper-limb injury, many subjects experience sensory disorder, and also cannot use their upper limbs as effectively as before because of temporary bandaging and/or fixation. As a result, sensory input is lower than before injury. In conclusion, the decline or disappearance of sensory inputs impairs cognitive processes, which may show as short-term memory impairment, as in this study.

In the present study, however, patients with traumatic upper-limb injury did not show significantly poorer executive function than the control group. This not in line with previous reports [36] that individuals with hand/wrist discomfort showed poorer executive function assessed by SCWT than healthy control participants. These contradictory results may be explained by difference in time since upper-limb injury. The hand/wrist discomfort in the previous study was of longer mean duration (67.7 months) than symptoms in the present study (median 51 days: i.e., about 2 months). Moreover, on multiple regression analysis, executive function was associated with short-term memory performance. Therefore, executive function deserves attention during therapy, and further research is needed to determine adaptations in rehabilitation for patients with traumatic upper-limb injury.

This study had some limitations that should be taken into consideration when interpreting its results. The study lacked data on patients' pre-injury cognitive function, which could have helped determine whether poor cognitive function pre-existed or developed secondarily. Additionally, cognitive assessment was restricted to memory and executive function on RAVLT and SCWT; although these measures are valid and reliable, there are others that might have shown different results.

Conclusion

In conclusion, individuals with traumatic upper-limb injury had greater cognitive deficit in short-term memory than uninjured individuals. Pain and sensation were predictors that could affect short-term memory in injured individuals. In contrast, there was no significant decline in executive function. To investigate possible cognitive impairment following traumatic upper-limb injury, further research with rigorous procedures is needed.

Disclosure of interest

The authors declare that they have no competing interests.

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Ethics

The study protocol was approved by the local Human Ethics Committee of the Guangdong Work Injury Rehabilitation Hospital (AF/SC-07/2021.47) according to the Declaration of Helsinki.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patients and volunteers.

References

[1] Moellhoff N, Throner V, Frank K, Benne A, Coenen M, Giunta RE, et al. Epidemiology of hand injuries that presented to a tertiary care facility in Germany: a study including 435 patients. Arch Orthop Trauma Surg 2023;143(3):1715–24.

[2] Lee A, Colen DL, Fox JP, Chang B, Lin IC. Pediatric hand and upper extremity injuries presenting to emergency departments in the United States: epidemiology and health care-associated costs. Hand (New York NY) 2021;16(4):519–27.

[3] Dębski T, Noszczyk BH. Epidemiology of complex hand injuries treated in the Plastic Surgery Department of a tertiary referral hospital in Warsaw. Eur J Trauma Emerg Surg 2021;47(5):1607–12.

[4] Zhang X, Tse T, Li T, Zoghi M. Is there an association between traumatic peripheral lesions and cognitive impairments in adults? A scoping review. Adv Rehabil 2023;37(1):1–11.

[5] Akdoğan S, Ayhan FF, Yıldırım Ş, Borman P. Impact of fatigue on cognitive functioning among premenopausal women with fibromyalgia syndrome and rheumatoid arthritis: the controlled study. J Musculoskelet Pain 2013;21:135–46.

[6] Jacobsen HB, Stiles TC, Stubhaug A, Landrø NI, Hansson P. Comparing objective cognitive impairments in patients with peripheral neuropathic pain or fibromyalgia. Sci Rep 2021;11:673.

[7] MahmoudAliloo M, Bakhshipour A, Hashemi T, Roofigari AR, Hassan-Zadeh R. The correlation of cognitive capacity with recovery of hand sensibility after peripheral nerve injury of upper extremity. NeuroRehabilitation 2011;29:373–9.

[8] Herman DC, Zaremski JL, Vincent HK, Vincent KR. Effect of neurocognition and concussion on musculoskeletal injury risk. Current sports medicine reports. Am Coll Sports Med 2015;14:194–9.

[9] Australian Bureau of Statistics. Australian and New Zealand standard classification of levels; [Internet]. 2022 [Cited 2022 December 20]. Available from:https://www.abs.gov.au/statistics/classifications/anzsco-australian-and-new-zealand-standard-classification-levels2022.

[10] Ministry of Education of the People's Republic of China. Education statute in the People's Republic of China; [Internet]. 2022 [Cited 2022 May 20]. Available from:http://www.moe.gov.cn/jyb_sjzl/sjzl_zcfg/zcfg_jyfl/202107/t20210730_547843.html2021.

[11] Guo Qihao, Lu Chuanzhen, Hong Zhen. Auditory verbal memory test in Chinese elderly. Chin Mental Health J 2001;15:13–5.

[12] Zhao Xiaoling, Wang Lei, Fang Sheng, Zhu Xi, He Liu, Gu Rui, et al. Early detection of post-stroke cognitive impairment by stroop color word test. Chin Gen Pract 2021;24:1896–901.

[13] Schmidt M. Rey auditory verbal learning test: a handbook. Los Angeles. CA: Western Psychological Services; 1996.

[14] Guo Q, Zhao Q, Chen M, Ding D, Hong Z. A comparison study of mild cognitive impairment with 3 memory tests among Chinese individuals. Alzheimer Dis Assoc Disord 2009;23(3):253–9.

[15] Scarpina F, Tagini S. The Stroop color and word test. Front Psychol 2017;8:557.

[16] Luo C, Proctor RW, Weng X. A Stroop effect emerges in the processing of complex Chinese characters that contain a color-related radical. Psychol Res 2015;79:221–9.

[17] Zhao Jiang-li, Mao Yu-rong, Xu Zhi-qin, Chen Shao-zhen, Huang Dong-feng. Validity of Chinese version of action research arm test in patients with early cerebral infarction. Chin J Rehabil Theory Pract 2019;25(8):946–55.

[18] McCormack HM, Horne DJ, Sheather S. Clinical applications of visual analogue scales: a critical review. Psychol Med 1988;18(4):1007–19.

[19] Hsu HY, Shieh SJ, Kuan TS, Yang HC, Su FC, Chiu HY, et al. Manual tactile test predicts sensorimotor control capability of hands for patients with peripheral nerve injury. Arch Phys Med Rehabil 2016;97(6):983–90.

[20] North Coast medical and rehabilitation production. Touch test sensory evaluators; 2021 [Internet]. 2022 [Cited 2022 May 20]. Available from:https://www.ncmedical.com/products/touch-test-sensory-evaluators_1278.html?objectID=1278&queryID=5dbd65e009a7745dc15061e7245a3059.

[21] Herman Daniel C, Zaremski JL, Vincent Heather K, Vincent Kevin R. Effect of neurocognition and concussion on musculoskeletal injury risk. Am Coll Sports Med 2015;14(3):194–9.

[22] Vranceanu A-M, Ring D. Cognitive coping predicts pain intensity and disability in patients with Upper extremity musculoskeletal pain. J Musculoskelet Pain 2014;22(4):373–7.

[23] Meng X, D'Arcy C. Education and dementia in the context of the cognitive reserve hypothesis: a systematic review with meta-analyses and qualitative analyses. PLoS One 2012;7e38268.

[24] Sherwin BB. Hormones, mood, and cognitive functioning in postmenopausal women. Obstet Gynecol 1996;87:20S–6S.

[25] Krapohl E, Rimfeld K, Shakeshaft NG, Trzaskowski M, McMillan A, Pingault JB, et al. The high heritability of educational achievement reflects many genetically influenced traits, not just intelligence. Proc Natl Acad Sci U S A 2014;111:15273–8.

[26] Li R, Singh M. Sex differences in cognitive impairment and Alzheimer's disease. Front Neuroendocrinol 2014;35:385–403.

[27] Coppieters I, De Pauw R, Kregel J, Malfliet A, Goubert D, Lenoir D, et al. Differences between women with traumatic and idiopathic chronic neck pain and women without neck pain interrelationships among disability, cognitive deficits, and central sensitization. Phys Ther 2017;97:338–53.

[28] Moriarty O, McGuire BE, Finn DP. The effect of pain on cognitive function: a review of clinical and preclinical research. Prog Neurobiol 2011;93:385–404.

[29] Lupien SJ, Gaudreau S, Tchiteya BM, Maheu F, Sharma S, Nair NPV, et al. Stress-induced declarative memory impairment in healthy elderly subjects: relationship to cortisol reactivity. J Clin Endocrinol Metab 1997;82:2070–5.

[30] Het S, Ramlow G, Wolf OT. A meta-analytic review of the effects of acute cortisol administration on human memory. Psychoneuroendocrinology 2005;30:771–84.

[31] Antepohl W, Kiviloog L, Andersson J, Gerdle B. Cognitive impairment in patients with chronic whiplash-associated disorder—a matched control study. NeuroRehabilitation 2003;18:307–15.

[32] Chen FY, Tao W, Cheng X, Wang H, Hu Y, Zhang X, et al. Brain glucose metabolic changes associated with chronic spontaneous pain due to brachial plexus avulsion: a preliminary positron emission tomography study. Chin Med J 2008;121:1096–100.

[33] Miller L. Neurosensitization: a model for persistent disability in chronic pain, depression, and posttraumatic stress disorder following injury. NeuroRehabiltation 2000;14:25–32.

[34] Verite F, Bachta W. Cognitive processes and a centre-of-pressure error-based moving light-touch biofeedback. Neurosci Lett 2021;749135743.

[35] Bentivoglio. The Proustian itinerary from sensation to memory. Ital J Neurol Sci 1995;16(3):195–8.

[36] Pelletier R, Paquette É, Bourbonnais D, Higgins J, Harris PG, Danino MA. Bilateral sensory and motor as well as cognitive differences between persons with and without musculoskeletal disorders of the wrist and hand. Musculoskelet Sci Pract 2019;44102058.