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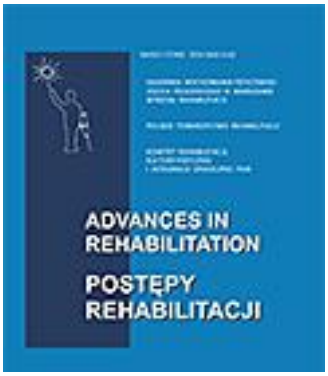

Review article

Title: Is there an association between traumatic peripheral lesions and cognitive impairments in adults? A scoping review

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Is there an association between traumatic peripheral lesions and cognitive impairments in adults? A scoping review

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Abstract

The aim of this scoping review was to critically review and synthesize the evidence investigating the relationship between traumatic peripheral lesions and cognitive impairments.

Five electronic databases (Medline, Cinahl, Psycinfo, Embase, and Cochrane Library) were searched from inception using the two key concepts "cognition" and "trauma". An additional manual search was conducted. Articles included were written in English, included an assessment of cognition, study participants experienced any acute peripheral lesion or physical trauma and were between 18 and 65 years. Articles were screened for eligibility by two independent reviewers. Disagreements were resolved by discussion or consensus with a third author.

A total of 11573 records were identified, of which 10 met the inclusion criteria. Whiplash injury, brachial plexus injury, soft tissue injury around the cervical spine, and fracture were found to be associated with cognitive impairments. The earliest cognitive assessment time point was 1-month post injuries, while the latest counterpart was 444 months. Cognition was assessed using 20 unique instruments, targeting 9 distinct cognitive domains.

There is an overall positive association between traumatic peripheral lesions and cognitive impairments. Therefore, further longitudinal research is needed to monitor the changes in cognitive functions post physical trauma.

Keywords injury, cognition, cognitive impairments, peripheral lesions, physical trauma**.**

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Introduction

Traumatic peripheral lesions, a severe bodily injury has traditionally been a prominent cause of disability across the globe [1,2], and it is responsible for around 4.4% of all hospital admissions [1]. Worse still, 34% of all patients suffered from recurring injuries [3]. This not only contributed to the growing financial burden of caring for patients but also led to a greater emphasis on preventing trauma from recurring. It is suggested that cognitive function [4,5] might contribute to the increased risk for subsequent injury within a short period of time [3], particularly in jobs that require a high level of concentration, memory, and executive function.

Although the correlation between cognitive impairments and traumatic peripheral lesions is less well established, there are an increasing number of reports suggesting that patients develop cognitive impairments post-traumatic peripheral lesions [6−17]. For instance, a variety of significant cognitive impairments were detected in patients with peripheral nerve injury [11,16−17], fibromyalgia syndrome [6-9] musculoskeletal injuries [10,12−14], and even burn injury [15]. These impairments referred to a wide range of cognitive domains, such as attention [11], memory [7], language [12], visuospatial capacities and cognitive flexibility [17]. The potential mechanisms were intricate and had been covered in a few papers, which demonstrated that pain [11,13], sensory recovery [17], exhaustion [8], psychology [8, 9,13], and sleeplessness [9] may mediate the association between traumatic peripheral lesions and memory impairment because they can produce altered neuroplasticity or dysregulated neurochemistry in the brain, which in turn impaired cognitive functions [18].

On the other hand, post-burn patients showed no significant differences in attention or memory [19], however, it was unclear whether this was related to the evaluation time point in the study design or not. Therefore, additional research and reviews are necessary to shed light on the possible association between traumatic peripheral lesions and cognitive impairments in patients. This is very important as it can affect the treatment plan post traumatic peripheral lesions.

The aim of this scoping review was to investigate whether there is an association between cognitive impairments and traumatic peripheral lesions using Arksey and O' Malley's (2005) scoping review framework [20]. The protocol was registered with Open Science Framework in September (Registration DOI: 10.17605/OSF.IO/7HV9W). For more details, please visit: https://osf.io/rp8nd/?view_only=7e9e5a87233b4b3bac6b37caeb73d28d

Materials and Methods

Search strategy

To allow the breadth of exploration, especially when the evidence base is relatively new and small, the search strategy was broad and included a wide range of study designs including observational, interventional, retrospective, and case studies. Five databases including MEDLINE, CINAHL, PSYCINFO, EMBASE, and COCHRANE LIBRARY, were searched in addition to hand searches to identify relevant studies published from inception until 4 August 2022 using the concepts of trauma and cognitive impairments in adults. Various combinations of Medical Subject Headings (MeSH) and keyword terms used as the identified keywords and index terms. Subject headings and synonyms were used to expand the search, along with wildcards (i.e. '?'), truncations (i.e. cognit*), and Boolean operators (i.e. AND, OR). Animal studies and studies on children (e.g. congenital or developing diseases) were excluded from the study. Additionally, cognitive impairments that were caused by other factors, such as aging, psychological and emotional problems, substance addiction, chronic disease, chronic pain, and post-injury with any damage to human sight, hearing, smell, or taste were excluded in this review, as well as trauma or disease in the central nervous system. Also, visceral nociception and burn were eliminated (Tab. 1).

If a full-text was not available we contacted the corresponding author. If no response was received within one month, those studies were excluded. A language limit was used to adapt to all the study team members' collaborating needs; thus, included all the studies that were published in English.

Tab. 1. Inclusion and exclusion criteria

Criteria	NO.	Details
Inclusion Criteria	1	Types of studies: observational, interventional, retrospective, and case studies
	2	Age: 18 - 65
	3	Cognitive impairments due to acute traumatic peripheral lesions
	4	Full text available in English
Exclusion Criteria	1	Animal studies
	2	Trauma or disease in the central nervous system
	3	Chronic injuries without a definite timepoint of trauma
	4	Congenital or developing diseases
	5	Cognitive impairments due to aging, psychological, emotional problems, or substance addiction
	6	Damage to sight, hearing, smell or taste
	7	Visceral nociception or burn
	8	Study protocols

Data extraction

Titles, abstracts, and full texts were screened by two independent reviewers using Covidence [21]. Conflicts were resolved through discussion after being reviewed in full, or by the third author, who made the final decision. This stage was followed by data extraction.

Two reviewers independently extracted the data using a predefined data extraction form. Disagreements were resolved by discussion or consensus with a third author. The extracted data included general information (i.e. title, authors, year, country, aims, key findings), participant characteristics (i.e. type of trauma, total number of participants, gender, mean age, earliest cognitive assessment time point post-injury, latest cognitive assessment time point post injury), cognitive assessment tools used in these studies, and distribution of domains evaluated. For studies with insufficient information, the team of reviewers contacted the corresponding authors, when possible, to acquire and verify the data.

Collating and summarizing results

Firstly, general information and other characteristics were collected and summarized in tables and figures. The earliest and latest cognitive assessment time point post-injury were reported, as well as the average counterpart, excepting two reports which provided mean time point only [22,23]. Both articles were published more than two decades ago, so no email or phone number was recorded in the reports, leading to partial data loss.

The outcome measurement tools for assessing the cognitive functions were identified as either full assessments or subtests used as stand-alone assessments. For example, the subtest *'Logical Memory'* [24] was derived from parts of the *'Wechsler Adult Intelligence Scale"* [25] and was used in isolation to evaluate a specific cognitive domain; hence, it was considered a stand-alone assessment tool in our review. However, different versions of the same assessment tool were considered the same assessment tool. For instance, *'Wechsler Adult Intelligence Scale-Revised'* [26,27] and *'Wechsler Adult Intelligence Scale-Third Edition'* [28] were considered as the same evaluation, named *'Wechsler Adult Intelligence Scale*' [25].

Additionally, cognitive domains were classified according to International Classification of Functioning, Disability, and Health (ICF) [29], following the previously published rule [30]. First, the raw domains reported by authors in each study were extracted. They were then mapped to certain categories by two reviewers. If there was any disagreement, the two reviewers would discuss it, or it was decided by the third author. The types of cognitive domain

content included ICF functions (b110–b139) and specific mental functions (ICF functions b140–b189). Also, if the same field of cognition was evaluated repeatedly by different scales in one study, the actual number of times involved would be calculated.

The entire flow of articles through identification to inclusion was operated in Covidence, and the available data of the included studies were documented and processed using Excel.

Results

The original search yielded 11,712 potentially relevant articles. After removing duplicates, 10,901 studies remained. Independent screening of the titles and abstracts identified 68 studies that were included in the full-text screening, of these 10 studies met the inclusion criteria and were included in this review. Studies were excluded due to the following reasons: including participants aged over 65 years (15 studies), no physical trauma (9 studies), not relevant to the research topic (7 studies), no cognitive function or related brain area evaluated (6 studies), chronic conditions such as lumbar disc herniation with no information about the onset of the injuries (5 studies), trauma or disease in the central nervous system (5 studies), visceral nociception (2 studies), burns (2 studies), see Figure 1 for more details. The flow of articles from identification to inclusion is shown in Figure 1.

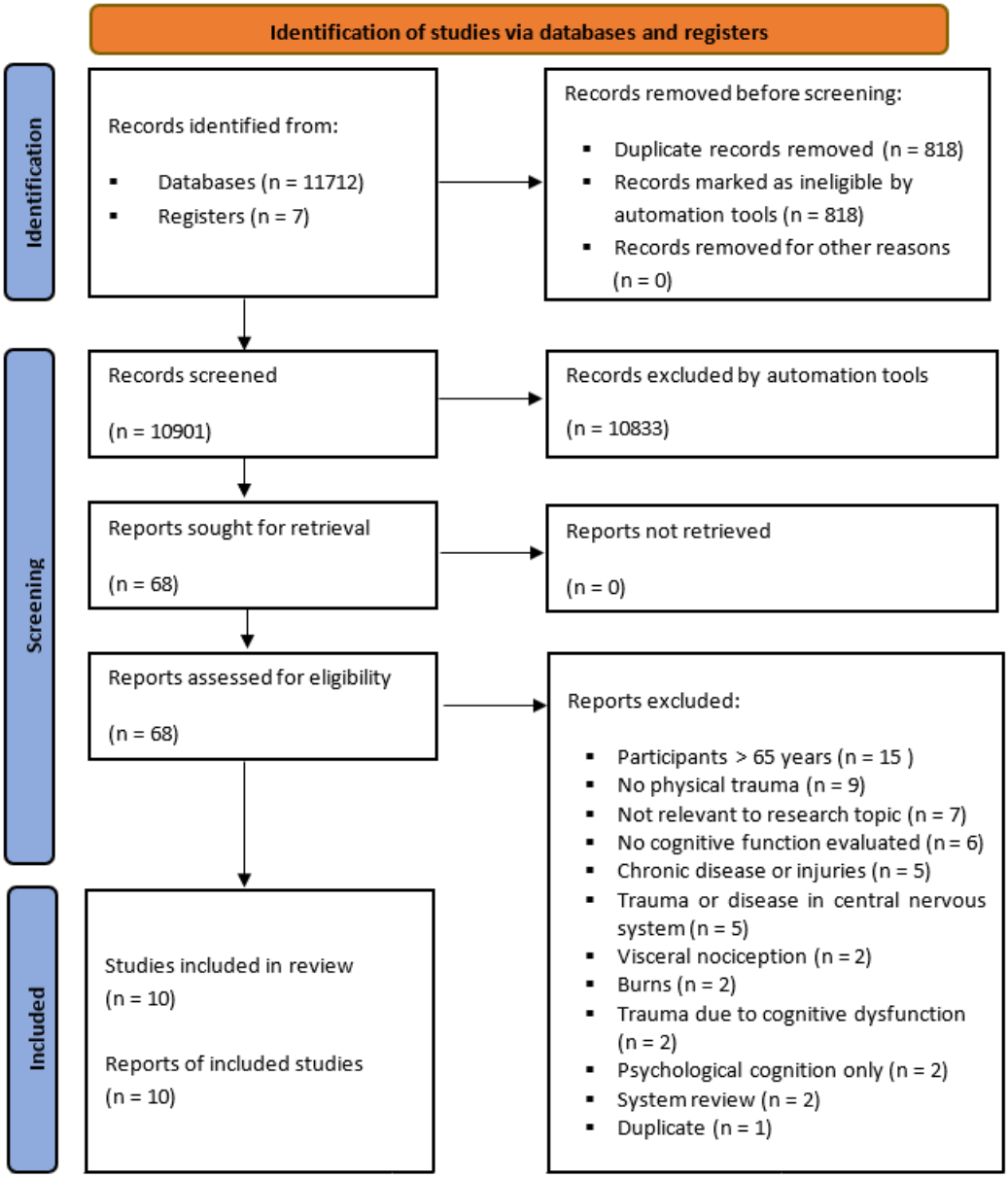

Fig. 1. Included studies and reasons for exclusion

General study characteristics

It is evident that there has been an upward trend in the literature on assessing cognitive functions after traumatic peripheral lesion. From the 10 included papers in the final review, 7 were published after 2001, with only 3 published prior to 2001. Moreover, all the studies were observational cohorts, including 7 case-control studies and 3 cohort studies. In addition, 354 patients with traumatic peripheral lesions were included in this review as a pooled sample. The cohort size ranged from 6 to 109 patients. Most study samples came from Europe (47.7%, including Belgium, Sweden, Switzerland, Denmark), followed by the United States (30.8%), Oceania (15.5%, Netherlands), and Asia (5.9%, China) (Tab. 2).

Tab. 2. Summary data from the studies included in the scoping review on cognition and peripheral trauma

Lead author	Year	Sample Size	Country	Aims	Key findings
Coppieters [31]	2017	32	Belgium	To examine differences in disability, cognitive impairments, and central sensitization between women with traumatic and idiopathic (nontraumatic) neck pain and women who were healthy.	1. Cognitive impairments in memory and executive function were present in participants with whiplash associated disorders 2. Strong correlations between disability and cognitive impairments were observed in participants with whiplash associated disorders.
Ickmans [32]	2016	27	Belgium	To examine postexercise cognitive performance in people with chronic Whiplash-Associated Disorders.	People with whiplash-associated disorders displayed significantly lower scores on attention and psychomotor, compared with healthy controls.
Jun-Tao [33]	2016	15	China	To explore the higher-level brain functional abnormality pattern of BPI patients from a large-scale network function connectivity dimension in right-handed BPI patients.	Brain functional disturbance in BPI patients extends in executive-control network which was revealed by functional MRI analysis, and this may lead to cognitive alterations in complex tasks post BPI.
Richards [34]	2011	109	USA	To examine the association of reamed IMN and long-term cognitive impairment in trauma intensive care unit survivors.	Fracture fixation with a reamed IMN is associated with cognitive impairment of Global (ICF-ch1), memory, attention, HLCF in multiple trauma patients at 1 year post injury.
Chen[35]	2008	6	China	To investigate the brain regions involved in chronic spontaneous pain due to BPA, to determine the glucose metabolic changes in patients with pain due to BPA.	Brain areas involved in attention and internal modulation of pain had significant glucose metabolism decreases in patients with BPA.
Antepohl[36]	2003	30	Sweden	To verify the occurrence of cognitive impairments in patients	Compared to healthy controls, patients with whiplash-associated

				with WAD and to provide a more detailed description of the impairment character and context.	disorder performed worse in psychomotor and memory.
Bosma [37]	2002	31	Netherlands	To investigate underlying mechanisms of cognitive impairments in whiplash syndrome.	Patients with whiplash performed worse on memory and attention tasks compared with the control group.
Kessels [22]	1998	24	Netherlands	To compare attentional dysfunctions in whiplash patients with age-matched controls.	Whiplash patients had lower scores on the attention identified by PASAT.
Smed [38]	1997	29	Denmark	To address which factors lead to the chronic syndrome of whiplash injury.	Patients with whiplash injury showed deficiencies in the score of Cognitive Function Scan. The performances of basic learning of the whiplash patients coping with stressful life events in addition to the accident were significantly worse than patients without, whereas memory was unaffected.
Radanov [23]	1992	51	Switzerland	To assess cognitive functions after soft tissue injury of the cervical spine.	1. Those suffering from cervicoencephalic syndrome had poorer results when tested for attention and HLCF. 2. All the findings above were not related to the length of the post-traumatic interval.

BPA − brachial plexus avulsion, BPI − brachial plexus injury, HLCF − higher-level cognitive functions, IMN − intramedullary nailing, PASAT − Paced Auditory Serial Addition Task [38], WAD − whiplash-associated disorder

All the reports were divided into two groups based on the location of trauma: soft tissue injury (9 reports - including 6 whiplash injury, 2 brachial plexus injury, 1 soft tissue injury of the cervical spine) and fracture (1 report). Accodingly, people with soft tissue disorders of the cervical spine and upper limb, as well as those with fracture fixation, developed significant cognitive impairments following trauma. These cognitive impairments can last from around one month to over 30 years post injury, and they were not related to the length of the post-traumatic interval. (more details are provided in Tab. 3).

Tab. 3. Summary of study participants pooled data grouped into three trauma/lesion types

Trauma/lesion	Number of participants	Gender		Mean age	Earliest cognitive assessment time point post injury	Latest cognitive assessment time point post injury
		male	female			
Soft tissue injury	245	79	166	36.6	1 month	444 months
a. Whiplash injury	173	45	128	37.0	1 month	444 months
b. Brachial plexus injury	21	19	2	32.9	1 month	240 months
c. Soft tissue injury around cervical spine	51	15	36	36.9	*	*
Fracture	109	62	47	42.7	12 months	12 months
Total	354	141	213	38.5		

*Not mentioned in corresponding reports

Assessment tools and evaluated domains

The assessment tools used to evaluate cognitive functions can be categorised into two: cognitive scales and brain data acquisition of cognitive regions by magnetic resonance imaging (MRI). Nine domains of cognition were involved, including HLCF (b164), memory (b144), attention (b140), psychomotor (b147), language (b167), global (ICF-ch1), basic learning (d130-159), consciousness (b110) and perceptual (b156).

As for the cognitive scales, the highest frequency of scales included *the Trail Making Test (TMT)* [40] *and the Paced Auditory Serial Addition Task (PASAT)*[39] (Tab. 4).

Tab. 4. Cognitive assessment tools used in these studies

NO.	Scale	Frequency
1	Trail Making Test	3
2	Paced Auditory Serial Addition Task (PASAT)	3
3	Stroop Test	2
4	Rey Osterreith Complex Figure Test	2
5	Mini Mental State Exam	2
6	Rey Auditory Verbal Learning Test	1
7	Psychomotor vigilance task (PVT)	1
8	Digit Symbol Coding	1
9	FAS Test	1
10	Verbal Reaction time task	1
11	Spatial Reaction time task	1
12	Reading Span Task	1
13	Matrix Test	1
14	Dutch adaptation of the California Verbal Learning Test (CVLT)	1

15	Bourdon-Wiersma cancellation task	1
16	Cognitive Function Scanner (CFS)	1
17	Wisconsin Card Sorting Test (WCST)	1
18	Number connection Test	1
19	Drawings and Rey Complex Figure	1
20	Bourdon- Wiersma Test	1
Total		33

In total, nine areas related to the cognitive domain were assessed in these studies. Of these, *higher-level cognitive functions (HLCF)(b164), memory (b144), and attention (b140)* were the most frequently covered categories ('b' stands for *body functions* in ICF), almost reaching 71.9% (Tab. 5).

Tab. 5. Distribution of Domains Evaluated

NO.	Domain	Frequency
1	HLCF (b164)	18
2	Memory (b144)	14
3	Attention (b140)	11
4	Psychomotor (b147)	4
5	Language (b167)	3
6	Global (ICF-ch1)	2
7	Basic learning (d130-159)	1
8	Consciousness (B110)	1
9	Perceptual (b156)	1
Total		55

Discussion

The purpose of this scoping review was to identify whether traumatic peripheral lesions could be associated with developing cognitive impairments post physical injuries. This scoping approach provided a preliminary understanding of cognitive impairments after acute trauma based on the reviewing 10 studies. All these studies showed that cognitive impairments could be developed post-traumatic peripheral lesions.

Noteworthily, even though all the samples of the included studies had excluded the cases with original head injuries, cognitive impairments could still be detected due to the secondary brain injury post-traumatic peripheral lesions [34]. The 'secondary brain injury' to the brain is used to explain the cerebral damage caused by peripheral lesions indirectly [34], which can be missed by therapists. On the other hand, the evoking activation of higher-level cognitive functions in the brain had been deactivated consistently in the executive-control network that was indicated by the Magnetic Resonance Imaging of participants with brachial plexus injury [33,35].

Possible explanations of the underlying mechanisms

Those possible reasons that may lead to the 'secondary injury' of the brain post traumatic peripheral lesions includes the following:

The important assumption is related to cerebral anoxia and/or hypoxia; as the brain requires a constant and abundant blood supply for oxygen and other nutrients, and any effect of the blood supply can have an impact on cerebral functions, including cognitive functions [41,42]. It has been proposed that soft tissue injuries or fractures could lead to suboptimal oxygen delivery to the brain [43,44]. Soft tissue injuries or fractures result in increased blood flow in the injured area as an emergency response to the injury, and this condition will continue during subsequent repair and regeneration period which might cause suboptimal oxygen delivery to the brain [45]. This condition then might cause transient or long-term changes in brain functions and thereby causing various degrees of neuropsychological changes [41,42].

Another possible reason is pain perception associated with the injuries [31,35,36], which is one of the common symptoms after acute trauma and has a potentially deleterious impact on cognitive tasks directly or indirectly [46]. Pain works as one of the most effective alarming systems in our body and can increase cerebral activity [36]. As a result, it creates a state of central functional remodeling [35], such as the dynamic epigenetic reprogramming of the prefrontal cortex, which has been identified one year after peripheral nerve injury, affecting the cognitive functions [47,48]. This phenomenon indicates neuroplastic changes in the brain due to pain. Additionally, pain can cause distraction and decrease the level of attention and concern when the participants are performing highly effortful mental tasks, especially during the verbal reaction time task [36].

The third possible contributing factor is pharmacological management during recovery post injuries or surgeries which has been reported as a critical contributing element in several studies [49–51]. Among these medications, the side effects of strong analgesic medications and anesthetics on cognitive functions have been clearly established, and they are not recommended as the first choice for pain management [52]. Furthermore, the negative effects of other anti-inflammatory analgesic drugs should be considered. For instance, based on a double-blind, randomized, placebo-controlled, repeated-dose clinical trial, patients taking hydrocodone bitartrate plus ibuprofen performed significantly worse on simple tracking task and reaction-time task [53]. Additionally, cautions should be taken when prescribing drugs that could affect the cerebral blood supply as side effects as it can affect the oxygen supply and other nutrients to the brain [52].

Fat embolism (FE) may occur frequently after traumatic peripheral lesions or during orthopaedic procedures. FE exerts its effect by mechanical blockage of vessels or by biochemical methods, such as breaking down the fat molecules to free fatty acids contributing to an inflammatory response [54]. However, the classical clinical entity of FE syndrome, such as pulmonary distress, neurologic symptoms, and petechial rash, is much less common [55]. The embolism of capillaries in brain tissue can occur and be ignored if the symptoms are not obvious but can be identified by cognitive impairments in patients [56,57]. In other words, an atypical FE can hit the brain and then affect cognitive impairments.

In addition, a potential hypothesis is that an elevated systemic inflammation could be associated with cognitive impairments [58]. A growing body of evidence has implicated the association between inflammation and neurocognitive functions in recent years. Even low-grade inflammation appears to play an etiological role in cognitive impairments [59]. Within 15 minutes of an acute traumatic peripheral lesion, the damaged tissues consisted of disrupted extracellular tissue and dead cells, platelets, and plasma, which release powerful enzymes, thereby setting off an inflammatory cascade [45]. Inflammatory chemicals then travel with the circulatory system and invade the brain tissue, impacting the negative influence on cerebral functions.

Psychologic distress post traumatic event which is so common after a severe musculoskeletal injury is another possible contributing factor that should be considered [37, 60, 61]. Patients with stress and distress seemed to perform unstably and worse in cognitive assessments, compared with those without any psychological distress [38]. Psychologic distress also causes sleep deprivation which in turn prevents corticosterone and interleukin 1β to signal for cell proliferation which will affect the hippocampal neurogenesis [62].

In summary, several possible contributing factors in developing cognitive impairments post traumatic peripheral lesions were discussed in this review. These possible factors were 1. cerebral anoxia / cerebral hypoxia, 2. pain, 3. analgesic medications, 4. FE, 5. Inflammatory responses, and 6. psychologic distress. Undoubtedly, other factors still need to be further investigated. All these contributing factors may overlap and be difficult to be discussed in isolation completely, inspiring more multi-dimensional future studies.

Time course

A month after whiplash or brachial plexus injuries was the earliest time point for cognitive assessment. Consequently, we still cannot determine whether cognitive impairments occur earlier than 1 month after a peripheral injury in adults. Meanwhile, animal studies may provide

some insight into the human condition. Illustrated by several adult rat studies, cognitive assessment was conducted 7 days post trauma [63,64], yet for those laboratory rats, 7 days are equivalent to about 7 months for an adult human [65]. In sum, as evidence outlined above, to be able to comment on when cognitive impairments appear post traumatic peripheral lesions, more studies need to be conducted as earlier as possible post trauma.

According to the latest cognitive assessment time point post trauma, cognitive impairments were still detected 444 months after whiplash injury. Moreover, a whiplash trauma study indicating that the cognitive performance declined and did not correlate with the duration between the actual accident and the time of testing [15]. This may suggest an association between poorer recovery of cognitive functions in the years following traumatic peripheral lesions, however further research and monitoring of cognitive functions after trauma is needed to elucidate this phenomenon. As there is no data available about the progression of cognitive impairments, it is unclear whether the symptoms get worse, better, or return to normal over time. To decide whether a rehabilitation program should include interventions around cognitive functions, we must have this information.

Cognitive assessment tools and domain

The findings identified a wide range of cognitive assessment tools were used in the included studies. 20 different measurement tools were identified in the 10 reports (see Table 5), and among them the most frequently used scales were *the Trail Making Test (TMT)* and *the PASAT*. There is no doubt that many cognitive measures are available, and they assess different domains of cognitive functions at different levels [66]. Although the TMT and the PASAT were the most frequently used tool of cognition, further research is needed to establish if these assessment tools are the best tools for assessing patients post traumatic peripheral lesions. It could be that assessment of patients with traumatic peripheral lesion needs more sensitive tools, since the cognitive impairments are not as obvious as those of brain injury.

Regarding the cognitive domains, our finding has indicated a wide breath of cognitive domains evaluated. *Higher-level cognitive functions (HLCF) (b164)* ranked first at 18 times, followed by *memory (b144), and attention (b140)* at 14 and 11 times, respectively, whereas other areas were of less concern. By reviewing cognitive assessment tools, the most appropriate and efficient scales will be able to be selected for further study. Particularly those domains that target vulnerable cognitive areas and require close attention. We should also continue to investigate the unexplored territory of cognitive domains to determine if they tend to be less affected or less studied by researchers.

Study limitations

The studies included in this review were all published in English, which means that there may be very interesting and useful findings in the literature that we didn't include.

Future directions

The findings of this scoping review suggest there may be an association between cognitive impairments and traumatic peripheral lesions in adults, but more high quality studies need to be conducted. Future studies should focus on a well defined population with one single type of peripheral injuries. Further, the assessment of cognition ought to commence as soon as possible after the injury and follow the study participants over time to track the changes in cognitive function.

Conclusions

There is an overall positive association between traumatic peripheral lesions and cognitive impairments. Peripheral injuries could cause cognitive impairment in both the acute and chronic phases of recovery. Apart from the most frequent cognitive scales and the most common domains assessed, further research is needed to investigate the more sensitive tools and unexplored territory.

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Conflicts of Interest

The authors have no conflict of interest to declare.

References

1. Soundarrajan A, Jena NN, Smith J, Douglass K. A retrospective observational study on epidemiology of traumatic injuries presenting to a tertiary care hospital in Madurai, India. Ann Emerg Med. 2017; 70(4): S66.
2. DiMaggio C, Ayoung-Chee P, Shinseki M, Wilson C, Marshall G, Lee DC, et al. Traumatic injury in the United States: in-patient epidemiology 2000-2011. Injury. 2016; 47(7): 1393-403.
3. Roding F, Lindkvist M, Bergstrom U, Svensson O, Lysholm J. Trauma recidivism at an

emergency department of a Swedish medical center. Inj Epidemiol. 2016; 3(1): 22.

4. Leite DA. The twenty-first century mechanistic theory of human cognition: a critical analysis. 1st ed. Cham (Switzerland) and New York: Springer Cham; 2021.
5. Hartwigsen G. Flexible redistribution in cognitive networks. Trends Cogn Sci. 2018; 22(8): 687-98.
6. Rodriguez-Andreu J, Ibanez-Bosch R, Portero-Vazquez A, Masramon X, Rejas J, Galvez R. Cognitive impairment in patients with fibromyalgia syndrome as assessed by the mini-mental state examination. BMC Musculoskelet Disord. 2009; 10: 162.
7. Ojeda B, Duenas M, Salazar A, Mico JA, Torres LM, Failde I. Factors influencing cognitive impairment in neuropathic and musculoskeletal pain and fibromyalgia. Pain Med. 2018; 19(3): 499-510.
8. Williams DA, Clauw DJ, Glass JM. Perceived cognitive dysfunction in fibromyalgia syndrome. J Musculoskelet Pain. 2011; 19(2): 66-75.
9. 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(2): 135-46.
10. 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; 44: 102058.
11. Jacobsen HB, Stiles TC, Stubhaug A, Landro NI, Hansson P. Comparing objective cognitive impairments in patients with peripheral neuropathic pain or fibromyalgia. Sci Rep. 2021; 11(1): 673.
12. Isbir AC, Duger C, Mimaroglu C, Kol IO, Kaygusuz K, Gursoy S. Effect of chronic knee pain on cognitive function: clinical study. J Musculoskelet Pain. 2014; 22(2): 187-92.
13. Soderfjell S, Molander B, Johansson H, Barnekow-Bergkvist M, Nilsson LG. Musculoskeletal pain complaints and performance on cognitive tasks over the adult life span. Scand J Psychol. 2006; 47(5): 349-59.
14. Pelletier R, Higgins J, Bourbonnais D. Laterality recognition of images, motor performance, and aspects related to pain in participants with and without wrist/hand disorders: an observational cross-sectional study. Musculoskelet Sci Pract. 2018; 35: 18-24.
15. Purohit M, Goldstein R, Nadler D, Mathews K, Slocum C, Gerrard P, et al. Cognition in patients with burn injury in the inpatient rehabilitation population. Arch Phys Med Rehabil. 2014; 95(7): 1342-9.
16. Boender ZJ, Ultee J, Hovius SE. Cognitive capacity: no association with recovery of

sensibility by Semmes Weinstein test score after peripheral nerve injury of the forearm. J Plast Reconstr Aesthet Surg. 2010; 63(2): 354-9.

17. 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(4): 373-9.
18. Moriarty O, McGuire BE, Finn DP. The effect of pain on cognitive function: a review of clinical and preclinical research. Prog Neurobiol. 2011; 93(3): 385-404.
19. Mimmie Willebrand FN, Morten K, Gerdin B, Ekselius L, Andersson G. Cognitive distortions in recovered burn patients: the emotional Stroop task and autobiographical memory test. Burns. 2002; 28: 465-71.
20. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. International Int J Soc Res Methodol. 2005; 8(1): 19-32.
21. covidence.org [Internet]. Melbourne: Covidence; c2022 [cited 2022 October 12]. Available from: https://www.covidence.org.
22. Kessels RPG, Keyse A, Verhagen WIM, van Luijtelaar ELJM. Cognitive deficits in patients after soft tissue injury of the cervical spine. Spine. 1992; 97(3): 188-93.
23. Radanov BP, Dvořák J, Valach L. Cognitive deficits in patients after soft tissue injury of the cervical spine. Spine. 1992; 17(2): 127-31.
24. Ahn YD, Yi D, Joung H, Seo EH, Lee YH, Byun MS, et al. Normative data for the logical memory subtest of the wechsler memory scale-IV in middle-aged and elderly Korean people. Psychiatry Investig. 2019; 16(11): 793-9.
25. Brown HS, May AE. A test-retest reliability study of the Wechsler adult intelligence scale. J Consult Clin Psychol. 1979; 47(3): 601-2.
26. Ashendorf L, Sugarman MA. Evaluation of performance validity using a Rey auditory verbal learning test forced-choice trial. Clin Neuropsychol. 2016; 30(4): 599-609.
27. Rabourn RE. The Wechsler adult intelligence scale (WAIS) and the WAIS-revised: a comparison and a caution. Prof Psychol Res Pr. 1983; 14(3): 357-61.
28. Ryan JJ, Schnakenberg-Ott SD. Scoring reliability on the Wechsler adult intelligence scale-third edition (WAIS-III): assessment. 2003; 10(2): 151-9.
29. who.int [Internet]. Geneva: World Health Organization; c2022 [cited 2022 October 10]. Available from: https://apps.who.int/classifications/icfbrowser/
30. Cieza A, Brockow, T., Ewert, T., Amman, E., Kollerits, B., Chatterji, S., Ustün, T. B., & Stucki, G. Linking Health-Status Measurements to the International Classification of Functioning, Disability and Health. J Rehabil Med. 2002; 34(5): 205-10.

31. Iris Coppieters RDP, Kregel J, Malfliet A, Goubert D, Lenoir D, Cagnie B, 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(3): 337-52.
32. Ickmans K, Meeus M, De Kooning M, De Backer A, Kooremans D, Hubloue I, et al. Exercise and cognitive functioning in people with chronic whiplash-associated disorders: a controlled laboratory study. J Orthop Sports Phys Ther. 2016; 46(2): 87-95.
33. Feng JT, Liu HQ, Hua XY, Gu YD, Xu JG, Xu WD. Brain functional network abnormality extends beyond the sensorimotor network in brachial plexus injury patients. Brain Imaging Behav. 2016; 10(4): 1198-205.
34. Richards J, Guillamondegui O, Archer K, Jackson J, Ely E, Obremskey W. The association of reamed intramedullary nailing and long-term cognitive impairment. J Orthop Trauma. 2011; 25(12): 707-13.
35. Chen F, 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(12): 1096-100.
36. Antepohl W, Kiviloog L, Andersson J, Gerdle B. Cognitive impairment in patients with chronic whiplash-associated disorder: a matched control study. NeuroRehabilitation. 2003; 18(4): 307-15.
37. Bosma FK, Kessels RP. Cognitive impairments, psychological dysfunction, and coping styles in patients with chronic whiplash syndrome. Neuropsychiatry Neuropsychol Behav Neurol. 2002; 15(1): 56-65.
38. Smed A. Cognitive function and distress after common whiplash injury. Acta Neurol Scand. 1997; 95(2): 73-80.
39. Gonzalez R, Grant I, Miller SW, Taylor MJ, Schweinsburg BC, Carey CL, et al. Demographically adjusted normative standards for new indices of performance on the paced auditory serial addition task (PASAT). Clin Neuropsychol. 2006; 20(3): 396-413.
40. Atkinson TM, Jeanne RP. The use of variants of the trail making test in serial assessment. J Psychoeduc Assess. 2008; 26(1): 42-53.
41. Sbordone RJ, Saul RE, Purisch AD. Neuropsychology for psychologists, health care professionals, and attorneys. Boca Raton, Florida, United States: CRC Press; 2007.
42. Park J, Jung S, Kim SM, Park IY, Bui NA, Hwang GS, et al. Repeated hypoxia exposure induces cognitive dysfunction, brain inflammation, and amyloidbeta/p-Tau accumulation through reduced brain O-GlcNAcylation in zebrafish. J Cereb Blood Flow Metab. 2021;

41(11): 3111-26.

43. Schultz IZ, Sepehry AA, Greer SC. Anoxia-hypoxia in forensic neuropsychological assessment: cognitive impact of pulmonary injuries, respiratory distress, cerebral blood hypoperfusion, and major surgeries. Psychol Inj Law. 2018; 11(2): 153-70.
44. Zderkiewicz E. Cerebral function disorders caused by ischemia and hypoxia. Pol Tyg Lek. 1977; 32(44): 1729-32.
45. Comfort P, Abrahamson E. Sports rehabilitation and injury prevention. 1st ed. Chichester, West Sussex, UK: John Wiley & Sons; 2010.
46. Berrocoso E. Gabapentin, a double-agent acting on cognition in pain? Pain. 2014;155(10):1909-10.
47. Topham L, Gregoire S, Kang H, Salmon-Divon M, Lax E, Millecamps M, et al. The transition from acute to chronic pain: dynamic epigenetic reprogramming of the mouse prefrontal cortex up to 1 year after nerve injury. Pain. 2020; 161(10): 2394-409.
48. Boada MD, Ririe DG, Martin CW, Martin SJ, Kim SA, Eisenach JC, et al. Nociceptive input after peripheral nerve injury results in cognitive impairment and alterations in primary afferent physiology in rats. Pain. 2020; 161(5): 960-9.
49. Evered L, Scott DA, Silbert B, Maruff P. Postoperative cognitive dysfunction is independent of type of surgery and anesthetic. Anesth Analg. 2011; 112(5): 1179-85.
50. Lewis MS, Maruff P, Silbert BS, Evered LA, Scott DA. Detection of postoperative cognitive decline after coronary artery bypass graft surgery is affected by the number of neuropsychological tests in the assessment battery. Ann Thorac Surg. 2006; 81(6): 2097-104.
51. Royter V, M Bornstein N, Russell D. Coronary artery bypass grafting (CABG) and cognitive decline: a review. J Neurol Sci. 2005; 229: 65-7.
52. Hendler N, Cimini C, Ma T, Long D. A comparison of cognitive impairment due to benzodiazepines and to narcotics. Am J Psychiatry. 1980; 137(7): 828-30.
53. Allen GJ, Hartl TL, Duffany S, Smith SF, VanHeest JL, Anderson JM, et al. Cognitive and motor function after administration of hydrocodone bitartrate plus ibuprofen, ibuprofen alone, or placebo in healthy subjects with exercise-induced muscle damage: a randomized, repeated-dose, placebo-controlled study. Psychopharmacology. 2003; 166(3): 228-33.
54. Milroy CM, Parai JL. Fat embolism, fat embolism syndrome and the autopsy. Acad Forensic Pathol. 2019; 9(3-4): 136-54.
55. Rothberg DL, Makarewich CA. Fat embolism and fat embolism syndrome. J Am Acad Orthop Surg. 2019; 27(8): e346-55.

56. Kotan D, Ayas ZO, Sayan S, Inanmaz ME, Acar BA. Cerebral fat embolism diagnosed by cognitive disorder. Eurasian J Med. 2014; 46(2): 135-7.
57. Manousakis G, Han DY, Backonja M. Cognitive outcome of cerebral fat embolism. J Stroke Cerebrovasc Dis. 2012; 21(8): 906 e1-3.
58. Walker KA, Gottesman RF, Wu A, Knopman DS, Gross AL, Mosley TH Jr, et al. Systemic inflammation during midlife and cognitive change over 20 years: the ARIC study. Neurology. 2019; 92(11): e1256-e67.
59. Ozawa M, Shipley M, Kivimaki M, Singh-Manoux A, Brunner EJ. Dietary pattern, inflammation and cognitive decline: the Whitehall II prospective cohort study. Clin Nutr. 2016; 36(2): 506-12.
60. Starr AJ. Fracture repair: successful advances, persistent problems, and the psychological burden of trauma. J Bone Joint Surg Am. 2008; 90(Suppl 1): 132-7.
61. Kearns NT, Powers MB, Jackson WT, Elliott TR, Ryan T. Posttraumatic stress disorder symptom clusters and substance use among patients with upper limb amputations due to traumatic injury. Disabil Rehabil. 2019; 41(26): 3157-64.
62. Mueller AD, Meerlo P, McGinty D, Mistlberger RE. Sleep and adult neurogenesis: implications for cognition and mood. In: Meerlo P, Benca RM, Abel T, editors. Sleep, neuronal plasticity and brain function. Berlin, Heidelberg: Springer; 2015. p. 151-81.
63. Cowen SL, Phelps CE, Navratilova E, McKinzie DL, Okun A, Husain O, et al. Chronic pain impairs cognitive flexibility and engages novel learning strategies in rats. Pain. 2018; 159(7): 1403-12.
64. Dong Y, Xu Z, Huang L, Zhang Y, Xie Z. Peripheral surgical wounding may induce cognitive impairment through interlukin-6-dependent mechanisms in aged mice. Med Gas Res. 2016; 6(4): 180-6.
65. Andreollo N, Santos E, Araújo M., Lopes, L. Rat's age versus human's age: what is the relationship? Arquivos Brasileiros De Cirurgia Digestiva : ABCD. 2012; 25(1): 49-51.
66. Saa JP, Tse T, Baum C, Cumming T, Josman N, Rose M, et al. Longitudinal evaluation of cognition after stroke: a systematic scoping review. PLoS One. 2019; 14(8): e0221735.