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Regular Football Practice Improves Autonomic Cardiac Function in Male Children

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Background: The role of the autonomic nervous system (ANS) in the cardiovascular regulation is of primal importance. Since it has been associated with adverse conditions such as cardiac arrhythmias, sudden death, sleep disorders, hypertension and obesity.
Objectives: The present study aimed to investigate the impact of recreational football practice on the autonomic cardiac function of male children, as measured by heart rate variability.
Patients and Methods: Forty-seven male children aged 9 - 12 years were selected according to their engagement with football oriented practice outside school context. The children were divided into a football group (FG; n = 22) and a control group (CG; n = 25). The FG had regular football practices, with 2 weekly training sessions and occasional weekend matches. The CG was not engaged with any physical activity other than complementary school-based physical education classes. Data from physical activity, physical fitness, and heart rate variability measured in time and frequency domains were obtained.
Results: The anthropometric and body composition characteristics were similar in both groups ($P > 0.05$). The groups were also similar in time spent daily on moderate-to-vigorous physical activities (FG vs. CG: 114 ± 64 vs. 87 ± 55 minutes; $P > 0.05$). However, the FG performed better ($P < 0.05$) in Yo-Yo intermittent endurance test (1394 ± 558 vs. 778 ± 408 m) and 15-m sprint test (3.06 ± 0.17 vs. 3.20 ± 0.23 s). Also, the FG presented enhanced autonomic function. Significant differences were detected ($P < 0.05$) between groups for low frequency normalized units (38.0 ± 15.2 vs. 47.3 ± 14.2 n.u (normalized units)), high frequency normalized units (62.1 ± 15.2 vs. 52.8 ± 14.2 n.u.), and LF:HF ratio (0.7 ± 0.4 vs. 1.1 ± 0.6 ms^2).
Conclusions: Children engaged with regular football practice presented enhanced physical fitness and autonomic function, by increasing vagal tone at rest.

Keywords: Heart rate; Soccer; Physical Education

1. Background

The role of the autonomic nervous system (ANS) in the cardiovascular regulation is of prime importance (1) since it has been associated with adverse conditions such as cardiac arrhythmias, sudden death, sleep disorders, hypertension and obesity (2-6). Therefore, heart rate variability (HRV) has been proposed as a quantitative marker of the ANS (7). Analyses of time and frequency domains of HRV provide a non-invasive method to evaluate the autonomic regulation of heart rate (8). Time domain methods are based on the sampling of heart rate at any point in time, whereas frequency domain methods decompose cardiac cycles in various basic waves of amplitude and frequency through a technique named Fast Fourier Transform (FFT). In the frequency domain, which seems to provide a more accurate and specific analysis of cardiac autonomic modulation, low frequencies are mostly associated with sympathetic activity, while high frequencies represent parasympathetic activity and vagal tone (7). An active lifestyle by performing regular moderate to vigorous physical activities is paramount for the prevention of cardiovascular diseases and the management of cardiovascular risk factors (9, 10). Regular physical activity is recommended for the prevention of overweightness and obesity (11), and has been showed to induce increased parasympathetic and decreased sympathetic activity at rest (12-14). Also, higher levels of physical activity and especially physical fitness seem to induce superior levels of parasympathetic activity and vagal tone in children (15, 16). Over the past few years, intermittent exercise activities have been recommended as effective health-promoting strategies (17). Football is essentially an aerobic intermittent sport, interspersing vigorous exercise with lower intensity exercise periods. Given its popularity among children and adolescents, independent of gender (18), football is likely to attract individuals to regular physical activity practice more easily than other sport activities. Thus, the clarification of the impact of recreational football practice on health parameters is of utmost importance. Several studies showed the beneficial impact of regular football practice on a considerable number of health parameters in distinct populations (19). Similarly, recreational football practice seems to have positive effects in heart rate variability; a 12-week football intervention on active adult men with mild hypertension showed significant increase in the vagal tone (20). Higher vagal-related indices have also been found in young and adult football players during post-exercise periods (8, 21). In overweight children, football training has been reported as effective on weight control, and induced improvements in physical capacity, physical fitness and self-esteem (22, 23). Also, football training resulted in positive structural and functional effects on the cardiovascular system in overweight preadolescent children (24). Nevertheless, little is known regarding the impact of recreational football practice in the autonomic function of the youth population.

2. Objectives

In the present study, we hypothesised that regular extra-school football practice would induce improvements on physical fitness and the autonomic function of children, namely its vagal tone.

3. Patients and Methods

Forty-seven male children aged 9 - 12 years were selected from three elementary schools in Braga, Portugal. The selection was made according to their engagement with football-oriented practice outside school context. Therefore, two groups were created, a football group (FG; n = 22) and a control group (CG; n = 25). The FG had been engaged with regular and oriented football practice in local clubs in the 9 months prior to the study, with two weekly 60-minute training sessions and sporadic weekend matches. The football training sessions consisted of a general warm-up, followed by technical exercises and several small-sided football games. The CG was not engaged with any physical activity other than complementary school-based physical education classes. Generally, school-based physical education classes consisted of a general warm-up, technical exercises of several sports, small-sided games and recreational activities lasting a total of 45 minutes. The emphasis of the physical education classes was on several different sports, according to the timing of the year and the national programme for physical education. The soccer season and the school season were coincident, and had the duration of 10 months. The parents or legal guardians provided written informed consent. The local university ethics committee approved ethical consent. All procedures were conducted according the declaration of Helsinki. The evaluation protocol included HRV measurement, anthropometry, physical activity and physical fitness tests. Testing took place in two interspersed days for each school. One session was dedicated to HRV measurements; the other session was devoted to anthropometry and physical fitness assessment. HRV was measured using Polar Team 2 TM (Polar Electro OY, Kempele, Finland) heart monitors set to record R-R intervals. HRV recording took place at 9:00 in a quiet and silent room, with low light, comfortable temperature and in a fast. The children were in the supine position; no visual contact was granted. The recording lasted 15 minutes, preceded by a 5-minutes explanation. Metronomic breathing was discarded because children have difficulty pacing their breathing with a pre-determined cadence, and therefore potential cardiac alterations might occur (25, 26). Raw data was converted to ASCII format in the form of R-R intervals in milliseconds, and exported to Kubios HRV TM version 2.0 (Department of Physics, University of Kuopio, Kuopio, Finland). The last 5 minutes of the test were used to analyse the R-R intervals using time and frequency-domain techniques. Custom artifact correction was used, and trend components were removed according to the smoothness priors method on Kubios software. Non-parametric methods, namely FFT, were used to obtain measures of HRV frequency-domain. Information regarding total power and three-frequency bands was obtained by default: very low frequency (VLF: 0 - 0.04 Hz), low frequency (LF: 0.04 - 0.15 Hz) and high frequency (HF: 0.15 - 0.4 Hz). VLF was discarded from the analysis due to its uncertain physiological meaning and interpretation (7). HF reflects vagal activity (7); no agreement exists regarding LF, yet it seems to reflect mainly sympathetic modulation, especially when normalized (7). LF and HF normalized units (n.u.) were also calculated. LF:HF ratio was calculated since it might express sympathovagal balance (7). Height (cm) (stadiometer model 708, Seca, Hamburg, Germany), weight (kg) and percent body fat (Tanita Inner Scan, BC-532, Tanita, Amsterdam, Netherlands), and physical activity questionnaires were assessed in the classroom. Lean mass (kg) was obtained by subtracting the fat mass to the weight of each individual. The short form of the international physical activity questionnaire (IPAQ) was applied to provide information regarding the time spent on moderate-to-vigorous physical activities (MVPA). The validity and reliability of this instrument was tested in several countries, including Portugal (27). IPAQ has been often used to assess children and early adolescents' physical activity (28-31). The questionnaire was applied during an interview led by the physical education teacher of each student. Information regarding the daily time spent on MVPA was obtained by summing the average duration per day spent in each intensity level. Fitness tests were administered on an indoor multi-sports ground. Prior to testing, the participants performed a 12-minute warm-up and familiarization trials with each test. Speed was evaluated with a 15-m sprint test. Elapsed times were obtained with photoelectric cells (Speed Trap II, Brower Timing Systems, Utah, USA) positioned at the starting line, and at 5 and 15 m. Participants sprinted from a standing position 30 cm behind the starting line. The fastest of 2 trials was considered. Jumping height was evaluated by countermovement jump (CMJ) on a special mat (Digitime 1000, Digitest, Jyvaskyla, Finland) maintaining hands on hips. The best of two trials was retained. The Yo-Yo intermittent endurance test - level 1 (Yo-Yo IE1) was used to evaluate aerobic capacity (32). Research has proven that Yo-Yo IE1 can be used as an indicator of aerobic fitness for children of this age range (33). The test consists of repeated 2 × 20-m shuttle runs between a start and finish line, interspersed by 5-s rest period between runs. Progressively increased speeds are controlled by audio bleeps from a CD-recorder. The aim of the test is to perform as many shuttles as possible. When the child failed twice to reach the finish line in time, the distance covered was recorded and used as the test result. One trial was given. Data was tested for normality using the Shapiro-Wilk test. Descriptive statistics consisted of mean ± standard deviation (SD); the non-normally distributed variables are presented as medians and interquartile (IQ) ranges. Differences between groups were obtained using independent-samples t-test. A Mann-Whitney test was performed to obtain differences between groups for non-normally distributed variables (LF, HF, total power). Standardised differences in means (effect sizes, d) were computed for comparisons. Effect sizes were classified according to Hopkins (34) as trivial ($d < 0.2$), small ($0.2 < d < 0.6$) moderate ($0.6 < d < 1.2$), large ($1.2 < d < 2.0$), very large ($2.0 < d < 4.0$), nearly perfect ($d > 4.0$), and perfect (d = infinite). Statistical significance was set at $P < 0.05$.

4. Results

Table 1 presents age, anthropometry, physical activity, physical fitness, and HRV data. FG and CG were similar for age, anthropometry, total power, countermovement jump and MVPA ($P > 0.05$). However, FG performed better than CG in Yo-Yo IE1 ($P < 0.05$, $d = 0.5$) and 15-m sprint tests ($P < 0.05$, $d = 0.3$). Also, FG presented higher values for HF n.u. ($P < 0.05$, $d = 0.3$), and lower values for LF n.u. ($P < 0.05$, $d = 0.3$) and LF:HF ratio ($P < 0.05$, $d = 0.4$) compared to CG.

Table 1. Comparisons Between the Football Group (FG) and Control Group (CG) in Age, Anthropometry, Physical Activity, Physical Fitness, and Heart Rate Variability [a,b]

Variables	FG	CG	Effect Size
Age, y	9.8 ± 0.8	9.4 ± 0.7	0.3
Weight, kg	35.7 ± 6.2	37.2 ± 6.6	0.1
Height, cm	140.3 ± 6.7	140.0 ± 5.7	0
BMI, kg/m^2	18.0 ± 2.0	19.0 ± 3.5	0.2
Lean Mass, kg	28.5 ± 4.7	28.3 ± 3.8	0
Fat, %	20.2 ± 6.1	22.5 ± 6.2	0.2
Physical activity			
Moderate-to-vigorous physical activity, min/day	114 ± 64	87 ± 55	0.2
Physical fitness			
Yo-Yo IE1, m	1394 ± 558	778 ± 408 [c]	0.5
5-m sprint, s	1.25 ± 0.07	1.28 ± 0.10	0.2
15-m sprint, s	3.06 ± 0.17	3.20 ± 0.23 [c]	0.3
Countermovement jump, cm	23.8 ± 6.0	21.2 ± 4.0	0.2
Heart rate variability			
LF, ms^2	1591.5 (769 - 2414)	1921 (326.5 - 3515.5)	-
LF, n.u.	38.0 ± 15.2	47.3 ± 14.2 [c]	0.3
HF, ms^2	3265 (1616.5 - 4913.5)	2670 (389 - 4951)	-
HF, n.u.	62.1 ± 15.2	52.8 ± 14.2 [c]	0.3
LF:HF, arbitrary unit	0.7 ± 0.4	1.1 ± 0.6 [c]	0.4
Total power, ms^2	5359.5 (3182.5 - 7536.5)	5577 (2366 - 8788)	-

[a] Abbreviations: CG, control group; FG, football group; HF, high frequency power; LF, low frequency power; MVPA, moderate to vigorous physical activity; n.u., normalized units; pNN50, percentage of pairs of successive R-R intervals that differ by more than 50 ms; RMSSD, square root of the mean squared difference of consecutive R-R intervals; and SDNN, standard deviation of R-R intervals.

[b] Values are presented as mean ± standard deviation or median (IQ).

[c] Significant differences between FG and CG ($P < 0.05$).

5. Discussion

The results of the present study indicate that regular extra-school football practice might enhance autonomic tone in children, by increasing parasympathetic activity at rest. Also, children engaged with regular extra-school football practice presented superior physical fitness compared to children not engaged with any oriented physical activity other than complementary school-based physical education classes. The distinctive characteristics of football, with high heart rate loading and multiple intense actions, have been shown to induce higher levels of aerobic capacity, muscle strength and speed, independent of level, genre or age of the participants (35). In this way, higher VO_{2max} (36), strength and speed (37) have been described for children engaged with football activities. Interestingly, however, the groups presented similar anthropometric and physical activity levels. The similarity on MVPA levels between groups is noteworthy given the fact that the FG participated in two weekly 60-minute structured football-training sessions and sporadic weekend matches. An explanation for this can reside in the particular geographic and social context of the sample. All schools were located in suburban areas and were surrounded by playgrounds. This might facilitate the practice of physical activities beyond the school context for the community. It is also important to highlight that the FG presented higher (~20 minutes), but non-significant daily MVPA than the CG. The reduced sample size limits extrapolations from the current data. Hence, the potential impact of MVPA in vagal tone needs further investigation. Notwithstanding, the context in which the physical activity takes place might influence its outcome in health parameters as much as the intensity, frequency, duration and volume of the exercise (38). This might help to explain the fact that, even with similar levels of physical activity, the groups presented significant differences in the autonomic tone. In the present study, the FG presented improved vagal tone compared to the CG. The groups differed mostly in HRV frequency domain, namely LF n.u., HF n.u. and LF:HF ratio. The FG presented higher HF n.u. and lower LF:HF ratio compared to the CG. This suggests that children might benefit from regular extra-school football practice by improving vagal tone, thus, reducing the risk of sustaining adverse conditions such as cardiac arrhythmias, sudden death, sleep disorders, hypertension and obesity (2-4, 6). The volume of sports participation might be a key factor in autonomic tone outcome. In fact, higher volumes of sports club participation have been reported to have an additional benefit on indices of autonomic tone in active children (39). Therefore, our results support evidence that young competitive football players presented high vagal-related indices of autonomic tone (21). The current study presents limitations, namely the reduced sample size, small effect sizes, the HRV measurement made only in supine position, the physical activity assessment via questionnaire and the omission of maturational status evaluation, which may limit extrapolations from the current data. However, it is noteworthy that higher HRV values are reported, compared to those commonly accepted as reference for individuals of this age and gender (15). Further investigation should consider larger sample sizes, HRV measurement in both standing and supine position and maturational data, as well as the evaluation of physical activity by accelerometry. The present study suggests that engagement in regular extra-school football practice might have been the key for improved markers of vagal tone in healthy children.

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