



INFLUENCE OF RESISTANCE EXERCISE ON AUTONOMIC NERVOUS SYSTEM AND SLEEP

UTICAJ VEŽBANJA UZ PRIMENU OTPORA NA AUTONOMNI NERVNI SISTEM I SPAVANJE

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Abstract

Physical activity changes our body in many aspects, including autonomic regulation of cardiovascular system and thermoregulation, changes in metabolism, secretion of hormones and, as a consequence, mental changes. Acute effect of physical effort is increased sympathetic activity leading to condition known as “fight or flight” which includes tachycardia, tachypnea, blood pressure increase, pupil dilatation and increased attention. Parasympathetic activity is increased between series of trainings, during the resting state, and its effect is often referred to as “rest and digest” state. It includes increased salivation, drop in heart rate, bronchoconstriction, myorelaxation and pupil constriction. There are other factors responsible for the influence of exercise on our body. Good feelings and better memory after exercise are caused by secretion of various compounds, such as BDNF, dopamine and endorphins, as well as blood flow, leading to the use of exercise as therapeutic method but also as an agent of addiction. Sleeping is also altered by physical activity directly through nervous system and indirectly through metabolism and hormones. There are various types, aerobic and resistance, and frequencies of physical activity that can be used as treatment of many disorders and states. In this article we will discuss multiple benefits of resistance training on autonomic nervous system function and sleep.

Keywords:

autonomic nervous system,
baroreflex,
blood pressure,
exercise,
heart rate,
sleep



Sažetak

Ključne reči:

autonomni nervni sistem,
barorefleks,
krvni pritisak,
vežbanje,
frekvencija rada srca,
spavanje

Fizička aktivnost utiče na naše telo iz različitih aspekata, uključujući autonomnu regulaciju kardiovaskularnog sistema i termoregulacije, promene metabolizma, sekrecije hormona i posledično promene mentalnog stanja. Akutni efekat fizičke aktivnosti je povećana simpatička aktivnost koja vodi u stanje poznato kao „bori se ili beži” koje obuhvata tahikardiju, tahipne, povišenje krvnog pritiska, dilataciju zenica i povećanu pažnju. Parasimpatička aktivnost je povišena između treninga, u stanju mirovanja i njegov efekat se često naziva „odmori se i vari” stanje. Uključuje pojačanu salivaciju, pad srčanog ritma, bronhokonstrikciju, miorelaksaciju i suženje zenica. Postoje drugi faktori odgovorni za uticaj fizičke aktivnosti na naše telo. Dobra osećanja i bolja memorija nakon fizičke aktivnosti su uzrokovani sekrecijom raznih jedinjenja kao npr. *BDNF*, dopamina i endorfina, kao i protokom krvi, što je dovelo do upotrebe fizičke aktivnosti kao terapijske mere, ali i kao posrednika zavisnosti. Fizička aktivnost utiče na promene u spavanju direktno kroz nervni sistem i indirektno kroz metabolizam i uticaj hormona. Postoje različiti načini, aerobni i uz primenu otpora, i učestalost praktikovanja fizičke aktivnosti, koja se može koristiti kao terapija mnogih poremećaja i stanja. U ovom članku ćemo diskutovati više-struke prednosti koje vežbe uz primenu otpora imaju na funkciju autonomnog nervnog sistema i na spavanje.

Introduction

Any bodily movement produced by skeletal muscles that requires energy is physical activity. Exercise is planned and structured physical activity with a purpose to improve physical fitness, set of attributes a person possesses that are often measured and used as assessment of health and adaptational possibility (1). Physical activity affects human organism in many ways. Adjustment to exertion includes autonomic regulation of cardiovascular system and thermoregulation, changes in metabolism, secretion of hormones and, as a consequence, mental changes. General effect of physical activity is acceleration of metabolism that consequently leads to enlargement of energetic demands and therefore to the increase in blood flow (2). Results of changes in the central nervous system (CNS) and metabolism lead to modified hormone secretion and thus affect sleep. Changes in autonomic nervous system (ANS) also alter other functions such as digestion, eye accommodation, breathing, urination, sexual arousal, sweating, liver and kidney function (3,4).

Usual purpose of exercise is to affect physical fitness rather than ANS function. There are different exercise modalities designed to affect different aspects of physical fitness such as endurance, speed, muscle strength, flexibility and coordination (5). Approach to the type of an exercise can be based on the cell metabolism and therefore we can differentiate aerobic and resistance exercise. Aerobic metabolism includes production of energy by oxidative phosphorylation. Physical activities usually considered as aerobic include lower intensity, defined by the heart rate or O_2 consumption, and duration longer than few minutes. On the other hand, resistance activities are of high intensity and shorter duration with acquisition energy from anaerobic glycolysis and phosphorylated supplies (6). An example of the aerobic exercise is maximal exercise test on a cycle ergometer, beginning with a workload of 100 W for men and 50 W for women, and then adding

30 W increase in power every 2 min until exhaustion, while maintaining 70–90 rotations per minute (7). Aerobic training is accepted as the golden standard prescribed by physicians. However, resistance exercise is superior over aerobic in some effects such as muscular hypertrophy, increase of bone mineral density, improving coordination, reeducating muscles and increasing range of joint motility (8,9). Resistance exercise also affects cardiovascular and metabolic health (10) and can be used as a public health method for prevention of diseases and improvement of health (11). Example of resistance exercise is lifting intensities 70–79 % of the 1 repetition maximum (RM), with time under tension of 6 s and rest between sets of 60 s (12). Even though resistance exercise is not as implemented in medical practice as aerobic exercise is, it bears many advantages. Especially in the recovery of muscle mass and strength after a long time of inactivity. Also, the effect on nervous system and sleep is not to be omitted.

The aim of this review is to provide current knowledge about influence of physical activity on autonomic nervous system and circadian rhythm.

Changes in the Autonomic Nervous System and Sleep Induced by Resistance Training

Resistance exercise can enlarge muscle mass, strength and bone mass. Muscle hypertrophy increases basal metabolic rate which effects energy consumption and body weight (13). Resistance exercise can also influence ANS (12). The ANS receives afferent impulses from other parts of the nervous system and from peripheral receptors. This is widely used in sport by increasing the sympathetic activity while performing mental and physical warm up before training and competition (14). Although there are afferent pathways, major part of the ANS is efferent, which transmits impulses to the periphery and maintains adaptation to dynamically changing demands. Changes

in ANS functions can be acute and chronic. Acute ones are mediated by secretion of neurotransmitters, acetylcholine in ganglia and norepinephrine or acetylcholine at target organ. The underlying processes of chronic changes affects neurons by generating new and remodeling old synapses and changes of glia and microenvironment, including blood supply (15). One of the vital functions of ANS is regulation of blood flow, but this process is reciprocal as the blood flow also has an influence on nervous system function, (16). Autoregulation in skeletal muscles during increased needs causes vasodilatation and therefore decreased amount of blood would be directed to the CNS if there were not any other regulatory mechanisms. The CNS perfusion is important and protected by autoregulation but also by sympathetic regulation of blood distribution in the whole body. This causes reduced splanchnic and skin circulation and increased blood pressure and heart rate during an effort. The result of these changes is adaptation by increased sympathetic and parasympathetic reactivity (17). Autonomic regulation of the heart is provided by thoracic part of sympathetic and cranial part of parasympathetic nervous system. Parasympathetic cranial part placed in the brainstem delivers impulses through the vagal nerve to the atria and sinoatrial (SA) node but especially to atrioventricular (AV) node to regulate heart rate. Vagal tone decreases during ageing and in some diseases, resulting in decrease of heart rate variability, positive prognostic cardiovascular marker explained below (18). Measuring those cardiovascular effects can give valuable information about functional and adaptational ability of the ANS.

Another vital function of ANS is involvement in sleep cycles and phases (19) and therefore it may have an impact on sleeping and related disorders. Researches have shown that both aerobic and resistance exercise training program improved sleep quality and reduced sleep latency, while duration of sleep was the same as in the control group. Therefore, exercise can be an effective method for treating some patients suffering from sleep disorders and decrease in consumption of sleeping medication (20). The key of how exercise affects sleep is complex but may be explained by increased serotonin neurotransmission in diencephalon and cerebrum during increased activity, and a rapid decrease once training has been completed (21). Raphe nuclei contain around 80 % of the brain serotonin and it is believed that its impact is indirect and that it affects the preoptic area of the hypothalamus, therefore modulating sleep regulation by synthesis of hypnogenic factors (22). Since serotonin is made out of tryptophan, in cases of increased serotonin production in the CNS tryptophan must be deployed in greater amounts. This is possible because adrenergic transmission is increased in exercise and it stimulates lipolysis. Faster lipolysis increases serum free fatty acids, which compete with tryptophan for proteins, therefore increasing serum tryptophan levels (23,24). It has also been proven that aerobic exercise can reduce resynchronization time for new light-dark cycles in laboratory animals and maybe it can reduce the time of a jet lag in humans. Animals with the ability to run on the wheel were able to adapt 200 % more rapidly than those who did not have the wheel in their cages (25).

Assessment of Autonomic Nervous System Functions and Circadian Rhythm

The ANS regulation of cardiovascular system can be measured by various maneuvers targeting different reflex mechanisms. Some of them are Valsalva maneuver, deep breathing, isometric handgrip test, cold pressor test, mental arithmetic, orthostatic test, head-up tilt test and baroreflex sensitivity testing (26).

Activity of autonomic functions may also be assessed by measuring circulating catecholamines, noradrenaline spillover rate and other radioisotope techniques (26).

Heart rate variability (HRV) is another, nowadays very popular, test for the ANS evaluation and prognostic factor for cardiovascular diseases. Variability in blood pressure is also assessed in clinical practice (26). HRV is believed to be in correlation with cardiovascular diseases and reduced HRV is connected with poor cardiovascular health (27-29).

Activity of peripheral sympathetic activity can be assumed by measuring production of sweat. Thermoregulatory sweat test, quantitative sudomotor axon reflex test (QSART) and sympathetic skin response (SSR) are used for that purpose. Sudoscan in particular is SSR test that can be used in various neuropathies (30). Another method for the assessment of peripheral ANS is microneurography, which records sympathetic nerve activity with microelectrodes inserted into the subcutaneous nerves (26).

Widely used method for assessment of ANS is the Composite Autonomic Symptom Score (COMPASS 31) (31) - valuable self-assessment instrument for the detection of dysautonomia in patients (32).

The simplest methods used for assessment of circadian rhythm are noninvasive methods such as questionnaires and actigraphy. The dim light melatonin onset (DLMO) is considered the most precise method of circadian timing in humans and it has showed significant correlation with the Morningness-Eveningness Questionnaire (MEQ) and the Munich ChronoType Questionnaire (MCTQ) (33). Other questionnaires such as The Epworth Sleepiness Scale (ESS) and the Pittsburgh Sleep Quality Index (PSQI) evaluate daytime sleepiness and sleep quality, respectively and they should be used together (34).

Another valuable diagnostic procedure is polysomnography which measures various physiologic parameters during sleep and use software to process information. Electroencephalogram, electro-oculogram, chin muscle activity, thoracic and abdominal excursion, nasal airway pressure and thermistery, body position, electrocardiogram and oxygen saturation are measured. By the usage of all these measurements we can recognize two different phases: rapid eye movement (REM) and non-REM phase (35,36).

Hormone oscillations are in compliance with circadian rhythm so measuring concentration of hormones lead us to typical peaks during daily cycle. Melatonin concentration in saliva (37), serum and even ascetic fluid indicates rhythm of secretion (38). That is important because melatonin is used as a drug for sleep inducement and shows antioxidant effects (39).

While conducting all of the tests above it is very important to standardize them so that they are comparable between the laboratories. It is also to be noted that age, sex, body position, and even diet may have significant influence on the test results (26).

Clinical Manifestations

Blood flow

Cardiovascular diseases are number one cause of death worldwide, with 31 % of all deaths by taking 17.7 million lives every year. Predisposing factors are raised blood pressure, elevated blood glucose and lipids and obesity caused by tobacco use, unhealthy diet, physical inactivity and the harmful use of alcohol. That is the reason why huge resources are invested in prevention of cardiovascular diseases, in first line heart attacks and strokes (40). Some of the biggest clinical studies are made with cardiovascular patients, such as Framingham heart study (41). There has been a huge breakthrough in the cardiac disease treatment, but the key point in reduction of fatal events, such as sudden cardiac death, is prevention. One of the noninvasive methods for the assessment of autonomic nervous system and the predictor of heart disease is heart rate variability. It is used as an independent factor of prediction in post-infarction period and even in the healthy population. Heart rate variability (HRV) is difference of duration of time between two following heart beats, difference between RR intervals in particular (42). Researches have shown that trained athletes have heart rate that is more variable and responsive to exertion than the average population. One of them implies that frequent aerobic exercise has beneficial effect on cardiovascular health (43). Other says that cardiorespiratory fitness (CRF), „the ability of the circulatory and respiratory systems to supply oxygen to skeletal muscles during sustained physical activity”, is valuable independent diagnostic predictor of cardiovascular mortality. Not only that, but it can also improve insulin sensitivity, blood lipids, blood pressure, inflammation and body composition (44). In consideration of the facts above, it is clear that exercise has many beneficial effects on cardiovascular and entire health. In fact, physical activity volume has been negatively correlated to the all-cause mortality (45). One of the commonly used drugs in the whole medical practice are beta-adrenergic receptor blockers and their effect is a decrease in the sympathetic output to the heart. Beta-adrenergic receptor blockers and high-intensity interval exercise induced increase of vagal tone have synergistic effect in reducing heart rate (46). Therefore, one could notice that frequent exercise can reduce the number of drugs prescribed for various conditions. We believe that various

types of exercise and their beneficial effects should be investigated in the future because of the promising results from the studies to this day.

Sleep

Sleep disorders are classified in several groups: insomnias, sleep-related breathing disorders, hypersomnias of central origin, circadian rhythm sleep disorders, parasomnias and sleep-related movement disorders (47). Although not as fatal as cardiovascular diseases, sleep disorders are highly represented in population and it is evident that they are much more common than previously thought. Studies have shown that around 30 % of population will suffer from some form of insomnia during its life course and it is estimated that 2 % of women and 4 % of men have minimal diagnostic criteria for obstructive sleep apnea syndrome (48). Consequently, the prevalence is high, taken into account that there are many other sleep disorders beside these two (49). Not only that sleep disorders affect daytime function but they can contribute to increased mortality in certain situations. It has been estimated that 10-15 % of fatal traffic crashes happen due to sleepiness (50). Although the mechanism how sleep disorders impact other diseases is not fully explained, it is proven that less than six and more than ten hours sleep time increases the prevalence of hypertension, diabetes and obesity (51). Research has shown that participants who are overweight or obese have poorer sleep quality than those of leaner body composition (52). There is also some evidence that sleep time shorter than 7 and longer than 8 hours contributes to cardiovascular diseases such as coronary heart disease and stroke (53). There are some researches on how aerobic exercise can cause phase-shifts in circadian rhythms (54,55). One research has shown difference in circadian rhythm and function of the ANS as a result of morning or evening aerobic exercise. Morning exercise increased the parasympathetic activity, as indicated by HRV, and did not influence the other parameters. Evening exercise increased heart rate during the sleep, delayed the falling phase of melatonin, attenuated the nocturnal decline of rectal temperature and affected stages of sleep measured by polysomnogram, which all lead to delayed phase shift of circadian rhythm (56). Nutrition also affects sleep and researchers have concluded that high-proteins, low-fat diet, proper caloric intake and tryptophan improve sleep quality and total sleep time (57).

Conclusion

Although there are many papers on how aerobic exercise modulates ANS response and sleep, so as on how resistance exercise effects muscle response, the evidence on how resistance training effects ANS and sleep are scarce. We believe that resistance exercise, in particular, has significant influence on ANS and circadian rhythm. Even though the mechanisms and effects are not fully explained, we hope that further researches are to be

conducted to make resistance exercise usable in medical practice for the prevention and treatment of various sleep and cardiovascular disorders.

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