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Cardiometabolic risk in children and adolescents: mediation analysis of crosssectional study

Riesgo cardiometabólico en niños y adolescentes: análisis de mediación del estudio transversal

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Abstract

The aims of this study were a) to assess whether obesity acts as a mediator between i) cardiorespiratory fitness (CRF) and mean blood pressure; and ii) between between physical activity (PA) and mean blodd pressure in children and adolescents. A cross-sectional study was conducted with a 632 children and adolescents. It was measured mean blood pressure, body mass index, fat mass and waist circumference. CRF and PA was assessing with Course Navette test and ActiGraph. The analysis of the mediation was performed using Process macro for SPSS. The results indicate that obesity acts as a partial mediation in the association between CRF and mean blood pressure in 10-12 years old children (z=from -5.81 to -5.40; all p<0.000). These results indicate that obesity acts as a complete mediator in the association between PA and mean blood pressure in 10-12 years old children (z=from -4.49 to -1.94; all p<0.000). Our result reinforces the relevance of prevent weight increse and improve cardiorespiratory fitness level since erly age in children and adolescents to prevent high mean blood pressure. Increasing the level of physical activity can influence on obesity and cardiorespiratory fitness.

Key words: hypertension; school; overweight; metabolic syndrome; cardiovascular disease.

Resumen

Los objetivos de este estudio fueron: a) evaluar si la obesidad actúa como mediador entre i) la aptitud cardiorrespiratoria (CRF) y la presión arterial media; y ii) entre la actividad física (AF) y la presión arterial media en niños y adolescentes. Se realizó un estudio transversal con 632 niños y adolescentes. Se midió la presión arterial media, el índice de masa corporal, la masa grasa y la circunferencia de la cintura. El CRF y la AF se evaluaron con la prueba de Course Navette y el dispositivo ActiGraph. El análisis de la mediación se realizó utilizando Process macro for SPSS. Los resultados indican que la obesidad actúa como mediadora parcial en la asociación entre el CRF y la presión arterial media (z=de -5,81 a -5,40; todos p<0.000) y que la obesidad actúa como mediador completo en la asociación entre la AF y la presión arterial media en niños de 10 a 12 años (z=de -4,49 a -1,94; todos p<0.000). Nuestro resultado refuerza la relevancia de prevenir el aumento de peso y mejorar el nivel de aptitud cardiorrespiratoria desde temprana edad para prevenir la presión arterial. El aumento del nivel de actividad física puede influir en la obesidad y en la aptitud cardiorrespiratoria.

Palabras clave: hipertensión; escuela; sobrepeso, síndrome metabólico; enfermedad cardiovascular.

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Introduction

Cardiovascular diseases are the first cause of death worldwide. Detection and early treatment will contribute to its prevention (World Health Organization (WHO), 2017). High blood pressure and overweight or obesity are described as cardiovascular risk factors in children and adolescents (Zimmet et al., 2007). It has been described a prevalence of 10.5% of hypertension in children and adolescents from 3 to 17 years-old according to KiGGS percentiles (Neuhauser, Adler & Sarganas, 2019). High level of blood pressure in children and adolescent have been correlated with high level in the adulthood (Falkner, Lurbe & Schaefer, 2010). The presence of overweight and obesity increased the probability of having high blood pressure (Duncan et al., 2013; Neuhauser et al., 2019).

High blood pressure has been related with low level of cardiorespiratory fitness (CRF) and physical activity (PA) (Anderssen et al., 2007; Kriemler & Zahner, 2008) in children and adolescents. Likewise, it is well known that overweight and obesity showed an inverse association with CRF (Fogelholm, Stigman, Huisman & Metsämuuronen, 2007; Rizzo, Ruiz, Hurting-Wennlof, Ortega & Sjostrom, 2007; Stodden, Goodway, Langendorfer, Roberton, Rudisill, Garcia, et al. 2008; Stratton, Canoy, Boddy, Taylor, Hackett & Buchan, 2007) and PA (Czyż, Toriola, Starościak, Lewandowski, Paul & Oyeyemi, 2017; Metcalf, Hosking, Jeffery, Voss, Henley & Wilkin, 2011; Monyek et al., 2017; Poitras et al., 2016; Raistenskis, Sidlauskiene, Strukcinskiene & Baysal, 2016; Stodden, Goodway, Langendorfer, Roberton, Rudisill, Garcia, et al. 2008; Tambalis, Panagiotakos, Psarra & Sidossis, 2019).

It has been studied the influence of obesity as a mediatior of the correlation between CRF and cardiometabolic risk (Díez-Fernández, Sánchez-López, Mora-Rodriguez, Notario-Pacheco, Torrijos-Niño & Martínez-Vizcaíno, 2014) or between PA and cardiometabolic risk (Segura-Jiménez et al., 2016) in children and adolescents. However, there are just one study (Pozuelo-Carrascosa, Sánchez-López, Cavero-Redondo, Torres-Costoso, Bermejo-Cantarero & Martínez-Vizcaíno, 2017) that assessed obesity as a mediatior of the relationship between CRF and blood pressure; and there are no studies that assess obesity as mediation the association between PA and blood pressure. Pozuelo-Carracosa et al. (2017) used body mass index (BMI) as a marked of the obesity in their study. Nevertheless, it has been highlighted the limitations of BMI in children and adolescent as an obesity mark. There are others techniques considered reference standard methods for measurement of body adiposity, such as bioelectrical impedance analysis, dual energy X-ray absorptiometry and skin-fold thickness measurement (Javed, Jumean, Mura, Okorodudu, Kumar, Somers & Sochor, 2014). In addition, the sample of this mentioned study (Pozuelo-Carrascosa et al., 2017) are 4-7 years old and studies with other ages in children and adolescents have not been carried out. On the other hand, mean blood pressure (MBP) has demonstrated to be a predictor of cardiovascular disease in adults (Franklin et al., 2015) but, although recent study use MBP (Díez-Fernández et al., 2014; Pozuelo-Carrascosa et al., 2017), the association of MBP with obesity and CRF in children and adolescents is no clear.

The hypothesis of the present study was that the obesity acts as a mediator between CRF and MBP; and between PA and MBP in children and adolescents. Therefore, the aims of this study were assess whether obesity (BMI, FM and WC) acts as a mediator between CRF and MBP in children and adolescents and to examine whether the association between PA and MBP is mediated by obesity (BMI, FM and WC).

Methods

Study Design

Date used in this cross-sectional study is derived from AFINA-te Project Study (PA and Nutritional Information for Adolescents), a longitudinal study being developed in Porto area, Portugal, with a research grant from the Foundation for Science and Technology [FCOMP-01-0124-FEDER-028619 (PTDC/DTP-DES/1328/2012)].

Setting and location

This study was conducted in 6 of middle and high school in Porto district (Portugal). All children, adolescents and parents/tutor were informed about the project and signed an informed consent. The cross-sectional study design followed Strobe Statement.

Study population

The sample comprised 632 children and adolescents (female=56.01%; male=43.99%) aged 13.28±2.47 years old. The sample consisted of 345 children (from 10 to 12 years old; mean=11.27±0.67 years old) and 287 adolescents (from 12 to 18 years; mean=15.69±1.58 years old), 54.59 y 45.41%, respectively.

Calculations to establish the sample size were performed using Rstudio 3.15.0 software. The significance level was set at α=0.05. According to the standard deviation established for the MBP and CRF in a previous studies (Pozuelo-Ccarrascosa et al., 2017; Wisnieski et al., 2019) and an estimated error of 1 mm Hg/ml or min/kg a valid sample size for a confidence interval of 95% was 270.41. A total of 632 students completed the trial will provide a power of 95% if between and within a variance of 0.65 mm Hg/ml or min/kg.

The study was approved by the Ethical Committee of the Faculty of Sport of the University of Porto (Process CEFADE 13/2013), the National Data Protection Commission (process n.6766/2015), and Regional Section of the Ministry of Education (process 0053200004), and was implemented according to the guidelines for human research of the Helsinki Declaration.

Measurements

The same trained researchs measured the participants in a single session between 09:00 and 11:00 hours. The participants were instructed to were in light clothes. By bare feet and random were collected antopometric varaibles and blood pressure. The laboratory temperature was standardised at 24º. There was a 5-minute rest between measures. 20m Shuttle test were performance without previous warm up.

Systolic blood pressure and diastolic blood pressure was measured with an automatic device (Colin BP 880, Critikron, Inc., Tampa, FL). Measures were taken on the left arm twice at 5-minutes interval, with the participant sitting. It was used mean blood pressure as a variable. The MBP was calculated with the following form: 1/3 (systolic blood pressure [SBP] – diastolic blood pressure [DBP]) + DBP. Mean blood pressure is used in clinical practica, evaluation procols and in a previous study as a mediation variable; and allows blood preassure to be used as a single variable (Ogunleye, Sandercock, Voss, Eisenmann & Reed, 2012; Pozuelo-Carrascosa et al., 2017).

Body mass was measure using a portable digital scale (TANITA BF-522 W, Tokyo, Japan) and SECA 217 stadiometer (SECA, Germany) was used for measure the hight. BMI was cacluated whit the formula: body mass (kg)/stretch stature (m)2 (Cole et al., 2000). Portable digital scale (TANITA BF-522 W, Tokyo, Japan) was implemented to measure percentage of body fat. WC was measured in ccordance with the international Sociaty for Advancement of

Kineantrhopmetry guidelines. It was used a metal tape measure (Lufkin W606 PM®, Parsippany, New Jersey, USA). It was measurement the circunference of the narroest point bettween the lower costal border and the iliac crest. When this point was not evident, it was measured at the midpoint between the last rib and the iliac crest. The data was noted in centimetres (Esparza-Ros, Vaquero-Cristóbal & Marfell-Jones, 2019).

CRF was assess with Course Navette test (20-meter Shuttle run test) as described elsewhere (Léger, Mercier, Gadoury & Lambert, 1988). The maximum oxygen consumption (VO2max, mL/kg/min) was stimated the number of laps performed by the participant in the test using the equation reported by Leger et al (Léger et al., 1988).

PA was assessed through ActiGraph accelerometer (GT3X-plus; ActiGraph, Pensacola, FL) and it was used the ActiLife software (version 6.11.4; ActiGraph). ActiGraph accelerometer has been validated in youth (Freedson, Pober & Janz, 2005). Participant wore an accelerometer for 7 consecutives days and and could only take it off for showering or water activities. Participant were the accelerometer attached tightly on the hip by and elastic belt on the right side. The register was considered valid for analysis if participant wore it for at least 4 days and at least 10 hours per day. Tri-axial vector magnitude was computed as VM3=√ (VT2 +AP2+ML2). MPA and VPA intensity was calculate in ccording with recommendade PA vector magnitude cut point. The data derived was interpreted as MPA a VM3 value from 2690 to 6166; and VPA a VM3 value higher than 6167 (Sasaki, John & Freedson, 2011). The sample period was set up for 5 seconds. It has been reported that this period is more suitable for the spontaneous and intermittent activities in yonger children (Vale, Santos, Silva, Soares-miranda & Mota, 2009).

Stadistical analysis

Kolmogorov-Smirnov was used to evaluate the normality of the data. In order to evaluated differences of continuous variables between two groups, unpaired t-test was used for parametric variables and U de Mann-Whitney stadistic was used for no parametric variables. X2 analyses (categorical variables) was used to analyses differences between groups. A post hoc comparison for 2xn tables was applied the statistic contingency coefficient; showing the value of the statistic and the p value. The maximum expected value is 0.707; showing low association $r<0.3$; moderate association r value between 0.3 and 0.5 and high association $r>0.5$.

To test the associations of the variables, it was performed linear regression where each veriable (BMI, FM, WC, MBP, CRF, moderate-vigorous PA [MVPA], moderate PA [MPA], viogorus PA [VPA] was individually introducted as independent variable and as a dependent variable. The analysis of the mediation variables was performed using Process macro for SPSS (SPSS Inc, Chicago, Illinois). It was used resample procedure of 10.000 bootstrap sample for nonparametric (Preacher & Hayes, 2008) and the classical Baron and Kenny (1986) step regression method was used for parametric. Sobel test was used to test the statistical significance of the mediation effect (Sobel, 2014). When the independent variable was not associated with the dependent variable after mediator has been controlled was considered as complete mediation; and when the association between independent and dependent variable is reduced but is not disappear is consider partial mediator. All analysis was performed for the total sample, with the aim of providing results that can be compared with research that includes the whole age range, and separately by children and adolescents. Statistical analysis was performed using IBM SPSS Statics (version 24.0). An error of $p\leq0.05$ was established.

Results

Table 1 shows descriptive data of the variables measurement and the differences between age groups.

Table 1. Characteristics of the study sample and differences between age groups (children vs adolescents).

	Total (n=632)	Children (10-12 years; n=345)	Adolescents (13-18 years; n=287)	p
Age (years)	13.28±2.49	11.27±.67	15.69±1.58	0.000
Weight (kg)	53.33±14.17	47.31±12.03	60.57±13.13	0.000
Height (cm)	156.57±11.11	149.85±7.58	164.64±9.14	0.000
BMI (kg/m^2)	21.49±4.02	20.88±4.12	22.22±3.77	0.000
Norma lweight (%(n))	81.17(513)	81.16(280)	81.18(233)	0.485
Over weight (%(n))	16.14(102)	16.81(58)	15.33(44)	
Obese(%(n))	2.69 (17)	2.03(7)	3.48(10)	
FM (%)	22.55±8.69	23.92±8.62	20.91±8.50	0.000
WC (cm)	71.72±10.35	70.72±11.07	72.92±9.29	0.007
SBP (mm Hg)	116.64±13.80	115.07±13.55	118.52±13.88	0.002
DBP (mm Hg)	61.56±8.36	60.43±8.27	62.92±8.29	0.000
MBP (mm Hg)	79.74±9.42	78.47±9.36	81.27±9.28	0.000
CRF (mL/kg/min^{-1})	33.00±19.50	26.64±14.26	40.64±22.06	0.000
MVPA (min)	43.50±21.59	41.26±22.15	46.19±20.60	0.004
MPA (min)	32.04±14.77	32.71±16.14	31.23±12.92	0.209
VPA (min)	11.46±10.60	8.55±8.01	14.97±12.19	0.001

BMI: body mass index; kg: kilogrames; cm: centimetres; FM: fat mass; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; MBP: mean blood pressure; CRF: cardiorespiratory fitness; MVPA: moderate-vigorous physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; min: minutes.

Preliminary linear regression shown that BMI, FM and WC was significantly associated with CRF in all the sample, children and adolescents. In addition, in the preliminary linear regression analysis, MBP was significantly associated with CRF in children (β=0.209±0.034; $p<0.000$) but no in all the sample or adolescents (Tables 2, 3, and 4). For this reason, the analysis of obesity (BMI/FM/WC) as mediator of the relation between MBP and CRF was just performance for children.

Table 2. Preliminary linear regression analysis for all the sample [β±ES;pvalor]

	BMI	FM	WC	MBP	CRF	MVPA	MPA	VPA
BMI		0.335± 0.013*	0.347±0.007*	0.157±0.016*	-0.047±0.000*	-0.008±0.007	-0.011±0.011	-0.015±0.015
FM	1.569±0.059*		0.527±0.026*	0.197±0.036*	-0.274±.014*	-0.109±0.015*	-0.100±0.023*	-0.259±0.031*
WC	2.304±0.046*	0.747±0.037 *		0.430±0.040*	-0.101±0.021*	-0.023±0.019	-0.038±0.028	-0.022±0.039
MBP	0.863±0.087*	0.231±0.042*	0.356±0.033*		-0.014±0.019	-0.018±0.017	-0.043±0.025	-0.008±0.035
CRF	-1.102±0.188*	-1.378±0.071*	-0.359±0.074*	-0.058±0.082		0.328±0.033*	0.279±0.05 *	0.819±0.065*
MVPA	-0.244±0.214	-0.674±0.095*	-0.101±0.083	-0.096±0.091	0.407±0.041*		1.310±0.026*	1.602±0.050*
MPA	-0.143±0.146	-0.289±0.067*	-0.078±0.057	-0.107±0.062	0.162±0.030*	0.613±0.012*		0.602±0.050*
VPA	-0.102±0.105	-0.386±0.046*	-0.023±0.041	0.010±0.045	0.245±0.020*	0.387±0.012*	0.310±0.026*	

Legend: BMI: body mass index; FM: fat mass; WC: waist circumference; MBP: mean blood pressure; CRF: cardiorespiratory fitness; MVPA: moderate-vigorous physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; min: minutes.

Table 3. Preliminary linear regression analysis for children [β±ES;pvalor]

	BMI	FM	WC	MBP	CRF	MVPA	MPA	VPA
BMI		0.42±0.01*	0.35±0.01*	0.19±0.02*	-0.13±0.01*	-0.03±0.01*	-0.03±0.01*	-0.10±0.03*
FM	1.87±0.05*		0.65±0.0*	0.38±0.05*	-0.34±0.03*	-0.102±0.020*	-0.11±0.03*	-0.31±0.06 *
WC	2.50±0.053*	1.08±0.04*		0.53±0.06*	-0.38±0.04*	-0.08±0.03*	-0.08±0.037*	-0.26±0.07*
MBP	0.97±0.11*	0.44±0.05 *	0.38±0.04*		-0.21±0.03*	-0.06±0.02*	-0.08±0.03*	-0.13±0.06*
CRF	-1.65±0.17*	-0.92±0.07*	-0.64±0.06*	-0.48±0.08*		0.27±0.03*	0.33±0.04*	0.78±0.09*
MVPA	-0.79±0.29*	-0.68±0.13*	-0.30±0.11*	-0.33±0.13*	0.66±0.08*		1.32±0.02 *	2.30±0.10*
MPA	-0.42±0.21*	-0.41±0.10*	-0.17±0.08*	-0.23±0.10*	0.42±0.06*	0.70±0.01*		1.30±0.08*
VPA	-0.37±0.10*	-0.26±0.05*	-0.14±0.04*	-0.10±0.05*	0.24±0.03*	0.30±0.01*	0.32±0.02*	

Legend: *=p<0.05; BMI: body mass index; FM: fat mass; WC: waist circumference; MBP: mean blood pressure; CRF: cardiorespiratory fitness; MVPA: moderate-vigorous physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; min: minutes.

Table 4. Preliminary linear regression analysis for adolescents [β±ES;pvalor]

	BMI	%FM	WC	MBP	CRF	MVPA	MPA	VPA
BMI		0.276±0.021*	0.342±0.013*	0.103±0.023*	-0.033±0.010*	0.009±0.001	0.028±0.017	-0.006±0.018
%FM	1.398±0.105*		0.368±0.050*	0.042±0.054	-0.255±0.017*	-0.103±0.024*	-0.082±0.039*	-0.204±0.040*
WC	2.068±0.079*	0.440±0.059*		0.289±0.057*	-0.017±0.025	0.036±0.027	0.050±0.043	0.046±0.045
MBP	0.624±0.141*	0.050±0.065	0.288±0.057*		-0.037±0.025	-0.020±0.027	0.037±0.043	-0.016±0.045
CRF	-1.115±0.340*	-1.717±0.115*	-0.094±0.141	0.211±0.140		0.325±0.060*	0.259±0.099*	0.638±0.100*
MVPA	0.266±0.323	-0.607±0.139*	0.175±0.131	0.099±0.131	0.288±0.053*		1.327±0.053*	1.367±0.059*
MPA	0.325±0.202	-0.188±0.089*	0.096±0.082	0.071±0.082	0.090±0.03*	0.521±0.021*		0.367±0.059*
VPA	-0.059±0.191	-0.419±0.081*	0.079±0.078	0.027±0.078	0.198±0.031*	0.479±0.021*	0.327±0.053*	

Legend: *=p<0.05; BMI: body mass index; FM: fat mass; WC: waist circumference; MBP: mean blood pressure; CRF: cardiorespiratory fitness; MVPA: moderate-vigorous physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; min: minutes.

To test if BMI/FM/WC acted as a mediator variable between MBP (dependent variable) and CRF (independent variable) the effect of the mediation was analysed (figure 1). After including obesity variable (BMI/FM/WC) the relationship between CRF and MBP decrease but still significance being the data similar regardless the variable used; BMI, FM and WC (BMI: β=-0.097±0.036, %=19,93; p=0.007; FM: β=-0.086±0.038, %=17,81; p=0.027; WC: β=-0.083±0.036, %=21.35; p=0.0211). The mediation analysis showed significantly direct and indirect effect with a significantly value for Sobel test in all the obesity variables (BMI: z=-5.407±0.020, p<0.000; FM: z=-5.163±0.023, p<0.000; WC: z=5.810±0.021, p<0.000). These results indicate that obesity (BMI/FM/WC) acts as a partial mediation in the association between CRF and MBP in 10-12 years old children.

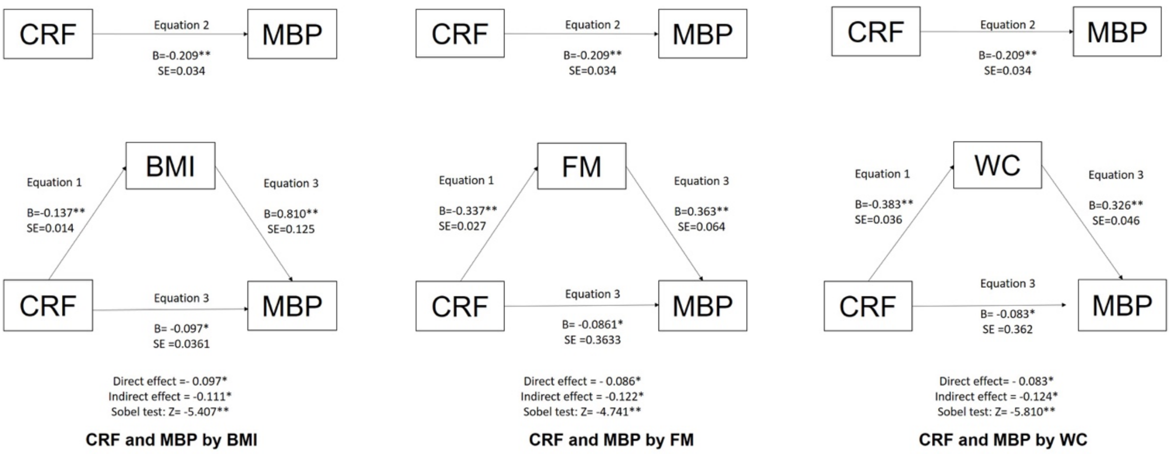

Figure 1. Moderation of CRF and MBP by BMI, FM or WC for children.
Legend figure 3: ** p<0.001; *<0.05; CRF=cardiorrepiratory fitness; MBP=median blood pressure; BMI=body mass index; FM=fat mass; WC=waist circunference.

In the preeliminary linel regression MBP did not show association with MVPA/MPA/VPA in the all sample or adolescents. For this reseaon the analysis of the mediation is just performed for children (figure 2). To test if BMI/FM/WC acted as a mediatior variable between MBP (dependent variable) and MVPA/MPA/VPA (independent variable) the effect of the mediation was analysis. After including obesity variable (BMI/FM/WC) in the ecuations of the association between MVPA/MPA/VPA and MBP, the conection between MVPA/MPA/VPA and MBP is no longer significative in any of the variables. The mediation analysis shown no significantly direct effect and significative indirect effect with a significantly value for Sobel test in all the obesity variables and classification of PA (MVPA/MPA/VPA). These result indicate that obesity (BMI/FM/WC) acts as a complete mediator in the association between MVPA/MPA/VPA and MBP in 10-12 years old children. Likewise, the highest association between PA and obesity was for VPA versus MPA in all the obesity measures.

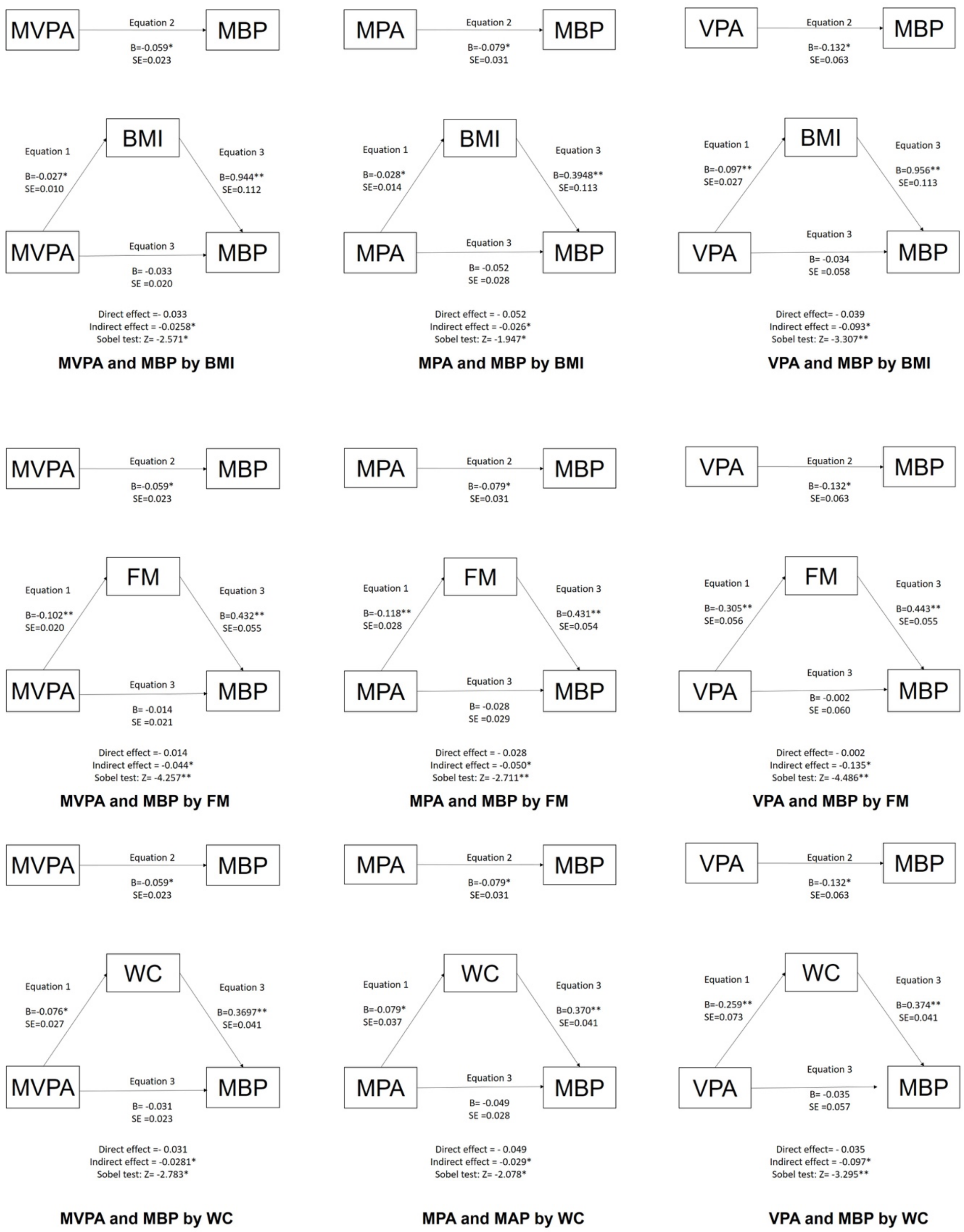

Figure 2. Moderation of MVPA/MPA/VPA and MBP by BMI/FM/WC for children.
Legend figure 4: ** p<0.001; *<0.05; CRF=cardiorrepiratory fitness; MBP=median blood pressure; BMI=body mass index; FM=fat mass; WC=waist circunference

Discusion

The present study shows that obesity status (BMI, FM and WC) is inversely associated with CRF and directly associated with MBP, while MBP was significantly and inversely associated with CRF in children. In addition, obesity (BMI, FM and WC) acted as a partial mediator between this association (CRF and MBP) in children. This result show that the association between CRF and MBP is partially attenuating by the obesity. In this respect, a less level of obesity would not fully mediator the independent action of CRF on MBP in children; being CRF an important factor on cardiovascular health.

The relationship between obesity with CRF (Eisenmann, 2007; Stratton et al., 2007) and MBP is reported extensively (Cadenas-Sanchez et al., 2017; Pozuelo-Carrascosa et al., 2017) and high blood pressure in children and adolescents has been related with low level of CRF (Anderssen et al., 2007; Kriemler & Zahner, 2008). Pozuelo-Carrascosa et al. (2017) shown a same association between BMI and MBP and between BMI and CRF in a sample of 4-7 years old children. Besides, as the same as the present, this study shows that obesity act as a partial mediator between the conection of MBP and CRF in girls. In this sense, Liu et al. (2014), after their longitudinal study, explain that higher CRF prevented the increasing MBP. In concordance with our results, previous studies have concluded that the associatin between CRF and metabolic variables depends on body composition (Cristi-Montero et al., 2019; Díez-Fernández et al., 2014; Pozuelo-Carrascosa et al., 2017) but CRF act as a protector of cardiometabolic risk factor and might act as an attenuate elevation MBP in children with overweight or obesity (Cristi-Montero et al., 2019; Nyström et al., 2017; Ogunleye et al., 2012). In acordance with cardiometabolic risk, Cristi-Montero et al. (2019) indicated that CRF acts as a partical mediator in the association between obesity and cardiometabolic risk factor, in a sample of 525 adolescents between 12,5 and 17,5 years old. In addition, Lee et al. (2015) in their study with 14345 children of 11,4 years, foung that reductions of CRF and increses of BMI predicted a higher mortality over time, however after adjusting for changes in CRF, BMI was no longer significative as mortality predictor.

In this sense, Fat and Fit Paradox showing that moderate to high level of CRF might attenuate the impact of total and central adipositvy on cardiometabolic risk in children and adolescents (Ortega, Ruiz, Labayen et al. 2017). As a consecuence, it is necessary reduce the obesity to reach a healthy MBP and decrease cardiometabolic risk, but this could be no sufficient and not fully protect the independent action of CRF on MBP or cardiometabolic risk. In this sense, increasing CRF it would indicate a decrease MBP; and CRF should be taking into account in the metabolically healthy phynotype (Ortega, Cadenas-s, Sui, Steven & Lavie, 2015). Therefore, the evidence of the relevance of CRF on its independent effect on cardiovascular disease supports the need to develop public health programmes and strategies involving schools to reduce overweight and obesity, and in turn improve CRF in children and adolescents, with the aim of reducing cardiovascular risk (Musa, Toriola, Goon and Jonatahn 2020).

The mediation role is around 20% for the 3 fatness variables studied (BMI, FM and WC). In this sense, it could be said that the differents analysis with the 3 obesity variable are similar. In addition, the obesity variable that show higher association was WC, followed of BMI and FM, respectively. These same results were found in the study of Cristi-Montero et al. (2019) and being in conrcondance with these authors (Cristi-Montero et al., 2019), this is an important found for public health strategic and clinical purpose.

In the present study, the association between MBP and CRF was just shown in children but no in adolescents. In this respect, Segura et al. (2016) shown high association between global physical fitness and cardiometabolic risk in children than adolescent concluding that healthy physical fitness could be more relevant over cardiometabolic risk in early ages, children versus adolescents. However, more studies are necessary.

On the other hand, the present study shows an association between PA (MVPA/MPA/VPA) and obesity in children (BMI, FM and WC) and adolescents (FM), and an association between MBP and PA (MVPA/MPA/VPA) in children. This find concurs with previous studies that connected PA with obesity (Czyż et al., 2017; Kriemler & Zahner, 2008; Monyek et al., 2017; Poitras et al., 2016; Raistenskis et al., 2016; Tambalis et al., 2019) and MBP with PA (Anderssen et al., 2007; Kriemler & Zahner, 2008). Conversely, the present study shown that obesity (BMI/FM/WC) act as a complete mediator in the association between MBP and MVPA/MPA/VPA in 10-12 years old children.

This is the first study that assess whether the obesity act as a mediator between the conection of MVPA/MPA/VPA and MBP. The find reported are in conection with previous studies in others cardiometabolic risk variables. Pahkala et al. (2012) studied a sample of 13 years old adolescents. This study reported a significative connection between systolic blood pressure and PA but this is disappearing when BMI is included in the model. Other study finds similar result between PA and cardiometabolic risk. Williams, Sisson, Ardern, Dubose & Johnson (2018) studied a samle of 12-17 years old. Adolescents were categorised as normalweight active, normalweight non active, overweight active and overweight non active. Authors found that there is no difference between be or not be active inside the normal or overweight groups. These findings in combination with those in the present study show that the association between PA and MBP is attenuating by the obesity (BMI, FM and WC). In this respect, a less level of obesity would fully protect by higher MBP independent of the PA.

In addition, VPA was the intensity of PA that shown the high association with obesity in children (BMI, FM and WC) and with adolescents (FM) and with MBP in children and adolescents. This concurs with previous studies, being VPA the only level of PA that is significantly association with WC, (Lucas-de la Cruz et al., 2018) metabolic syndrome (Lucas-de la Cruz et al., 2018) or cardiometabolic disease risk factor (Segura-Jiménez et al., 2016). Segura et al. (2016) shown a similar result with respect of children and adolescent. This autors report that VPA was the PA level that high association show with cardiometabolic risk in children but MVPA was the PA level more relevant for adolescnts. This is consistent with anticipated research that indicates that VPA is more relevant in early age (childhood) in relation to cardiometabolic risk. However, with growth and developement, both relevant intensities are shown for adolescents (Rendo-Urteaga et al., 2015).

Our study is not without limitations. Cross-sectional design is a limitation of the present study that prevent us form making cause-effect inferences. Future longitudinal studies are needed. The results cannot be generalized, since there are many factors that can influence blood pressure: genetic, demographic, and environmental or family history.

Strengths of this study include it is the first study that assess the effect of obesity between the conection between MBP and CRF using mediation anlysis in children and adolescents. Other strengths from the preset study are the objetivetly PA assesstment that it is more sutitable than self-reported (Vale et al., 2009), CRF was measured with valid a reliabre test widely used in children and adolescents in conecction with cardiometabolic risk variables (Díez-Fernández et al., 2014; Léger et al., 1988; Nyström et al., 2017; Ortega et al., 2015; Pozuelo-Carrascosa et al., 2017); and it was assessed and compare several measures of adiposity (BMI, FM and WC).

Conclusion

Independient association indicate that obesity (BMI, FM and WC) is associated with CRF and with MBP in children and in adolescents, MBP is associated with CRF and PA in children; and PA (MVPA/MPA/VPA) show association with obesity in children (BMI, FM and WC) and adolescents (FM). Obesity acted as a partial mediation between the association of CRF with MBP and act as a complete mediator in the association between MBP and MVPA/MPA/VPA in children. Agreeing with Lavie, Parto & Archer (2016), our result reinforces the relevance of prevent weight increse and improve CRF level since erly age in children and adolescents to prevent high MBP. Increasing the level of PA can influence on obesity and CRF, making special mention of the VPA in children, being in line with the WHO recommendation (2020), which recommends that children and adolescents perform at least 3 times a week vigorous-intensity aerobic activities.

References

Anderssen, S. A.; Cooper, A. R.; Riddoch, C.; Sardinha, L. B.; Harro, M.; Brage, S.; Lars, B.; Sardinha, L. B.; Harro, M.; Brage, S., & Andersen, L. B. (2007). European Journal of Cardiovascular Prevention & Rehabilitation independent of country, age and sex. *European Journal of Cardiovascular Prevention & Rehabilitation, 14*(1), 526–531. https://doi.org/10.1097/HJR.0b013e328011efc1

Baron, R. M., & Kenny, D. A. (1986). The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *Journal of Personality and Social Psychology, 51*(6), 1173–1182. https://doi.org/10.1037//0022-3514.51.6.1173

Cole, T. J.; Bellizzi, M. C.; Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *British Medical Journal (Clinical Research Ed.), 320*(6), 1–6.

Cristi-Montero, C.; Courel-Ibañez, J.; Ortega, F. B.; Castro-Piñero, J.; Santaliestra Pasias, A.; Polito, A.; Vanhelst, J.; Marcos, A.; Moreno, L. M.; Ruiz, J. R., & Group, on behalf of the H. study. (2019). Mediation role of cardiorespiratory fitness on the association between fatness and cardiometabolic risk in European adolescents: The HELENA study. *Journal of Sport & Health Science, 8*(1), 55-62. https://doi.org/10.1016/j.jshs.2019.08.003

Cadenas-Sánchez, C.; Ruiz, J. R.; Labayen, I.; Huybrechts, I.; Manios, Y.; González-Ggross, M.; Breidenassel, C.; Kafatos, A.; Henauw, S. De.; Vanhelst, J., Widhalm, K.; Molnar, D.; Bueno, G.; Censi, L.; Plada, M.; Sjöström, M.; Moreno, L. A.; Castillo, M. J., & Ortega, F. B. (2017). Prevalence of Metabolically Healthy but Overweight / Obese Phenotype and Its Association Withwith Sedentary Time, Physical Activity, and Fitness. *Journal of Adolescent Health, 61*(1), 107–114.

Czyż, S.; Toriola, A.; Starościak, W.; Lewandowski, M.; Paul, Y., & Oyeyemi, A. (2017). Physical Fitness, Physical Activity, Sedentary Behavior, or Diet — What Are the Correlates of Obesity in Polish School Children? *International Journal of Enviromental Research and Public Health, 14*(1), 1–21. https://doi.org/10.3390/ijerph14060664

Díez-Fernández, A.; Sánchez-López, M.; Mora-Rodriguez, R.; Notario-Pacheco, B.; Torrijos-Niño, C., & Martínez-Vizcaíno, V. (2014). Obesity as a Mediator of the Inf luence of Cardiorespiratory Fitness on Cardiometabolic Risk: A Mediation Analysis. *Diabetes Care, 37*(1), 855–862. https://doi.org/10.2337/dc13-0416

Duncan, M. J.; Mota, J.; Vale, S.; Santos, M. P.; Duncan, M. J.; Mota, J.; Vale, S.; Santos, M. P.; Duncan, M. J.; Mota, J.; Vale, S.; Santos, M. P., & Ribeiro, J. C. (2013). Annals of Human Biology Associations between body mass index, waist circumference and body shape index with resting blood pressure in Portuguese adolescents Associations between body mass index, waist circumference and body shape index with resting bloo. *Annals of Human Biology, 40*(2), 163–167. https://doi.org/10.3109/03014460.2012.752861

Eisenmann, J. (2007). Aerobic fitness, fatness and the metabolic syndrome in children and adolescents. *Acta Pædiatrica, 96*(1), 1723–1729. https://doi.org/10.1111/j.1651-2227.2007.00534.x

Esparza-Ros, F.; Vaquero-Cristóbal, R., & Marfell-Jones, M. (2019). International Standards for Anthropometric Assessment. *The International Society of the Advancement on Kinanthropometry*: Murcia, Spain.

Falkner, B.; Lurbe, E., & Schaefer, F. (2010). High Blood Pressure in Children: Clinical and Health Policy Implications. *The Journal of Clinical Hypertension, 12*(4), 261–276. https://doi.org/10.1111/j.1751-7176.2009.00245.x

Fogelholm, M.; Stigman, S.; Huisman, T., & Metsämuuronen, J. (2007). Physical fitness in adolescents with normal weight and overweight. *Scandinavian Journal of Medicine & Science in Sports, 18*(2), 162–170. https://doi.org/10.1111/j.1600-0838.2007.00685.x

Franklin, S. S.; Lopez, V. A.; Wong, N. D.; Mitchell, G. F.; Larson, M. G.; Vasan, R. S., & Levy, D. (2015). Single Versus Combined Blood Pressure Components and Risk for Cardiovascular *Disease the Framingham Heart Study. Circulation, 119*(2), 243–250. https://doi.org/10.1161/CIRCULATIONAHA.108.797936

Freedson, P.; Pober, D., & Janz, K. F. (2005). Calibration of Accelerometer Output for Children. Medicine & Science in Sports & Exercise, 37(Supplement), S523–S530.

Javed, A.; Jumean, M.; Murad, M.H.; Okorodudu, D.; Kumar, S.; Somers, V.K., & Sochor, O. L.-J. F. (2014). Diagnostic performance of body mass index to identify obesity as defined by body adiposity in children and adolescents: a systematic review and meta-analysis. *Pediatric Obesity, 10*(3), 234–244. https://doi.org/10.1111/ijpo.242

Kriemler, S., & Zahner, L. (2008). Reduced cardiorespiratory fitness, low physical activity and an urban environment are independently associated with increased cardiovascular risk in children. *Diabetologia (2008), 51*(1), 1408–1415. https://doi.org/10.1007/s00125-008-1067-z

Lavie, C. J.; Parto, P., & Archer, E. (2016). Obesity, Fitness, Hypertension, and Prognosis Is Physical Activity the Common Denominator? JAMA Internal Medine, 176(2), 217–218. https://doi.org/10.1001/jamainternmed.2015.7444.3

Lee, D.; Sui, X.; Artero, E. G.; Lee, I.; Church, T. S.; Mcauley, P. A.; Stanford, F. C.; Iii, H. W. K. & Blair, S. N. (2015). Long-Term Effects of Changes in Cardiorespiratory Fitness and Body Mass Index on All-Cause and Cardiovascular the Aerobics Center Longitudinal Study. *Circulation, 124*(23), 2483–2490. https://doi.org/10.1161/CIRCULATIONAHA.111.038422

Léger, L. A.; Mercier, D.; Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences, 6*(2), 93–101. https://doi.org/10.1080/02640418808729800

Liu, J.; Sui, X.; Park, Y. M.; Cai, B.; Liu, J., & Blair, S. N. (2014). Effects of Cardiorespiratory Fitness on Blood Pressure Trajectory with Aging in a Cohort of Healthy Men. *Journal of American College of Cardiology, 64*(12), 1246–1253. https://doi.org/10.1016/j.jacc.2014.06.1184

Lucas-de la Cruz, L.; Martínez-Vizcíno, V.; García-Prieto, J. C.; Arias-Palencia, N.; Diez-Fernandez, A.; Milla-Tobarra, M., & Notario-Pacheco, B. (2018). Movement behaviors and cardiometabolic risk in schoolchildren. *Plos One, 13*(11), 1–12.

Metcalf, B. S.; Hosking, J.; Jeffery, A. N.; Voss, L. D.; Henley, W., & Wilkin, T. J. (2011). Fatness leads to inactivity, but inactivity does not lead to fatness: a longitudinal study in children (EarlyBird 45). *Archives of Disease in Childhood, 96*(1), 942–947.

Monyek, M.; Awotidebe, A.; Moss, S.; Sparks, M.; Wushe, S.; Coetzee, B.; Pienaar, C.; Bruwer, E.; Dde ridder, H.; Swanepoel, M.; Du toit, D.; Glapa, A.; Kemper, H., & Twisk, J. (2017). Relationship between physical activity, body fatness and cardiorespiratory fitness in South African adolescents: The PAHL Study Relationship between physical activity, body fatness and cardiorespiratory fitness in South African adolescents: The PAHL S. *African Journal for Physical Activity and Health Sciences, 23*(1), 111–128.

Neuhauser, H.; Adler, C., & Sarganas, G. (2019). Selective Blood Pressure Screening in the Young: Quantification of Population Wide Underestimation of Elevated Blood Pressure. *International Journal of Hypertension*, 2314029, 1–8.

Nyström, C.; Henriksson, P.; Martínez-Vizcaíno, V.; Medrano, M.; Cadenas-Sanchez, C.; Arias-Palencia, N.; Löf, M.; Ruiz, J.; Labayen, I.; Sánchez-López, M., & Ortega, F. (2017). Does Cardiorespiratory Fitness Attenuate the Adverse Effects of Severe / Morbid Obesity on Cardiometabolic Risk and Insulin Resistance in Children? A Pooled Analysis. *Diabetes Care, 40*(1), 1580–1587.
https://doi.org/10.2337/dc17-1334

Ogunleye, A. A.; Sandercock, G. R.; Voss, C.; Eisenmann, J. C., & Reed, K. (2012). Prevalence of elevated mean arterial pressure and how fitness moderates its association with BMI in youth. *Public Health Nutrition, 16*(1), 2046–2054.
https://doi.org/10.1017/S1368980012004466

Ortega, F. B.; Cadenas-s, C.; Sui, X.; Steven, N., & Lavie, C. J. (2015). Role of Fitness in the Metabolically Healthy but Obese Phenotype: A Review and Update Francisco. *Progress in Cardiovascular Diseases, 58*(1), 76–86.

Pahkala, K.; Heinonen, O. J.; Lagström, H.; Hakala, P.; Hakanen, M.; Hernelahti, M.; Ruottinen, S.; Sillanmäki, L.; Rönnemaa, T.; Viikari, J.; Raitakari, O. T., & Simell, O. (2012). Clustered metabolic risk and leisure-time physical activity in adolescents: effect of dose? *British Journal of Sports Medicine, 46*(1), 131–137.
https://doi.org/10.1136/bjsm.2010.073239

Poitras, V. J.; Gray, C. E.; Borghese, M. M.; Carson, V.; Chaput, J.; Janssen, I.; Katzmarzyk, P. T.; Pate, R. R.; Gorber, S. C.; Kho, M. E.; Sampson, M., & Tremblay, M. S. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth 1. *Appl Physiol Nutr Metab, 41*(1), 197–239.

Pozuelo-Carrascosa, D. P.; Sánchez-López, M.; Cavero-Redondo, I.; Torres-Costoso, A.; Bermejo-Cantarero, A., & Martínez-Vizcaíno, V. (20167). Obesity as a Mediator between Cardiorespiratory Fitness and Blood Pressure in Preschoolers. *The Journal of Pediatrics, 182*(1), 114–119.

Preacher, K., & Hayes, A. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40*(3), 879–891.
https://doi.org/10.3758/BRM.40.3.879

Raistenskis, J.; Sidlauskiene, A.; Strukcinskiene, B., & Baysal, S. U. (2016). Physical activity and physical fitness in obese, overweight, and normal- weight children Physical activity and physical fitness in obese, overweight, and normal-weight children. *Turkish Journal of Medical Sciences, 4681*(1), 1411–1119. https://doi.org/10.3906/sag-1411-119

Rendo-Urteaga, T.; César, A.; Moraes, F. De; Sadalla, T.; Manios, Y.; Hagströmer, M.; Sjöström, M.; Kafatos, A.; Widhalm, K.; Vanhelst, J.; Marcos, A.; González-Gross, M.; Henauw, S. D.; Ciarapica, D.; Ruiz, J. R.; España-Romero, V.; Molnár, D.; Carvalho, H. B., & Moreno, L. A. (2015). The combined effect of physical activity and sedentary behaviors on a clustered cardio-metabolic risk score: The Helena study. *International Journal of Cardiology, 186*(1), 186–195.

Rizzo, N. S.; Ruiz J. R.; Hurting-Wennlof, A.; Ortega, F. B., & Sjostrom, M. (2007). Relationship of Physical Activity, Fitness, and Fatness with Clustered Metabolic Risk in Children and Adolescents: The European Youth Heart Study. *The Journal of Pediatrics, 150*(4), 388-94.

Sasaki, J. E.; John, D., & Freedson, P. S. (2011). Validation and comparison of ActiGraph activity monitors. *Journal of Science and Medicine in Sport, 14*(5), 411-416.

Segura-Jiménez, V.; Parrilla-Moreno, F.; Del Rosario Fernández-Santos, J.; Esteban-Cornejo, I.; Gómez-Martínez, S.; Martínez-Gómez, D.; Marcos, A., & Castro-Piñero, J. (2016). Physical fitness as a mediator between objectively measured physical activity and clustered metabolic syndrome in children and adolescents: the UP&DOWN study. *Nutrition, Metabolism and Cardiovascular Diseases, 26*(11), 1011-1019.

Sobel, E. (2014). Asymptotic confidence intervals for indirect effects in structural equation models. Sociol Methodol, 13(1982), 290-312.

Stodden, D. F.; Goodway, J. D.; Langendorfer, S.J.; Roberton, M.A.; Rudisill, M.E.; Garcia, C., & Grcía, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. *Quest, 60*(1), 290–306.

Stratton, G.; Canoy, D.; Boddy, L. M.; Taylor, S. R.; Hackett, A. F., & Buchan, I. E. (2007). Cardiorespiratory fitness and body mass index of 9 – 11-year-old English children: a serial cross-sectional study from 1998 to 2004. *International Journal of Obesity, 31*(1), 1172–1178. https://doi.org/10.1038/sj.ijo.0803562

Tambalis, K.; Panagiotakos, D.; Psarra, G., & Sidossis, L. (2019). Concomitant Associations between Lifestyle Characteristics and Physical Activity Status in Children and Adolescents. *Journal of Research in Helath Sciences, 19*(1), 1–7.

Vale, S.; Santos, R.; Silva, P.; Soares-Mmiranda, L., & Mota, J. (2009). Preschool Children Physical Activity Measurement: Importance of Epoch Length Choice. *Pediatric Exercise Science, 21*(1), 413–420.

Williams, B. D.; Sisson, S. B.; Ardern, C. A.; Dubose, K. D., & Johnson, T. M. (2018). Physical Activity, Body Mass Index, and Clustered Metabolic Risk in U.S. Adolescents: 2007–2012 Nhanes. *Metabolic syndrome and related disorders, 16*(2), 97–103. https://doi.org/10.1089/met.2017.0072

Wisnieski, L.; Dalimonte-Mmerckling, D., & Robbins, L. B. (2019). Cardiorespiratory Fitness as a Mediator of the Association between Physical Activity and Overweight and Obesity in Adolescent Girls. *Childhood Obesity, 15*(5), 9–13. https://doi.org/10.1089/chi.2018.0360

World Health Organization (WHO) (2020). Who guidelines on Physical activities and sedentary behaviour. Rodl Helath Organization.

World Health Organization (WHO). (2017). Cardiovascular diseases. https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

Zimmet, P.; Alberti, K.; Kaufman, F.; Tajima, N.; Silink, M.; Arslanian, S.; Wong, G.; Bennett, P.; Shaw, J.; Caprio, S., & Group, C. (2007). The metabolic syndrome in children and adolescents – an IDF consensus report. *Pediatric Diabetes, 8*(1), 299–306.