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THE EFFECTS OF PROLONGED PHYSICAL INACTIVITY INDUCED BY BED REST ON COGNITIVE FUNCTIONING IN HEALTHY MALE PARTICIPANTS

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ABSTRACT

A growing body of scientific evidence indicates that physical activity beneficially influences cognitive functioning. Less thoroughly investigated are the cognitive outcomes of reduced physical activity levels. The purpose of the study was to determine the effects of prolonged physical inactivity induced by bed rest on the participant's cognitive functioning.

Bed rest is a well-accepted method by which an acute stage of human adaptation to weightlessness in space flights is simulated, as well as an important model to study the consequences of extreme physical inactivity in humans. The subjects participating in the study consisted of fifteen healthy males aged between 19 and 65 years who were exposed to 14-day horizontal bed rest in a strict hospital environment. To assess the cognitive functions of the participants, a neuropsychological test battery was administered before and after the bed rest experiment. There was no significant impairment in cognitive performance after the 14-day bed rest on all tests, except in the measurements of delayed recall in the group of older adults. The results suggest that cognitive functions remained relatively stable during the period of physical immobilization. The obtained results have been discussed taking the possible contributing factors into account such as the practice effect, the relatively short duration of bed rest, and the choice of the cognitive measures administered. The study also provides evidence that favourable living and psychosocial conditions can protect one against cognitive decline in the case of extreme physical inactivity.

Keywords: *physical inactivity, bed rest studies, cognitive functioning, adults*

UČINKI DOLGOTRAJNE GIBALNE NEAKTIVNOSTI V POGOJIH SIMULIRANE BREZTEŽNOSTI NA KOGNITIVNO DELOVANJE PRI ZDRAVIH UDELEŽENCIH

IZVLEČEK

Vse več znanstvenih izsledkov potrjuje, da ima gibalna aktivnost ugoden vpliv na kognitivno delovanje. Manj pa je raziskav, ki bi preučevale kognitivne zmožnosti pri izrazito omejenem obsegu gibalne aktivnosti. Ena od pomembnejših metod za spremljanje učinkov popolne gibalne neaktivnosti na človekov organizem je bed rest (BR) model, ki predvideva daljše mirovanje v ležečem položaju. Namen raziskave je bil proučiti učinke skrajne gibalne neaktivnosti na kognitivno delovanje odraslih udeležencev. Petnajst zdravih moških, starih med 19 in 65 let, smo vključili v eksperiment 14-dnevnega mirovanja v strogo vodoravnem položaju v bolnišničnem okolju. Njihove kognitivne funkcije smo ocenili s pomočjo nevropsihološke baterije testov pred in po eksperimentu. Rezultati so pokazali, da pri udeležencih ni prišlo do upada kognitivnih sposobnosti po obdobju skrajne gibalne neaktivnosti, z izjemo mere odloženega priklica, pri kateri so se rezultati poslabšali le v skupini starejših udeležencev. Na podlagi ugotovitev lahko sklenemo, da so ostale kognitivne sposobnosti relativno stabilne skozi eksperimentalno obdobje. V prispevku opozorimo na morebitne dejavnike, ki so lahko prispevali k dobljenim rezultatom, na primer učinek učenja, razmeroma kratko trajanje bed rest raziskave in izbira uporabljenih kognitivnih testov. Prav tako poudarimo pomen ugodnih bivanjskih in psihosocialnih pogojev v času popolne gibalne neaktivnosti, ki so lahko predstavljali pomembno varovalo pred poslabšanjem kognitivnih funkcij.

Ključne besede: *gibalna neaktivnost, bed rest raziskave, kognitivno delovanje, odrasli*

INTRODUCTION

The beneficial effects of regular physical activity and sports on the human body are well-documented. Sufficient physical activity provides the maintenance of an adequate psychophysical condition and the functional abilities of the body (Turner & Robling, 2004) while also playing an important role in the preservation and enhancement of mental health (Kim et al., 2012; Landers & Arent, 2007). Some current epidemiological studies have also established the beneficial effects of regular physical activity on cognitive functions, such as attention, concentration, working memory, speed in information processing and problem-solving ability (Antunes et al., 2006; Etnier, Nowell, Landers, & Sibley, 2006; Smith, 2010).

On the other hand, physical inactivity is becoming a very serious problem in modern society. Strong evidence shows that physical inactivity increases the risk of many adverse health conditions, including major non-communicable diseases such as coronary heart disease, type 2 diabetes, breast and colon cancers, and shortens life expectancy (Lee et al., 2012).

Less clear is how reducing physical activity levels affect cognition, as it is very difficult to induce and monitor long-term physical inactivity in everyday life. The extent to which cognition is affected by prolonged physical inactivity is potentially addressed by studies that have investigated the consequences of bed rest (Lipnicki & Gunga, 2009). Simulated weightlessness, better known as *bed rest (BR) experiments*, were introduced and recognized as a valid ground-based model for studying the effects of zero gravity on humans. The BR model, particularly as conducted in a head-down position (HDBR), has been used to study physiological changes associated with spaceflight, including those that occur to the cardiovascular system, regulation of body fluid, skeletal muscle, and bone (de Boer et al., 2008; Pavy-Le Traon, Heer, Narici, Rittweger, & Vernikos, 2007; Pišot et al., 2008; Rittweger et al., 2009). BR experiments, which presuppose strict rest in a horizontal position, today represent an important method for studying the consequences of prolonged physical inactivity.

Microgravity due to prolonged BR may cause changes in cerebral circulation, which in turn can affect brain functions (Montgomery & Gleason, 1992). Although there are not many studies that have examined cognitive functions in response to BR, they have provided quite inconsistent outcomes (Lipnicki & Gunga, 2009).

Randa L. Shehab and her colleagues (1998) studied the effects of a 17-day HDBR on cognitive performance in eight male volunteers with the application of the NASA Performance Assessment Workstation test battery, which measures six performance tasks to assess directed and divided attention, spatial, mathematical and memory skills as well as tracking ability. No statistically significant differences in performance were observed when comparing BR with the baseline period. In a more recent study, Ishizaki and her colleagues (2009) examined the effects of a 16-day period of HDBR on executive functions in twelve healthy young men. Four kinds of neuropsychological tests were performed on the baseline and on the day 16 of the experiment. There was no significant difference in the results between pre- and post-BR period for any of the tests (Ishizaki et al., 2009). Also, in a particularly long-term BR study, Seaton and colleagues (2009) reported no detrimental effects following a 90-day confinement to bed rest to the participants' cognition.

Some research findings have indicated a worsening in cognitive performance due to BR. A study by Lipnicki, Gunga, Belavý and Felsenberg (2009), found that a 60-day HDBR had a detrimental effect on executive functions assessed using the Iowa Gambling Task in twenty-four young men. Their results also showed longer reaction time latencies under HDBR (Lipnicki et al., 2009). Similar results were reported by Liu, Zhou, Chen and Tan (2012) who used an emotional flanker task to evaluate the effect of 45 days HDBR on executive functioning in sixteen young participants at different time periods throughout the experiment. The task results (accuracy and reaction time) provided some evidence as to the detrimental effects of prolonged BR on executive functions (Liu et al., 2012). In some earlier studies, the authors reported a worsening of performance in at least one cognitive measure, but no effect for other measures

(Asyamolov, Panchenko, Karpusheva, Bondarenko, & Vorob'ev, 1986; Ryback, Lewis, & Lessard, 1971).

Alternatively, some studies witnessed improvements in cognitive performance during BR. For example, Pavy-Le Traon and her colleagues analysed the effects of a 28-day HDBR on several cognitive abilities (attention span, short-term memory, spatial representation, grammatical reasoning) in male participants. While the majority of the studied abilities remained stable during BR, the participants' performance on tests of short-term memory and automated perceptual attention were enhanced (Pavy-Le Traon et al., 1994). Similarly, DeRoshia and Greenleaf (1993) studied cognitive function during a 30-day HDBR in eighteen healthy male subjects who completed different cognitive tests, including verbal reasoning, visuo-spatial ability, short-term memory, and simple reaction time before, during and after the BR period. Although a mild decrease in the parameter of reaction time was established at the mid-point of the experiment, overall cognitive performance improved in response to prolonged BR.

In a recent review, Lipnicki and Gunga (2009) emphasized that the reported effects of bed rest on cognitive performance vary considerably, from the generally expected deterioration to improvements. It should be noted that these mixed results can be at least partially attributed to methodological issues such as the number and selection of subjects, an inconsistent use of cognitive measures, and the duration of BR studies.

Due to the lack of research concerning cognitive aspects of reduced physical activity and the aforementioned inconsistency of the previous findings, we conducted a study aimed to establish the effects of 14-day bed rest on cognitive condition in healthy male volunteers using a wide range of neuropsychological tests. An important element of added value in the study was also the inclusion of older participants, since BR studies normally address younger individuals. The research findings provide strong support for age-related changes in cognitive performance, particularly in the field of executive function abilities (Gunstad et al., 2006). Thus, the results of the effects of prolonged physical inactivity on cognitive functions were presented separately for the groups of younger and older participants.

METHODS

Participants

Twenty-three males aged between 19 and 65 volunteered to participate in the project *"Bed Rest Study – PANGeA, Valdoltra 2012 – The effects of simulated weightlessness on the human organism"*. The participants were divided into two groups based on age: the first group included seven young adults (19 – 28 years old; *M* = 23.1 *SD* = 2.9), while the second group comprised sixteen older adults (53 – 65 years old; *M* = 59.6; *SD* = 3.4). The participant selection process consisted of two steps: first, an interview about a past history and a present condition of the participant's physical and psychosocial status, followed by a thorough medical examination to exclude skeletal muscle and cardiovascular diseases. The selected participants were healthy, non-smokers and took no medications or drugs. A written informed consent was obtained after a detailed explanation of the study (its purpose and research hypotheses, experimental procedures and methods, research conditions). The participants received a financial award after the study had been completed. The National Committee for Medical Ethics at the Ministry of Health, Slovenia, approved the experimental procedure.

For the purposes of the present study only fifteen participants were included: the group of young adults (already presented above) and a part of the older adult group ($N = 8$; 56–65 years old; $M = 59.9$; $SD = 3.3$). These participants were subject only to the BR experiment, while the other older participants went additionally through a mental training program during the BR period. In order to exclude the possible influence of this confounding factor in determining the effects of prolonged physical inactivity on cognition, the group with mental training intervention was not taken into account.

Experimental protocol

The study investigating the effects of simulated microgravity on human organism was conducted in August and September 2012 at the Orthopaedic Hospital Valdoltra, Slovenia, and was part of a broad-based research project *PANGeA: Physical Activity and Nutrition for Quality ageing.*

BR refers to bed confinement in a horizontal supine position for 14 days. The participants were housed in hospital rooms (3-4 in each room) and were under constant video surveillance and provided with 24-hour medical care. Physicians regularly checked physical condition of the participants. They performed all daily activities lying down and were not allowed to leave their beds. The participants were transferred with their beds to the bathroom for personal hygiene. They received standard hospital meals three times a day at 7.30 a.m., 12 a.m. and 6 p.m. The bedrooms were air-conditioned and the room temperature was kept comfortably below 25 °C. Throughout the whole BR experiment the participants were allowed to freely communicate with each other, to watch television and video, to listen to radio, to read books and magazines, to work on computer and use the Internet, and to receive visitors. The BR experiment was followed by a 30-day rehabilitation period. The BR study comprised two types of interventions carried out on a subgroup of participants: mental training intervention during the BR period and a nutrition intervention during rehabilitation. All measurements were performed during the pre-BR period, after the BR period and at the end of the rehabilitation period.

In order to evaluate the BR effects on cognitive functioning, participants were tested with a battery of cognitive tests before BR (3 days prior to the experiment) and after BR (on day 14 of the experiment). The neuropsychological testing was conducted in the morning, after breakfast, in a quiet environment. The participants completed the tasks individually in a sitting position.

Instruments

The following cognitive tests were used in the study:

1. *Rey's Auditory Verbal Learning Test (RAVLT)* is a neuropsychological assessment designed to evaluate verbal memory. The test consists of two 15-word lists; the person listens to a sequence of words in each trial and is asked to recall as many words as possible from the list. RAVLT provides scores for assessing immediate memory, new verbal learning, susceptibility to interference (proactive and retroactive), retention of information after a period of time and memory recognition (Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2005). In this study, the dependent measures used were the total number of words recalled after five learning trials (RAVLT – TL) and the total number of words recalled after 30 minutes (RAVLT – DR). With these measures we assessed new verbal learning and delayed recall.
2. *Trail Making Test (TMT).* The TMT (Reitan & Wolfson, 1985) is a test of visual attention and task switching and provides information on visual search, scanning, speed of processing, mental flexibility and executive functioning (Tombaugh, 2004). It consists of two parts, A and B. Both parts consist of 25 circles distributed over a sheet of paper. In part A, the circles are numbered from 1 to 25. The participant is required to connect the numbers in the increasing order, beginning with 1 and ending with 25, in the shortest possible time. Part B is more complex than Part A because it requires the participant to connect numbers and letters in an alternating pattern (1-A-2-B-3-C, etc.) as fast as possible. The latency scores in seconds, separately for Part A and Part B, were used as dependent measures for analyses (TMT-A, TMT-B).
3. *Digit Span* subtest of the Wechsler Adult Intelligence Scale-III (WAIS-III) (Wechsler, 1987) was used to evaluate working memory. The test consists of two parts: Digits Forward requires the subject to repeat sequences of digits which are read aloud to them that increase in length from three to nine digits; Digits Backward requires sequences of two to eight digits to be repeated in reverse order. The total score was calculated as an average of the longest correctly repeated forward and backward digit strings.
4. *Verbal Fluency Test FAS.* Verbal fluency is a cognitive function that facilitates information retrieval from memory. There are two types of verbal fluency tests: semantic and phonemic. The FAS test is probably the best known phonemic fluency test. Although it was developed as a test of language abilities, it is also considered a test of executive functions (Barry, Bates, & Labouvie, 2008). A subject has to name as many words as possible beginning with letters "F", "A" and "S", one at a time for one minute, excluding proper nouns, such as city, people or river names and the same words with a different suffix. The subjects were given the following instruction: "I will say a letter. Then, I want you to give me as many words you can that begin with this letter, as quickly as possible. For example, if I say "B", you can say

bird, bad, but you can't say Brazil or Barbara. Also, you can't say the same word with a different ending (brother and then brotherhood)." The average number of words per letter was used as a dependent measure.

5. *Mental Rotation Test (MRT)* is a test of spatial abilities (Peters et al., 1995). It is based on a redrawn version of the Vandenberg and Kuse (1978) mental rotation test. An individual is presented with 24 drawings of 3-dimensional objects composed of a series of 10 connected tubes. Each drawing is presented with four alternatives. The subject must select two out of four alternatives that represent the drawing in a rotated position. 3 minutes are given for each subset of 12 drawings, separated by 4 minutes. Dependent variable is the number of correctly solved items (both alternatives are correctly chosen). Thus, the maximum score is 24.
6. *Perspective Taking/Spatial Orientation Test (PTSOT)*: This test was revised by Hegarty, Kozhevnikov, and Waller (2008) from the test used by Kozhevnikov and Hegarty (2001). The PTSOT measures the ability to imagine different perspectives or orientations in space from a configuration of objects. The participants are asked to imagine being at one of the objects of the configuration, facing another object, and to indicate the direction of a third. A circle was used for representing the responses, made by drawing an arrow out towards the edge of the circle itself. There were 12 items in this test, one on each page. Five minutes were allotted for completing this task. Dependent variable was an average deviation in degrees from the veridical location of the target. A higher score indicates poorer performance.

Statistic analysis

The data was analyzed with the software package SPSS for Windows. The paired samples *t*-test was used to determine the differences in the studied variables before and after the BR experiment. In addition to statistical significance testing, practical significance (Kline, 2004) was assessed using the effect sizes, which are resistant to sample size influences (Ferguson, 2009). There is no agreement on what magnitude of effect is necessary to establish practical significance. Cohen (1988) presented the benchmarks for interpreting the differences between two groups (*d* coefficient), whereby 0.2 equates to a small effect, 0.5 equates to a medium effect, and effects larger than 0.8 equate to large effects. Ferguson (2009) offers slightly different guidelines: the recommended minimum effect size representing a "practically significant effect" for social science data is 0.41. The cut-off that equates to a medium effect is 1.15 and the cut-off for strong effect is 2.70. Due to the nature of the study, we decided to use Ferguson's recommendations for the interpretation of effect sizes, so the weak effect sizes are not overinterpreted.

RESULTS

The mean (*M*) and standard deviation (*SD*) of scores on neuropsychological tests in the group of younger participants are presented in Table 1. The paired sample *t*-test showed that there was no significant change following the BR period in any of the measurements of cognitive functions, except in spatial visualization (as measured by Mental Rotation Test). Younger participants performed significantly better after the BR period than at the baseline (before the BR period). Cohen's *d* coefficient additionally showed practically significant improvements in verbal fluency, visual attention (TMT-A), perspective and spatial orientation (PSTOT).

Table 1: Differences in neuropsychological tests before and after BR in younger participants.

Neuropsychological tests	before BR M (SD)	after BR M (SD)	difference M	t (df=6)	p	d
RAVLT – TL	52.86 (5.58)	53.43 (6.58)	-0.57	-0.28	0.79	-0.09
RAVLT – DR	12.43 (2.22)	11.71 (2.36)	0.71	1.51	0.18	0.31
Mental Rotation	8.28 (5.53)	11.43 (3.41)	-3.14	-2.42	0.05	-0.68
Trial Making-A*	25.28 (9.25)	21.00 (5.74)	4.28	1.92	0.10	0.56
Trial Making-B*	52.17 (18.58)	47.33 (15.96)	4.83	.86	0.43	0.28
Digit Span	6.14 (1.07)	6.00 (1.19)	0.14	0.47	0.65	0.12
Verbal fluency	8.81 (1.56)	9.81 (2.77)	-1.00	-1.34	0.23	-0.44
PTSOT*	27.28 (11.93)	19.00 (8.52)	8.28	1.94	0.10	0.80

*Note: *Higher scores denote poorer performance; RVLT-TL: Rey's Auditory Verbal Learning Test — total learning; RVLT-DR: Rey's Auditory Verbal Learning Test — delayed recall; PTSOT: Perspective Taking/Spatial Orientation Test*

Table 2: Differences in neuropsychological tests before and after BR in older participants.

Neuropsychological tests	before BR M (SD)	after BR M (SD)	difference M	t (df=7)	p	d
RAVLT - TL	44.38 (3.58)	44.88 (5.46)	-0.50	-0.31	0.76	-0.11
RAVLT – DL	8.50 (2.14)	7.12 (2.30)	1.38	2.31	0.05	.62
Mental Rotation	5.12 (3.60)	5.50 (3.42)	-0.38	-0.53	0.61	-0.11
Trial Making-A*	43.00 (26.61)	38.38 (18.10)	4.62	0.53	0.62	0.20
Trial Making-B*	98.12 (42.73)	96.12 (46.10)	2.00	0.18	0.86	0.04
Digit Span	5.56 (1.29)	5.18 (1.36)	0.38	1.16	0.28	0.29
Verbal fluency	8. 54 (1.79)	9.75 (2.31)	-1.21	-1.86	0.10	-0.58
PTSOT*	77.62 (52.91)	67.00 (54.27)	10.62	0.71	0.50	0.20

*Note: *Higher scores denote poorer performance; RVLT-TL: Rey's Auditory Verbal Learning Test — total learning; RVLT-DR: Rey's Auditory Verbal Learning Test — delayed recall; PTSOT: Perspective Taking/Spatial Orientation Test*

Table 2 shows mean (*M*) and standard deviation (*SD*) scores on neuropsychological tests in the older age group. There was no significant change following the BR period in any of the measurements of cognitive functions, except in delayed recall, assessed by RAVLT test. In the second testing (after the BR period) the participants showed poorer performance than at the baseline. Cohen's *d* coefficient (for paired samples) also showed practically significant improvement in verbal fluency.

DISCUSSION AND CONCLUSIONS

To evaluate the effects of BR on cognitive functioning in participants, a neuropsychological test battery was used before and after the experiment. The tests administered in the study included different cognitive measures: verbal learning, delayed recall, executive functions, working memory, processing speed, verbal fluency, mental visualization and spatial orientation.

According to research, there is a generally accepted assumption that cognitive abilities decline with age, especially in terms of processing speed, memory and executive functions (Hedden & Gabrieli, 2004), therefore the results have been presented separately for the younger and older age groups.

There was no significant difference in the results of the neuropsychological tests between the baseline and the day 14 of BR in the young adult group, except in the result of mental visualization assessed by the Mental Rotation Test, where a significant improvement was observed after the BR experiment. Also, a tendency towards improved performance was noticed in the measures of executive functions (e.g. visual attention, task switching) and spatial orientation assessed by Perspective Taking/Spatial Orientation Test and Trial Making Test, respectively.

In the older age group, no significant changes in cognitive performance occurred after prolonged physical inactivity, except in the results of delayed recall, where a significant impairment was noticed, indicating that older participants exhibited more difficulties in retrieving words after a time period at the end of the BR experiment compared with the beginning. There was also a slight tendency towards an improvement in language abilities, assessed by Verbal Fluency Test in the older age group. On average, they were able to generate more words beginning with a specific letter after the BR period compared to the baseline.

On the basis of the results of both age groups, we can assume that in general cognitive functions were not deteriorated following the period of total physical inactivity. Our findings are in accordance with some previous studies that generally reported no effects in cognitive functioning (Ishizaki et al., 2009; Seaton et al., 2009; Shebab et al., 1998), while mostly inconsistent with other studies indicating a multi-measure impairment of cognitive performance after BR (Lipnicki et al., 2009; Liu et al., 2012). It is often difficult to compare the results of different BR studies with each other, as they can vary considerably in terms of BR duration (short-term or long-term), position (horizontal or head-down), as well as in the choice of cognitive test administered. Therefore, these factors should be considered when interpreting research findings.

It should be noted, that the Bed Rest Study – PANGeA, Valdoltra 2012, was performed in horizontal position, while the majority of BR studies were conducted in a head-down tilt position, since this type comes closest to matching the conditions of weightlessness that occurs during space flights. This specificity of the experimental protocol may influence our results, although the comparison between the two types has revealed that cognitive test results obtained from subject in a head-down position during BR were as variable as those obtained from subjects positioned horizontally (Lipnicki & Gunga, 2009).

One potential element that should be taken into account when explaining our results is practice effect, defined as improvements in cognitive test performance due to repeated evaluation with the same test materials. Practice effects have been discussed in relation to BR studies, suggesting that greater the overall task exposure the more likely was a performance effect to be found that was higher on a scale from worsening, though no effect, to improvement (Lipnicki & Gunga, 2009). Furthermore, the authors assume that practice effect could mask an underlying detrimental effect of bed rest on cognitive functioning. In our case the practice effect on some of cognitive measures can be attributed to relative short duration of the BR experiment and therefore short interval between the two test applications. In some tests, a tendency towards a positive change in performance is probably a result of a generalized rule or method learned by the participants.

It has been reported in many studies that due to prolonged BR, microgravity causes cardiovascular deconditioning (Antonutto & di Prampero, 2003) that affects brain circulation processes (Montgomery & Gleason, 1992). Higher brain functions and executive functions are expected to be particularly sensitive to these psycophysiological changes (Ishizaki et al., 2009). The results of our study suggest that these changes were perhaps too small to affect higher brain functions. It can be observed that those BR studies that were longer in duration reported some clear evidence for a detrimental effect of bed rest on executive functioning (Lipnicki et al., 2009; Liu et al., 2012), whereas the study of Ishizaki and colleagues (2009) which was comparable to our study by duration found no worsening of cognitive function due to bed rest. Another possible explanation which was already highlighted in some previous studies (Dolenc & Pišot, 2011; Seaton, Bowie, & Sites, 2009) is that cognitive performance is related to the mental health of the subjects. The results obtained in our study may also be associated with the highly favourable habitability factors that were present during the BR experiment. These factors included maintenance of a stimulating environment, the possibility to use various media, acess to various means of communication to stay in touch with friends and relatives, as well as researchers and medical personnel. The participants were allowed to a variety of mental activities, such as reading, writing, working on a PC, playing games, using e-mail and the Internet, watching TV etc., which may have contributed to the maintenance of high motivation and preservation of cognitive function levels. Our results suggest that the provision of favourable living conditions, a positive psychological state of participants along with the maintenance of mental activity during the period of prolonged physical immobilisation represent some kind of "protective factors" that might alleviate an impairment of cognitive condition.

Although the comparison of results between the younger and the older group showed similar patterns of stability and change, there were also some specifics. The younger age group showed stability in cognitive functions or even a tendency towards a better performance after the BR period, whereas in the older group the cognitive performance remained stable, with the exception of memory functions, which reflected a decline across the BR period. Memory represents a cognitive domain that shows decline with age (Zupančič, 2004). Based on our findings it seems that long-term physical inactivity or extremely sedentary lifestyle could have an additional adverse effect on memory functions in older adults. This leads to the conclusion that participation in physical activities may be of particular importance when other risk factors for cognitive decline are present (Aichberger et al., 2010).

An important contribution of the present research within the "Bed Rest Study Project – PANGeA, Valdoltra 2012 was the inclusion of older adult participants, since the previous BR studies examined young adults and primarily used this paradigm as a model for determining the effects of weightlessness related to space flight. Moreover, this study emphasized the usefulness of the BR model for evaluating the consequences of long-term physical inactivity. Thus, it seems reasonable to pay bigger attention to the study of psychological and cognitive aspects under the conditions of restricted physical activity in the future.

It should be noted that all the subjects of the BR studies volunteered to participate. They had been informed in advance about both the duration of the inactivity experimentsand the expected time of conclusion. These individuals are certainly intrinsically motivated in a different way than people who do not voluntarily choose a condition of inactivity. Although our findings cannot be directly related to ill and hospitalized people, we may conclude that the research on cognitive functioning within BR studies potentially has an applied value in the field of health prevention and rehabilitation. The obtained results can be applied to the individuals who are otherwise healthy but whose physical activity is temporarily very limited, e.g. orthopeadic post-operative conditions requiring long-term recovery or other indications which presuppose a longer period of physical inactivity. In all those cases additional means of maintaining psychological health and cognitive functioning should be vigorously pursued.

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