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MODULATORY EFFECTS OF AEROBIC EXERCISE ON THE AUTONOMIC NERVOUS SYSTEM IN HEALTHY SUBJECTS: A REVIEW

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Abstract: Physical exercise is a practice of the physical activity programmed, periodized and timed. Thus, it can be subdivided into 2 specific types of practice, anaerobic and aerobic exercises. Resistance or aerobic exercises are the most practiced and easily accessible to the population. In this sense, the regular practice of exercise is capable of promoting modulations in several systems such as the autonomic system, in which sympathetic and parasympathetic reflexes are essential for homeostatic control. Thus, the objective of this study was to, through a review, investigate the modulatory effects of aerobic exercise on the autonomic nervous system in healthy people. To carry out this work, articles were searched in the PUBMED database, with the descriptors "autonomic nervous system " and “aerobic exercise". We found 193 articles in the first search with the descriptors, but 9 articles were selected for this review. In this context, physical exercise produces modulatory effects on the post-exercise heart rate recovery time and modulates the levels of catecholamines that act on this autonomic system. Further investigations with a greater variety of physical exercises should be carried out, for future understanding of the modulatory effects in healthy individuals.

Keywords: Autonomic Nervous System; Physical Exercise; Modulation.

Efeitos modulatórios do exercício aeróbico sobre sistema nervoso autônomo em sujeitos saudáveis: uma revisão

Resumo: O exercício físico é a prática regular de atividade física programada, periódica e cronometrada. Portanto, pode ser dividida em dois tipos específicos de prática, exercícios anaeróbicos e aeróbicos. Exercícios de resistência ou aeróbicos são os mais praticados e acessíveis à população. Então, a prática regular de atividade física é capaz de modular diferentes sistemas, como o sistema autônomo, o qual os reflexos simpáticos e parassimpáticos são essenciais para controle homeostático. Então, o objetivo deste estudo foi, por meio de uma revisão, investigar os efeitos modulatórios do exercício aeróbico sobre sistema nervoso autônomo em sujeitos saudáveis. Para o desenvolvimento, os artigos foram buscados no PUBMED, com seguintes descritores “sistema nervoso autônomo” e “exercício aeróbico”. Foram encontrados 193 artigos na busca, porém apenas 9 foram selecionados para esta revisão. Neste contexto, o exercício físico produz efeitos modulatórios como tempo de recuperação da frequência cardíaca pós-exercício e modula níveis de catecolaminas que atuam no sistema autônomo. Novos estudos com maior variedade de exercícios físicos devem ser realizados para futura compreensão dos efeitos modulatórios em indivíduos saudáveis.

Palavras-chave: sistema nervoso autônomo; exercício físico; modulação.

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1 INTRODUCTION

The physical exercise is a subtype of physical activity, characterized for being programmed, scheduled and timed activity. Currently, two types of physical exercise are known as aerobic and anaerobic exercise (Sousa et al., 2021). Thus, anaerobic exercises are classified as short duration (0,3 seconds - 180 seconds) and high intensity exercises that have one or multiple external resistance which may be the body mass of the practitioner of the activity. This is justified by the recruitment of the white fibers, also named as type II or fast contraction (Qaisar et al., 2016). On the other hand, aerobic exercise or resistance exercise has a greater consumption of oxygen and longer duration of activity than resistance exercise, this is because it is responsible for recruiting red fibers also named type I or slow contraction (Garber et al., 2011).

In this context, both exercises would have a good physiological adaptation to the human body, it is well established that physical exercise is capable of reducing several diseases or pathological conditions, for example the cardiovascular diseases (Sousa et al., 2021).

In that condition, it is known that the autonomic nervous system plays a crucial role of the homeostasis like the regulation of blood pressure, by the baroreflex mechanism with the sympathetic stimulation, gastrointestinal responses to food, contraction of the urinary bladder, focusing of the eyes, and thermoregulation are just a few of the many homeostatic functions regulated by this system (Mccorry, 2007) . Therefore, the autonomic nervous system also can be influenced by physical exercise. The autonomic nervous system may be involved in many mechanisms like heartbeat (Perini; Veicsteinas, 2003) which can be seen in an electrocardiogram, and other mechanisms (Billeci et al. 2019).

Although the mechanisms that can be altered by inhibition or stimulation of the autonomic are known, it is important to discover the modulatory effects that aerobic physical exercise has on the autonomic nervous system. However, the aim of this study is, through a narrative review, to investigate the modulatory effects of aerobic exercise on the autonomic nervous system in healthy people.

2 METHODS

This study is a review, where articles with the descriptors "autonomic nervous system" and “aerobic exercise” were searched on the PUBMED website on May 21st, 2022. The inclusion criteria for this review were clinical trials that aimed to observe the modulatory effects of physical exercise combined or not with other therapies including only healthy subjects, and English language, since we assume that there is a greater variety of results on the topic, between 2017 and 2022. The exclusion criteria were articles that did not meet the inclusion criteria.

3 RESULTS

The results of the search of this study were described on the TABLE 1. In the first moment of this study, we found 193 articles just the descriptors, 171 articles were excluded due to inadequacy of the objective of this review. In the second moment of this study, we read the titles of the articles and found 22 articles, of which 5 were excluded because the summary did not meet the objective. In the next process we read the abstract of the 17 articles and we observed that 2 were not in line with the main idea of this study. In the last step, we read 15 articles before, 6 were excluded because they were based on animal models, only 9 articles were selected for this review.

Table 1. Summary of articles included in this review.

Author	Year	Title	Subjects	Intervention	Outcomes
Wong et al.	2017	Cardiac autonomic and blood pressure responses to an acute bout of kettlebell exercise	17 healthy subjects (age=23±1 years) (10 male and 7 female)	Kettlebell (KB) training or nonexercise control trial in randomized order	Our findings indicate that KB exercise increases sympathovagal balance for 30 minutes post intervention, which is concurrent with an important hypotensive effect.
da Silva et al.	2017	Endurance running training individually-guided by hrv in untrained women	36 untrained women aged between 18-35 years	HRV-guided training group (HRVG) and a control group (CG). The CG followed a predefined program, alternating moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT).	In this study, it shows that exercise intensity is the determining factor for autonomic modulations. Since treadmill exercise provides greater modulation of reflex response compared to exercise by bikes in the same time interval. And Velocity peak only improvated in HRVG. This reinforced that intensity of activity is also related to mouth sympathovagal modulation.
Kliszczewicz et al.	2018	Autonomic response to a short and long bout of high-intensity functional training	10 healthy males (28.1 ± 5.4 yrs)	two HIFT sessions (<5-minute and 15-minute) in a crossover fashion	This study showed the release of epinephrine and noradrenaline, with biochemistry markers, the time of sympathetic stimulus remains 2 hours after the activity with high intensity. It demonstrates with the HIFT sessions that it is a good exercise for autonomic nervous system modulation.
O'Driscoll et al.	2018	Cardiac autonomic and left ventricular mechanics following high intensity interval	40 physically inactive and highly sedentary men(age 21± 1.7 years)	two weeks of HIIT and control period. The HIIT protocol consisted of 3 × 30-s maximal cycle ergometer sprints against a resistance of 7.5% body weight, interspersed with 2 min of active recovery.	This study demonstrates that a 2-wk HIIT intervention provides significant improvements in cardiac autonomic modulation and myocardial function and mechanics in a large cohort of young physically inactive and highly sedentary individuals.

Michael et al.	2018	Influence of exercise modality on cardiac parasympathetic and sympathetic indices during post-exercise recovery	13 males (age 26.4±4.7years)	performed maximal arm-cranking (MAX-ARM) and leg-cycling (MAX-LEG). Subsequently, participants undertook separate 8-min bouts of submaximal HR-matched exercise of each mode (ARM and LEG).	Compared with submaximal lower-body exercise, HR-matched upper-body exercise elicited a similar recovery of HR and HRV indices of parasympathetic reactivation, but delayed recovery of PEP (reflecting sympathetic withdrawal).
Crawford et al.	2019	Heart rate variability mediates motivation and fatigue throughout a high-intensity exercise program.	55 healthy men and women (ages 19-35 years)	smartphone application to monitor daily HRV status throughout a 6-week high-intensity exercise intervention.	In this article the participants reported an exercise state motivation and fatigue decrease before each exercise session. Temporary shifts toward increased parasympathetic reactivation resulted in significant increases in daily fatigue and decreases in motivation to exercise . Through modulation of exercise volume, in response to these temporary shifts in HRV, these effects were reversed via increased parasympathetic withdrawal. For the first time, these data demonstrate a mediating effect of HRV on adherence-related trait states throughout a high-intensity exercise program.
Rodrigues et al.	2019	Effects of different periodization strategies of combined aerobic and strength training on heart rate variability in older women	54 physically active older women (61.6 ± 6.3 years)	All the subjects performed 12 weeks of training, 3 times per week, with the sessions divided into aerobic (bicycle or treadmill) and strength exercises.	The RMSSD increased in the NLP and LF/HF ratio increased in the FNLP during the rest period. There were no differences during the exercise test and recovery after test for LF, HF, LF/HF, or RMSSD. In active women, nonlinear periodization strategies of CT improved one of the cardiovascular health outcomes because HRV is a direct predictor of cardiovascular risk.
Burma et al.	2020	Effects of high-intensity intervals and moderate-intensity exercise on baroreceptor sensitivity and heart rate variability during recovery	9 subjects(seven male and two female) with an average age of 26 ± 5 years	moderate-intensity continuous exercise (MICE; 45 min at 50% heart rate reserve), high-intensity interval exercise (HIIE; 25 min including ten 1-min intervals at 85% heart rate reserve), and control (30 min quiet rest).	The current findings demonstrate measures return to baseline at ~60 min after exercise. Moreover, these metrics demonstrated high levels of within- and between-day reliability. Previously, a 12-h minimum restriction from exercise was required before participation in HRV/BRS studies. Recovery from moderate-intensity exercise for HRV and BRS metrics was <60 min; whereas, high-intensity intervals led to alterations for approximately 60 min. Spontaneous HRV and cardiac BRS demonstrated high levels of within-day reproducibility.
Facioli et al.	2021	Study of heart rate recovery and cardiovascular autonomic	60 men aged between 18 and 45	cardiopulmonary exercise test	However, we did not find differences in cardiovascular autonomic modulation parameters and BRS in relation to

		modulation in healthy participants after submaximal exercise	years		cardiorespiratory fitness neither before nor after the cardiopulmonary test.

BRS: Cardiac Baroreceptor Sensitivity; CG: Control Group; CT: Combined Training; FNLP:Flexible Nonlinear Periodized; HF: High-Frequency;HRGV: HRV Guided Training Group; HIFT: High-Intensity Functional Training; HIIE: High-Intensity Interval Exercise; HIIT: High-Intensity Interval Training; HR: Heart Race; HRV: Heart Rate Variability; HR: Heart Race;KB: Kettlebell; LF: Low-Frequency; MAX-ARM: Maximal Arm-Cranking; MAX- LEG: Leg-Cycling; MICE: Moderate-Intensity Continuous Exercise; MICT: Moderate-Intensity Continuous Training; NLP: Non Linear Periodized; PEP: Pre-Ejection Period; RMSSD: Root Mean Square Successive Difference of RR Intervals.

4 DISCUSSION

The main findings of this study were that aerobic physical exercise is able to modulate baroreflex conditions and heart rate, also in the structure of the heart, increasing the wall of the left ventricle, thus improving cardiovascular health. In this sense, exercise is one therapeutic alternative for modulating the autonomic nervous system, since its modulation promotes changes mainly in cardiovascular health. In addition, the autonomic nervous system plays the complex and crucial maintenance of the homeostasis, this system works without the voluntary control (Mccorry, 2007).

These studies show that the exercise session produced an decrease in sympathetic functions. We have found articles that related aerobic exercise intervention, for example Wong et al. (2017) showed that there was a significant increase in heart size and the indicators of sympathetic activity (nFL), the sympathovagal balance (nFL/hFL) for 30 minutes after 12 weeks of the kettlebell sessions while in the control group, there were also significant increase makers vagal tone (RMMSD/nHF), as well reduction in systolic and diastolic pressure (Michael et al., 2018).

These findings are These data are in accordance with the Michael et al. (2018) that showed the heart rate peak, a predictor of cardiovascular health, in men, was higher in practitioners of maximal-intensity cyclic exercise - arms and legs- and the recovery after this peak frequency was lower than baseline, showing the importance of vagal activity for increased parasympathetic stimulation after maximal intensity exercise, generating an improvement in cardiac preload (Crawford et al., 2020). In this context, 6 weeks of high exercise was able to modulate parasympathetic activity, increasing recovery time after high-intensity exercise, through an application, the daily variation of heart rate (Kliszczewicz et al., 2018).

Also, through the analysis of the R-R interval, to measure the heart rate variability (HRV), showed that moderate-intensity continuous exercise and high-intensity interval exercise affects HRV and cardiac cardiac baroreflex or baroreceptor sensitivity during acute recovery. In this context, Kliszczewicz et al. (2018), analyzed in 10 apparently healthy men, through plasma epinephrine and norepinephrine, demonstrated that there was a significant improvement in the time of return of autonomic activity, confirming that the modulatory effects of physical exercise, in this case of high intensity, was able to improve the sympathetic and parasympathetic reflex and guarantee benefits in cardiovascular health (Kliszczewicz et al., 2018). However, in untrained women, Da Silva et al. (2019), in an analysis of heart rate variation during a periodized 5 km running exercise, showing that the exercise decreased the magnitude of the sympathovagal recovery interval (Burma et al., 2020). In addition, Burma et al. (2020) showed that regardless of the stimulus intensity, whether it was high or moderate, the variation in heart rate can return to baseline levels showing that the exercise intensity, from moderate to high, only changes the variation peak and not the return of the baroreflex system since it remained constant (Rodrigues et al., 2019). Currently, in older women, 12 weeks of exercises may be able to result in a difference between the autonomic recovery groups interval, non-periodized and periodized, but in interspersed exercises there was a longer rest time between the heart rate peaks, which improved one of the cardiovascular health outcomes because the heart rate variation is a direct predictor of cardiovascular risk (O'driscoll et al., 2018).

O'Driscoll et al. (2018) when evaluating the combined adaptations of the autonomic nervous system and myocardial functional and mechanical parameters during a High Intensity Interval Training protocol (HIIT), it was found that, in physically inactive men, there was an increase in total spectral power and a decrease in heart rate, thus producing, through from an echocardiographic analysis, an improvement in diastolic function in the left ventricle, with this, they found that there was an improvement in the rate of systolic pressure influenced by high-intensity interval exercise (Mcardle et al., 2004). That is, moderate-to-high-intensity physical exercises were able to attenuate a sympathetic and parasympathetic recovery response, in cardiovascular function, in a shorter heart rate recovery time, thus improving vagal tone and baroreflexes.

Aerobic training causes an imbalance between the tonic mechanisms of sympathetic accelerator neurons, being also a parasympathetic accelerator, which tries to compensate for this imbalance, this occurs in favor of a vagal response. In this situation, aerobic training also reduces the rate of the pacemaker of the sinoatrial (SA) node. These adaptations contribute to physiological bradycardia at rest and during submaximal exercise in highly conditioned endurance athletes or individuals previously sedentary people who train aerobic exercises. Resistance exercise reduces the frequency submaximal heart rate - important to autonomous control - for a standard physical task at 12 beats per minute (bpm) to 15 bpm. These changes in the heart rate increased according to training demand. That is, regular resistance exercise reduces systolic and diastolic pressures during the rest and submaximal activity (Tsuji et al., 1996). In addition, autonomic dysregulation is associated with health problems (Rodrigues et al., 2018).

A considerable factor that can change markers of autonomic modulation are sex and age (Hart; Charkoudian, 2014). This may be associated with biological mechanisms such as hormonal regulation cycles that stimulate autonomic activity, in addition to changes in plasma volume associated with reduced blood pressure and, consequently, reduced heart rate in elderly individuals (Stanley et al., 2013).

The heart beat and its variation can quantify autonomic nervous system regulation, emerging as an important popular tool to access autonomic activity. Nevertheless, note that most articles have an assessment of exercise responses in chronotropic and inotropic markers, requiring new strategies that are more specific, since the functions related to chronotropism and inotropism are associated with several functions (Sunagawa et al., 1998).

5 CONCLUSION

The practice of physical exercise is essential for better benefits in human health. Our findings revealed that it is necessary to standardize protocols to obtain a conclusive effect of physical exercise upon the autonomic nervous system, but our findings suggest that the modulations of the autonomic nervous system are related to the time and practice of physical activity. However, new clinical trials with different training protocols should be carried out for a better understanding of the modulation of this autonomic system in the cardiovascular health of physical exercise practitioners.

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Conflict of interest

Authors have no conflict of interest.

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