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Cardiovascular Fitness in Normal Weight and Obese Children and Adolescents – A Systematic Review of Studies Published After 2000s

Condición Cardiovascular en Niños y Adolescentes con Peso Normal y Obesos: Una Revisión Sistemática de Estudios Publicados Después de la Década del 2000

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SUMMARY: The primary aim was to gather available data published after the 2000s, on cardiovascular fitness in normal weight and obese children and adolescents. Based on the data, the secondary aims were to identify the most used outcomes and to determine the differences in cardiovascular fitness in the mentioned populations. Following PRISMA recommendations, multiple databases were searched: Google Scholar, PubMed, Cochrane Library, ProQuest, and Research Gate, with additional inclusion criteria: original study published in English, normal weight and obese children and adolescents as participant sample, studies that have assessed cardiovascular fitness parameters, and studies with participant's nutrition state. A total of 19 studies, with a total of 4,988 included participants (both obese and normal weight) were identified, with the most common participants have presented better results in terms of BMI, BF%, VO_2max, VO_2peak and METs, while the HR values are inconsistently presented. Despite deficiencies the study deficiency in the last two decades, there are differences in the mentioned populations. Further studies should focus on including the technology that reaches teens and families for overweight and obesity prevention and advancements in standard measurements for juvenile overweight and obesity, as well as for the creation, adaption, and validation of measuring instruments. As good framework for future directions, there is a need for more concise and unified measurements of cardiovascular fitness parameters in normally weight and obese children and adolescents.

KEY WORDS: Endurance; Aerobic; Anaerobic; Overweight; Youngster.

INTRODUCTION

Obesity among children and adolescents is increasing worldwide in both developed and developing countries (Lobstein *et al*., 2004). Compared to children's physical activity until the age of ten, the trend of being physically active decreased by as much as 50 % during adolescence in boys and especially in girls (Kimm *et al*., 2002). There has been a decline in physical activity and an increase in energy intake from food during the last few years because children are increasingly prone to inactivity and a sedentary lifestyle (Stankovic *et al*., 2021). The misbalance of energy consumption and food intake leads to obesity, which further causes heart diseases with poor cardiorespiratory fitness. Likewise, obesity, a worldwide epidemic, is characterized by an excessive accumulation of fat tissue in the body, and its causes are genetic susceptibility, sex, age, occupation, diet, etc. (Blüher, 2019). In that regard, obesity is caused by insufficient physical activity (Solmi *et al*., 2021) - as many as 60-85 % of obese pubertal children remain obese in old age. Data from 1975 show us that only 11 million young people (from 5 to 19 years old) were obese, and in 2016, that number was raised to 124 million (Bentham *et al*., 2017). Obesity was found to be most prevalent in southern European

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countries, particularly in Italy (36 % of 9 years old), Spain (27 % of children and adolescents), and Greece (26 % of boys and 19 % of girls aged 6-17). Undernutrition and obesity are less common in Northern European countries, found in 20 % of children in Great Britain, 18 % of 10 year olds in Sweden, and 13 % of children in Finland (Lobstein & Frelut, 2003; Lissau *et al*., 2004; Garrido-Miguel *et al*., 2019).

According to the World Health Organization (2010), health fitness is the ability to perform moderate to intense physical activity. On the other hand, it is not accompanied by fatigue and it requires strength, endurance or flexibility. The components of health fitness are cardiorespiratory fitness, muscle fitness, flexibility, and body composition (Chiang *et al*., 2022). Physical activity can influenced these components, thereby improving the overall health status of each individual (World Health Organization, 2010; Chiang *et al*., 2022). The positive effects of physical activity influence the proper growth and development of children, especially in the domains of cardiovascular fitness, lipids, lipoproteins, blood pressure, and symptoms of anxiety and depression (Strong *et al*., 2005). Cardiorespiratory fitness is considered the paramount parameter in health status monitoring and it consists of the cardiovascular and respiratory systems for prolonged exercise under load (Ortega *et al*., 2008). An increase in cardiorespiratory endurance can only be achieved with a proper physical activity plan and program, regardless of children's weight (Burns *et al*., 2018). Depending on a child's sex and age, reference values represent a predefined range of parameters for cardiovascular fitness, heart rate responses and systolic blood pressure at a maximal exercise test (Paridon *et al*., 2006). Cardiorespiratory fitness, also know as aerobic endurance, represents the ability of the whole body to maintain high and long-term efforts (Bosquet *et al*., 2002). On the other hand, indicators of autonomic nervous function are heart rate recovery after exercise (Jolly *et al*., 2011), heart rate variability and resting heart rate (Barbieri *et al*., 2005). All autonomic nervous function indicators mentioned are greatly influenced by aerobic fitness (Djordjevic *et al*., 2021).

Previous research has confirmed that obese children have significantly higher blood pressure compared to normally weight children (Reich *et al*., 2003; Burke *et al*., 2004; Li *et al*., 2016). Children who are more physically active have higher aerobic fitness (boys 42.9 ml/kg/min and girls 30.8 ml/kg/min), while obese children (boys 35.9 ml/kg/min and girls 25.8 ml /kg/min) have much lower (Mitova *et al*., 2012). According to Dosic *et al*. (2020), the risk of obesity is reduced by 10 % with an increase in maximal oxygen consumption (VO2max) of only 1 ml/kg/min. In that regard, Strong *et al*. (2005) recommend appropriate and enjoyable physical activity, depending on the age of the child, lasting at least 60 minutes each day, followed by the desired health outcomes.

Based on all the above, the primary aim was to gather available data published after 2000s, on cardiovascular fitness in normal weight and obese children and adolescents. Based on the data, the secondary aims were to identify the most used outcomes and to determine the differences in cardiovascular fitness in the mentioned populations.

MATERIAL & METHOD

Literature Identification. This study followed the PRISMA recommendations (Page *et al*., 2021; Rethlefsen *et al*., 2021). Multiple databases (Google Scholar, PubMed, Cochrane Library, ProQuest, and Research Gate) were used to identify the literature, with an extra publication time criteria (2000-2023). Likewise, in order to find relevant studies that have reported cardiovascular fitness in normal weight and obese children and adolescents, the following keywords (individual or combination) were searched in the above mentioned databases: („cardiovascular " OR „VO_2max" OR „heart rate" OR „cardiac" OR „heart" OR „blood vessels" OR „vascular") AND („fitness" OR „aerobic" OR „condition" OR „endurance" OR „coordination") AND („well-fed" OR „healthy" OR „normally weight") AND („obese" OR „overweight" OR „massive" OR „corpulent") AND („youngster" OR „toddler" OR „youth" OR „children" OR „adolescent").

Following the first identification, the studies were evaluated. All titles, abstracts, and full-text studies were examined for prospective inclusion using a descriptive approach. In addition, the authors were independently doing study search and evaluation, using the reference list from previously examined and published studies. Then, each author has cross-examined all identified literature and studies were included or excluded based on that search point.

Inclusion Criteria. The following inclusion criteria were defined when choosing studies for the final analysis: (1) original scientific publication; (2) written and published in English language; (3) normally weight and obese children and adolescents as participant sample; (4) studies that have assessed cardiovascular parameters; (5) studies that have included the participant's nutrition state.

Risk of Bias Assessment. For the purpose of determining the study quality and the possible risk of bias, Physiotherapy Evidence Database, i.e. the PEDro scale was used (de Morton, 2009). Two authors were separately examining it, by using checklists. To examine the complete text and to determine relativity and bias risk, k-statistics data was used to estimate reviewer concordance. In a case of a disagreement, the data was evaluated by the third reviewer, who have also made the final decision. The k rate of concordance between reviewers' findings was k=0.93.

Data Extraction. After cross-examination relevant information was extracted only if it was related to the study's aim. Following that, the Cochrane Consumer and Communication Review Group was used to extract the information, which included the following: the first author and the year of publication, study aim, sample size and age, examined tests, outcomes and study results.

RESULTS

Study Quality. Regarding the included studies, risk of bias assessment was determined based on the points scored by each study on the PEDro scale. Likewise, an optimal gained points are between 8-11 (Maher *et al*., 2003). Of all included studies, 4 studies showed fair quality, 12 studies showed good quality and 3 studies showed excellent quality. Table I presents all PEDro scale results.

Study Selection and Characteristics. A descriptive method and theoretical analysis were used for collecting, classifying, and analyzing targeted research. After a general database search, 1,246,481 studies were identified. Right at the beginning, a total of 2,762 duplicates were excluded. Subsequently, 1,243,719 studies underwent further screening. Based on the pre-defined inclusion criteria, 117 studies have left. What is more, an additional 65 studies were excluded after increased sensitivity and a more in-deeper check and 33 studies with non-relevant outcomes. At last, 19 studies were included in the systematic review. PRISMA flow chart (Fig. 1) was used as an illustration to present the study selection, while closer description/ characteristics of the included studies can be seen in Table II.

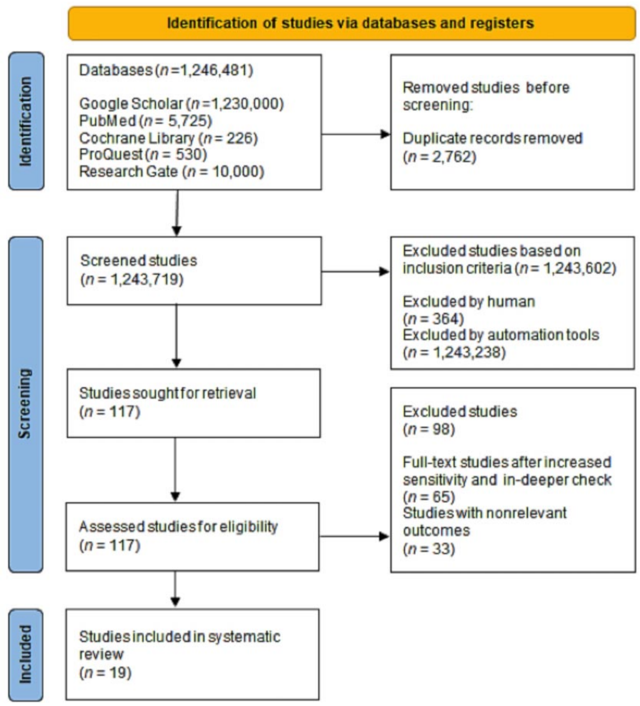

Fig. 1. Process of collecting adequate studies.

Table I. PEDro scale results.

	Criterion											
Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Σ**
He *et al*. (2000)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	**8**
Martini *et al*. (2001)	Y	N	N	N	Y	N	N	Y	Y	Y	Y	**6**
Loftin *et al*. (2001)	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	**6**
Ekelund *et al*. (2004)	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	**8**
Chatterjee *et al*. (2005)	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	**9**
Mota *et al*. (2006)	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	**7**
Bunc (2006)	Y	N	N	N	Y	N	N	Y	Y	Y	Y	**6**
Schiel *et al*. (2006)	Y	N	N	N	N	N	N	Y	Y	Y	Y	**5**
Calders *et al*. (2008)	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	**8**
Carletti *et al*. (2008)	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	**9**
Paschoal *et al*. (2009)	Y	N	N	N	N	N	Y	Y	Y	Y	Y	**6**
Vanderlei *et al*. (2010)	Y	N	N	Y	N	N	Y	Y	Y	Y	Y	**7**
Esmaeilzadeh & Ebadollahzadeh (2012)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	**8**
Calcaterra *et al*. (2013)	Y	N	N	N	N	N	N	Y	Y	Y	Y	**5**
Tsiros *et al*. (2016)	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	**7**
Zivkovic *et al*. (2018)	Y	N	N	N	N	N	N	Y	Y	Y	Y	**5**
Plaza-Florido *et al*. (2019)	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	**9**
Dosic *et al*. (2020)	Y	N	N	N	N	N	N	Y	Y	Y	Y	**5**
Iskenderoglu *et al*. (2023)	Y	N	N	N	N	N	Y	Y	Y	Y	Y	**6**

Legend: 1—eligibility criteria; 2—random allocation; 3—concealed allocation; 4—baseline comparability; 5—blind subject; 6—blind clinician; 7—blind assessor; 8—adequate follow-up; 9—intention-to-treat analysis; 10—between group analysis; 11—point estimates and variability; Y—criterion is satisfied; N—criterion is not satisfied; Σ—total awarded points.

There was a total of 4,988 participants that have been included in the systematic review. The minimum number of participants included was 18 (Ekelund *et al*., 2004), while the highest was 1,333 (He *et al*., 2000). The youngest participants ranged from 0.1-6.9 years old (He *et al*., 2000) and the oldest were 19.9 years old (Ekelund *et al*., 2004). A total of 3,456 were males and 2,062 were females. Likewise, there were around 1,887 participants who were obese, whereas around 2,197 were normally weight (except the total participant sample, the rest of the presented numbers should be used with caution). In addition, two studies have included male participants only (Esmaeilzadeh & Ebadollahzadeh, 2012; Dosic *et al*., 2020), and only one study (Loftin *et al*., 2001) had female participants only. The other 16 included studies had mixed gender participants.

Table II. Participants and group in-close characteristics.

First author and publication year	Study Aim	Participants sample		Tests	Outcomes	Results
		Group	Age			
He *et al*. (2000)	To examine the association between obesity and BP in preschool Chinese NW and O	N-1322 M-748 F-574 O-667 NW-667	0.1-6.9	/	BMI DBP SBP	SBP and DBP are significantly ($p<0.05$) positively related to BMI values ($p<0.05$) for O and NW after adjustment for age, gender and BH
Martini *et al.* (2001)	To determine an early sign of CAD in O, analyzing time and frequency domain measures of healt period variability by 24h recording	N-45 M-24 F-21 O-32 NW-13	12-13	24h monitoring	HR SBP DBP	(before 24h) HR (bpm) (O) 77.1±8.1 (NW) 76±10.3 ($p<0.42$) SBP (mm/Hg) (O) 127.6±13 (NW) 119.5±9.1 ($p<0.004$) DBP (mm/Hg) (O) 83.5±8.8 (NW) 73.3±9.2 ($p<0.004$) (after 24h) HR (bpm) (O) 83±10 (NW) 74.4±6 ($p<0.01$) SBP (mm/Hg) (O) 118.6±8.5 (NW) 112.5±8.1 ($p<0.03$) DBP (mm/Hg) (O) 69.1±5.6 (NW) 64.1±4.2 ($p<0.02$)
Loftin *et al.* (2001)	To compare the VO_2peak of O with NW girls according to allometric scaling measures and methods	F-46	7-18	T (Run/walk)	HR VO_2peak	HR (bpm) (O) 191.7±9.3 (NW) 202.6±8.4 ($F=34.6$; $p=0.00$) VO_2peak (mL/kg/min) (O) 22.8±7.3 (NW) 45.8±7.2 ($F=232.6$; $p=0.00$)
Ekelund *et al.* (2004)	To test whether VO_2 and VO_2max differs between O and NW	N-18 M-8 F-10	14.1-19.9	T (5min. walk at 4km/h)	VO_2 VO_2max	VO_2 (mL/kg/min) (M/F) (O) 2.8±0.18/2.6±0.17 (NW) 3.6±0.26/3.4±0.56 group, $p<0.01$ VO_2max (mL/kg/min) (M/F) (O) 36.3±3.6/28.4±5.8 (NW) 50.9±7.6/41.1±8 sex, $p<0.001$; group, $p<0.001$
Chatterjee *et al.* (2005)	To determine CrF in terms of VO_2max in O	M-119 O-49 NW-70	10-16	QCT	VO_2max	VO_2max (mL/kg/min) (O) 39.6±2.6 (NW) 48.4±1.8 $p<0.001$
Mota *et al.* (2006)	To examine differences of CrF among weight groups normal, overweight and obese), and the associations of CrF with obesity (BMI)	N-255 M-127 F-128	8-10	1mile run test	BMI	BMI and CrF ($p=0.000$) between all groups (M) BMI and CrF ($p=0.000$) between all groups (F) CrF and BMI (M) ($r=-0.161$, $p<0.061$) CrF and BMI (F) ($r=-0.363$, $p<0.000$)
Bunc (2006)	To determine the interdependence of some BC variables and VO_2max in NW	N-1235 M-756 F-479	6-14	T (5% inclined)	VO_2max	VO_2max and BF% (M) $r=-0.511$; $p<0.0001$ (F) $r=-0.584$; $p<-0.0001$ VO_2max with BC parameters in NW are good predictors of AF

First author and publication year	Study Aim	Participants sample		Tests	Outcomes	Results
		Group	Age			
Schiel *et al.* (2006)	To determine the association and interactions between BH, BW, BMI, and BP values in O and NW children and adolescents	N-172 O-86 NW-86	6-16	/	DBP SBP BMI	DBP (mm/Hg) (O) 75.6±8.8 (NW) 69.5±8.8 $p<0.001$ SBP (mm/Hg) (O) 117.9±9.7 (NW) 114.4±11 $p<0.001$ (O) BMI with SBP (R^2=0.26, Beta=0.52, $p<0.001$) DBP with BH (R^2=0.22, Beta=0.48, $p<0.001$) (NW) Age (Beta=0.32, p=0.01) and BH (Beta=0.28, p=0.03) with SBP (R^2=0.15) BH (Beta=0.39, $p<0.001$) with DBP (R^2=0.28)
Calders *et al.* (2008)	To identify predictors that contribute to the variability in the distance achieved during a 6min. walk test or 12min. walk/run test in O	N-64 M-44 F-20	10-18	6 min. walk test 12 min. walk/run test (3 months, pre-post)	VO_2peak HR	(pre vs. after 3 months) VO_2peak (mL/kg/min) 24.6±6.37 vs. 29.4±6.05 ($p<0.001$) HR (begin) (bpm) 111±11.4 vs. 99±11.1 ($p<0.001$) HR (end) (bpm) 172±14.9 vs. 167±14.9 ($p<0.05$) 6min. walk test (m) 611±71.9 vs. 653±95.9 ($p<0.001$) 12min. walk/run test (m) 1362±222.2 vs. 1673±363.6 ($p<0.001$)
Carletti *et al.* (2008)	To determine the response of CV variables to acute physical exertion in O	N-104 M-56 F-48 O-52 NW-52	11-15	ESM (pre-post measurement)	DBP SBP VO_2max HR	(F) O vs. NW DBP (mm/Hg) Pre 67±8 vs. 65±7 (p=0.46) 100%VO_2max 53±6 vs. 55±6 (p=0.22) SBP (mm/Hg) Pre 114±11 vs. 106±10 (p=0.009) 100%VO_2max 143±11 vs. 138±13 (p=0.16) VO_2max (mL/kg/min) 33.35±5.3 vs. 36.73±7.12 (p=0.07) HR 100% VO_2max 197±12 vs. 194±16 (p=0.52) (M) O vs. NW DBP (mm/Hg) Pre 69±9 vs. 67±7 (p=0.38) 100%VO_2max 57±9 vs. 56±7 (p=0.74) SBP (mm/Hg) Pre 120±14 vs. 109±10 (p=0.003) 100%VO_2max 156±20 vs. 146±14 (p=0.03) VO_2max (mL/kg/min) 36.24±7.2 vs. 42.6±6.6 (p=0.001) HR 100% VO_2max 195±12 vs. 195±13 (p=0.97)

First author and publication year	Study Aim	Participants sample		Tests	Outcomes	Results
		Group	Age			
Paschoal *et al.* (2009)	To determine the effects of obesity on HRV, BL and physical capacity of O	N-30 M-16 F-14 O-15 NW-15	9-11	T (initial velocity of 2km/h, 2min. and 0.5km/h increments every subsequent minute)	BMI DBP SBP HR VO_2peak METs	O vs. NW BMI (kg/m^2) 23.8±1 vs. 17.7±1.6 (p=0.0001) DBP (mm/Hg) 72.8±7.9 vs. 71.3±9.1 (p=0.7) SBP (mm/Hg) 114.6±8.5 vs. 112.3±10.1 (p=0.3) HR (bpm) 84.8±11.2 vs. 80.2±7.4 (p=0.1) VO_2peak (mL/kg/min) 15.7 vs. 33.6 METs 4.5 vs. 9.6
Vanderlei *et al.* (2010)	To analyze heart rate dynamics in O by measuring short- and long-term fractal exponents and HRV	N-112 M-53 F-59 O-51 NW-61	8-12	/	HR (LF/HF)	O vs. NW LF (ms^2) 260.1±183 vs. 384.4±211.7 (p<0.001) HF (ms^2) 207.3±186 vs. 251.6±155 (p<0.019)
Esmaeilzadeh & Ebadollahzadeh (2012)	To examine differences in physical fitness among participants with different BMI	M-766	7-11	1mile walk/run	VO_2max BMI	VO_2max (mL/kg/min) (O) 40±2.8 (NW) 47±2 (p≤0.01) BMI (kg/m^2) (O) 25.1±2.9 (NW) 16.2±1.3 (p≤0.01) VO_2max gradually decreased with increasing BMI
Calcaterra *et al.* (2013)	It was a 12 week recreational training program for sedentary O	N-22 M-13 F-9	9-16	12 weeks, 2x a week, 90min (fitness, basketball, volleyball, rugby); 60-75% maximal HR (pre-post measurement)	VO_2max BMI DBP SBP	VO_2max (mL/kg/min) 47.5±6.5 vs. 51.3±6.3 (p<0.001) BMI (kg/m^2) 32.9±4.3 vs. 31.9±4.6 (p=0.002) DBP (mm/Hg) 72.1±7.3 vs. 68.4±5.5 (p=0.12) SBP (mm/Hg) 118.3±10 vs. 111±9.8 (p=0.04)
Tsiros *et al.* (2016)	The relationship in PA level and CrF in O and NW	N-239 O-107 NW-132	10-13	CE (60-70 revolutions per min.)	BMI BF% VO_2peak	O vs. NW BMI (kg/m^2) 29.6±0.4 vs. 18.2±0.2 (p<0.01) BF% 21.7±0.6 vs. 45.4±0.5 (p<0.01) VO_2peak (mL/kg/min) 89.36±1.6 vs. 116.95±1.7 (p<0.001)
Zivkovic *et al.* (2018)	To determine the relationship between fitness parameters and morphological characteristics of 7 years old O	N-103 M-40 F-63	7.04	/	BMI HR VO_2max	(M vs. F) BMI (kg/m^2) 23.24±1.93 vs. 22.62±1.84 HR (bpm) 95.90±13.80 vs. 96.60±14.49 VO_2max (mL/kg/min) 44.51±1.18 vs. 43.29±1.32 (R^2=0.35, p<0.008) (R^2=0.30, p<0.051) Children with larger body dimensions have lower CrF values

First author and publication year	Study Aim	Participants sample		Tests	Outcomes	Results
		Group	Age			
Plaza-Florido *et al.* (2019)	To determine the relationship between HR, HRV and CrF in O	N-107 M-62 F-45	10.3±1.13	T (4.8km/h, start at 6% slope with 1% increment every minute)	BMI BF% VO_2peak HR (LF/HF)	M vs. F BMI (kg/m^2) 26.92±3.74 vs. 26.58±3.47 BF% 42.87±5.04 vs. 45.65±5.87 VO_2peak (mL/kg/min) 37.71±4.94 vs. 36.77±4.14 HR (bpm) 80.4±9.33 vs. 82.93±10.12 LF (ms^2) 1331.40±1687.08 vs. 1260.57±1385.01 HF (ms^2) 1410.64±2945.46 vs. 1142.54±2316.98 HR is strongest predictor of CrF (β=-0.222, R^2=0.111, p<0.001)
Dosic *et al.* (2020)	To determine the correlation of morphological characteristics and fitness parameters in O	M-198	7.11±0.38	/	BMI BF% VO_2max	BMI (kg/m^2) 22.42±3.14 BF% 33.03±7.54 VO_2max (mL/kg/min) 44.68±8.74 (R^2=0.98, p<0.000) (R^2=0.95, p<0.000) (R^2=0.81, p<0.000)
Iskenderoglu *et al.* (2023)	Physical fitness and activities of daily living participation limitations in O and NW adolescents	N-31 M-15 F-16 O-15 NW-16	12-18	MFT MSWT	BMI VO_2peak HR DBP SBP	M vs. F BMI(kg/m^2) (O) 30.90±1.51 vs. 33.23±4 (NW) 19.42±0.9 vs. 19.19±2.28 (p=0.000) VO_2peak (mL/kg/min) (O) 22.8±6.35 vs. 21.67±3.43 (NW) 30.24±4.46 vs. 29.72±9.37 (group, p=0.000; group_gender, p=0.870) HR (bpm) (O) 91.62±4.20 vs. 81.12±25.57 (NW) 90.12±13.08 vs. 93.12±15.04 (group, p=0.144; group_gender, p=0.745) DBP (mm/Hg) (O) 5.14±9.30 vs. 10±14.06 (NW) 11.25±12.78 vs. 11.37±3.20 (group, p=0.342; group_gender, p=0.546) SBP (mm/Hg) (O) 36.29±21.60 vs. 32±15.18 (NW) 33.12±14.12 vs. 38.12±11.08 (group, p=0.804; group_gender, p=0.425) VO_2Peak is significantly associated with BMI

Legend: N–total number of participants; M–male; F–female; O–obese children; NW–normally weight children; HR–heart rate; DBP–diastolic blood pressure; SBP–systolic blood pressure; BP–blood pressure; BW–body weight; BH–body height; BMI–Body Mass Index; bpm–beats per minute; CAD–cardiac autonomic dysfunction; VO2peak–peak oxygen consumption; T–treadmill; CE–cycle ergometer; VO2max–maximum oxygen consumption; VO2–resting oxygen uptake; CrF–cardiorespiratory fitness; QCT–Queen's College Step Test; FBT–Fitnessgram Battery test; BC–body composition; BF%–body fat percentage; AF–aerobic fitness; PA–physical activity; CV-cardiovascular; ESM-ergospirometer, HRV–heart rate variability; BL–blood lipid level; METs–metabolic equivalent; LF–low frequency; HF–high frequency; MFT–Munich Physical Fitness Test; MSWT–Modified Shuttle Walk test; F–variation between sample means; p–statistical significance (p≤0.05); r–Pearson's correlation coefficient.

The treadmill was the most commonly used evaluation test (Loftin *et al*., 2001; Ekelund *et al*., 2004; Bunc, 2006; Paschoal *et al*., 2009; Plaza-Florido *et al*., 2019), with the walking/running tests (Mota *et al*., 2006; Calders *et al*., 2008; Esmaeilzadeh & Ebadollahzadeh, 2012). As far as the included variables are concerned, they are various: BMI, BF%, VO_2max, VO_2peak, HR (both LF and HF) DBP, SBP and METs. Additionally, evaluation tests, such as Queen's College Step Test (Chatterjee *et al*., 2005), cycle ergometer (Tsiros *et al*., 2016), Modified Shuttle Walk test and Munich Physical Fitness Test (Iskenderoglu *et al*., 2022) were used. Furthermore, there were two longitudinal studies, that lasted for 12 weeks (Calders *et al*., 2008; Calcaterra *et al*., 2013), while the other 17 included studies were cross-sectional.

DISCUSSION

The primary aim of this study was to gather available data published after the 2000s, on cardiovascular fitness in normal weight and obese children and adolescents. Based on the data, the secondary aims were to identify the most used outcomes and to determine the differences in cardiovascular fitness in the mentioned populations. Based on the analysis of included studies, the findings suggests that normal weight participants present better results in terms of BMI, BF%, VO_2max, VO_2peak and METs, compared to the obese participants, while the values of resting heart rate (HR) is presented inconsistently.

The body composition of children and adolescents goes through various metabolic changes that provide us with information about the future growth and development. Adipose tissue is endocrinologically active and involved in the interaction between adipocytokines, insulin, and sex-steroid hormones, thereby influencing cardiovascular fitness and metabolic processes (Bunc, 2006). In that regard, Pantelic (2017) considers that excess fat tissue is an obstacle to developing fitness abilities and motor tasks, which is in accordance with another studies (Zivkovic *et al*., 2018; Dosic *et al*., 2020), who have identified that children with higher fat mass have worse results in cardiovascular endurance, leg strength, flexibility, and running speed. Hence, overall BMI values are significantly associated with cardiorespiratory fitness, and therefore, multiple included studies have confirmed this statement (Mota *et al*., 2006; Paschoal *et al*., 2009; Esmaeilzadeh & Ebadollahzadeh, 2012; Tsiros *et al*., 2016).

Some authors (Plaza-Florido *et al*., 2019; Alagesan & Brite Saghaya Rayna, 2020) suggests that HR is one of the strongest predictor of cardiovascular fitness. The heart rhythm is regulated by the sympathetic nervous system, while both HR and BP are associated with sympathetic decline, whereas increased heart rate is associated with obesity (Loftin *et al*., 2001; Martini *et al*., 2001; Ekelund *et al*., 2004; Vanderlei *et al*., 2010; Téllez *et al*., 2018). Thus, higher BP and HR with metabolic changes such as hyperinsulinemia, euglycemia, and dyslipidemia, are also associated with obesity (Martini *et al*., 2001; Schiel *et al*., 2006). Increased triglyceride values and a decrease in high density lipoprotein (HDL), cholesterol and physical capacity are accompanied by an increase in obesity (Paschoal *et al*., 2009). Likewise, by revealing the significant relation between BP and BMI (He *et al*., 2000; Schiel *et al*., 2006), these results are in accordance with other study results (Gundogdu, 2008; He *et al*., 2008), whereas SBP only (He *et al*., 2000) is related to BMI (Gundogdu, 2008; He *et al*., 2008). Regardless of the fact that these results were presented in normally weight participants, in those terms, only He *et al*. (2000), can be relatable. In regard to the previous, Reinehr *et al*. (2005), discovered that children above the age of 12 had a slightly increased risk of hypertension, most likely due to the impact of the obesity duration. This means that a slight disturbance in BP in children and adolescents would have huge public health consequences in terms of avoiding hypertension and cardiovascular disease in the future (He *et al*., 2008).

We have identified that VO_2max values were lower in obese children, because the fat mass represents a burden for the heart when taking in the oxygen, as well as transporting oxygen, which leads to impaired aerobic capacity (Mota *et al*., 2006; Esmaeilzadeh & Ebadollahzadeh, 2012; Alagesan & Brite Saghaya Rayna, 2020). The results by Ara *et al*. (2007), have shown a statistically significant relationship between VO_2max and the nutritional level that obese children had lower VO_2max values, where obesity was more prevalent in females than males (8 % and 5 %, respectively). This could be expected, because of the fact that females have a greater BF% than males, and deposit it in a different manner, with more adipose tissue in the hips and thighs (Manolopoulos *et al*., 2010; Karastergiou *et al*., 2012). There may be a potential link with other published studies (Parikh *et al*., 2018; Arora *et al*., 2021) as well, who have stated that children with higher visceral fat had lower aerobic fitness than those with normal visceral fat. Regardless of the fact that Dosic *et al*. (2021), have revealed the influence of body mass on VO_2max in 8.9 years old boys only, we can assume that there could be gender differences, but further confirmations are needed.

After a three-month study with the application of physical activity positive effects in obese children were shown - an increase in VO_2peak, a decrease in HR and a slight increase in vital capacity, lung function, and residual volume (Calders *et al*., 2008). VO_2max in studies by Ekelund *et al*. (2004), was higher in men in both groups, but with appropriate adjustments, neither group differed. In terms of VO_2peak being relative to mass, it was 50 % lower in obese children, and with several adjustments for mass and height, they were 10-11 % lower in obese females than in normally weight females (Loftin *et al*., 2001; Calcaterra *et al*., 2013). Gender impacts daily activity performance, with obese female adolescents doing worse than non-obese female adolescents. Peripheral muscular strength, endurance, power and cardiorespiratory fitness, measures of physical fitness, are severely impacted and the involvement of adolescents with obesity diminishes owing to limitations in physical function and sports, happiness and their overall functions (Iskenderoglu *et al*., 2022). Likewise, obese children have poor relative oxygen consumption, which suggests that reduced oxygen use by adipose tissue reduces VO_2max. Therefore, the implementation of regular physical activity contributes to the preservation of cardiovascular fitness. More research is needed to determine the effects of fun and appropriate activities or exercise treatments, cardiovascular risk factors in obese children and adolescents.

We are aware of the fact that there is a scarce number of included studies, regardless of the fact that this topic is popular and commonly known, this is a main study limitation. Additionally, the study faced limitations due to a broad age range and the omission of participants' previous physical activity levels.

CONCLUSION

In regard to the study aim, a total of 19 studies were included in the systematic review. Likewise, the most commonly used tests are BMI, BF%, HR, VO_2max, VO_2peak and METs. Obese children have lower relative oxygen consumption, implying that decreased oxygen utilization by adipose tissue affects VO_2max and METs as well. The normally weight participants performed better in terms of BMI, BF%, VO_2max, VO_2peak and METs than the obese participants, while HR values were inconsistently represented, so we could not draw any deeper conclusions. Also, further studies should focus on separating treatments by age and groups, including the technology that reaches teens and families for overweight and obesity prevention, advancements in standard measurements for juvenile overweight and obesity are required, as well as for the creation, adaption and validation of measuring instruments for children who are at high risk of obesity. The current study provides a solid framework for future directions, such as the need for more concise and unified measurements of cardiovascular parameters in normal weight and obese children and adolescents.

CAPRIC, I.; STANKOVIC, M.; SPIRTOVIC, O.; COROVIC, M.; MUJANOVIC, D.; MOJSILOVIC, Z.; JELASKA, I. & ZILIC-FISER, S. Condición cardiovascular en niños y adolescentes con peso normal y obesos: Una revisión sistemática de estudios publicados después de la década del 2000. I*nt. J. Morphol., 41(6)*:1852-1862, 2023.

RESUMEN: El objetivo principal fue recopilar datos disponibles publicados después de la década del 2000 sobre la condición cardiovascular en niños y adolescentes con peso normal y obesos. En base a estos datos, los objetivos secundarios fueron identificar los resultados más utilizados y determinar las diferencias en la condición cardiovascular en las poblaciones mencionadas. Siguiendo las recomendaciones de PRISMA, se realizaron búsquedas en múltiples bases de datos: Google Scholar, PubMed, Cochrane Library, ProQuest y Research Gate, con criterios de inclusión adicionales: estudio original publicado en inglés, niños y adolescentes con peso normal y obesidad como muestra participante, estudios que hayan evaluado enfermedades cardiovasculares, parámetros de condición física y estudios con el estado nutricional de los participantes. Se identificaron un total de 19 estudios, con un total de 4.988 participantes incluidos (tanto obesos como con peso normal), siendo las variables más comunes: IMC, %BF, VO_2máx, VO_2pico, FC, PAD, PAS y MET. Generalmente, los participantes con peso normal han presentado mejores resultados en términos de IMC, %BF, VO_2máx, VO_2peak y MET, mientras que los valores de FC se presentan de manera inconsistente. Independientemente de la deficiencia de estudios en las últimas dos décadas, existen diferencias en las poblaciones mencionadas. Estudios futuros deberían centrarse en incluir tecnología que llegue a adolescentes y familias para la prevención del sobrepeso y la obesidad y avances en las mediciones estándar del sobrepeso y la obesidad juvenil, así como para la creación, adaptación y validación de instrumentos de medición. Como buen marco para direcciones futuras, se necesitan mediciones más concisas y unificadas de los parámetros de la condición cardiovascular en niños y adolescentes con peso normal y obesos.

PALABRAS CLAVE: Resistencia; Aeróbica; Anaeróbica; Sobrepeso; Joven.

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