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Cognitive-physical-functional correlates in chronic brain injury: a pilot study

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Abstract:

Introduction: Functional challenges persist even years following brain injury. Integrating multiple domains as part of therapy may improve global outcomes. The purpose of this study is to investigate the relationships among cognitive, physical and functional domains in adults with chronic brain injury.

Material and methods: Seventeen community-dwelling brain injury survivors (Stroke n = 8, TBI n = 9) aged 20–60 years, long-term post-brain injury participated in the study. Cognition, including attention, memory, and executive functioning, were examined by select measures of Woodcock-Johnson tests; physical abilities were determined based on muscle strength, gait and balance; functionality was measured based on self-reported questionnaires: community-integration, activities of daily living (ADLs), and satisfaction with life.

Results: The relationships between cognitive, physical and functional domains were evaluated using Spearman's nonparametric correlational analyses. The physical domains of balance and mobility correlated positively with the cognitive domains of visual-auditory learning (r = 0.90, p = 0.037), as well as with the functional domain scores for Satisfaction with Life (r = 0.671, p = 0.048). Similarly, the productivity subscale of the Community Integration measure was significantly associated with the cognitive domain of concept formation (r = 0.676, p = 0.032). Higher scores on the productivity subscale were moderately related to higher memory scores (r = 0.588) and fluency (r = 0.531).

Conclusions: The relationships between physical, cognitive, and functional domains could be exploited in long-term periods of recovery following a brain injury. Engagement of one domain to help improve another domain could enhance rehabilitation outcomes. More research is needed to explore the feasibility and benefits of integrative therapies.

Keywords: ADL, balance, brain injury, daily function, satisfaction with life

Introduction

Acquired brain injury, traumatic or non-traumatic, is a leading cause of disability in the United States [1]. Two common forms of acquired brain injury, with significant long-term sequlae, are traumatic brain injury and stroke. Nearly a third of adults with stroke have lifelong disability. Similarly, traumatic brain injury (TBI), especially moderate to severe TBI, can result in various cognitive, physical, and functional disabilities [2].

Rehabilitation programs have proven beneficial in mitigating some of the short-term and long-term sequelae following brain injuries [3].

Despite making significant gains in the initial stages of recovery (e.g. six-month post-TBI), long-term outcomes, especially in areas of home and community integration are limited [4], and can entail residual cognitive, psychological, and physical impairments [5]. Therefore, researchers and clinicians are beginning to recognize the benefits of integrative approaches to mitigate chronic long-term functional outcomes. Integrative approaches combine multiple rehabilitation strategies and/or techniques to accomplish the desired outcomes. For example, rehabilitation programs may integrate physical exercises (e.g. aqua therapy) to improve daily functionality. These integrative approaches have demonstrated gains in both preservation (in healthy adults) and enhancement (in adults with brain injuries) of cognitive and psychological function [6–8].

In recent years, researchers have begun to explore the relationships between these cognitive, physical, and functional domains. A recent study found positive correlations between cognitive performance (attention and verbal fluency measures) and physical performance (motor speed and balance) [9]. Adults with TBI, despite being considered well-recovered, reported physical problems such as difficulty running, clumsiness in arm movements, and fatigue [10,11]. More research is needed to understand the correlation between cognitive, physical abilities and daily functionality. Therefore, the current pilot study examined the correlation between cognitive, physical, and daily functionality in adults with brain injury, including TBI and Stroke. It is anticipated that this preliminary study would lay the grounds for a more extensive multidisciplinary (e.g., Occupational, Speech, and Physical Therapy) project aimed at studying integrative therapies to improve clinical outcomes in brain injury rehabilitation.

Materials and methods

Participants

The study included 17 community-dwelling brain injury survivors aged 20–60 years with documented evidence of brain injury. All participants were in chronic stages of recovery (i.e., who sustained a brain injury at least six months ago). The inclusion criteria also included being native English speakers, with minimum high school/ equivalent education, willing to participate in three to four hours of paper-pencil based testing, being able to walk (with assistance, if needed), speak and follow verbal instructions. Exclusion criteria for the study comprised (a) significant uncorrected hearing and vision impairments, (b) significant verbal communication deficits, (c) participants who were wheelchair bound and unable to participate in basic mobility around the home, and (d) history of significant neurological and psychological illnesses prior to the brain injury, as these deficits and illness could affect performance on the testing procedures. No exclusion criteria were based on race or gender.

Participants were recruited from a local brain injury network/community center. Informed consent was obtained from all participants in accordance with the guidelines of the Institutional Review Board of Woodcock Institute (Ethics committee approval number: 20328) The participants were informed that the program is a research study, and that their participation is voluntary.

Procedures

The current study involved three testing procedures including cognitive, physical/motor, and functional assessments. Cognitive domains including reasoning, working memory, fluency, learning, memory, and processing speed were examined based on the subtests of Woodcock Johnson-IV Tests of Cognitive Abilities, Tests of Oral Language, and Tests of Achievement [12–14]. Physical (motor performance) was examined according to the domains of gait, balance, mobility, and muscle strength. Daily life functionality was examined according to self-reported measures of daily life activities, and satisfaction with life (Tab. 1). Further details of the subtests are presented in Table 1.

Each participant was remunerated a total of $70 for taking part in the testing procedures. Due to difficulties associated with scheduling or test performance, some participants were unable to complete all testing procedures.

Statistical analysis

Scores for cognitive, physical and functional measures were obtained from 11 participants. Spearman's nonparametric correlational analyses (SPSS-28) were used to examine the relationships between cognitive, physical and daily life (functional) performance. Because of the small sample size, r coefficients were used to represent the strength of relationships between each domain. Additionally, significant relationships, *p*-values; indicated by $p < .05$ are also reported.

Results

The study group comprised 17 participants (11 males and six female). Eight participants were stroke survivors and nine had a history of a TBI. Scores on all three domains (i.e., cognitive, physical and functional measures) were obtained for 11 participants.

Tab. 1. Cognitive, physical, and functional assessments

Cognitive Assessments	
Domain	Measure: brief description
Reasoning, Concept formation	• Number Series: The examinee is presented with a series of numbers with one number missing. The examinee must determine the missing number. • Concept Formation: The examinee is presented with a complete stimulus set from which to derive a rule for each item. Except on the last several items, the examinee is given immediate feedback regarding the correctness of each response before a new item is presented, thus providing a controlled learning task.
Attention and Working Memory	• Verbal attention: The task requires the examinee to listen to an intermingled series of animals and digits presented on the audio recording. The examinee is asked to answer a specific question regarding the sequence. • Object number sequencing: The examinee is asked to listen to a series of digits and words on the audio recording, such as "dog, 1 shoe, 8, 2, apple." The examinee is asked to answer a specific question regarding the sequence – for example: "Say the animal that came before the 5.
Fluency	• Rapid picture naming: The examinee names a series of stimulus pictures in a 2-minute period (verbal fluency). • Retrieval fluency: The examines names as many examples as possible from a given category within a 1 minute time period (e.g. things to eat or drink).
Memory	• Story recall: The test requires the examinee to recall increasingly complex stories that are presented from an audio recording. After listening to a passage, the individual is asked to recall as many details of the story as he or she can remember.
Learning, Associative Memory	• Visual auditory learning: The examinee is asked to learn, store, and retrieve a series of visual-auditory associations (rebuses) that are eventually combined into phrases of increasing length and complexity.
Processing Speed	• Pair cancellation: In a 3-minute time period, the examinee is asked to locate and mark a repeated pattern as quickly as possible. This task provides information about interference control, sustained attention, and processing speed.
Physical Assessments	
Domain	Measure: brief description
Gait	• The FGA: Assesses postural stability during various walking tasks [15].
Balance	• The BBS: A 14-item objective measure designed to assess static balance and fall risk in adult populations [16].
Mobility	• The CBMS: Detects 'high level' balance and mobility deficits based on tasks that are commonly encountered in community environments [17].
Muscle strength	• The MMT: Is a standardized set of assessments that measure muscle strength and function [18].
Functional Assessments	
Domain	Measure: brief description
Daily life activities	• The BI: Assesses the ability of an individual with a neuromuscular or musculoskeletal disorder to care for him/herself [19].The CIQ : Self-report of a general overview of an individual's functioning based on responses to 15 questions related to participation in activities at home, social, and education or vocation settings., and productivity [20].
Life satisfaction	• The SWLS: A five-question questionnaire that asks to rate overall satisfaction on a scale of 1 (strongly disagree) to 7 (strongly agree) [21].

BBS − Berg Balance Scale, BI − Barthel Index, CIQ − Community Integration Questionnaire, FGA − Functional Gait Assessment, CBMS − Community Balance and Mobility Scale, MMT − Manual Muscle Test, SWLS − Satisfaction With Life.

Spearman's nonparametric correlational analyses were used to examine the relationships between cognitive, physical and daily life (functional) domains. Participant demographics are detailed in Table 2.

Tab. 2. Descriptive measures of the participant sample

	N	%		
Gender				
Female	6	35.3		
Male	11	64.7		
Injury type				
Stroke	8	47.1		
TBI	9	52.9		
	N	M	SD	Median
Age	17	44.66	15.02	48.83
Time since injury	17	6.53	5.82	4.33

M − mean, N − number of participants, TBI − traumatic brain injury, SD – standard deviation, % − percent.

Raw scores on all measures are detailed in Table 3.

Significant correlations between the three domains were identified (Tab. 4).

Higher scores on CBMS correlated with (a) higher visual-auditory learning (r = 0.900, p = 0.037), and inversely with (b) scores on pair cancellation (interference capacity) (r = –0.900, p = 0.037). With regard to correlations between the functional and physical domains, scores on BBS correlated significantly with SWLS scores (r = 0.671, p = 0.048).

CIQ productivity was significantly associated with high concept formation, and this relationship was strong (r = 0.676, p = 0.032). No significant relationships were found between other CIQ subscales and the cognitive domain, possibly due to the small sample size. However, when looking at the effect size, better CIQ productivity appears to be moderately related to higher story recall (r = 0.588) and better retrieval fluency (r = 0.531). Surprisingly, higher CIQ home integration was moderately correlated with lower visual auditory learning (r = -0.489), and higher CIQ social integration

Tab. 3. Descriptive statistics on outcome measures

Continuous variable	N	M	SD	Median	Min	Max
Cognitive performance						
Number Series	10	99.20	12.93	103.50	74.00	115.00
Verbal Attention	10	95.20	18.21	101.00	71.00	123.00
Story Recall	10	81.30	31.16	93.50	40.00	117.00
Concept Formation	10	94.80	20.65	88.50	69.00	127.00
Visual Audi Learning	9	74.67	16.89	74.00	50.00	104.00
Object Num Seq	11	96.09	20.75	100.00	49.00	117.00
Pair Cancellation	11	61.82	13.01	64.00	40.00	80.00
Rapid Pic Naming	11	70.27	14.55	72.00	49.00	93.00
Retrieval fluency	11	69.09	18.89	72.00	40.00	93.00
Physical performance						
CBMS	8	31.50	25.67	27.00	.00	80.00
FGA	9	17.67	8.12	17.00	5.00	29.00
BBS	9	47.11	6.86	47.00	34.00	56.00
Functional performance						
CIQ-Home	17	4.54	2.19	5.00	1.25	8.75
CIQ-Social	17	7.06	2.77	8.00	3.00	10.00
CIQ-Productivity	17	4.12	0.70	4.00	3.00	5.00
CIQ-total	17	15.72	3.54	16.50	10.25	21.50
BI	17	95.12	6.32	95.00	78.00	100.00
SWLS	17	19.71	7.58	21.00	8.00	33.00

BBS − Berg Balance Scale, BI − Barthel Index, CBMS − Community Balance and Mobility Scale CIQ − Community Integration Questionnaire, FGA − Functional Gait Assessment, M – mean, Max – maximum, Min – minimum, N − number of participants, SWLS − Satisfaction With Life, SD – standard deviation.

Tab. 4. Correlation of cognitive scores with physical and functional performances in the overall sample

	Physical (N = 4–6)			Functional (N = 9–11)					
	CBM	FGA	BBS	CIQ_total	CIQ_H	CIQ_SI	CIQ_P	BI	SWLS
Number Series	–0.4	–0.56	–0.7	0.3	0.31	0.03	0.16	–0.07	–0.26
Verbal Attention	–0.2	–0.41	0.1	0.04	–0.07	0.04	0.24	0.21	0.19
Story Recall	–0.1	0.26	–0.56	–0.29	–0.22	–0.32	0.59	0.01	–0.02
Concept Formation	–1**	0.15	–0.4	–0.26	0.04	–0.52	0.68*	–0.19	0.35
Visual Audi Learning	0.9*	0.23	0.03	–0.28	–0.49	0.03	0.06	–0.32	0.17
Object Num Seq	0.5	–0.12	–0.43	0	–0.02	0.06	0.09	0.35	–0.14
Pair Cancellation	–0.9*	–0.4	0.31	0.13	0.05	0.08	0.32	0.2	–0.08
Rapid Pic Naming	–0.6	–0.29	0.31	–0.12	–0.29	0.1	0.21	0.22	–0.17
Retrieval Fluency	–0.2	0.58	–0.09	–0.23	0.02	–0.46	0.53	0.01	–0.12

CIQ − Community Integration Questionnaire, CIQ-H − CIQ-Home, CIQ-SI − CIQ-Social Integration, CIQ-P − CIQ Productivity, N − number of participants, * indicates p < 0.05, ** indicates p < 0.01.

Tab. 5. Correlation between physical and functional performances by injury type

	Stroke (N = 5)			TBI (N = 4)		
Variable	CBMS	FG	BBS	CBMS	FG	BBS
CIQ-total	.359	.359	.342	–.500	–.316	–.400
BI	.051	.051	.789	<.001	<.001	.258
SWLS	<.001	<.001	.564	<.001	<.001	.738

BBS − Berg Balance Scale, BI − Barthel Index, CBMS − Community Balance and Mobility Scale, CIQ − Community Integration Questionnaire, FG − Functional Gait, N − number of participants, SWLS − Satisfaction With Life Scale, TBI − traumatic brain injury.

was moderately correlated with lower concept formation (*r* = –0.525) and retrieval fluency (*r* = –0.462).

To further confirm whether the relationships between physical and functional performances differed by injury type, the subsamples were subjected to Spearman's rho nonparametric correlation analyses. As shown in Table 5, no significant relationship was found in either injury group, partly due to the small sample size.

Therefore, the effect size (r coefficient) was used to assess the magnitude of the relationships. In the stroke group, higher scores on BBS were strongly related to better self-care scores on BI (*r* = 0.789), but this relationship was not found in the TBI patients. A positive relationship between BBS and SWLS was found in both the stroke (*r* = 0.564) and the TBI group (*r* = 0.738). This result was consistent with the result for the overall sample described in the previous section.

Discussion

Participation and engagement in life tasks in a complex interrelated phenomena between multiple domains. The present study found a positive relationship between cognitive, physical and functional domains in adults with brain injury. These findings support prior evidence that one domain exerts an influence on another [9]. In recent years, several studies have examined the benefits of combining/ integrating multiple rehabilitation therapies to optimize outcomes. For example, in a Virtual Reality based feasibility trial, researchers found that combining arm reaching with attention and memory training yielded gains in chronic stroke survivors [22]. Similarly, positive effects on emotional, motor, and cognitive aspects were demonstrated in adults with multiple sclerosis with integrated cognitive and neuromotor training [23]. Clinically, the current findings emphasize the potential benefits of integrating/ combining multiple domains during therapy sessions. It is intuitive to rehabilitation professions that all three domains play a role in daily function. While each domain is unique, each one supports, and could potentially enhance, another. As seen in the current study, this interplay between domains can be exploited by rehabilitation professionals.

Physical/ motor activities could be integrated as preparatory activities for performing a functional task, such as completing balance exercises before attempting self-care interventions. A short jog or stretching could be a warm-up prior to starting cooking tasks in the kitchen. Similarly, these physical exercises could serve as a warm-up prior to a initiating a cognitively challenging task, such as preparing for a class or a lecture. All three domains are important for long-term outcomes including home and community integration.

Case example: Consider a 50-year-old, Mr. J, who sustained a moderate TBI three years previously. Prior to his injury, Mr. J worked full time as a food service business owner, was a gym enthusiast, and actively involved in social and community activities. Mr. J received acute inpatient and outpatient therapy services and was able to return to his food service business at part time capacity with the help of his family members. Yet, Mr. J has significantly reduced his participation in home management tasks and social activities. He also reports increased fatigue after work and occasional forgetfulness and feeling stuck when it comes to generating ideas for his food service business. He was recently referred to occupational, physical, and speech therapy to improve his participation, fatigue, and cognitive abilities. An integrative therapy plan could start with 10–15 minutes of jogging or stationary bike (given Mr. J is a gym enthusiast) as a warm up, followed by helping his wife in laundry and house cleaning. Similarly, planning a meeting with a friend for coffee could be followed by working with work colleagues to plan a new recipe or item for his food business. Exploring options to be a part-time volunteer at his local library or place of worship could improve social engagement and manage his fatigue. Taking neighborhood walks with his family members during the weekend could be added to the therapy home program. By tailoring Mr. J's therapy sessions to engage cognitive, physical, and functional domains, the therapy could likely increase his participation, independence, cognition, and overall satisfaction with life.

There are at least five limitations of the study that need to be considered for further research. Firstly, the samples in both the Stroke and TBI groups were rather small; larger sample sizes are needed to help generalize the findings. Secondly, while documenting initial injury severity is critical to accurately establish the relation between initial injury severity, recovery, and current level of functioning, the participants were recruited primarily from the community at periods years after brain injury. Third, it is likely that coexisting or preexisting medical conditions (e.g. COPD) or current living situations, may have contributed to variations in performance across groups. Fourth, the current study examined daily functionality on self-rated questionnaires; these are restricted to the self-perception of function, which may be inaccurate. A more accurate characterization of daily function would be provided by an assessment of real-life task performance. Fifth, the current study included wide age ranges, including age at testing and age at injury (3–40 years). We propose that future studies should more rigorously specify initial injury severity to confirm the current findings; for example, the relationship between cognitive and physical domains in mild TBI/ mild Stroke may be different from those in moderate TBI/ moderate stroke. Research has demonstrated that frontal network myelination continues into the early third decade of life (i.e., into the early twenties), and an injury at a young age disrupts the maturation of frontal functions that affect functional outcomes [24]. Future studies could examine the effect of age at injury while examining cognitive function, either as an outcome measure or a treatment factor.

Conclusions

Rehabilitation professionals, such as occupational, physical, and speech therapists, are always looking for efficient ways to improve outcomes. Clients may prefer engaging in activities that draw upon one domain (e.g., physical exercises) even if the focus of the rehabilitation therapy session is on another (e.g., cognition). Exploiting the interplay between cognitive, physical, and daily function domains could be one way to improve rehabilitation outcomes.

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Conflicts of Interest
The authors have no conflict of interest to declare.

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