

The effects of adapted physical exercise during rehabilitation in patients with traumatic brain injury

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ABSTRACT

Objectives: This study aims to investigate the effects of adapted physical exercise on the level of muscular ability and attention process in patients with traumatic brain injury (TBI).

Patients and methods: Between September 2018 and November 2018, a total of 25 male patients with TBI (mean age: 41.1±9.7 years; range, 30 to 50 years) that occurred two years ago were included in this randomized-controlled study. The patients were divided into two groups as the experimental group (n=13) and the control group (n=12). The experimental group implemented a regular rehabilitation program and an additional program of adapted physical exercise. The control group implemented only a regular rehabilitation program (morning gymnastics and gymnastics for the brain). Motor and functional abilities were assessed by a Senior Fitness battery and Berg's balance scale. Attention process was assessed by a standardized d2 test.

Results: A significant improvement in physical abilities (strength, flexibility and balance) and attention process was observed in both groups (p<0.01). The improvement was greater in the experimental group (p<0.01).

Conclusion: Traumatic brain injury causes difficulties in the memory and executive functions of the body and impairs working ability. The short-term adapted physical exercise program can yield a positive change in working abilities of patients with TBI.

Keywords: Attention process, balance, flexibility, physical therapy, strength, traumatic brain injury.

Traumatic brain injury (TBI) is regarded as the largest medical and social problem in the developed countries,^[1] which is supported by the fact that in 2016, the incidence of TBI worldwide was 27.08 million new cases (Global Burden of Diseases, Injuries, and Risk Factors [GBD] 2016 Traumatic Brain Injury and Spinal Cord Injury Collaborators, 2019), and it is most commonly identified between the ages of 15 to 45 years.^[2,3] Depending on the degree of impairment, this injury causes difficulties in the memory and executive functions of the body. The constraints that occur

affect the individual's autonomy, in all areas of life, most notably in terms of daily living activities.^[3] Several studies have shown that men are twice as likely to be exposed to TBIs compared to women,^[2,4] nevertheless, the sedentary lifestyle and poor physical form associated with health and work capacity are equally identified by injury in both sexes.

Traumatic brain injury can be categorized as mild, moderate, or severe, depending on the clinical presentation^[5,6] Mild TBI is characterized by loss

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of consciousness for a few seconds or minutes (max 30 min), alteration of consciousness/mental state may last up to 24 h and post-traumatic amnesia which may last up to one day; moderate TBI is characterized by loss of consciousness that may last up to a few hours (>30 min and <24 h), and confusion may last up to weeks, and post-traumatic amnesia may last for one to seven days; severe TBI is characterized by loss of consciousness more than 24 h, as well as alteration of consciousness/mental state, but post-traumatic amnesia may last more than seven days.^[7] The complications can last for months and can be permanent. These complications can be physical, cognitive, or behavioral.^[7]

Traumatic brain injury is related to changes in brain function, or other evident pathology of the brain caused by an external force (mechanical injury). Post-TBI conditions are related to temporary or permanent consequences that can be identified in an individual physically (biologically), psychologically, and socially^[3] and, thus, affecting their working ability. Changes are most commonly manifested as a disorder of cognitive function, speech, language, reasoning, information processing, abstract thinking ability, but in most cases, a disorder of bodily function (locomotor function) occurs. The most common disorder of bodily function is movement disorder, which includes varying degrees of paresis or plegia, impaired movement coordination, and/or involuntary movements (ataxia) that interfere with natural movement.^[4,8]

In individuals with TBI, reduced values of maximal aerobic capacity are identified. Compared to healthy sedentary persons, these values are 25 to 30% lower and can be increased by the use of adapted physical exercise that improves the cardiorespiratory capacity of a patient with TBI.^[9] The use of an aerobic exercise program has been shown to not only improve cardiovascular and endurance performance, but also influence cognitive function in patients with TBI,^[10] that is, the better functioning of the brain structures in which the processes of memory and learning take place has been observed.

Muscle ability (strength, endurance) is significantly correlated with coordination and balance. Poor balance and spasticity are the main causes of mobility restriction. They are related to insufficient production of muscle strength and identified in a patient after a TBI.^[11,12] Strength exercises increase muscle mass, provide better stability and coordination, and can further prevent

falls. Strength exercises affect muscle trophism, body awareness and perception, as well as improvement of the nervous system function.^[13-15]

Good physical work ability is also related to an individual's personal feeling of being in good health. Reduced work or physical ability in TBI patients is associated with mobility limitations, but also with poor emotional health.^[16,17] The use of physical activity (adapted exercise) in patients with TBI is the first prerequisite for maintaining health, well-being, and working ability.^[18] In the present study, we aimed to investigate the effects of adapted physical exercise on the level of muscular ability and to assess the attention process as a significant factor in general physical work ability in patients with TBI.

PATIENTS AND METHODS

This randomized-controlled study was conducted at Faculty of Sport and Tourism (Serbia) Center for people with traumatic brain injury - "Naprej" from Maribor (Slovenia), between September 2018 and November 2018. A total of 25 male patients with TBI (mean age: 41.1±9.7 years; range, 30 to 50 years) that occurred two years ago were included in the study. Before the start of the study, the sample was homogenized in relation to the type, severity and duration of trauma. Patients were carefully selected and the study included only those who voluntarily joined the study and all of them were categorized as moderate and severe TBI after injury, could move independently without support, having a rehabilitation process for two years, having the same occupational and behavioral therapy and having no other (acute and chronic) diseases. The similarity of the clinical picture and voluntariness influenced the sample size, giving it the characteristics of an intentional controlled sample.

The study sample was divided into two groups randomly by the lottery method. The first group (experimental) consisted of 13 patients and the second group (control group) consisted of 12 patients. Prior to treatment, the groups were statistically homogenized (group equality was determined by t-test). Before the study, all participants were informed about the content and the aim of the research, and a written informed consent was obtained. The study protocol was approved by the Center Naprej Maribor Ethics Committee (No: 007-1/2017). The study was conducted in accordance with the principles of the Declaration of Helsinki.

In this study, an additional adaptive exercise program was used. The same motor, functional, and psychological tests were applied before and after the experiment. The treatment was implemented over a period of eight weeks by the experts of kinesiology and psychology.

All participants attended to a regular rehabilitation program, five days a week (Monday to Friday), including two basic activities:

- Morning exercise, which was implemented as a daily activity for 45 min, with the aim of improving circulation (endurance exercises), empowering the body (strength exercises), and increasing the volume of movement and general flexibility of the body (stretching exercises);
- Brain gymnastics, which is a set of simple and easy movements that are performed to improve brain function, that is, activation of both hemispheres of the brain.^[21] Exercises include movements such as diagonal movements, head movements, balance exercises, breathing exercises (abdominal), drawing (laid eight, symmetrical drawing), and exercises to improve proprioception,^[21,22] that are performed twice a week, on every Tuesday and Thursday, for 45 min in each session.

The experimental program (training) involved the use of adapted physical exercise, which was administered twice a week for 90 min. The adaptation was aimed at facilitating the execution of certain exercises. Progressive load was applied. Each training session began with the Nordic walking using Gymnastic® rods (elastic band/rubber is an integral part of the rod, NW Gym) for 30 to 40 min (depending on the week the program was implemented). The realization of the exercises, then, began with the help of the Gymnastic® for 50 to 60 min. Each training session included eight strength-enhancing exercises performed in two rounds (eight repetitions each), two body balance-enhancing exercises, and four general flexibility exercises that were performed in two rounds (15 repetitions each). During the eight-week program, progressive load was applied, the number of repetitions in the series increased, the break time between rounds was shortened, and the duration of aerobic activity increased.

Assessment variables

The respondents' work ability was identified based on variables that included motor and functional ability and assessment of attention process. Motor and

functional ability were assessed with five variables, using a Senior Fitness battery tests^[23,24] and Berg's Balance Scale (BBS).^[25]

The four variables assessed by the Senior Fitness battery were as follows: (i) lower extremity strength was measured by the Chair Stand Test (CST) lasts for 30 sec, and the result of the test was the number of repetitions; (ii) upper limb strength was measured by the Biceps Curl Test (BCT) lasts for 30 sec, and the result of the test was the number of repetitions; (iii) general flexibility was measured by the Chair Sit and Reach Test (CSRT), and it was measured in distance (cm). If distance indicates the touch of fingertips and the toes, it means 0 cm, if it does not touch, it means a negative score, if it overlaps, it means a positive score; (iv) aerobic fitness was measured by the 6-Minute Walk Test (6MWT), and it was measured in distance (m), indicating endurance.

In the BBS, 14 motor tasks were evaluated: sitting to standing, standing unsupported, sitting with back unsupported, standing to sitting, transfers (the transition from chair to chair), standing with eyes closed, standing with feet together, reaching forward with outstretched arm, retrieving object from floor, turning to look behind, turning 360 degrees, placing alternate foot on step, standing with one leg in front, and standing on one leg. The observers rated their evaluation selecting the appropriate position on a five-point scale. Position 1 marked the lowest, and position 5 the highest level of the skill.

Attention process was assessed by a standardized d2 test,^[26,27] and three variables were tested: (i) the ability to identify the number of specific symbols (d2SN), (ii) the number of errors during perception (d2EN), and (iii) the measure of concentration (d2MC).

All test procedures were performed under standardized conditions. During the measurements, the respondents were in sports equipment and of stable health status (without acute health changes).

Statistical analysis

The study power and sample size calculation were performed using the G*Power version 3.1.9.7 software (Heinrich-Heine Universität Düsseldorf, Düsseldorf, Germany).^[19] Using the Cohen's recommended effect size index ($f[V]=0.6$), a error probability 0.05 and power analysis ($1-\beta$) 0.8, the following tests were used: (i) test family - F-test; (ii) statistical test - analysis of variance (ANOVA), repeated measures

within-between interaction; and (iii) type of power analysis - a priori: Compute required sample size - given α , power and effect size. The effect size decided upon was 0.6, as it indicates surely a middle impact of independent variables,^[20] thus requiring the total sample size of 24 participants.

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean \pm standard deviation (SD), median (min-max) or number and frequency, where applicable. To test the significance of differences between the results of groups on the pre-test (groups' homogenization), independent samples t-test was applied. To analyze the effects of the experimental treatment, repeated measures ANOVA that combined two subjects was used: the time and the specificity of groups, which is called the mixed between-within subjects ANOVA.^[28] The Box's tests of equality of covariance matrices and Levene's test of equality of error variances were

used to confirm whether the assumptions were fulfilled for all the variables. A p value of <0.05 was considered statistically significant.

RESULTS

Descriptive data of the study groups are shown in Table 1. Statistically significant differences between the experimental and control group in pre-test were not obtained for any of the eight variables: CST ($t=1.699$; $p=0.103$), BCT ($t=0.967$; $p=0.344$), CSRT ($t=1.487$; $p=0.151$), 6MWT ($t=1.830$; $p=0.080$), BBS ($t=1.443$; $p=0.163$), d2SN ($t=-0.710$; $p=0.485$), d2EN ($t=-0.446$; $p=0.660$) and d2MC ($t=-0.546$; $p=0.591$).

During the eight-week experimental period, a statistically significant improvement was observed in five of the eight variables. The patients increased lower extremity strength, upper limb strength, balance and concentration, and reduced the number

TABLE 1
Descriptive data of the study participants

Patients (groups)	Number	Sex	Mean age	Category of TBI	Duration of treatment*
Experimental	13	Male	40.62	Moderate/severe	2 years
Control	12	Male	41.66	Moderate/severe	2 years
<i>Total</i>	25	Male	41.12	Moderate/severe	2 years

* The duration of the rehabilitation treatment before the beginning of the experiment.

TABLE 2
Descriptive statistics of pre-test and post-test in experimental and control group for motor and functional ability

Variables	Groups	Pre-test	Post-test
		Mean \pm SD	Mean \pm SD
CST	Experimental	9.2 \pm 2.2	10.7 \pm 3.4
	Control	7.6 \pm 2.4	8.2 \pm 3.3
BCT	Experimental	10.9 \pm 4.3	14.9 \pm 5.6
	Control	8.8 \pm 6.8	11.7 \pm 5.2
CSRT	Experimental	-1.5 \pm 12.0	-2.2 \pm 13.3
	Control	-10.6 \pm 18.3	-10.4 \pm 14.7
6MWT	Experimental	471.1 \pm 154.5	479.8 \pm 153.8
	Control	371.0 \pm 114.0	367.0 \pm 112.6
BBS	Experimental	50.5 \pm 8.7	52.2 \pm 7.3
	Control	45.0 \pm 10.2	46.3 \pm 9.8

SD: Standard deviation; CST: Chair Stand test; BCT: Biceps Curl test; CSRT: Chair Sit and Reach test; 6MWT: 6-minute Walk Test; BBS: Berg's Balance Scale.

TABLE 3
Statistics of mixed between-within subjects ANOVA for motor and functional ability

Variable/impact	Wilks' lambda	F	p	Partial eta squared	Achieved power
CST					
Factor interaction	0.939	1.485	0.235	0.061	0.215
Treatment impact	0.758	7.330	0.013	0.242	0.737
Group difference	-	3.573	0.071	0.134	0.441
BCT					
Factor interaction	0.983	0.408	0.529	0.017	0.094
Treatment impact	0.580	16.628	0.000	0.420	0.974
Group difference	-	1.774	0.196	0.072	0.248
CSRT					
Factor interaction	0.992	0.182	0.674	0.008	0.069
Treatment impact	0.997	0.075	0.786	0.003	0.058
Group difference	-	2.251	0.147	0.089	0.301
6MWT					
Factor interaction	0.929	1.766	0.197	0.071	0.247
Treatment impact	0.990	0.241	0.628	0.010	0.076
Group difference	-	3.842	0.062	0.143	0.467
BBS					
Factor interaction	0.995	0.110	0.743	0.005	0.062
Treatment impact	0.746	7.847	0.010	0.254	0.765
Group difference	-	2.490	0.128	0.098	0.327

ANOVA: Analysis of variance; CST: Chair Stand Test; BCT: Biceps Curl Test; CSRT: Chair Sit and Reach Test; 6MWT: 6-minute Walk Test; BBS: Berg's Balance Scale.

TABLE 4
Descriptive statistics of pre-test and post-test in experimental and control group for the attention process

Variables	Groups	Pre-test	Post-test
		Mean±SD	Mean±SD
d2SN	Experimental	204.5±103.0	238.5±91.7
	Control	240.3±147.3	223.8±117.3
d2EN	Experimental	30.3±28.2	13.8±14.6
	Control	38.3±57.9	20.8±26.9
d2MC	Experimental	57.2±35.7	85.7±36.7
	Control	65.0±36.2	75.3±37.4

SD: Standard deviation; d2: Test of attention; SN: Number of specific symbols; EN: Number of errors; MC: Measure of concentration.

of errors in the d2 test under the influence of adapted physical exercise. A significant effect of treatment was absent in the variables of general flexibility, aerobic fitness, and number of specific symbols perception (Tables 2 and 3). The absence of statistically significant changes in these three variables can be explained by a relatively short experimental period.

The post-test scores were better than the pre-test scores for all eight variables (Tables 4 and 5), indicating that adapted physical exercise caused positive changes in motor abilities and attention processes in patients with TBI. A higher improvement of all abilities was recorded in the experimental group, but the differences were not statistically significant ($p > 0.05$).

TABLE 5
Statistics of Mixed between-within subjects ANOVA for the attention process

Variable/impact	Wilks' lambda	F	<i>p</i>	Partial eta squared	Achieved power
d2SN					
Factor interaction	0.812	5.318	0.030	0.188	0.598
Treatment impact	0.973	0.639	0.432	0.027	0.119
Group difference	-	0.055	0.816	0.002	0.056
d2EN					
Factor interaction	1.000	0.010	0.921	0.000	0.051
Treatment impact	0.684	10.616	0.003	0.316	0.877
Group difference	-	0.329	0.572	0.014	0.085
d2MC					
Factor interaction	0.771	6.836	0.015	0.229	0.707
Treatment impact	0.425	31.168	0.001	0.575	1.000
Group difference	-	0.008	0.930	0.000	0.051

ANOVA: analysis of variance; d2: Test of attention; SN: Number of specific symbols; EN: Number of errors; MC: Measure of concentration.

DISCUSSION

In patients with TBI, the most commonly impaired physical abilities are movement coordination, balance, muscle strength, and aerobic ability. All these, combined with insufficient attention and inadequate emotional regulation, result in impairment of overall psychophysical and working ability. Adapted endurance exercises (aerobic exercises) result in significant adaptation of the cardiovascular system in terms of cardiac (improvement of arterial diameter) and muscular function characterized by increased numbers of capillaries. A large number of studies have supported these adaptive processes that affect the improvement of aerobic power and endurance and, usually affect the improvement of cardiovascular health in sedentary individuals.^[9,29-31] In a sample of 10 patients with TBI, Chin et al.^[10] demonstrated that intense aerobic exercise three times a week for 30 min significantly increased aerobic ability and reduced the subjective feeling of exercise exertion. The results of our study did not show a significant improvement in aerobic fitness, which is probably due to a relatively short exercise period or an insufficiently strong training stimulus.

In regard to strength testing (upper and lower extremities), a significant improvement was observed in this study, which is consistent with the findings of Peters.^[32] At the final measurement, higher values were found in the experimental group, compared to the control group. However, the results indicated that a statistically significant increase occurred in both groups and, therefore, the improvement achieved

cannot be attributed with certainty to the effects of the experimental program. The exercise compliance (frequency, attendance) is probably a more important factor in rehabilitation than the volume and intensity of activity. In this study, both groups exercised every weekday, and the experimental group had additional activities.

Although not statistically significant, the higher average values in the experimental group can be explained by the greater motivation of the participants. All patients were the users of the Center for People with Traumatic Brain Injury and were already enrolled in the rehabilitation program before the experiment. Additional treatment was only applied in the experimental group and probably contributed to an increase in exercise motivation. Still, a short-term intervention with adapted exercise program proved successful in terms of strength improvement.

Normal functioning of the musculoskeletal system is necessary to maintain balance. In addition to reducing muscle strength and reduced flexibility as well as movement volume, TBI patients also reduce the ability to respond to changes in movement that can lead to a fall. The experimental program in this study did not produce a significant increase in flexibility, which may be explained by a relatively short treatment duration or poor training stimuli.

After the experimental program, the respondents of both groups scored significantly more points on the BBS, and it can be speculated that the intervention

had a significant impact on the balance. In the study of Peters^[32] that lasted for four weeks with five training sessions per week, the participants showed an improvement in walking speed, mobility and balance, as assessed by the BBS. Clinically significant changes in balance after applying exercises, identified on the BBS in patients with TBI, are related to the decrease in the risk of falling.^[33]

The results of this study indicate a significant effect of adapted physical exercise on improving attention. The speed criterion, that is, the total number of all crossed out characters in a given unit of time, did not improve significantly. However, there was a significant improvement in the processing accuracy that was obtained by summing up all the errors made. Likewise, a positive result was obtained in the concentration measurement determined by subtracting the number of errors from the number of correctly crossed characters. This is of utmost importance, as the d2 test requires the individual to concentrate on external visual stimuli. Under the term concentration, it refers to an efficient, continuous, and focused choice of stimuli, that is, an individual's ability to selectively choose particular symbols, while excluding irrelevant stimuli in continuous, quickly and correctly analyzed tasks and in accordance with internal and/or external stimuli. The results of this study suggest that adapted physical exercise can improve social or psychological outcomes, which are important aspects of quality of life after TBI.

Nonetheless, there are some limitations to this study, which could be related to the small number of subjects in the sample, insufficient anamnestic data on the level of physical ability before traumatic brain injury.

In conclusion, the eight-week experimental treatment produced a statistically significant improvement of strength, balance, attention and concentration in patients with TBI. These results indicated a significant improvement in both groups (in the control who had only the regular rehabilitation treatment and the experimental who had additional sessions of adapted physical exercise). Based on these findings, compliance (continuity) is a more important factor in rehabilitation than the volume and intensity of activity. This study confirms the findings of previous studies, proving that daily exercise plays an important role in improving the working ability of patients with TBI.

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