



## Effects of exercise on cardiac autonomic modulation in children: literature update

*Efeitos do exercício sobre a modulação autonômica em crianças: atualização de literatura*

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### Abstract

**Introduction:** It is known that physical exercise is beneficial and precipitates adjustments to the autonomic nervous system. However, the effect of exercise on cardiac autonomic modulation in children, despite its importance, is poorly investigated. **Objective:** To bring together current information about the effects of exercise on heart rate variability in healthy and obese children. **Methods:** The literature update was performed through a search for articles in the following databases; PubMed, PEDro, SciELO and Lilacs, using the descriptors “exercise” and “child” in conjunction with the descriptors “autonomic nervous system”, “sympathetic nervous system”, “parasympathetic nervous system” and also with no descriptor, but the key word of this study, “heart rate variability”, from January 2005 to December 2012. **Results:** After removal of items that did not fit the subject of the study, a total of 9 articles were selected, 5 with healthy and 4 with obese

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children. **Conclusion:** The findings suggest that exercise can act in the normalization of existing alterations in the autonomic nervous system of obese children, as well as serve as a preventative factor in healthy children, enabling healthy development of the autonomic nervous system until the child reaches adulthood.

**Keywords:** Physical exercise. Child. Heart rate variability. Autonomic nervous system.

### Resumo

**Introdução:** Sabe-se que a prática de exercícios físicos é benéfica e proporciona adaptações ao sistema nervoso autônomo. No entanto, o efeito do exercício sobre a modulação autonômica cardíaca em crianças, apesar de ser uma condição importante, é pouco investigada. **Objetivo:** Reunir informações atuais a respeito dos efeitos do exercício físico sobre a variabilidade da frequência cardíaca de crianças saudáveis e obesas. **Método:** A atualização da literatura foi realizada por meio de uma busca dos artigos nas bases de dados PubMed, PEDro, Scielo e Lilacs — por meio dos descritores “exercício” e “criança” em cruzamento com os descritores “sistema nervoso autônomo”, “sistema nervoso simpático”, “sistema nervoso parassimpático” e também com o não descritor, mas palavra chave deste estudo, “variabilidade da frequência cardíaca” — publicados no período de janeiro de 2005 a dezembro de 2012. **Resultados:** Após a eliminação dos artigos que não se enquadravam no tema do artigo foi selecionado um total de nove artigos, sendo cinco com crianças saudáveis e quatro com obesas. **Conclusão:** Os achados sugerem que o exercício físico pode atuar na normalização das alterações existentes no sistema nervoso autonômico de crianças obesas, assim como servir como um fator de prevenção em crianças saudáveis, para que ocorra um desenvolvimento saudável do sistema nervoso autonômico até que a criança atinja a idade adulta.

**Palavras-chave:** Exercício físico. Criança. Variabilidade da frequência cardíaca. Sistema nervoso autônomo.

## Introduction

The influence of the autonomic nervous system (ANS) on homeostatic functions of the body has been widely studied. In the heart, the performance of the ANS depends on information from various structures, among them: baroreceptors, chemoreceptors, atrial and ventricular receptors, respiratory system modifications, the vasomotor system, the renin-angiotensin-aldosterone system and the thermoregulatory system (1-3).

One of the tools that has received considerable attention in the study of autonomic action on the heart is heart rate variability (HRV), which describes the oscillations between consecutive heart beats (RR intervals) noninvasively (4-7) and has proven to be a promising measure; potentially informative for both physical and emotional health, being considered a useful prognostic index and used as a marker of morbidity and mortality (8-11).

The wide possibilities for using HRV added to the ease of data acquisition enables its use for the identification of ANS-related phenomena in individuals

of different ages and states of health, as well as making evaluation possible in individuals during rest or exercise (1, 12-17).

Transversal cohort studies carried out in children, young people and adults using HRV for ANS assessment showed that the autonomic modulation of the sinus node changes with growth and maturation (18-20). In addition, children have lower cardiovagal baroreflex sensitivity at rest compared with adolescents and young adults, suggesting that reflex cardiovascular autonomic regulation evolves from childhood to adulthood (18, 21, 22).

Knowledge of this change in HRV from childhood to adulthood enables alterations in the ANS to be studied in order to prevent the onset of major diseases during the development of the individual such as hypertension, diabetes, acute myocardial infarction, obesity, etc. (23-28).

It is known that, in general, high HRV is a sign of good adaptation, featuring a healthy individual with an effective ANS; on the other hand, a reduction in HRV is an indicator of abnormal and inefficient ANS adaptation (1). One method already known to cause

significant adjustments to the functioning of the cardiovascular system and its mechanisms of autonomic adjustment is the practice of physical exercise, which has been identified as an important tool for modification of HRV, indicating that it promotes changes in autonomic modulation (29-31).

Despite existing knowledge about the benefits of physical exercise and ANS adaptations during human development, a search in the literature revealed a paucity of studies that addressed the effect of exercise on the ANS of children. This is an important condition, since the ANS controls some of the internal functions of the body and, in this sense, deserves attention.

Thus, this study aimed to bring together current information about the effects of exercise on HRV in children, in order to insert elements in the literature and contribute to a better understanding in researchers and clinicians who work in this area.

## Method

This literature update was performed in May and June 2013, with articles selected from a search in the databases Medical Literature Analysis and Retrieval System Online (MEDLINE/Pubmed), Physiotherapy Evidence Database (PEDro), Scientific Electronic Library Online (SciELO) and Latin American and Caribbean Health Science Literature (Lilacs), published from January 2005 to December 2012.

To perform the search the following keywords were used, defined on the basis of Descriptors in Health Sciences (DeCS): "exercise" and "child" crossed through the Boolean operator "and" with the descriptors "autonomic nervous system", "sympathetic nervous system", "parasympathetic nervous system" and also with the non-descriptor, but keyword from this study, "heart rate variability"; in the English language the search terms used were based on Medical Subject Headings (MeSH).

All references of the selected studies were also reviewed to complement the search. All search steps were performed by only one evaluator, with the supervision of a senior reviewer.

Studies published in the last eight years, in English, Portuguese and Spanish, with children aged from seven up until 12 years, according to the Statute of Children and Adolescents (32), that analyzed the effects of physical exercise on autonomic modulation using HRV as an instrument, were included.

Cross-sectional studies and randomized and non-randomized clinical trials available free on the internet were included. Studies published in editorial format, letters to the editor, abstracts, dissertations or academic theses were excluded in addition to studies with adolescents and adults.

After the search in the databases, the selection of articles was based on four steps. The first step was the analysis of the titles, taking into consideration the inclusion criteria of the study. The titles were required to present the main idea: analysis of the autonomic nervous system in children, through HRV, during or after exercise. The effects of all types of exercises were analyzed.

After this initial selection, the second step was initiated with a new filtering to exclude duplicate titles, since the search was conducted in more than one database. Subsequently, a detailed reading of the abstracts was performed to ensure that the articles conformed to the main ideas listed above (third step). After excluding abstracts that did not address the theme of the study, the final step was performed, characterized by reading the full articles, and selecting only those which were not excluded due to the criteria of the study.

Data were analyzed qualitatively and tabulated according to the authors and year of the study, population description, objective of the study, protocol carried out, HRV indices evaluated and conclusions found.

## Results

In total, nine articles were selected, which were read in full and composed this review (Tables 1 and 2). Of the nine articles included, five related to apparently healthy children, three to obese children and one comparing eutrophic and obese children.

The sample sizes varied from 10 to 100 individuals in the studies involving only healthy children, and 29 to 103 individuals in the studies involving pathological children. In total, the studies with healthy children included 113 boys and 99 girls; only one of the articles used a control group. In the studies with pathological children, two articles did not cite the division by sex, the participants of the two remaining articles were divided into a total of 165 boys and 34 girls, of these, only one article used a placebo group for vitamin C supplementation

**Table 1** - Characteristics of studies that analyzed the effects of physical exercise on ANS using HRV in healthy children

(To be continued)

Author and year	Study objectives	Study population	Physical exercise performed	Indices evaluated	Conclusion
Gamelin et al., 2009 (35)	To investigate the effects of high intensity intermittent training of short duration on autonomic cardiovascular control.	52 children. - Training group (n = 26; 15 boys and 11 girls; 9.8 ± 0.7 years). - Control group (n = 26; 14 boys and 12 girls; 9.3 ± 1.2 years).	Intermittent exercise for 30 minutes, 3 times per week for 7 weeks. The sessions were composed of short and intermittent running with an intensity of between 100 and 190% of maximal aerobic speed (MAS).	SDNN, rMSSD, LF, HF, SD1 and SD2.	The high-intensity intermittent training improved aerobic conditioning, but did not affect cardiac autonomic regulation in children.
Goulopoulou et al., 2010 (18)	To analyze the differences in the blood pressure response and cardiovascular autonomic modulation during isometric handgrip exercises between children and adults.	- 23 healthy children aged 7 to 9 years. - 23 healthy adults aged 20 to 25 years.	Participants were seated, positioned with the elbow of the dominant upper limb at 90°. A maximal voluntary strength test (MVS) was performed and the best of three attempts used as the value of MVS. After determining the maximum force, the subjects performed a sustained isometric contraction to 30% of MVS for 3 minutes.	SDNN*, rMSSD <sup>x</sup> and HF <sup>x</sup> .	The differences in blood pressure responses of children and adults during an isometric contraction cannot be explained by differences in cardiovascular autonomic modulation and appear to be associated with factors that contribute to the force.
Iwasa et al., 2005 (36)	To investigate the relationship between HRV at night and physical activity in children.	29 children (17 boys and 12 girls; 7.5 ± 1.4 years).	Using a pedometer and multimemory accelerometer, the authors measured the number of steps and the intensity of the exercise performed during the day. These findings were associated with HRV collected during the night (12 p.m. – 5 a.m.).	SDNN*, rMSSD <sup>x</sup> , SDANN, LF, HF <sup>x</sup> , LF/HF and RR50 <sup>x</sup> .	Physical activity increases heart rate during sleep, but reduces the activity of the parasympathetic nervous system during the night, characterized by reduction in the HF and RR50 indices.
Leicht et al., 2008 (37)	To examine the moderate term reproducibility of heart rate and frequency domain indices of HRV at rest and during light to moderate exercise in children.	10 healthy and active children (6 boys and 4 girls, aged 7 to 12 years).	Training for 8 weeks, continuous walking on a treadmill at 3 workloads: 2 km/h at 0% inclination, 50% and 60% of MHR predicted by age. Each work intensity lasted for 10 minutes.	FC, LF (ms <sup>2</sup> /hz), LF* (nu), HF <sup>x</sup> (ms <sup>2</sup> /hz), HF <sup>x</sup> (nu) and LF/HF.	During eight weeks of training with light and moderate exercise, the reproducibility of HRV was considered low, but there were limitations regarding the sample size, and only measures of HRV in the frequency domain were analyzed.

**Table 1** - Characteristics of studies that analyzed the effects of physical exercise on ANS using HRV in healthy children

(Conclusion)

Author and year	Study objectives	Study population	Physical exercise performed	Indices evaluated	Conclusion
Longin et al., 2009 (33)	To introduce a battery of autonomic tests, specifically for children and adolescents, to establish normative parameters of HRV and compare the impact of these autonomic tests.	100 healthy individuals between 6 and 15 years of age (51 girls and 49 boys). - Group of children (5 to 11 years). - Group of adolescents (12 to 15 years).	Sustained manual isometrics for 2 minutes with 30% of the established maximum power.	rMSSD (ms), LF (ms <sup>2</sup> ) and HF (ms <sup>2</sup> ).	The study provides the first normative data for HRV for the battery of autonomic tests specifically for children and adolescents in addition to quantifying autonomic changes induced by the test procedures compared with measurements from the database.

Note: Statistically significant difference between the indices that reflect sympathetic (\*) and parasympathetic (°) autonomic modulation; + statistically significant difference in the duration of exercise.

**Table 2** - Characteristics of studies that analyzed the effects of physical exercise on ANS through HRV in children with disorders of any kind

(To be continued)

Author and year	Study objectives	Study population	Physical exercise realized	Indices evaluated	Conclusion
Lira et al., 2012 (34)	To compare the parameters of cardiac autonomic modulation between obese and eutrophic individuals and to analyze the effect of supplementation with vitamin C on cardiac autonomic modulation in obese children, at rest and during isometric exercise respectively.	8 eutrophic (BMI = 18 ± 1 kg/cm <sup>2</sup> ) and 21 obese (BMI = 29 ± 1 kg/cm <sup>2</sup> ) children, aged 8 to 11 years, both genders, divided into two groups: supplemented with 500 mg of vitamin C (n = 11) and placebo (n = 10) for 45 days.	Isometric handgrip of the dominant limb.	FC (bpm), LF* (un), HF* (un) and LF/HF*.	Obese children present higher sympathetic activity and lower vagal activity at rest and during isometric exercise when compared with eutrophic children. In addition, oral supplementation with vitamin C, in high doses, can restore cardiac autonomic dysfunction in obese children.
Lucini et al., 2013 (38)	To evaluate whether the cardiac baroreflex and autonomic indices are altered in overweight football players.	103 boys of 11.1 ± 1 year, soccer practitioners.	3 weekly training sessions of 1 and-a-half hours composed of resistance exercise at moderate/vigorous intensity and a football match at least 1 hour per week.	LF (ms <sup>2</sup> ), LF (nu), HF (ms <sup>2</sup> ), HF (nu), LF/HF and LF+ (mmHg).	Overweight child soccer players have an altered cardiovascular autonomic profile despite intense aerobic training.

**Table 2** - Characteristics of studies that analyzed the effects of physical exercise on ANS through HRV in children with disorders of any kind

(Conclusion)

Author and year	Study objectives	Study population	Physical exercise realized	Indices evaluated	Conclusion
Nagai et al., 2004 (39)	To investigate cardiac autonomic activity in slim and obese children; focused on different levels of physical activity.	1080 healthy children (576 boys and 504 girls) aged 6 to 12 years. Subsequently 96 children were selected divided into four groups: active slim (23 boys and 1 girl); inactive slim (8 boys and 16 girls); active obese (23 boys and 1 girl); and inactive obese (8 boys and 16 girls).	Physical activity was classified as the frequency of participation in extracurricular activities (active: 3 times a week; inactive: none).	LF*+ (ms <sup>2</sup> ) and HF*+ (ms <sup>2</sup> ).	Obese children exhibited a reduction in sympathetic and parasympathetic modulation compared with slim children who had similar levels of physical activity. This autonomic reduction was related to the amount of body fat in the inactive state. On the other hand, normal physical activity can contribute to improvement in the overall autonomic activity in both slim and obese children.
Prado et al., 2010 (40)	To assess the relationship between heart rate recovery in one minute, ANS activity, cardiorespiratory fitness, and anthropometric variables in obese children undergoing hypocaloric diet in isolation and diet associated with training.	33 children aged 8 to 12 years, BMI > 95th percentile and without participating in an exercise program. They were divided into two groups: hypocaloric diet (n = 15) and hypocaloric diet associated with exercise (n = 18).	Maximum stress test on a treadmill, using a progressive ramp protocol, with minute by minute load progression. The training program consisted of 3 sessions of 60 minutes of training per week over a period of 4 months. Each session was held with a 30 minute walk and/or run on the jogging track followed by 30 minutes of recreational exercises.	FC* (bpm), LF* (nu), LF* (ms <sup>2</sup> ), HF* (nu), HF* (ms <sup>2</sup> ) and LF/HF ratio*.	The hypocaloric diet combined with physical training, in contrast to the hypocaloric diet alone, promoted improvement in heart rate recovery in 1 minute and in the activity of the ANS in obese children.

Note: Statistically significant difference of indices that reflect sympathetic (\*) and parasympathetic (°) autonomic modulation; + statistically significant difference between obese and non-obese; \* statistically significant difference between the type of diet associated with exercise.



Of the articles selected with healthy children; two studied the effects of isometric contraction of the dominant limb; one studied the effects of intermittent exercise for 30 minutes; one a measurement of the number of steps and intensity of exercise performed during the day and the consequences of this on HRV during the night; and one article studied the effects of continuous walking on a treadmill over a period of eight weeks.

For the articles selected with pathological children; one article studied the effects of isometric handgrip of the dominant limb; one article studied moderate/vigorous intensity exercise three times a week; one article included a football game every week; one the frequency of participation in extracurricular activities; and one the effects of three weekly sessions of running and recreational exercises.

Among the variables studied in the selected studies, besides the HRV indices, age, sex, weight, height, calculation of body mass index (BMI), body surface area (BSA), waist circumference, body fat percentage, daily consumption of energy and fat, fat mass and obesity were also analyzed. In addition hemodynamic parameters such as heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), total peripheral resistance (TPR) and mean arterial pressure (MAP), as well as indices related to exercise such as maximal aerobic speed (VAM),  $VO_{2peak}$ , maximum heart rate ( $HR_{max}$ ) and maximal voluntary contraction (MVC) were studied.

## Discussion

The analysis of the articles selected for this review showed that physical activity in apparently healthy children does not always lead to changes in cardiac autonomic modulation, regardless of whether the activity is high intensity intermittent training, isometric contraction exercises or moderate intensity exercise. It was also observed that obesity, diet and supplementation can directly affect HRV indices in children.

HRV indices were evaluated in three articles that studied the isometric contraction of the dominant upper limb. Goulopoulou et al. (18) analyzed blood pressure differences and cardiovagal autonomic modulation during isometric handgrip exercises of children and adults (23 healthy children aged 7 to 9 years and 23 healthy adults aged 20 to 25 years) and concluded that differences in blood pressure responses of children and adults during an isometric contraction cannot be explained by differences

in cardiovagal autonomic modulation; these blood pressure differences are directly correlated with the force produced at 30% of MVC.

Another study (33) conducted a battery of autonomic tests, specifically for children and adolescents, in order to establish normative parameters of HRV and compare the impact of these autonomic tests. The authors used 100 individuals between 6 and 15 years old (51 girls and 49 boys) divided into two groups: a group of children aged six to 11 years and a group of adolescents aged 12 to 15 years. The study provided the first normative data for the HRV battery of autonomic tests specifically for children and adolescents, in addition to quantifying autonomic changes induced by the test procedures compared with database measurements.

Lira et al. (34) compared the indices of cardiac autonomic modulation at rest and during isometric exercise between obese and eutrophic individuals. In addition, they analyzed the effects of supplementation with vitamin C on cardiac autonomic modulation in obese children, at rest and during isometric exercise. According to the authors, obese children present higher sympathetic activity and lower vagal activity during rest and during isometric exercise when compared with eutrophic children. Supplementation with vitamin C, in high doses, can restore cardiac autonomic dysfunction in obese children.

The selected studies (18, 33, 34) that evaluated autonomic modulation patterns during isometric contraction showed that obesity may be a causal factor of increased sympathetic activity and decreased vagal activity both at rest and during exercise and can be restored with supplementation of high doses of vitamin C. In apparently healthy children, it is not possible to conclude whether the blood pressure differences between children and adults are caused by differences in cardiovagal autonomic modulation.

Gamelin et al. (35) investigated the effects of high intensity intermittent training of short duration on cardiovascular autonomic control. The study population consisted of 52 children, divided into a training group ( $n = 26$ ; 15 boys and 11 girls;  $9.8 \pm 0.7$  years) and a control group ( $n = 26$ ; 14 boys and 12 girls;  $9.3 \pm 1.2$  years). From this study the authors concluded that high intensity intermittent training of short duration improved aerobic conditioning, however, did not affect cardiac autonomic modulation in children.

According to some authors (36), physical activity increases heart rate during sleep, but reduces the

activity of the parasympathetic nervous system during the night. As the HF and RR50 variables decrease with advancing age, the inhibition of the parasympathetic nervous system related to exercise, could be a development stimulus to achieve a balanced ANS pattern in adulthood.

Leicht et al. (37), examined the moderate term reproducibility of heart rate and HRV indices in the frequency domain at rest and during light to moderate exercise in ten healthy, active children (six boys and four girls aged between 7 and 12 years). The authors considered that the reproducibility of HRV was low during the eight weeks of training, but stated limitations regarding sample size and the fact that only the HRV indices in the frequency domain were analyzed.

Lucini et al. (38), evaluated whether cardiac baroreflex and autonomic indices were altered in overweight soccer players. The sample consisted of 103 male soccer players, aged  $11.1 \pm 1$  year. The authors concluded that overweight child soccer players have a profile of cardiovascular autonomic changes, even though they are submitted to intense aerobic training.

Another study (39) investigated cardiac autonomic modulation in slim and obese children, focusing on different levels of physical activity. The 96 children were divided into four groups: active slim (23 boys and one girl); inactive slim (eight boys and 16 girls); active obese (23 boys and one girl); and inactive obese (eight boys and 16 girls). Physical activity was classified as the frequency of participation in extracurricular activities, whereby children were considered as active if they practiced physical activity three times a week and inactive if they did not practice any activity outside school. The authors concluded that obese children present a reduction in sympathetic, as well as parasympathetic modulation compared to slim children who have similar levels of physical activity. This reduction was related to the level of body fat in the inactive state. However, physical activity can contribute to the improvement in global autonomic modulation, both in slim and obese children.

Finally, Prado et al. (40) analyzed the relationship between heart rate recovery in one minute, ANS activity, cardiorespiratory fitness, and anthropometric variables in obese children submitted to a hypocaloric diet in isolation and associated with training. The authors evaluated 33 children aged 8 to 12 years, divided into a hypocaloric diet group and a diet associated with exercise group. The authors concluded that a hypocaloric diet combined with physical exercise,

in contrast to the hypocaloric diet alone, promoted improvement in heart rate recovery in one minute and ANS activity in obese children.

In summary, the studies selected for this review showed varied responses of ANS to the performance of physical exercise in healthy children. It was possible to present the first normative HRV data for a battery of specific autonomic tests for children and adolescents. Physical activity seemed to cause an increase in heart rate during sleep and reduced activity of the parasympathetic autonomic nervous system at night. However, physical exercise was not responsible for the different blood pressure responses between children and adults, in the same way as the high-intensity intermittent training had no effect on cardiac autonomic regulation in children.

In obese children, physical exercise proved to have good potential as a tool to assist in the normalization of ANS patterns and combined with supplemental feeding and diet, may leverage these beneficial effects of training. Compared to eutrophic children, obese children had higher sympathetic activity and lower vagal activity; overweight children, even with regular practice of physical activity, presented profiles of autonomic alterations; obese children, compared with slim children with similar levels of physical activity, featured a reduction in sympathetic and parasympathetic modulation. These alterations appeared to be related to the amount of body fat.

As limitations of this review, the lack of specificity in relation to physical exercise protocols performed, the inclusion of studies with different types and intensities of effort, and the methodological differences used to assess HRV can be pointed out. The realization of stratification according to the type and intensity of exercise, in addition to verification of the effect of exercise in adolescents of different age groups and maturation stages are prospects for future studies, allowing a more enriching scenario with deeper discussion.

## Conclusion

Studies have shown that physical exercise could be an important tool for the normalization of existing alterations in the ANS of obese children and may have greater power when combined with supplemented and balanced diets. In healthy children, physical exercise seems to be more a preventative factor,



enabling healthy development of the ANS until the child reaches adulthood. Both in healthy and obese children, further studies need to be performed with larger sample sizes in order to achieve more significant results regarding the changes caused by exercise in the autonomic modulation of the ANS.

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