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Effect of physiotherapy on Autonomic Nervous System

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Abstract: The autonomic nervous system (ANS) plays a crucial role in regulating involuntary bodily functions, encompassing aspects such as heart rate, blood pressure, and digestion. It comprises the sympathetic, parasympathetic, and enteric nervous systems. Understanding the impact of different therapeutic approaches, like physiotherapy and exercise, on the ANS is vital for optimizing treatment interventions.

The ANS, an integral part of the peripheral nervous system, governs functions vital for sustaining life, such as maintaining blood pressure and digestive processes. It responds to various stimuli, with the sympathetic system facilitating the "fight or flight" response and the parasympathetic system promoting relaxation and digestion. The complexities of ANS modulation through exercises and therapeutic interventions necessitate deeper exploration.

The analysis integrates findings from multiple studies exploring the effects of different physical therapy approaches on the ANS. These studies investigated interventions like manual therapy, exercise, massage, heat application, and dry needling, providing insights into their impacts on sympathetic and parasympathetic activity. Studies revealed varied responses of the ANS to therapeutic interventions. Physiotherapy, including joint mobilization and exercise, demonstrated a positive influence by enhancing parasympathetic activity while reducing subjective pain perception. Similarly, massage and heat application exhibited a decrease in sympathetic activity, as indicated by changes in serum cortisol and norepinephrine levels. However, certain interventions, such as dry needling, triggered short-term increases in sympathetic nervous system activity post-treatment.

Physiotherapy interventions, including exercise and manual therapy, show promise in modulating the ANS positively. They bolster parasympathetic activity and alleviate subjective pain perception. However, understanding the intricacies of these effects requires further investigation to elucidate optimal intervention methods and comprehend the full spectrum of their impact on the ANS. Continued research efforts will refine these interventions, optimizing their efficacy in influencing the autonomic nervous system for therapeutic benefits.

Keywords: *Autonomic nervous system, Physiotherapy, Exercise, Manual therapy, Massage, Heat application, Sympathetic nervous system, Parasympathetic nervous system, Intervention effects, ANS modulation.*

I WHAT'S AN AUTONOMIC NERVOUS SYSTEM?

The nervous system is divided into two main parts: the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS consists of the brain and spinal cord, while the PNS consists of nerves that run throughout the body. The PNS is further divided into two subdivisions: the somatic nervous system and the autonomic nervous system (ANS)

The PNS regulates the body’s unconscious actions, which can be summarized as the “rest and digest” response, as these return the body functions back to normal: blood pressure lowers, heart rate slows down, intestinal and gland activity increases, sphincter muscles in the gastrointestinal tract relax,

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etc. The structures in which the parasympathetic preganglionic neurons can be found are the sacral spinal cord and the brainstem. The parasympathetic nuclei of the glossopharyngeal, oculomotor, vagus and facial nerves and the cardiac preganglionic neurons are located in the nucleus ambiguus. The primary parasympathetic neurotransmitter is acetylcholine (Ach), which has been shown to regulate various processes such as arousal, learning and memory, cognition and modulation of sensory information. The cholinergic receptors can be divided into two types, nicotinic (nAChRs), which are ion channels, or G protein-coupled muscarinic receptors (mAChRs). Neuronal nicotinic receptors are located at pre- and/ or postsynaptic sites in many cortical areas. The α7 nAChR subtype is highly expressed in regions of the brain involved in learning and memory, such as the hippocampus and the neocortex. [11]

The ANS is responsible for regulating involuntary body functions, such as breathing and heart rate. It carries signals from internal organs to the CNS and from the CNS to internal organs. The ANS is further divided into three branches: the sympathetic nervous system, the parasympathetic nervous system, and the enteric nervous system[8].

The sympathetic nervous system is responsible for the "fight or flight" response, which prepares the body for action in response to stress or danger. It increases heart rate, dilates pupils, and diverts blood flow away from the digestive system and towards the muscles[7]. Preganglionic and postganglionic sympathetic neurons facilitate communication between the SNS and the peripheral organs. The point at which the axon of the preganglionic neuron connects with the postganglionic neuron is also the place where the cell body of the preganglionic neuron can be found, between the segments of the first thoracic and third lumbar spinal cord. Subsequently, the postganglionic neuron axon reaches the target organ. [11]

Norepinephrine (NE), epinephrine (E) and dopamine (DA) are neurotransmitters. In response to a stimulus, most sympathetic postganglionic neurons release NE, which activates the adrenergic receptors (ARs) located on the target organ. The ARs family includes three β (β1, β2, β3), three α1 (α1A, α1B, α1D) and three α2 (α2A, α2B, α2C) receptor subtypes [12]. The sympathetic endings of sweat glands and the arterioles of somatic muscles are cholinergic. Matsukawa et al. published the results of a study conducted on animals showing that hypothalamic stimulation produces the vasodilatation of small arteries (with an internal diameter of 50–500 µm) in skeletal muscle [13]. This vasodilation is thought to be the result of a neural mechanism through sympathetic cholinergic nerves. NE adapts physiological processes like mood, arousal, learning and memory, blood flow and metabolism. DA plays a variety of roles in humans and is involved in movement, memory, behavior, cognition, pleasure, sleep and personality. Monoamine deficiency influences anxiety disorders, depression, drug addictions, bipolar disorders and Parkinson's disease, while excess monoamine is noticed in schizophrenia. [11]

The parasympathetic nervous system, on the other hand, is responsible for the "rest and digest" response, which promotes relaxation and digestion. It slows heart rate, constricts pupils, and increases blood flow to the digestive system[7].

The enteric nervous system is sometimes considered a separate branch of the ANS, but it can also function independently. It is responsible for regulating the digestive system and contains over 100 million neurons[9].

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Overall, the ANS is responsible for regulating many of the body's internal processes, including heart rate, blood pressure, digestion, and sexual arousal. It is always active, even when we are asleep, and is key to our continued survival[8].

In addition to the ANS, the nervous system also includes the somatic nervous system, which is associated with voluntary movement and carries signals from the CNS to skeletal muscles. The nervous system also includes the enteric nervous system, which is responsible for regulating the digestive system[9].

In summary, the nervous system is divided into the CNS and PNS, with the PNS further divided into the somatic nervous system and the ANS. The ANS is responsible for regulating involuntary body functions and is further divided into the sympathetic, parasympathetic, and enteric nervous systems. The sympathetic nervous system prepares the body for action in response to stress or danger, while the parasympathetic nervous system promotes relaxation and digestion. The enteric nervous system is responsible for regulating the digestive system.

II BIOLOGICAL MECHANISMS THROUGH WHICH EXERCISE IMPACTS THE ANS

The autonomic nervous system is vital in regulating the cardiovascular response during exercise in both animals and humans. Oxygen uptake during exercise relies on heart rate, stroke volume, and oxygen difference. Factors determining maximal oxygen uptake include heart rate, stroke volume, and oxygen difference. The body's response during exercise involves "central command" and "exercise pressor reflex," impacting cardiovascular response and arterial baroreflex resetting. Patients with autonomic disorders often exhibit lower V˙O2max levels, indicating reduced fitness. Chronic exercise training exhibits protective effects on the autonomic nervous system, improving vascular function, insulin resistance, and mental health. Recommendations suggest at least 30 minutes of moderate-intensity exercise five days a week, with supervised training being beneficial, especially for those with autonomic disorders. [10]

Regular physical exercise stands as a pivotal element in preventing numerous chronic illnesses. It serves as a primary non-pharmacological tool, enhancing antioxidant capacity, minimizing oxidative stress and inflammation, and boosting energy efficiency. The biochemical and physiological responses induced by exercise depend on its volume, intensity, and frequency. Typically, exercise intensity is gauged as a percentage of an individual's maximum oxygen uptake (VO2max), representing the peak aerobic capacity. The concept of metabolic equivalent (MET) quantifies oxygen consumption at rest, signifying an individual's functional capacity or tolerance during specific exercises. Classifying exercise using VO2max and MET designates it as light, moderate, vigorous/intense, or maximal/dangerous. Effort types are categorized based on contraction (isotonic, isometric, isokinetic) and oxygen supply (aerobic, anaerobic, mixed). While physical activity's beneficial impacts are well-researched, its potential negative effects, influenced by the type, duration, and individual characteristics of the exerting person, are less explored. These negative effects seem associated with oxidative stress and inflammation provoked by exercise, evidenced by an increase in oxidants and a decrease in antioxidants. Age, considering the declining levels of antioxidants, significantly influences the body's response to oxidative stress. [11]

Exercise prompts heightened respiration and oxygen uptake targeting the body's essential organs. Elevated

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energy demands escalate oxygen consumption, resulting in increased reactive oxygen and nitrogen species, fostering oxidative stress within vital organs. Cells counter this stress using antioxidants. These antioxidants fall into two categories: endogenous antioxidants (like glutathione, vitamins C, A, and E, uric acid, and iron-binding proteins) and antioxidant enzymes (AOE) such as superoxide dismutase, CAT, and glutathione peroxidase. AOE activity fluctuates with alterations in oxygen consumption, indicative of oxidative stress within the body. The systemic antioxidant levels during exercise hinge on its type, mode, intensity, frequency, and duration. Exercise augments blood flow to vital organs and muscles but reduces it to the liver, affecting antioxidant levels. This flux also impacts glutathione's intra and extracellular transport, as well as its synthesis and degradation. Consequently, the effectiveness of antioxidant systems differs after acute exercise and exercise training. [14]

Liu, W. L. Et. Al. (2022) in his narrative review concluded exercise profoundly influences the autonomic nervous system (ANS). It triggers increased respiration and oxygen uptake directed toward vital organs, elevating energy demands and consequently escalating levels of reactive oxygen species. This oxidative stress prompts cellular defense mechanisms utilizing antioxidants. Exercise impacts antioxidant levels systemically, affected by exercise type, mode, intensity, frequency, and duration. Blood flow alterations during exercise affect organ-specific antioxidant levels, influencing the intra and extracellular transport, synthesis, and degradation of key antioxidants like glutathione. As a result, the efficacy of antioxidant systems post-exercise, both acute and with training, varies significantly. [15]

III DIFFERENT TYPES OF EXERCISES AND THEIR SPECIFIC IMPACTS ON THE ANS

1. Polyvagal Exercises

The Polyvagal theory, proposed by Porges, suggests that the vagus nerve plays a significant role in regulating the autonomic nervous system and impacting emotional states, stress responses, and social engagement. Engaging in activities that stimulate the vagus nerve, such as specific exercises, might encourage relaxation, decrease anxiety, and improve emotional control. These activities activate the parasympathetic nervous system, increasing vagal tone while decreasing sympathetic activity. This change may lead to reduced pain and improved well-being. Additionally, vagal stimulation has anti-inflammatory effects, regulating immune responses and potentially easing inflammation in arthritic joints, contributing to pain relief. Furthermore, by influencing central pain mechanisms and neural pathways, Vagus Nerve Stimulation (VNS) can modify how pain is perceived and processed, potentially enhancing pain relief. [18]

2. Aerobic Exercise

Park, H. Y. Et. Al. (2020) explored the impact of a 12-week aerobic exercise intervention performed at the lactate threshold (LT) in women with obesity. Participants undergoing exercise training at a heart rate corresponding to the LT showed significant improvements in various aspects compared to the control group. These improvements encompassed body composition, aerobic performance, and autonomic nervous system (ANS) function. Specifically, the exercise group exhibited enhancements in body weight, body mass index, body fat percentage, fat-free mass, as well as improvements in aerobic performance indicators such as oxygen consumption and treadmill/bicycle performance at HR_LT. Additionally, ANS function parameters like mean RR interval, standard deviation of NN intervals, root mean square of successive

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differences, total power, high frequency, and low frequency/high frequency ratio demonstrated positive changes. Therefore, engaging in aerobic exercise at the lactate threshold appears to be a feasible and effective approach for improving body composition, aerobic performance, and ANS function in women with obesity.

Borghi-Silva, A. Et. Al. (2009) observed markedly higher sympathetic activity at rest in COPD patients compared to normal HRV values, attributing this autonomic disorder to factors such as hypoxemia and disease severity. Supplemental oxygen and aerobic exercise training showed potential in reversing autonomic nervous system dysfunction. Aerobic exercise training notably improved HRV, reducing sympathetic activity and enhancing parasympathetic activity at rest and during exercise. The study suggests that these positive adaptations might stem from mechanisms involving reduced anxiety, altered ventilatory mechanics, muscle adaptations, and improved lung inflation reflexes. Overall, the 6-week aerobic exercise training program significantly improved exercise tolerance, ventilatory patterns, and autonomic modulation of heart rate in COPD patients, signifying its positive impact. [20]

3. Resistance Exercise

Kelley, G. A. Et. Al. (2000). Progressive resistance exercise and resting blood pressure: a meta-analysis of randomized controlled trials. Hypertension, 35(3), 838-843. concluded that progressive resistance exercise is efficacious for reducing resting systolic and diastolic blood pressure in adults

Kingsley et. Al. (2016). Acute and training effects of resistance exercise on heart rate variability. Clinical physiology and functional imaging, 36(3), 179-187. HR recovery after exercise is influenced by parasympathetic reactivation and sympathetic recovery to resting levels. Therefore, examination of HRV in response to acute exercise yields valuable insight into autonomic cardiovascular modulation and possible underlying risk for disease. Acute resistance exercise has shown to decrease cardiac parasympathetic modulation more than aerobic exercise in young healthy adults suggesting an increased risk for cardiovascular dysfunction after resistance exercise. Resistance exercise training appears to have no effect on resting HRV in healthy young adults, while it may improve parasympathetic modulation in middle-aged adults with autonomic dysfunction. Acute resistance exercise appears to decrease parasympathetic activity regardless of age.

IV EFFECT OF VARIOUS PHYSICAL THERAPY APPROACHES ON ANS

1. Mobilization & Manual Therapy

A study conducted on male patients with non-specific subacute low back pain found that physiotherapy treatment produced an increase in parasympathetic nervous system activation and a decrease in subjective pain perception[1][2]. The study involved a 50-minute session consisting of manual therapy based on joint mobilization and soft tissue techniques in the lumbo-pelvic area, a stretching program, and motor control exercises of the core muscles. The autonomic modification of participants was assessed before and after the physiotherapy treatment[2].

Farrell, et. Al. (2023) revealed that applying manual therapy to specific areas of the cervical spine can distinctly impact the stress response. After thirty minutes of lower cervical mobilization, there was a notable decrease in cortisol concentration within the same group. Furthermore, there existed a significant difference in cortisol levels between groups following upper and lower cervical mobilization after 30 minutes. [16]

2. Thermal Therapy & Massage

Lee et. al. (2011) conducted a study to investigate the influence of massage and heat on the autonomic nervous system (ANS). They observed a notable reduction in sympathetic activity following 2 weeks

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of heat and massage application, evidenced by decreased serum cortisol levels. Additionally, after 4 weeks, there was a significant decrease in serum norepinephrine levels, indicating an overall down regulation of sympathetic activity. Analysis of heart rate variability (HRV) demonstrated increased TP and standard deviation, primarily mediated by the sympathetic nervous system. However, specific autonomic nerve conduction measures, such as increased latency at 2 and 4 weeks and decreased amplitude at 4 weeks, also suggested reduced stress response. Notably, a minority of participants (7.2%) reported temporary increases in low back pain, potentially attributed to factors like tissue damage from heat and massage or pre-existing discomfort in the lower back. Overall, this study supports the notion that massage and heat have a discernible impact on the autonomic nervous system, as indicated by changes in sympathetic activity and related markers.

3. Dry Needling

Another study found that dry needling resulted in a significant increase in activity of the sympathetic nervous system for up to 30 minutes after the treatment. They provided evidence that dry needling results in a significant increased activity of the sympathetic nervous system for up to 18 minutes. Between 18 and 21 minutes autonomic activity returned to a non-significant difference compared to baseline [5].

V RESULTS BASED ON PATIENT HEALTH STATUS

Hautala, A. J. Et. Al. (2009). provides an overview of the evidence regarding the role of ANS activity concerning acute and chronic aerobic exercise, specifically focusing on human heterogeneity in response to aerobic training interventions related to VO2max or VO2peak. The authors showed that good aerobic fitness and regular aerobic training are associated with increased cardiac vagal modulation of HR. Additionally, it was demonstrated that ANS functioning plays a pivotal role in determining an individual's response to aerobic training among healthy subjects. High vagal modulation at the baseline is linked to a greater improvement in VO2peak compared to individuals with less pronounced vagal modulation. Moreover, the study indicated that monitoring ANS status daily during endurance training effectively enhances aerobic fitness. In cases where reduced vagal modulation of HR occurs, a lower-intensity training stimulus proves beneficial in achieving a favorable response in aerobic training. [19]

VI CONCLUSION

In summary, the application of physiotherapy treatment has emerged as a significant influencer of the autonomic nervous system (ANS). The ANS, a vital part of the peripheral nervous system, governs involuntary bodily functions crucial for regulating various physiological processes like blood pressure, digestion, and temperature control throughout life. It plays a pivotal role in the body's response to exercise, showcasing distinct reactions to different exercise types that warrant in-depth exploration.

From existing evidence, it's evident that physiotherapy treatment yields a positive impact on the ANS, notably augmenting parasympathetic nervous system activation while simultaneously reducing subjective pain perception. However, a more comprehensive understanding of the intricate effects of physiotherapy on the ANS demands further investigation.

The complexities and variations in how different exercises influence the ANS underline the necessity for more detailed comparative studies. While acknowledging the observed positive outcomes of physiotherapy on the ANS, continued research efforts

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are imperative for uncovering the full spectrum of effects, potential nuances, and optimal application methods. This deeper understanding will contribute to refining physiotherapy interventions for maximizing their beneficial impact on the autonomic nervous system.

VII LIMITATIONS & FUTURE SCOPE

The study faces certain limitations and opportunities for future exploration:

1. Physiotherapy's impact on various ANS aspects is understood, but a direct comparison between different physiotherapeutic interventions for their ANS effects is lacking, warranting further investigation.

2. Comparing the effects of physiotherapy interventions with other pharmacological treatments could provide a clearer understanding of their relative efficacy on ANS modulation.

3. There's a need for more comprehensive research into the specific effects of different types of exercises on the autonomic nervous system to unveil their distinct impacts.

4. Limited data inclusion from databases like Google Scholar, PubMed, and Sci-Hub suggests a potential for broader and more exhaustive data searches across various sources to enrich the understanding of the subject.

5. Future studies focusing on dissecting outcomes based on patient demographics, such as age, gender, and health status, could provide more intricate and detailed insights into how these factors influence the effects of physiotherapy on the autonomic nervous system.

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