PHYSICAL INACTIVITY EFFECTS ON MORPHOLOGICAL AND MUSCULOSKELETAL CHANGES

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Abstract

Human responses on sedentary lifestyle induce physical inactivity. The aim of the research study was to detect morphological, musculoskeletal and some functional responses in young healthy men after total physical inactivity (bed rest) continuing 35-days, including nutrition countermeasures that could prevent some catabolic adaptations with individually balanced energy intake. 30 males in average age 24 ± 3 years have been submitted to 35 days of horizontal and head down tilt bed rest. Musculoskeletal, morphological and psychological characteristics were assessed before, during, and after bed rest while also after recovery phase. Functional characteristics as orthostatic intolerance, postural and clinical balance, gait, maximal and explosive power and psychological stress were monitored. Psychological tests "State Anxiety Inventory", "Emotional Regulation and Control Scale" and "Test of Concentration and Achievement" were completed by participants. Results shown orthostatic intolerance developed after head down tilt bed rest, while just in 30 % after horizontal bed rest. Skeletal muscle adopts in lower muscle volume, lower fascicle length, and pennation angle. Overall body muscle mass was reduced but significantly just in legs. Mineral bone density was lower in leg muscles but in high correlation to muscle tendon attachments. Leg maximal and explosive power was reduced during isometric trials and vertical jumps. Significant increase was observed in fat mass but only when nutrition intake was not regulated and balanced. Changes in posture resulted in poor balance were observed after bed rest. No significant decrease in the examined psychological variables was established in participants after the period of physical immobility. The level of anxiety, emotional regulation and control, and concentration ability, expressed as the quantity of achievement, remained relatively stable during the experiment.

Keywords

Physical inactivity, psychological response, bed rest, psychomotor status, adaptation.

1 INTRODUCTION

Physical activity and sports for all constitute one of the major components of a healthy lifestyle, along with healthy diet, tobacco free life and avoidance of other substances harmful to health (WHO, 2003). Available experience and scientific evidence show that the regular practice of appropriate physical activity and sports provides people, of all ages and conditions, with wide range of physical, social and mental health benefits. Aerobic exercise mostly improves cardiovascular characteristics, while anaerobic exercises skeletal muscle with bone characteristics. Therefore, exercise with supporting nutrition intake are one of the major contributors of healthy lifestyle, physical health with increased performance and high quality of life throughout whole human lifespan.

Numerous research findings determined that unsufficient physical actvitiy and sedentary life style represent an imoprtant risk factor related to different health problems and diseases (Blinc in Bresjanac, 2005; Keim, Blanton & Kretsch, 2004). Several studies reported a relationship between physical inactivity and coronary disease, which is within in developed devisede laborated formulate devolved unrolled unfurled unwound uncoiled unraveled unfolded opened undone unpacked countries a major cause of mortality (Fras, 2002; Kohl, 2001). From the other side, sufficient physical activity provides the mainenance of adequate psychophysical condition and functional abilities of the body (Pate, Pratt & Blair, 1995; Turner & Robling, 2004; Završnik & Pišot, 2005). Physical inactivity is becoming a very serious problem for the world's population. It is very difficult to induce and monitor long-term physical inactivity in everyday life. Scientists approach to this problem in different manners – many of them research how prolonged physical inactivity affects the human body.

Different contemporary studies are confirming that fitness and physical/sport activity have an important role in the maintenance and enhancement of mental health (Biddle, Fox & Boutcher, 2000; Hassmen, Koivula & Uutela, 2000; Landers & Arent, 2007; Salmon, 2001): contribute to the reduction of depressive and anxious symptoms (Arent, Landers, Matt & Etnier, 2005; Dunn, Trived & O'Neal, 2001), enhance resistence to stress (Alderman, Rogers, Johnson & Landers, 2003) and provide the formation of positive physical self-concept and self-esteem (Ekeland, Heian, Hagen, Abbott & Nordheim, 2004; Fox, 2000). In the last decade we can notice an increased research interest in clarifying the relation between physical actvity and some indicators of mental health and psychological adaptation. Although the causality of this relationship is not clear, the pattern of evidence suggests the theory that exercise training recruits a process which confers enduring resilience to stress. Some current epidemiological studies also establish 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, Santos, Cassilhas, Santos, Bueno & de Mello, 2006; Etnier, Nowell, Landers & Sibley, 2006).

Simulated weightlessness, better known as *bed rest* (BR) studies were introduced and recognized as a valid ground-based model for studying the effects of zero gravity on humans while the results might also be applied to physical inactivity or ageing studies. Numerous research studies have proven that the physiological and psychological changes that occur following a prolonged period of BR are very similar to the changes observed in astronauts on their return from space travel (Convertino, 1997; Krasnoff & Painter, 1999; Sato & Maeda, 2002). Bed rest experiments, which presuppose strict rest in a lying-down position, represent today an important method to study the consequences of prolonged physical inactivity. World literature that addresses human adaptation to a prolonged period of rest in the lying-down position discusses horizontal bed rest (HBR) experiments and 6-degree head-down tilt bed rest (HDTBR) experiments. In comparison to the HBR, the HDTBR appears more appropriate, considering that simulation of this type speeds up all physiological processes in human organism and comes closest to matching the conditions of weightlessness occurring during space missions (Hyeteok et al., 2003; Iwase et al., 2004). The effects on human organism are similar to ones that take place after physical inactivity, immobilization, spaceflight, sedentary lifestyle or aging.

Sub-systems of human body that are affected by bed rest are:

Cardiovascular

- cardiac atrophy and increased heart beat (Perhonen et al., 2001)
- changes in cardiovascular regulation by the autonomic nervous system (Blomqvist et al. 1994)
- increases in venous compliance (Blomqvist et al. 1994)
- decreased orthostatic tolerance (Pavy-Le Traon et al. 1998)

Skeletal

- Bone mineral loss (LeBlanc et al., 1990)
- Bone mineral structure transform (Rittweger et al., 2009)

Muscular

- Muscle mass and strength decrease (Grigoryeva and Kozlovskaya, 1987)
- Muscle diameter, fascicle length, and pennation angle decrease (De Boer et al., 2008)
- Muscle stiffness decrease (Pišot et al., 2008).

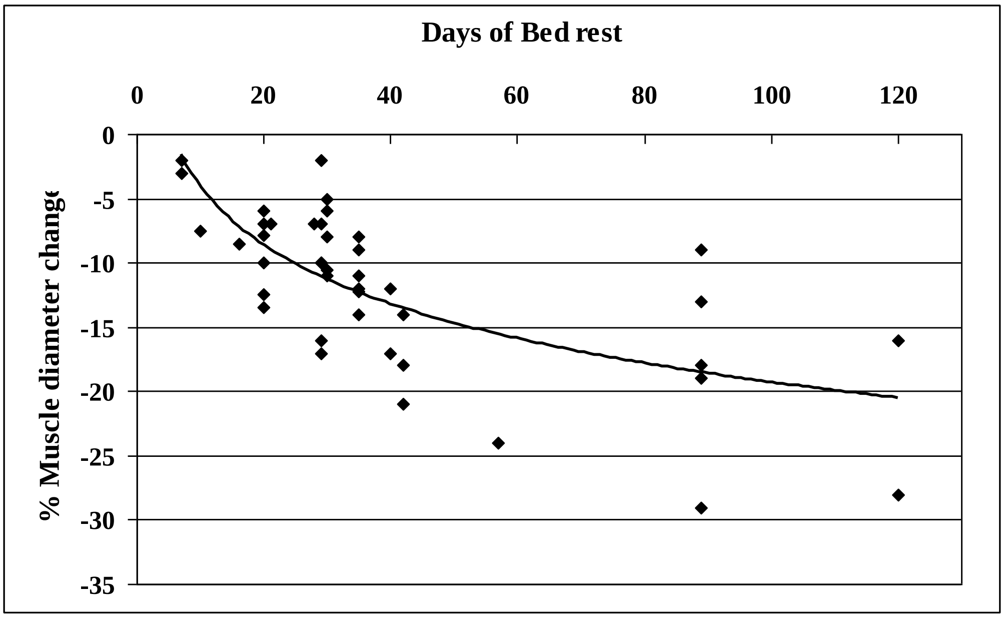

Figure 1: Overview of relevant data for leg skeletal muscle diameter change after days of bed rest.

Regarding to the described changes also other human physiological adaptations could take place, like balance, gait, posture, power, etc. Furthermore, changed nutrition during spaceflight or experiments could additionally contribute to those changes, especially in bone and muscle adaptations. Biolo et al. (2008) recently proved that individualised and balanced nutrition during 5 week bed rest could diminish fat deposits and decrease muscle atrophy.

Research determining the effects of prolonged physical inactivity on the mental state and feelings of individuals is deficient or almost non-existent. Psychological factors play an important role in the processes of adaptation under conditions of extreme confinement and isolation such as occur, for instance, during exposure to weightlessness or simulation thereof. Adaptation to new conditions undoubtedly represents an important source of stress which can induce in psychological and behavioral disturbances (Weiss, Nicolas & Charras, 2005). The investigation of the psychological aspects of adaptation in bed rest studies is important not only to contribute to a more appropriate selection and training of astronauts and to optimize psychological preparations and monitoring of volunteers, but also to create possibilities for the application of obtained results to other groups exposed to similar conditions (Gunji, 1997).

Several studies evaluated the effects of prolonged inactivity induced by horizontal BR on participants' mental health (Ishizaki et al., 1994; Ishizaki et al., 2000). Results showed a tendency toward development of depression and neurotic symptoms. This tendency had disappeared two months after the BR study. Changes in psychological status in healthy male subjects were evaluated also during a 20-day head-down BR (Ishizaki et al., 2002). Depressive and neurotic level were enhanced, mood state "vigor" was impaired, whereas "confusion" was increased during BR compared to pre-BR and ambulatory control periods.

Styf, Hutchinson, Carlsson & Hargens (2001) investigated back pain, mood state, and depression during two forms of BR (head-down BR and horizontal BR). Subjects experienced significantly more intense lower back pain, lower abdominal pain, headache, and leg pain during head-down BR, and reported more depressive symptoms and poorer mood status during head-down BR compared to horizontal BR. A recent study examined the effect of acute simulated microgravity on nocturnal sleep, daytime vigilance, and psychomotor performance. Participants were maintained for 3 days of head-down and horizontal bed rest in a counter-balanced design. Results suggest that nocturnal sleep, daytime vigilance, and psychophysiological functions were not disturbed in head-down conditions, although there was a mild deterioration of higher attention function in the morning (Komada, Inoue & Mizuno, 2006).

Some authors tried to determine cognitive functions (directed and divided attention, spatial, mathematical, and memory skills, tracking ability) in response to prolonged BR (DeRoshia & Greenleaf, 1993; Shehab, Schlegel, Schiflett & Eddy, 1998). Although a trend of mild decrease in the values of the measured parameters was established during the experiment, no statistically significant differences in cognitive performance were observed when comparing BR with control period. Also cardiovascular and skeletal-muscle changes due to the microgravity simulated by BR might induce headache, back pain, sleep disturbances, and other problems (Kume, 1997) which could affect the psychological well-being of an individual (e.g. greater depression levels and poorer mood status).

2 AIMS AND POSTULATES

The main aim was to detect morphological, musculoskeletal and selected functional responses in young healthy men after 35days of total physical inactivity (bed rest) including nutrition countermeasures that could prevent some catabolic adaptations with individually balanced energy intake. The next aim was to evaluate psychological parameters of well-being during the research.

Postulates:

Extreme and prolonged confinement to bed and immobility resulting from simulated weightlessness might contribute to psychological changes.

3 METHODS

The project was organized and coordinated by the Institute of Kinesiology

Research at the Science and Research Centre of Koper, University of Primorska. Three studies were carried out in the summer 2006, 2007 and 2008 at the Orthopaedic Hospital in Slovenia, approved by the National Committee for Medical Ethics at the Slovenian Ministry of Health and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

3.1 Material

30 males (approx. average age 24 ± 3 years) have been submitted to horizontal (BR 2006, 2007) and head down tilt bed rest (BR 2008); ten of them each year from 2006 to 2008. The selection process included an interview about a past history and a present condition of the subject's physical and psychosocial status, and a physical examination, where routine medical and laboratory analyses were used to exclude chronic diseases. Selected ten participants were university students, non-smokers and took no medications or drugs. Written informed consent was obtained from all participants, following a detailed explanation of the study (purpose and research hypotheses, research conditions, possible problems and complications).

3.2 Procedure and methods

Experimental protocol included a 35-day bed rest reflecting total physical inactivity. Subjects performed all daily activities lying down. Physical activity was strictly forbidden throughout the experiment. Subjects were under constant video surveillance and provided with 24-hour medical care. Three times a week they received physiotherapy, which included passive exercise of the joints and gentle neck and back massage. During this time, subjects were allowed to read, watch TV, listen to music, and use computers and the Internet. Bed rest 2007 and 2008 also included nutrition countermeasures with individually balanced energy intake.

Musculoskeletal, morphological and psychological characteristics were assessed before, during, and after bed rest while also after recovery phase. Furthermore, functional characteristics, such as orthostatic intolerance, posture, postural and clinical balance, gait, maximal and explosive power, were also investigated.

Follow test were applied:

- Body composition according classical anthropology;
- Testing of the orthostatic intolerance;
- Postural and clinical balance;
- Gait, maximal and explosive power;

Psychological tests:

- GHQ - General Health Questionnaire (GHQ-12; Goldberg & Williams, 1988);
- SWLS - Satisfaction with Life Scale (Diener et al., 1985);
- CES-D - Center for Epidemiological Studies Depression Scale (Radloff, 1977);
- STAI - State-Trait Anxiety Inventory (Spielberger, 1983);
- ESQ - Emotional States Questionnaire (Lamovec, 1988);
- CRI – Coping response inventory (Moos, 1993).

4 RESULTS AND DISCUSSION

Body composition

Body composition changed similar to every physical innactivity related situation. Body fat increased between for 2.5 ± 1.6 % ($P < 0.001$) and muscle mass decreased in average for 4.4 ± 1.9 % ($P < 0.001$). Changes were even bigger in lower body parts as participants were allowed to maintain upper body muscles (arms, shoulders, neck) with daily activities (hygiene, consuming food, etc.).

Orthostatic intolerance

Sincopy is the first cardiovascular repsonse after participant reambulation. The cardiac muscle atrophy as well, looses stroke volume, vains distence and leg muscles are too week to maintain addecuate blood pressure in vertical posture. During bed rest orthostatic intolerance is not a problem but arrises as soon as participants stand up. During horizontal bed rest (2006 and 2007) we found 30 % of the participants orthostatically intolerant and even 70 % of them in head down tilt bed rest (2008). This clearly demonstrate cardiovascular response which has to be considered as a big threat to astronauts or others subjected to similar stress. But luckiliy after 15-30 minutes after reambulation or constant moving – walking, all subjects were orthostaticaly tolerant and could countinue with other criterion tests.

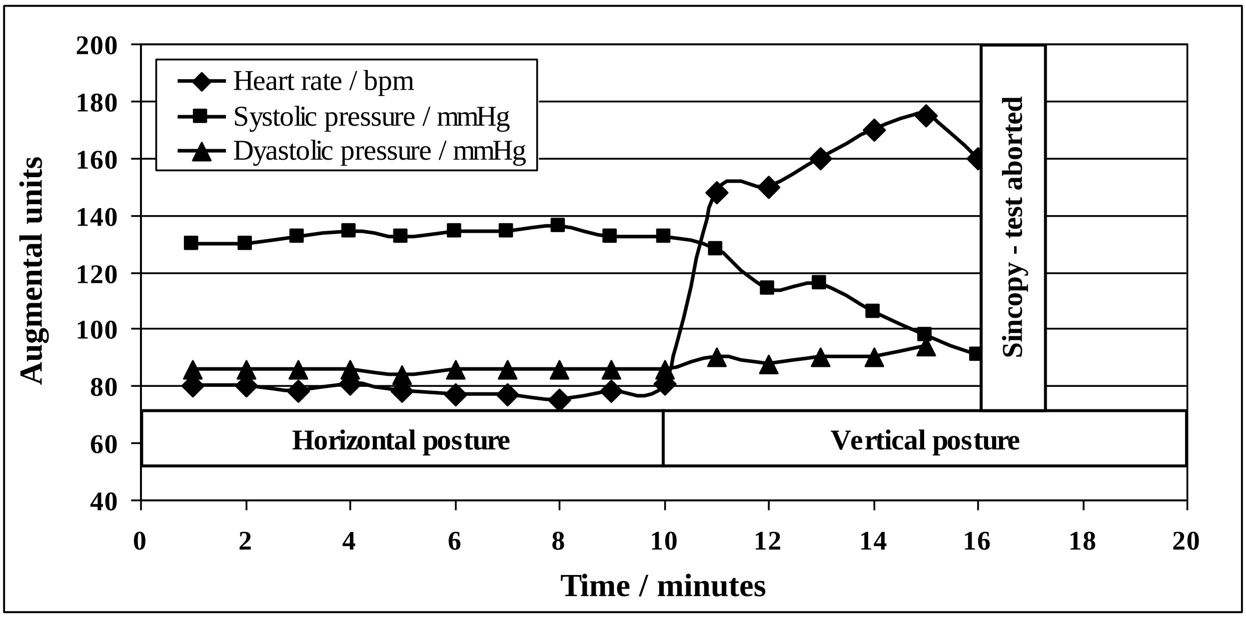

Figure 2: Presentation of typical cardiovaascular responses in orthostaticaly intolerant participant after reambulation.

Skeletal muscle

As mentioned before it is justified to expect that skeletal muscle will atrophy during bed rest (Figure 1). We were the first to present that adaptations in postural muscles are bigger than in non-postural muscles (De Boer et al., 2008). Postural muscles or weight bearing muscles or loading muscles have different function roles within the body functioning. We found geometrical remodelling in skeletal muscle thickness, fascicle length and pennation angle in postural muscles such are vastus lateralis and gastrocnemius medialis, while no significant changes in non-postural muscles such are tibialis anterior and biceps brachii (Table 1).

Table 1: Geometrical remodelling of four skeletal muscles after 35-days of bed rest.

	Thickness change	Fascicle length change	Pennation angle change
Vastus laterlis	-8.0 % ($P < 0.05$)	-5.9 % ($P < 0.01$)	-13.5 % ($P < 0.05$)
Gastrocnemius medialis	-12.2 % ($P < 0.005$)	-4.8 % ($P < 0.001$)	-14.3 % ($P < 0.001$)
Tibialis anterior	N.S.	N.S.	N.S.
Biceps brachii	N.S.	N.S.	N.S.

N.S. Not significant

Important finding in our research was an calibrational and validational study of Tensiomyographic method for detection of skeletal muscle stiffness and contraction time. Tensiomyography is a non-invasive and selective method for detection of mechanical twitch response and was developed at Faculty of Electrical Engineering in Ljubljana, Slovenia (Valenčič and Knez, 1997). We found that muscle belly thickness decreases in close relation with its mechanical properties changes as is stiffness decrease (Pišot et al., 2008). The Pearson correlation coefficient in gastrocnemius medialis muscle was 0.7 ($P < 0.01$). This finding enables new methodlogical approach for assessment of muscle atrophy in more details as described in next two paragraphs.

Dynamics of muscle atrophy was rearly a subject of research. In Figure 1 it is obvious that there are no data for muscle atrophy after bed rest shorter than 7 days, altgough there are numerous situations for physical innactivity periods shorter that 7 days (injuries, illnesses, sport breaks, etc.). Furthermore, Berg et al. (1993) and Conley et al. (1996) reported at least two events that could change geometry and mechanical properties of skeletal muscles subjected to bed rest: fluid redistribution towards torso and protein degradation. This fact should be consideded with caution when assessing muscle geometry and mechanical properties after bed rest. But there are no data on the time dynamics of those events, which lead us to analyse dynamics of geometrical and mechanical changes of skeletal muscle. Using tensiomyography and ultrasound scaning we followed muscle stiffness and thickness change during bed rest and passive recovery. Resutls show significant change in muscle thickness after just one day of bed rest and also after just one day of recovery (Figure 3). This phenomenom is contributed to fluid redistribution after posture direction change. Furthermore figure 3 presents time dynamics of muscle vastus medialis longus atrophy during bed rest and also muscle hypertrophy after reambulation. The amplitude of muscle atrophy after 35-day bed rest is higher (23 %) than in available data overview average presented in figure 1 (12 %). This has to be contributed to at least following facts. If we compensate fluid redistribution effect and compare results from day 35 of bed rest to the day 1, we estimated atrophy of only 19 %. Furthermore, vastus medialis longus is a postural muscle with its clear function – preservation of knee joint stability, which is very effected by bed rest. From the same graph we could see also mechanical twitch amplitude change, that was measured with Tensiomyography. As we demonstrated in Pišot et al. (2008) the amplitude of transversal muscle belly mechanical response shows significant correlation to muscle thickness loss and could be interpreted as a representative marker for muscle atrophy. With simple corelation of time series of both varisables presented in figure 3 we found significant Pearson’s correlation of -0.89 ($P < 0.01$). This findind puts Tensiomyography as a suitable method for detection of changes of skeletal muscle contractile properties as a result atrophy/hypertrophy

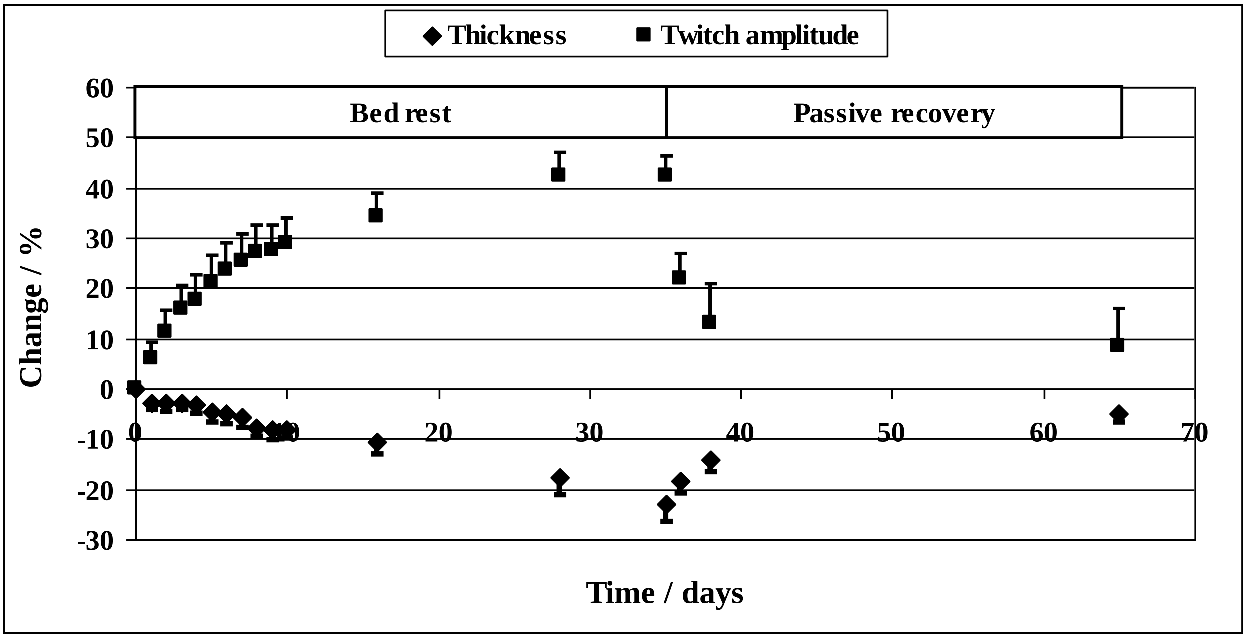

Figure 3: Muscle vastus medialis longus thickness change and mechanical twitch amplitude change during 35 day bed rest and during 30 day passive recovery.

Skeletal muscle contraction time is another contractile parameter that could be altered after bed rest. Berg et al. (1997) did not find any significant changes in muscle vastus lateralis composition after 42 day bed rest. But nobody studied non-postural muscles. In our work on two muscles we compared twitch contraction time chages after bed rest and after recovery in postural vastus medialis longus and non-postural biceps femoris. In table 2 we could see non significant changes in contraction time for vastus medialis longus, while significant ($P < 0.001$) contraction time increase for biceps femoris. Furthermore, biceps femoris changes did not recover after passive recovery. It is very well known that biceps femoris has large proportion of satellite type cells and with it large adaptative possibilities (Dahmane et al., 2006). This finding is very important for understanding muscle's adaptive potential to physical activity/innactivity with it's practical applications in the field of rehabilitation and sports.

Table 2: Twitch contraction time of postural muscle (vastus medialis longus) and non-postural muscle (biceps femoris) at baseline data collection, after 35 day bed rest and after 30 day recovery.

	Baseline data collection	After 35 day bed rest	After 30 day passive recovery
Vastus medialis longus	24.4 ± 1.0 ms	24.7 ± 0.8 ms	25.9 ± 1.1
Biceps femoris	26.3 ± 2.4 ms	33.5 ± 1.9 ms	32.2 ± 2.2 ms

Bones

With long term living in space (4 – 14 months) skeletal system looses mineral bone density – monthly from 0.4 to 2 % (Le Blanc et al., 2000). Rittweger et al. (2006) found significant bone loss already after 7 days of limb immobilisation. Furthermore, the same author found continuation of bone loss 90 days after reambulation. Of course there have been proposed countermeasures for bone loss but with limited success in space flights (Alkner and Tesch, 2004). In our study we found the same results during and after 35 day bed rest (Rittweger et al., 2009) but with two important additions. Our results supports the suggestion of the subendocortical layer as a transitional zone, which can readily be transformed into trabecular bone in response to b ed rest. The latter will lead to cortical thinning, a factor that has been associated with the risk of fracture and with osteoarthritis. Furthermore, we observed greater bone loss in the part of the patella and patellar ligament attachement place. This suggest that muscle tension could prevent bone loss at least in attachment places.

Postural stability

Postural and locomotor instability is reported during and after space flight (Homick and Reschke 1977. It is believed that this is due to adaptive processes in the processing of vestibular information (Von Baumgarten et al. 1975) which, in turn, leads to postural instability (Clement et al. 1984). Although it has been argued that the altered vestibular input during bed rest should elicit similar problems (Clement et al. 1985), there is paucity of data regarding the effects of bed rest on postural stability. No study to date has investigated the possible effects of bed rest upon postural stability using clinical tools. After 35 day horizontal bed rest we found no changes in the Short physical performance battery (SPPB) score. However, we found higher relative muscle power (18 %; P = 0.013), lower muscle power frequency density distribution (-15 %; P < 0.001), higher lateral sway (24 %; P = 0.011), higher sagittal sway (18 %; P < 0.001), and higher overall sway length (7 %; P < 0.001) in tandem test on the force plate. It is concluded that postural stability is impared after bed rest and that clinical test battery (SPPB score) was not sensitive to evaluate postural stability changes in young males after bed rest, while parameters of force-time series were.

Nutrition

Countermeaseres in bed rest are nowadays very popular and widely used to counteract various deteriorations within human body during space flight, bed rest or similar – physical innactivity inducing situations. But there was no data on using nutrition as a countermeasure tool. We have demonstrated that positive energy balance during inactivity is associated with greater muscle atrophy and with activation of systemic inflammation and of antioxidant defenses (Biolo et al., 2009). The data used for this results comes from two horizontal bed rest studies on 19 participants (2006, 2007). In one study we let them adopt their nutrition caloric intake to the bed rest condition, while in other group we adopt their caloric intake to the limited energy conumption situation that occure during bed rest. Optimizing caloric intake may be a useful strategy for mitigating muscle loss and fat gain during period of chronic inactivity

Psychological characteristics

To evaluate the effects of complete physical inactivity during a 35-day BR on psychological states in healthy young males, different psychometric incentories were assessed before and after the experiment. Within the Bed rest 2006 study participants' state anxety level, emotional regultation and control, and the concentration ability were examined, according to the State-Trait Anxiety Inventory, the Emotional Regulation and Control Scale (Takšić, 2003) and the Test of Concentration and Achievement (Bele-Potočnik, 1976), respectively. After the period of physical immobility no significant decrease in the examined psychological variables was established. The level of anxiety, emotional regulation and control, and concentration ability, expressed as the quantity of achievement, remained relatively stable during the experiment.

Bed rest studies 2007 and 2008 included more detailed investigation on psychological adaptation under condition of complete physical inactivity, induced by 35 days of horizontal and 35 days of head-down tilt BR, respectively. Examined psychological variables are presented in the table 1.

Table 3: Changes in the studied psychological variables during the BR period.

	BR 2007	***BR 2008***
GHQ-Neurotic level	↑ (P = 0.045)	↑ (P = 0.073*)
SWLS-Satisfaction with life	↔	↔
CES-D-Depression	↔	↔
STAI- State anxiety	↔	↔
ESQ-Emotional states	↔	↔
CRI-Coping strategies	↓ Seeking support (P = 0.034) ↓ Problem solving (P = 0.035) ↑Emotional discharge (P = 0.004)	↓Seeking support (P = 0.002) ↓Problem solving (P = 0.070*) ↓Positive reappraisal (P = 0.073*)

*Note: ↓ - variable values decreased during BR; ↑- variable values increased during BR; ↔ - variable values remained stable during BR; * - value at the limit of statistical significance, P < 0.05*

GHQ -General Health Questionnaire (GHQ-12; Goldberg & Williams, 1988); SWLS - Satisfaction with Life Scale (Diener et al., 1985); CES-D - Center for Epidemiological Studies Depression Scale (Radloff, 1977); STAI - State-Trait Anxiety Inventory (Spielberger, 1983); ESQ - Emotional States Questionnaire (Lamovec, 1988); CRI – Coping response inventory (Moos, 1993).

No significant differences were seen in participants' reported satisfaction with life, depression and anxiety symptoms, and different emotional states (contentment, agression, indifference, positive and negative self-concept) comparing the pre- and post-experiment period in both types of BR prefomed. There was an increase of participants' general sense of well-being (assessed with the General Health Questionnaire), manifested in an increase of neurotic symptoms during horizontal BR (2007) and a tendency toward an impairment of participants' metal helath during head-down tilt BR (2008). Even after the period of physical immobilization, however, the expression of these symptoms remains relatively low and does not represent a risk to the mental health of the subjects.

These results are mostly inconsistent with the majority of research findings reporting mood impairments and increased values of depressive and neurotic experience after BR period (Ishizaki et al., 2002; Styf et al., 2001). However we have to consider, that previous BR studies were carried out under strict experimental conditions where, in addition to the conditions of physical immobility, also conditions of extreme social isolation and seclusion were created.

The considerable degree of paricipants' adaptability to the conditions in our study was attributed to the selection of subjects with optimal characteristics for adaptation to confinement and restricted mobility and to the highly favourable environmental habitability factors in our study relative to previous studies. These habitability factors included maintenance of a stimulating environment, the possibility to use various media (TV, radio, computer and Internet), acess to communications with friends and relatives, and absence of stuff/subject conflicts.

We can assume that some changes in studied psychological characteristics during our experiments were more the consequence of prolonged lying in a horizontal/head-down position and the accompanying physiological changes than of the living conditions and psychosocial conditions during the experiment. The results suggest that favourable living conditions and the possibility of social interaction during a period of total physical inactivity represent a kind of "protective factors" against an impairment of mental state, or, in other words, that they mitigate the negative effects caused by prolonged physical inactivity.

5 CONCLUSIONS

On the basis of the results, we found some changes in coping behaviour during prolonged physical inactivity. The use of coping strategies "seeking support" and "problem solving" decreased during both forms of performed BR, use of strategy "emotional discharge" increased only during horizontal BR, while "positive reappraisal" decreased during head-down BR. Other evaluated coping strategies (logical analysis, cognitive avoidance, acceptance, alternative rewards) remained relatively unchanged after the two BR experiments. Physical immobility required a great degree of adaptation capability in completely new and never before experienced circumstances (performing all activities in lying-down position, frequent measurements and physiological tests, other demands from experimental protocol). For that reason the participants depended upon information and help of others. Probably the need for support was especially noticeable before and at the beginning of BR and then decreased, because the experimental situation became more familiar and predictable. Another important issue was the constant contact with medical staff and researchers during the experiment, so the help and support to participants were provided.

Prolonged physical immobility undoubtedly represents an important source of physical and psychological stress. The experimental condition certainly influenced the participants, in sense that were stimulated so reduce tension through relaxation of negative emotions. To summarize, this dependent and passive condition, induced by BR, promoted especially the use of coping strategies focused on emotions and reduced the use of coping strategies oriented to the problem. Our results are comparable to other findings within similar research contexts (Folkman & Moskowitz, 2000).

The study of psychological and psychosocial aspects under conditions of prolonged physical inactivity deserves special attention and in-depth consideration in the future.

Research on the psychological aspects within bed rest studies potentially has a great applied value in the field of health prevention and rehabilitation. Namely, we could apply the findings in the study of the effects of physical inactivity on human mental health (post-operative conditions requiring long-term recovery; in cases of health indications requiring physical inactivity or bed rest; in lifestyles dominated by extreme physical inactivity) and anticipate the use of appropriate psychological interventions to prevent psychological stress and increase the quality of life under conditions of prolonged physical inactivity.

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