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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

How Do Different Types of Physical Activity Affect Cardiac Functions in Children?

Farklı Fiziksel Etkinlik Türleri Çocuklarda Kardiyak Fonksiyonları Nasıl Etkiler?

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Abstract

This study aims to investigate how different types of regular physical activity affect cardiac functions in school children.

This is a cross-sectional review of 15 children who are not engaged with any regular physical activity (controls) and 60 athletes who swim (n=15), play basketball (n=15), play volleyball (n=15), and play tennis (n=15) regularly. The mean age of the control children was computed as 11.3±1.8 years whereas the mean ages of swimmer children, the children who play basketball, volleyball and tennis regularly were calculated as 10.7±1.5 years, 12.0±1.9 years, 12.6±2.2 years and 10.6±1.4 years respectively.

The children who are not engaged with any sports, the children who swim, and the children who play basketball, volleyball, and tennis are statistically similar with respect to age, sex, height, weight, and body mass index (p>0.05 for all). When compared to the controls and other athletes, the swimmer children have significantly higher left ventricle diastolic mass, higher left ventricle posterior wall systolic thickness, lower mitral A wave, higher mitral annular plane systolic excursion, and higher mitral E/A ratio (p=0.006, p=0.035, p=0.030, p=0.025 and p=0.043 respectively). The swimmer children have significantly lower interventricular septum E and A waves and significantly longer left ventricle isovolumic relaxation time than the controls and other athletes (p=0.001, p=0.040 and p=0.004 respectively). When compared with the controls and other athletes, the swimmer children have significantly lower p-wave dispersion and QT dispersion values (p=0.038 and p=0.035 respectively). The swimmer children have significantly higher total power and SDNN values than the controls and other athletes (p=0.046 and p=0.026 respectively).

Swimming might contribute to the growth of cardiac muscles and help to improve the cardiac conduction system and enhance parasympathetic innervation of the heart in children.

Keywords: Child, echocardiography, electrocardiography, heart rate variability, sports

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Öz

Bu çalışma, farklı fiziksel etkinlik türlerinin okul çocuklarındaki kalp fonksiyonlarını nasıl etkilediğini incelemeyi amaçlamaktadır.

Bu kesitsel çalışmada; hiçbir fiziksel etkinliği olmayan 15 çocuk (kontrol grubu), düzenli olarak yüzen 15 çocuk, düzenli olarak basketbol oynayan 15 çocuk, düzenli olarak voleybal oynayan 15 çocuk ve düzenli olarak tenis oynayan 15 çocuk karşılaştırılmıştır. Kontrol grubundaki olguların ortalama yaşı 11.3±1.8 yıl olarak hesaplanırken düzenli olarak yüzen, basketbol, voleybol ve tenis oynayan çocukların ortalama yaşları sırasıyla 10.7±1.5 yıl, 12.0±1.9 yıl, 12.6±2.2 yıl ve 10.6±1.4 yıl olarak kaydedildi.

Kontrol grubunda bulunan çocuklar ile düzenli olarak yüzen, basketbol, voleybol ve tenis oynayan çocuklar; yaş, cinsiyet, boy, vücut ağırlığı ve vücut kitle indeksi bakımından istatistiksel olarak benzer bulunmuştur (hepsi için p>0.05). Kontrol grubunda yer alan çocuklar ve diğer sporları yapan çocuklar ile karşılaştırıldığında, yüzücü çocuklarda sol ventrikül diastolik kütle, sol ventrikül posterior duvar sistolik kalınlığı, mitral annular plan sistolik ekskursiyon ve mitral E/A oranı değerlerinin anlamlı olarak yüksek olduğu belirlendi (sırasıyla p=0.006, p=0.035, p=0.025 ve p=0.043). Kontrol grubunda yer alan çocuklar ve diğer sporları yapan çocuklara göre, yüzücü çocuklarda mitral A dalgası, interventriküler septum E ve A dalgaları da anlamlı olarak düşüktü (sırasıyla p=0.030, p=0.001 ve p=0.040). Yüzücü çocuklarda sol ventrikül izovolumik dinlenme zamanı anlamlı olarak uzun bulundu (p=0.004). Kontrol grubunda yer alan çocuklar ve diğer sporları yapan çocuklar ile kıyaslandığında, yüzücü çocuklarda p dalgası dispersiyonu ve QT dispersiyonu değerleri anlamlı olarak düşüktü (sırasıyla p=0.038 ve p=0.035). Ayrıca, yüzücü çocukların toplam güç ve SDNN değerleri anlamlı olarak daha yüksekti (sırasıyla p=0.046 ve p=0.026).

Yüzme sporu, çocuklarda kalp kaslarının gelişmesine katkıda bulunabilir ve kalbin parasempatik innervasyonunu hızlandırarak kalpteki ileti sisteminin iyileşmesine katkı sağlayabilir.

Anahtar Kelimeler: Çocuk, ekokardiyografi elektrokardiyografi, kalp hızı değişkenliği, spor

INTRODUCTION

Heart rate variability (HRV) is defined as the variation in the time interval between consecutive heartbeats in milliseconds. This physiological phenomenon designates the autonomic innervation of the heart, indicating the current status of wellbeing and long-term health consequences(Cygankiewicz & Zareba, 2013 ; Xhyheri, Manfrini, Mazzolini, Pizzi, & Bugiardini, 2012). It has been reported that a decrease in HRV might predict mortality after myocardial infarction (Brateanu, 2015 ; Sen & McGill, 2018). Decreased HRV can be also associated with diabetic neuropathy, cardiac transplantation and sudden cardiac death (Islam, Kim, Lee, & Moon, 2018 ; Lin et al., 2017 ; Sessa et al., 2018).

It has been hypothesized that interventions that increase HRV may be protective against cardiac mortality and sudden cardiac death. These interventions consist of beta adrenergic blockade, anti-arrhythmic drugs, muscarinic receptor blockers, thrombolysis, and physical activity (Kur'yanova, Tryasuchev, Stupin, & Teplyi, 2017, 2018 ; Larosa et al., 2005). Amongst these, regular physical training might contribute to cardiac health by modulating the autonomic functions. A body of evidence for this hypothesis is the "training bradycardia" of the individuals who do physical exercises routinely (Besnier et al., 2017 ; Doyen, Matelot, & Carré, 2019 ; Larosa et al., 2005).

As for the young adults, studies focusing on the impact of physical activity on HRV have yielded discrepant outcomes (Sandercock, Bromley, & Brodie, 2005). A study that has examined the effects of physical activity habits in different age groups is unable to report significant results in young adults (Prodel et al., 2017). On the other hand, similar studies have demonstrated that adolescents who are physically active have greater HRV than their sedentary counterparts (Felber Dietrich et al., 2008 ; Henje Blom, Olsson, Serlachius, Ericson, & Ingvar, 2009 ; Kaikkonen et al., 2014 ; Vivek, Senthil, Vinayathan, & Rajathi, 2015). Additionally, it has been shown that autonomic cardiovascular regulation is improved in obese adolescents who have been engaged in regular physical training (Lucini et al., 2013 ; Nagai & Moritani, 2004). However, the major limitation of these studies is the negligence of different types of physical activity. That is, either individual or team sports were considered as one type of physical activity. Moreover, some studies evaluated just total physical activity (Felber Dietrich et al., 2008 ; Kaikkonen et al., 2014) and other studies assessed leisure-time physical activity (Lucini et al., 2013 ; Nagai & Moritani, 2004 ; Vivek et al., 2015). This study aims to investigate how different types of regular physical activity affect echocardiography findings and heart rate variability in school children.

METHODS

The parents of all participants were informed about the study and their written informed consents were obtained for the participation of their children. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Afyonkarahisar Health Sciences University (Grant no: 2019/1-10).

This is a cross-sectional review of 15 children who were not engaged with any regular physical activity or sports (controls) and 60 athletes who swam (n=15), played basketball (n=15), played volleyball (n=15), and played tennis (n=15) regularly. An athlete has been identified as a student, beginning from the age of 7 years, who routinely participates in sporting events like matches, games, and tournaments and undergoes supervised physical conditioning training for a minimum of 25 hours a week or does vigorous-intensity physical activity exercises to achieve physical strength, speed and/or endurance exercises for at least 30 minutes per day, three times a week (Coe & Fiatarone, 2014 ; Fox, 2011 ; World Health Organization, 2011). This study has been designed to investigate the benefits of different physical activity types on echocardiography findings and heart rate variability of the athlete children. That's why children who belonged to the same age group but vigorously involved in different physical activities were recruited to make up the study groups.

The children with cardiovascular diseases, diabetic children, children with neurological disorders, and handicapped children were excluded. The use of alcohol, tobacco, and/or other drugs; consumption of caffeine 12 hours preceding the HRV analysis, and performing any physical exercise 24 hours before the clinical evaluations were the other exclusion criteria.

Data related to age, sex height, and weight are recorded. Body mass index (BMI) is computed as follows: Body mass index= Weight (kg) / Height^2 (m^2). The mean ages of the control, swimmer children, the children who play basketball, volleyball and tennis regularly were calculated as were computed as 11.3±1.8 years, 10.7±1.5 years, 12.0±1.9 years, 12.6±2.2 years and 10.6±1.4 years respectively.

Echocardiography Examination: Echocardiography examination was made by using equipment with 3-5 MHz transducers (Vivid I, GE Healthcare, Chicago, IL, USA). The patients were made to rest for 5 minutes before the measurements and breathe slowly throughout the procedure. Recordings were performed with subjects in the supine or left lateral positions. All children underwent M-mode, Doppler-continuous, and pulse wave-echocardiography examination.

M-mode tracings were obtained at the level of the tips of mitral leaflets in the parasternal long-axis position, and measurements of the left ventricular end-systolic and end-diastolic dimension were performed according to the recommendations of the American Society of Echocardiography (Nagueh et al., 2016). Left ventricular end-systolic and end-diastolic dimensions, as well as aorta and interventricular septum dimensions, were measured from the parasternal long-axis window. Left ventricular ejection fraction and fractional shortening were provided using Teichholtz in M-mode echocardiography.

Tissue Doppler measurements were performed to measure the myocardial velocities during systole, early diastole and late diastole. The isovolumic contraction time (IVCT) was the time period between the end of the myocardial wave during late diastole (Am) and the beginning of the myocardial wave during systole (Sm). The isovolumic relaxation time (IVRT) was the time period between the end of the Sm wave and the beginning of the myocardial wave during early diastole (Em). Ejection time was the duration of ventricular outflow. Myocardial performance index (MPI) was the sum of IVCT and IVRT values, divided by ejection time.

The mean values were recorded by averaging the results of three consecutive measurements.

Electrocardiography Evaluation: All children had 12-lead electrocardiography (ECG) which was saved at a paper speed of 50 mm/hour and gain of 10 mm/mV (Cardiofax V; Nihon Kohden Corporation, Tokyo, Japan) in supine position. The patient was allowed to breathe spontaneously, but speaking was not permitted during the recording. All measurements were done manually by using a magnifying glass and the mean values were recorded by averaging three consecutive measurements.

The electrical axis of the heart in the frontal plane was represented by the QRS-axis. P-wave duration was measured in lead II, from the beginning to the end of P-wave. PR interval was also measured in lead II, from the beginning of P-wave to the beginning of R-wave. QRS complex duration was measured in lead V, from the beginning of Q wave to the end of the S wave. The measurement of the QT interval was started from the onset of the QRS complex until the end of the T-wave. Corrected QT interval was specified by Bazett's formula (Bazett, 1920). P-wave dispersion was calculated by subtracting minimum P-wave duration from maximum P-wave duration. QRS dispersion was the difference between the maximum and minimum QRS complex durations. Corrected QT dispersion was found by subtracting minimum corrected QT interval from maximum corrected QT interval. T-peak to T-end the interval was measured as the distance between the peak and end of T wave.

Heart Rate Variability Analysis: Holter monitoring was performed for 24 hours by means of a digital monitor (DL800, Compact Flash Card Holter Recorder, Minnesota, USA). Holter monitoring was started between 8 and 9 a.m. during the working days of the week and all patients were asked to continue their normal daily activities during the test days. In order to specify HRV parameters, the data stored were processed by Holter software (Cardiolight FMC.A, Medizintechnik, Hamburg, Germany). Before HRV analyses were performed, the precision of computer-assisted methods was provided and ectopic beats, noisy data, and artifacts were identified and excluded from the analysis. All Holter recordings were interpreted by the same investigator (A.P.). At least 21 hours of analyzable signals with a less than 2 hours difference between consecutive recordings were analyzed using the time-domain method. The parameters analyzed included standard deviation of all the adjacent NN intervals (SDNN), the standard deviation of the averages of NN intervals in all 5-min segments (SDANN), square root of the mean of the sum of the squares of the differences between adjacent NN intervals (RMSSD) and geometric measure of the integral of the density of the RR interval histogram divided by its height (triangular index).

Statistical Analysis: Collected data were analyzed by Statistical Package for Social Sciences version 20.0 (SPSS Inc., SPSS IBM, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (range: minimum-maximum) and categorical variables were denoted as numbers or percentages. *Kolmogorov-Smirnov* test was used to test the distribution of data while *Mann Whitney U* test and *Wilcoxon* test were used for the comparisons. Two-tailed p values less than 0.05 were accepted to be statistically significant.

RESULTS

Table 1. Demographic Characteristics of the Participants

	Basketball (n=15)	Volleyball (n=15)	Swimming (n=15)	Tennis (n=15)	Controls (n=15)	p
Age (years)	12.0±1.9	12.6±2.2	10.7±1.5	10.6±1.4	11.3±1.8	0.688
Male/Female	9-6 (60%-40%)	5-10 (33.3%-66.7%)	8-7 (53.3%-46.7%)	9-6 (60%-40%)	8-7 (53.3%-46.7%)	0.577
Height (cm)	155.2±28.4	159.4±31.6	149.1±24.7	148.9±22.3	149.4±25	0.133
Weight (kg)	46.9±3.5	53.5±4.2	40.3±2.6	43.2±3.1	52.3±4	0.452
BMI (kg/m^2)	19.4±1.7	20.7±2.1	17.9±1.2	19.3±1.8	23.4±2.2	0.379

BMI: body mass index

Table 1 shows the demographic characteristics of the participants. The children who are not engaged with any sports, the children who swim, and the children who play basketball, volleyball and tennis are statistically similar with respect to age, sex, height, weight and BMI (p>0.05 for all).

Table 2. Echocardiography Findings of the Participants

	Basketball (n=15)	Volleyball (n=15)	Swimming (n=15)	Tennis (n=15)	Controls (n=15)	p
Ejection fraction	74.4±1.9	75.2±1.8	75.9±1.7	71.6±1.9	73.3±1.5	0.573
Fractional shortening	45.2±2.1	44.1±1.7	44.4±1.8	40.5±1.7	43.2±.6	0.226
Systolic volume	54.6±4.2	59.8±5.4	54.2±3.1	49.7±3	55.7±4.8	0.189
End-diastolic volume	72.6±4.7	77.8±7.2	71.4±3.6	69.9±3.4	74.5±6.3	0.344
Left ventricle systolic mass	119.8±10.7	121.7±11.1	112.3±11.6	102.8±6.3	114.5±9.2	0.189
Left ventricle diastolic mass	130.5±2.9	109.2±6.8	138.7±9.9	124.8±10.4	128.6±8.4	0.006*
LVPW systolic thickness	1.58±0.2	1.60±0.3	1.62±0.3	1.50±0.1	1.38±0.1	0.035*
LVPW diastolic thickness	0.91±0.1	0.94±0.04	0.88±0.1	0.89±0.01	0.92±0.02	0.804
Mitral E wave	1.19±0.06	1.1±0.06	1.1±0.1	1.13±0.1	1.15±0.04	0.292
Mitral A wave	0.7±0.03	0.72±0.04	0.59±0.04	0.62±0.03	0.75±0.05	0.030*
Mitral E/A ratio	1.76±0.1	1.55±0.09	1.9±0.1	1.84±0.1	1.88±0.08	0.043*
Tricuspid E wave	0.82±0.07	0.78±0.04	0.7±0.05	0.78±0.1	0.8±0.06	0.361
Tricuspid A wave	0.47±0.04	0.48±0.02	0.4±0.04	0.48±0.03	0.5±0.02	0.315
Tricuspid E/A	1.78±0.1	1.68±0.08	1.81±0.1	1.66±0.1	1.77±0.06	0.513
TAPSE	3.77±0.15	3.99±0.21	3.8±0.17	3.64±0.2	3.82±0.24	0.567
MAPSE	3.33±0.1	3.16±0.14	2.89±0.2	2.9±0.2	3.54±0.2	0.025*

*p<0.05 was accepted to be statistically significant

LVPW: left ventricle posterior wall

TAPSE-MAPSE: tricuspid-mitral annular plane systolic excursion

Table 2 demonstrates the echocardiography findings of the participants. When compared to the controls and other athletes, the children who swim have significantly higher left ventricle diastolic mass, higher left ventricle posterior wall systolic thickness, lower mitral A wave, higher mitral annular plane systolic excursion and higher mitral E/A ratio (p=0.006, p=0.035, p=0.030, p=0.025 and p=0.043 respectively).

Table 3. Tissue Doppler Echocardiography Findings of the Participants

	Basketball (n=15)	Volleyball (n=15)	Swimming (n=15)	Tennis (n=15)	Controls (n=15)	p

Left ventricle E wave	0.2±0.01	0.19±0.01	0.19±0.01	0.21±0.01	0.20±0.01	0.312
Left ventricle A wave	0.08±0.01	0.08±0.01	0.1±0.01	0.1±0.01	0.09±0.01	0.782
Left ventricle S wave	0.12±0.01	0.11±0.01	0.11±0.01	0.11±0.01	0.10±0.01	0.424
Left ventricle MPI	44.7±3.1	42.2±1.3	40.3±1.6	47.1±3.4	46.4±2.6	0.946
Left ventricle IVRT (ms)	56.9±2.4	53.0±2.7	60.9±2.5	59.7±3.8	55.4±3.3	0.001*
Left ventricle IVCT (ms)	56.9±3.2	53.7±2.3	52.5±3.3	53.2±2.4	55.7±2.8	0.390
Interventricular septum E wave	0.14±0.01	0.15±0.01	0.13±0.01	0.16±0.01	0.18±0.01	0.040*
Interventricular septum A wave	0.08±0.01	0.11±0.01	0.07±0.01	0.09±0.01	0.1±0.01	0.004*
Interventricular septum S wave	0.08±0.01	0.09±0.01	0.1±0.01	0.14±0.01	0.15±0.01	0.362
Interventricular septum MPI	45.4±2.6	47.6±1.9	44.1±1.7	43.7±1.6	46.1±2.5	0.525
Interventricular septum IVRT (ms)	55.1±2.6	56.4±3.1	58.7±2.9	58.4±2.6	57.3±2.8	0.309
Interventricular septum IVCT (ms)	57.7±2.1	58.5±2.1	57.7±2.6	54.9±2.5	59.1±3.2	0.440
Right ventricle E wave	0.17±0.01	0.18±0.01	0.17±0.01	0.19±0.01	0.2±0.02	0.846
Right ventricle A wave	0.12±0.01	0.12±0.01	0.11±0.01	0.11±0.01	0.14±0.01	0.653
Right ventricle S wave	0.13±0.01	0.13±0.01	0.14±0.01	0.15±0.01	0.14±0.01	0.170
Right ventricle MPI	48.9±2.5	51.4±3.9	48.4±2.9	49.3±2.7	50.5±3.0	0.906
Right ventricle IVRT (ms)	58.3±2.2	60.1±2.6	59.7±2.3	62.0±3.1	61.1±2.8	0.742
Right ventricle IVCT (ms)	60.8±3.7	57.4±2.8	53.3±2.2	61.2±2.6	62.0±3.1	0.263

*p<0.05 was accepted to be statistically significant.

MPI: myocardial performance index, IVRT-IVCT: isovolumic relaxation-contraction time

Table 3 displays the tissue Doppler echocardiography findings of the participants. The children who swim have significantly lower interventricular septum E and A waves and significantly longer left ventricle IVRT than the controls and other athletes (p=0.001, p=0.040 and p=0.004 respectively).

Table 4. Electrocardiography Findings of the Participants

	Basketball (n=15)	Swimming (n=15)	Tennis (n=15)	Volleyball (n=15)	Controls (n=15)	p
Heart rate	89.6±0.8	83.9±3.7	85.1±4.1	85.6±3.1	86.1±3.5	0.582
p-wave duration	62.3±2.3	63.9±1.9	61.9±1.8	66.4±2.2	65.6±2.1	0.407
p-wave dispersion	42.9±2.7	38.7±1.3	48.6±4.5	42.5±3.1	45.2±3.3	0.038*
PR interval	114.4±4.7	120.1±4.6	117.3±4.1	121.5±5.4	122.7±6.1	0.673
QRS complex duration	69.7±3.8	73.8±3.9	75.9±4.5	75.2±2.4	77.4±3.6	0.547
QT interval	334.6±6.2	336.9±5.4	343.6±5.4	328.4±4.6	346.5±6.1	0.104
QT dispersion	64.3±5.2	60.3±4.9	62.9±6.2	68.8±7.1	70.7±5.4	0.035*
Corrected QT interval	389.1±6.7	396.2±4.9	408.3±8.4	397.2±5.1	394.7±8.1	0.190
Corrected QT dispersion	81.9±8.6	80.3±5.5	88.2±8.5	92.6±8.4	86.6±7.7	0.721
T-peak to T-end interval	64.1±2.3	64.0±2.3	62.3±1.6	65.6±2.7	64.2±1.9	0.453

*p<0.05 was accepted to be statistically significant.

Table 4 summarizes the electrocardiography findings of the participants. When compared with the controls and other athletes, the children who swim have significantly lower p-wave dispersion and QT dispersion values (p=0.038 and p=0.035 respectively). Table 5 enlists the heart variability of the participants. The children who swim have significantly higher total power and SDNN values than the controls and other athletes (p=0.046 and p=0.026 respectively).

Table 5. Heart Rate Variability of the Participants

	Basketball (n=15)	Swimming (n=15)	Tennis (n=15)	Volleyball (n=15)	Controls (n=15)	p
Total power	4505.4±775.6	5019.3±663.4	2689.1±433.1	3728.5±529.3	1788.9±387.5	0.046*
VLF	2954.4±605.3	3277.7±465.9	2057.9±224.1	2446.5±356.1	1556.4±326.4	0.196
LF	975.7±112.4	979.5±125.4	663.5±116.6	752.8±118.2	546.3±96.3	0.140
HF	528.5±91.7	707.9±97.7	422.7±101.8	479.4±82.6	249.2±57.5	0.115
LF/HF ratio	2.2±0.2	1.6±0.2	2.1±0.3	1.7±0.1	2.2±0.4	0.208
SDNN (msec)	144.7±10.9	153.9±9.1	106.5±11.2	137.5±12.1	79.6±8.5	0.026*
SDANN (msec)	132.8±10.4	141.1±10.3	97.5±13.4	123.5±11.9	84.3±9.2	0.079
SDNN index	66.6±5.5	72.3±4.9	56.8±3.2	62.6±4.3	55.1±2.8	0.108
RMSSD	50.3±6.8	52.5±4.2	45.3±4.8	48.2±4.4	37.6±3.5	0.671
PNN50	24.1±4.7	26.1±2.7	21.4±3.9	22.3±2.8	19.1±2.2	0.662

*p<0.05 was accepted to be statistically significant.

DISCUSSION

Physical activity is an important factor in the establishment and maintenance of good health. That's why; World Health Organization recommends structured physical activity for both children and adolescents (Fox, 2011 ; World Health Organization, 2011). Beneficial effects of physical activity on cardiorespiratory health have been reflected by attenuated heart rate and increased oxygen consumption during exercise (Felber Dietrich et al., 2008 ; Lavie, Church, Milani, & Earnest, 2011).

Children dealing with sports have significantly lower resting heart rate than the children with sedentary lifestyle because they have larger hearts in size and higher stroke volumes (Vivek et al., 2015). Decreased heart rate in association with increased stroke volume leads to a rise in maximum oxygen consumption because the highest heart rates recorded during exercise are similar in physically active and sedentary individuals (Lavie et al., 2011 ; Vivek et al., 2015).

In fact, heart rate is the result of a balance between sympathetic and parasympathetic nervous activities. Parasympathetic nervous activity is enhanced and sympathetic nervous activity is weakened in individuals who have good cardiorespiratory health status (Besnier et al., 2017). One reason for the enhancement in parasympathetic activity is vigorous exercise as it has been shown that doing physical activity for three months improves vagal activity (Sandercock et al., 2005). Regular physical training might induce repetitious stimulation of sympathetic activity, which is followed by deactivation of sympathetic activity and reciprocal acceleration in parasympathetic activity subsequently (Kaikkonen et al., 2014).

The HRV analysis has been adopted as a non-invasive and practical technique which can be used to assess the activity of autonomic nervous system and, more specifically vagal activity, by means of different time and frequency domain measures. This technique allows the investigation of short and long term health consequences and monitorization of performance in athletes (Plews, Laursen, Stanley, Kilding, & Buchheit, 2013). However, studies focusing on the HRV analysis of children/adolescents dealing with sports are still scanty in number and yield controversial results (Moraes et al., 2019 ; Sharma et al., 2017).

It has been reported that all parameters of HRV can be used to predict mortality or transplantation in a cohort of children with severe pulmonary hypertension (Lammers, Munnery, Hislop, & Haworth, 2010). Another study claimed that total cavopulmonary connection leads to a significant reduction in overall cardiac autonomic tone which had been interpreted as a good prognostic factor for children undergoing univentricular heart repair (Madan et al., 2014). Similarly, a Turkish study found that transcatheter closure of secundum atrial septal defect improves HRV which reduces morbidity and improves prognosis (Ozyilmaz et al., 2015).

Swimming is a popular physical activity which may help to reduce pain and alleviate psychological symptoms (Maged et al., 2018 ; Tian et al., 2018). Prior research has highlighted the benefits of swimming in the prevention and treatment of cardiovascular diseases (Nualnim et al., 2012 ; Tanaka, 2009).

Several studies have described the adaptive remodeling of the heart in swimmers. Swimming in prone position accelerates venous blood flow to the right atrium and ventricle which subsequently causes a disproportionate increase on the load of the right ventricle. This may lead to an acute dilatation in right ventricle but this dilatation is not usually associated with the dysfunction of right ventricle (D′Andrea et al., 2015 ; Martinez et al., 2019 ; Shoemaker et al., 2019). Prior research has specified that individuals who regularly train swimming have left ventricular dilatation, normal wall thickness to dimension ratio and increased stroke volume with normal diastolic filling (Lazar, Khanna, Chesler, & Salciccioli, 2013). In contrast, this study found that the swimmer children who had significantly higher left ventricle diastolic mass, significantly higher posterior wall systolic thickness, significantly lower mitral A wave and significantly lower interventricular septum E and A waves. Such discrepancy might be attributed to the relatively small cohort size, lack of longitudinal data and technical variations in the measurement and recording of echocardiography, ECG and HRV parameters.

P wave dispersion has been addressed as a marker for atrial remodeling and as an indirect predictor for atrial fibrillation. Increased p wave dispersion reflects the delay in intra-atrial and inter-atrial conduction time and this delay can be due to the lack of a well-coordinated conduction system within the atrial muscles (Izci et al., 2015). QT dispersion is an electrocardiography parameter which depends on the heterogeneity of repolarization. This marker might be used to predict ischemia related cardiac dysrhythmias in patients with ischemic heart diseases (Izci et al., 2015). Accordingly, this study specified the significant reduction in p-wave dispersion and QT dispersion values of the swimmer children.

The SDNN is a time-domain measurement which is accepted as the "gold standard" for identifying the risk of cardiac morbidity and mortality when it has been recorded over a period of 24 hours (Shaffer & Ginsberg, 2017). Total power is a frequency-domain measurement which refers to overall autonomic activity to which sympathetic activity contributes primarily (Shaffer & Ginsberg, 2017). An animal study has concluded that parasympathetic activity is the possible physiological mechanism for the resting bradycardia determined in swimmers (Medeiros et al., 2004). Complying with literature, the children who trained swimming in this study had significantly higher total power and SDNN values than the controls and other athletes.

CONCLUSION

Swimming is a physical activity type which can be practiced by children and young adults. This activity differs from other sports as it is related with prone positioning and immersion in water. The alterations in echocardiography, electrocardiography and HRV measurements of the swimmer children suggest that this sport might contributes to the growth of cardiac muscles, improve the cardiac conduction system and enhance parasympathetic innervation of the heart in children. However, the findings of the present study should be interpreted carefully as their power is limited by the cross-sectional study design, relatively small cohort size and lack of longitudinal data. Further research is warranted to clarify the effects of regular training in different physical activity modalities on the cardiac well being of children and adolescents.

AUTHOR CONTRIBUTIONS

AP designed the study, collected data and wrote the manuscript. MBP drafted the manuscript and critically revised the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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