Received: 30 June 2023 | Revised: 11 September 2023 | Accepted: 31 October 2023

DOI: 10.1111/apa.17035

ACTA PÆDIATRICA
NURTURING THE CHILD
WILEY

ORIGINAL ARTICLE

Association of daily steps on lipid and glycaemic profiles in children: The mediator role of cardiorespiratory fitness

Irene Sequí-Domínguez[1,2,3] | Vicente Martínez-Vizcaíno[1,4] | Eva Rodríguez-Gutiérrez[1,2] | Bruno Bizzozero-Peroni[1] | Vanesa Martinez-Madrid[5] | Enrique Prada de Medio[5] | Irene Martínez-García[1] | Ivan Cavero-Redondo[4]

[1]Health and Social Research Center, Universidad de Castilla-La Mancha, Cuenca, Spain

[2]Research Network on Chronicity, Primary Care and Health Promotion (RICAPPS), Cuenca, Spain

[3]Facultad de Enfermería, Universidad de Castilla-La Mancha, Albacete, Spain

[4]Facultad de Ciencias de la Salud, Universidad Autónoma de Chile, Talca, Chile

[5]Clinical Laboratory Department, Hospital Virgen de la Luz, Cuenca, Spain

Correspondence
Vicente Martínez-Vizcaíno, Edificio Melchor Cano, Centro de Estudios Socio-Sanitarios, Universidad de Castilla-La Mancha, Santa Teresa Jornet s/n, 16071 Cuenca, Spain.
Email: vicente.martinez@uclm.es

Funding information
European Social Fund, Grant/Award Number: 2020-PREDUCLM-16746; Health Outcomes-Oriented Cooperative Research Networks, Grant/Award Number: RD21/0016/0025; Ministry of Economy and Competitiveness-Carlos III Health Institute and FEDER funds, Grant/Award Number: PI19/01126

Abstract

Aim: To analyse, in schoolchildren, the relationship between daily steps with metabolic parameters; and to examine whether this association is mediated by cardiorespiratory-fitness (CRF).

Methods: A cross-sectional analysis of baseline data from a feasibility trial was performed in children from two primary schools in Cuenca, Spain. Daily steps were measured using the Xiaomi MI Band 3. Lipid and glycaemic profiles were analysed from blood samples. CRF was assessed using the 20-m shuttle run test. ANCOVA models were used to test the mean differences by daily steps quartiles. Mediation analyses were conducted to examine whether CRF mediates the association between daily steps and lipid and glycaemic parameters.

Results: A total of 159 schoolchildren (aged 9–12 years, 53% female) were included in the analysis. Schoolchildren in the highest daily steps quartiles (>10 000 steps) showed significantly lower triglycerides and insulin levels ($p = 0.004$ and 0.002, respectively). This association did not remain after controlling for CRF. In mediation analyses, a significant indirect effect was observed through CRF in the relationship between daily steps with triglycerides and insulin.

Conclusion: Children who daily accumulate more than 10 000 steps have better lipid and metabolic profile, and CRF mediated their relationship in schoolchildren.

KEYWORDS
cardiorespiratory fitness, children, daily steps, insulin, triglycerides

1 | INTRODUCTION

Atherosclerotic cardiovascular diseases (ACVDs) are one of the leading causes of death and disability globally and have become one of the most important public health challenges in the world.[1] Previous studies, such as the Bogalusa Health study, the PDAY study, the Cardiovascular Risk in Young Finns Study and the Muscatine study, have shown a significant positive association of established ACVD risk factors in childhood, namely, low-density lipoprotein cholesterol (LDL-c), triglycerides, blood pressure and body mass index, with

Abbreviations: ACVDs, Atherosclerotic cardiovascular diseases; CI, Confidence intervals; CRF, Cardiorespiratory fitness; HbA1c, Glycated haemoglobin; HDL-c, High density lipoprotein cholesterol; LDL-c, Low-density lipoprotein cholesterol; MVPA, Moderate-to-vigorous physical activity; PA, Physical activity; VO_2max, Maximal oxygen consumption; WHO, World Health Organisation.

atherosclerotic lesions and ACVD events later in life,[2–6] probably because levels of such ACVD risk factors tend to persist from childhood through adolescence into adulthood,[7] a phenomenon known as tracking patterns meaning the correlation between early and later measurements over the lifetime with respect to a certain variable.[8]

Something similar occurs with glycaemic parameters, such that elevated levels of plasma insulin, which are considered a sensitive indicator of insulin resistance even in children without elevated glycaemia,[9] are considered as an ACVD risk factor that is strongly associated with other ACVD risk factors including obesity, dyslipidaemia and hypertension.[10–12] Such high levels of insulin tend to persist over time in children through adulthood.[13–16]

Thus, evidence supports that the timely detection of cardiometabolic risk factors in early life, if it is accompanied by preventive measures at that age, may reduce the incidence of adult ACVD. The benefits of physical activity (PA) on cardiovascular health in both children and adults are currently beyond dispute.[17,18] However, despite the well-known importance of engaging in active lifestyles, in Spain the prevalence of children failing to meet World Health Organization (WHO) movement behaviour recommendations is approximately 70%, with a similar prevalence worldwide.[19–21]

Walking is an easily measurable, cost-effective modality of PA that does not require any special skills and can be easily fitted into daily routine, which postulates as an alternative to promote light-to-moderate PA.[22] Hence, despite its limitations in estimating PA intensity levels, daily steps may be considered an appropriate parameter to assess the total amount of PA an individual engages on a daily basis. Furthermore, previous evidence suggest that the recommended 60 min of moderate-to-vigorous PA can be achieved, on average, with a total volume of 13000–15000 steps/day for boys and 11000–12000 steps/day for girls.[22]

Moreover, an association between the steps/day and cardiorespiratory fitness (CRF) levels has been suggested.[23] If we add to all this the ease of use of PA monitors and the accessibility of their price, the measurement of steps/day is destined to be the way to objectively monitor the PA of the population.

Hence, the objective of this study was twofold: (1) to analyse, in schoolchildren, the relationship between daily steps and CRF with lipid and glycaemic parameters, and (2) to examine whether the association between daily steps with lipid and glycaemic parameters is mediated by CRF.

Key notes

- Walking is an easily measurable, cost-effective modality of physical activity that does not require special skills and can be easily fitted into daily routine.
- Schoolchildren in the highest daily steps quartiles (>10000 steps) showed significantly lower triglycerides and insulin levels ($p=0.004$ and 0.002, respectively), and this relationship was mediated by cardiorespiratory fitness.
- Our results postulate daily steps as an interesting instrument to evaluate daily physical activity in children.

2 | MATERIALS AND METHODS

2.1 | Study design and population

This was a cross-sectional analysis of baseline data from the feasibility trial aimed at assessing the suitability of a mHealth intervention for promoting PA in schoolchildren. This study included 159 schoolchildren, aged 9–12 years from two public primary schools in Cuenca, Spain. Finally, 100 participants were included in our analysis, as only they had all the data on the variables of interest for this study.

The Clinical Research Ethics Committee of the Cuenca Health Area approved the study protocol. After obtaining the approval of the director of each school, and after informing parents, written approval was requested for their children's participation. Moreover, the schoolchildren were asked to collaborate with informative talks held class by class.

2.2 | Study variables

2.2.1 | Exposure variable: Daily steps

Daily steps were measured using the Xiaomi MI Band 3 Smart Bracelet. The mean daily steps for the 2 weeks following the baseline measurements were used. Daily steps were also recorded by the children in a daily step log that was collected by a member of the research team.

2.2.2 | Outcome variable: Lipid and glycaemic profile

Blood samples were drawn at school from the cubital vein between 8.15 and 9.00 AM and after 12-h fasting period. These determinations were performed in duplicate and include lipid profiles (total cholesterol, high-density lipoprotein cholesterol (HDL-c), LDL-c and triglycerides) analysed in a Cobas c701 system from Roche Diagnostics- Insulin levels, were assessed using an Alinity i-series platform from Abbott Diagnostics and glycated haemoglobin (HbA1c) was determined by HPLC (high-resolution liquid chromatography) using a D-100 analyser (BIO-RAD Diagnostics).

2.2.3 | Potential mediator: cardiorespiratory fitness (CRF)

CRF was assessed using the 20-m shuttle run test, validated to measure aerobic fitness in children. Children were asked to run between two lines 20m apart while keeping pace with audio signals emitted by a prerecorded compact disc. The initial speed was 8.5km/h and increased by 0.5km/h every minute. Participants were encouraged to keep running during the test and the last completed half stage was recorded. Maximal oxygen consumption (VO_2max) was estimated using the Leger 20-m shuttle-run formula (31.025 + (3.238 × velocity) − (3.248 × age) + (0.1536 × age × velocity)) as an indicator of their CRF.[24]

2.2.4 | Covariates

Self-reported information was obtained on age (years), sex (female, male) and Tanner stages were assessed to analyse sexual development with a graded 5-point ordinal scale.[25] Trained nurses measured anthropometric variables, and weight was measured to the nearest 100g with a calibrated digital scale (SECA model 861; Vogel & Halke, Hamburg, Germany), with the children lightly dressed and without shoes. Height was measured to the nearest millimetre with a wall-mounted stadiometer.

Data collection was performed during March 2021 by a team of trained researchers, following standardised conditions.

2.3 | Statistical analysis

Statistical (Kolmogorov–Smirnov) and graphical (normal probability plots) methods were used to evaluate the fit to normal distribution of continuous variables (daily steps, VO_2max, total cholesterol, HDL-c, LDL-c, triglycerides, insulin, HbA1c). Descriptive characteristics and differences by sex were calculated for continuous variables using Student's *t*-test. Pearson correlation coefficients were calculated to examine the relationship between daily steps, VO_2max, total cholesterol, HDL-c, LDL-c, triglycerides, insulin and HbA1c. ANCOVA models were used to test raw mean differences in VO_2max, lipid and glycaemic parameters as dependent variables by daily step categories (model 0), controlling for age, sex and Tanner stage (model 1), and adding VO_2max as a covariate (model 2). Daily step categories were established according to daily step quartiles due to the change shown in the dependent variables (Figures S1 and S2) as follows: first quartile (>7968 steps/day), second quartile (7968–10030 steps/day), third quartile (10030–12036 steps/day) and fourth quartile (>12036 steps/day). Post hoc pairwise hypotheses were tested using a Bonferroni correction for multiple comparisons.

Mediation analyses were conducted to examine whether CRF mediates the association between daily steps and lipid and glycaemic parameters using the PROCESS SPSS Macro, version 3.5.[26] For these analyses, mediation model 4 was selected using 5000 bootstrap samples to examine the total (path c) and direct effects (paths a, b, c'), which reflect the unstandardised regression coefficient and significance between the independent and dependent variables in each model. The indirect effect (IE) was also calculated to indicate the change in lipid and glycaemic parameters per unit change in daily steps that are mediated by CRF and were considered significant when the confidence intervals (CIs) did not contain zero.

All statistical analyses were performed using IBM SPSS Statistics software (Version 24.0; IBM Corp., Armonk, NY), and $p < 0.05$ was considered to indicate significance.

3 | RESULTS

The participants' characteristics by sex are summarised in Table 1. Overall, boys accumulated a higher mean of steps/day (11140) than girls (9171) ($p < 0.001$) and had higher VO_2max (mL/kg/min) values (49.48) than girls (47.47) ($p = 0.015$). In terms of lipid and glycaemic parameters, statistically significant differences by sex were found only for insulin, where girls showed significantly higher levels than boys, 9.16 and 7.05mU/L, respectively.

Table 2 displays the bivariate correlation coefficients between daily steps, VO_2max, total cholesterol, HDL-c, LDL-c, triglycerides, insulin and HbA1c. Steps and VO_2max were significantly correlated with triglycerides, and insulin.

Mean differences in VO_2max, lipid and glycaemic parameters by daily step quartiles are shown in Table 3. Participants with a higher number of daily steps showed significantly higher levels of VO_2max ($p < 0.001$), and lower levels of triglycerides and insulin ($p = 0.007$ and $p < 0.001$, respectively). When the ANCOVA models were adjusted for age, sex and Tanner stage, the statistical significance of these differences disappeared when controlling for VO_2max (model 2).

Considering the aforementioned results and the Baron and Kenny criteria,[27] only triglycerides and insulin were analysed in the mediation models presented in Figure 1. For triglycerides, in the first regression equation, daily steps were positively correlated with VO_2max (path a = 0.0004; 95% CI, 0.0001–0.0006; $p = 0.0011$); in the second regression equation or total effects, daily steps were negatively associated with triglycerides (path c = −0.0016; 95% CI, −0.0031 to −0.0002; $p = 0.0264$), and when VO_2max was incorporated into the model, in the third equation, the association between daily steps and triglycerides was reduced, losing statistical significance (path c' = −0.0010; 95% CI, −0.0025 to 0.0004; $p = 0.1676$).

For insulin levels, in the first regression equation, daily steps were positively correlated with VO2max (path a = 0.0004; 95% CI, 0.0001–0.0006; $p = 0.0011$); in the second regression equation daily steps were negatively associated with insulin (path c = −0.0002; 95% CI, −0.0004 to 0.0000; $p = 0.0267$). Nevertheless, when VO_2max was incorporated into the model, in the third equation, the association between daily steps and insulin was also reduced, losing statistical significance (path c' = −0.0001; 95% CI, −0.0003 to 0.0001; $p = 0.4084$). The percentage of mediation was 36.0% for triglycerides and 66.7% for insulin.

ACTA PÆDIATRICA NURTURING THE CHILD -WILEY

TABLE 1 Characteristics of the study sample.

	Total $n=100$	Boys $n=47$	Girls $n=53$	p Value
Age (years)	10.28±0.92	10.21±0.88	10.34±0.96	ns
Weight (kg)	41.04±9.33	41.22±8.45	40.88±10.13	ns
Height (cm)	144.78±7.70	145.41±6.53	144.22±8.62	ns
BMI (kg/m^2)	19.44±3.46	19.43±3.45	19.44±3.50	ns
Steps/day	10096±2929	11140±2695	9171±2836	**<0.001**
Vo2máx (mL/kg/min)	48.41±4.47	49.48±4.89	47.47±3.87	**0.015**
Lipid parameters				
Total Cholesterol (mg/dL)	160.46±29.03	162.11±29.02	159.00±29.24	ns
HDL-c (mg/dL)	67.50±14.36	66.40±13.25	68.47±15.33	ns
LDL-c (mg/dL)	95.61±27.13	99.70±30.25	91.98±23.73	ns
Triglycerides (mg/dL)	58.59±29.38	53.83±16.01	62.82±37.11	ns
Glycaemic parameters				
Insulin (mU/L)	8.17±3.85	7.05±3.59	9.16±3.83	**0.005**
HbA1c (%)	5.14±0.24	5.15±0.22	5.13±0.26	ns

Note: Values are means±SDs. Bold values indicate statistical significance based on $p \le 0.05$.

Abbreviations: BMI, body mass index; HbA1c, glycated haemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; n.s., not significant; VO_2max, predicted maximal oxygen capacity.

TABLE 2 Bivariate correlations presented as Pearson correlation coefficients (r) between steps, VO_2max, lipid and glycaemic parameters.

	Steps	Total cholesterol	HDL-c	LDL-c	TG	Insulin	HbA1c
VO_2máx	**,371**[b]	0,071	**,327**[b]	−0,059	**−,325**[b]	**−,474**[b]	−0,110
Steps		0,012	0,135	−0,063	**−,247**[a]	**−,257**[b]	0,157
Total cholesterol			**,335**[b]	**,687**[b]	**,195**[a]	−0,141	0,100
HDL-c				0,019	**−,418**[b]	**−,371**[b]	−0,069
LDL-c					**,173**[a]	−0,041	0,121
TG						**,511**[b]	0,077
Insulin							0,076

Note: Data are shown as the correlation coefficient R. Bold values indicate statistical significance based on $p \le 0.05$.

Abbreviations: HbA1c, glycated haemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, Triglycerides; VO_2max, predicted maximal oxygen capacity.

[a]Correlation is significant at $p<0.05$ (two-tailed).

[b]Correlation is significant at $p<0.001$ (two-tailed).

4 | DISCUSSION

This study is to our knowledge, the first to elucidate the role of CRF in the relationship between daily steps, as a daily PA measure, with lipid and glycaemic parameters in children using mediation analysis. The main findings were that children who accumulated more than 10000 steps daily had better lipid (lower triglycerides) and metabolic profiles (lower insulin levels), and that CRF (VO_2max) mediated the relationship between daily steps and insulin and triglycerides in schoolchildren.

Such results are in line with previous evidence supporting the association between higher PA levels and improved cardiometabolic profile in children and adolescents.[28,29] Likewise, the relationship between cardiometabolic health and CRF has been extensively established.[30–32] However, despite abovementioned evidence supporting PA beneficial effects on lipid and glycaemic parameters, our results showed no statistically significant differences between active and less active schoolchildren for total cholesterol, LDL-c or glycated haemoglobin, which may be due to underpower of our study.

Previous evidence suggests that CRF had a stronger association with cardiometabolic profile than objectively measured PA,[33] it remains to be clarified whether the influence of daily steps on cardiometabolic parameters is conveyed through improvements in CRF. Our study confirms the mediating role of CRF in the relationship between steps, triglycerides and insulin.

We established that the daily step threshold for classifying between active and inactive schoolchildren, according to the effect of

TABLE 3 Mean differences in cardiorespiratory fitness, lipid profile and glycaemic parameters by physical activity category (daily step quartiles).

	Steps/day quartiles				*p* value		
	<7968 steps	7968–10030 steps	10030–12036 steps	>12036 steps			
n	29	30	29	29	M_0	M_1	M_2
Vo_2max (mL/kg/min)	45.40±2.56	46.98±3.46	50.18±4.50	50.03±4.45	**<0.001**[a]	**<0.001**[a]	–
Lipid parameters							
Total Cholesterol (mg/dL)	160.96±28.98	159.96±37.64	161.10±23.32	159.85±26.24	0.998	0.979	0.982
HDL-c (mg/dL)	64.99±13.30	64.43±13.19	70.02±15.34	71.02±14.79	0.176	0.129	0.857
LDL-c (mg/dL)	97.88±24.06	98.74±36.24	91.76±22.86	94.41±25.40	0.797	0.593	0.837
Triglycerides (mg/dL)	76.36±46.95	56.35±14.50	49.80±14.08	52.19±21.57	**0.004**[b]	**0.015**[b]	0.062
Glycaemic parameters							
Insulin (mU/L)	10.04±4.27	8.96±4.32	6.25±2.64	7.54±3.10	**0.002**[c]	**0.038**[c]	0.321
HbA1c (%)	5.12±0.28	5.09±0.21	5.16±0.24	5.17±0.22	0.647	0.527	0.793

Abbreviations: HbA1c, glycated haemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; M_0, Crude values; M_1, Adjusted by age, sex and Tanner; M_2, Adjusted by VO_2max; VO_2max, predicted maximal oxygen capacity.

Bold values indicate statistical significance based on $p \leq 0.05$.

[a]Significant pairwise comparisons: 1<3, 1<4, 2<3, 2<4.

[b]Significant pairwise comparisons: 1>3, 1>4

[c]Significant pairwise comparisons: 1>3.

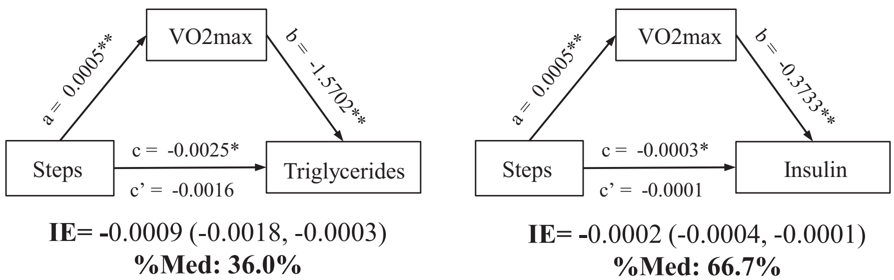

FIGURE 1 Cardiorespiratory fitness mediation models of the relationship between daily steps, triglycerides and insulin. $^{**}p \leq 0.001$; $^{*}p \leq 0.05$. Mediation model of the relationship between daily step count and triglycerides/insulin using VO_2max as a mediator. The data are presented as unstandardised beta coefficients, 95% CI, and standard error of beta estimates where c is the total effect and a, b, c' are direct effects measures. IE, Indirect effect (95% CI); VO_2max, predicted maximal oxygen capacity.

PA on cardiometabolic health in our sample, was in the median of daily steps (10000 steps per day, hence first and second daily steps quartiles were considered inactive while third and fourth quartiles were considered active), which, for children at this age, is a lower than the suggested threshold of 13000–15000 steps/day for boys and 11000–12000 steps/day for girls, as equivalent to the recommended 60min of moderate-to-vigorous PA (MVPA) for primary/elementary schoolchildren.[22] Thus, taking into account that early signs of atherosclerosis, as well as risk factors for ACVD, are present at an early age, our results shed light on the relationship between steps, CRF and cardiometabolic risk factors because they suggest that steps/day could be a good indicator of daily PA and that the same recommendation of 10000 steps day for adults may be already beneficial for schoolchildren.[19]

Our data support that much of the effect of daily steps in improving cardiometabolic risk is mediated by improvement in CRF, highlighting the pivotal role of CRF in this relationship. This relationship may be explained by the fact that regular PA, quantified as daily steps, improves cardiorespiratory fitness levels due to the increases on oxygen demand of muscles during PA, which entails cardiovascular (increase in cardiac preload volume) and respiratory adaptations (greater lung capacity and better oxygen exchange in the lungs), which in turn, results in various physiological changes (improved lipoprotein profile, enhanced muscle glucose uptake by increased the number and activity of GLUT-4) that enhance cardiovascular health.[34]

CRF mediation role is particularly significant for glycaemic parameters, probably because muscle is the main site of insulin-stimulated glucose uptake and, consequently, insulin levels are more susceptible to CRF influence than lipid parameters due to the strong relationship of CRF with muscle, as this parameter is mainly affected by genetic constitution and PA performed by the individual.

These findings transcendence lies in the fact that if the hypothesis that daily steps convey their effect on cardiometabolic risk through CRF, the intensity at which these steps should be performed would become of relevance, hence highlighting the importance of promoting higher intensities of PA and of improving the information that daily steps measured through wearable activity trackers provide, including parameters such as cadence.

Our study's main limitation is the cross-sectional design, which prevents us from making cause-effect inferences; hence, data from prospective studies may be useful to test our findings. Second, the limited sample size. Third, additional testing will be required to improve the generalisability of our results because of the complexity of influences on the children's cardiometabolic profile (dietary intake, genetic and environmental influences, etc.). Fourth, the mediation models have an exploratory nature; hence, we cannot exclude other mediators that could have influenced the association between steps with lipids and glycaemic parameters. Likewise, although such analyses were adjusted for some major potential confounders, such as age, sex and Tanner stage, residual confounders cannot be ruled out.

5 | CONCLUSIONS

Our findings have important clinical and public health implications since they confirm that the objective measurement of steps is a good instrument to evaluate daily PA in children. Furthermore, despite the small sample size, our findings suggest that compared to what has been suggested in previous works, 10000 steps could be a target in children from which substantial improvements in cardiometabolic health are produced and that such improvements in health outcomes could be mediated through improvements in CRF; hence, not only steps but also higher intensities of PA should be promoted to accomplish better cardiometabolic results. Finally, our data support that much of the effect of PA in improving cardiometabolic risk is mediated by improvement in CRF.

CONFLICT OF INTEREST STATEMENTS

None declared.

AUTHOR CONTRIBUTIONS

Irene Sequí-Domínguez: Conceptualization; data curation; formal analysis; investigation; methodology; writing – original draft. **Vicente Martínez-Vizcaíno:** Conceptualization; funding acquisition; investigation; project administration; resources; supervision; writing – review and editing. **Eva Rodríguez-Gutiérrez:** Conceptualization; data curation; investigation; project administration; writing – review and editing. **Bruno Bizzozero-Peroni:** Data curation; formal analysis; investigation; methodology; resources; writing – review and editing. **Vanesa Martinez-Madrid:** Investigation; methodology; resources; software; validation; visualization. **Enrique Prada:** Investigation; methodology; resources; software; validation. **Irene Martínez-García:** Funding acquisition; project administration; resources; visualization; writing – review and editing. **Ivan Cavero Redondo:** Conceptualization; formal analysis; software; supervision.

FUNDING INFORMATION

B.B.-P. is supported by a grant from the University of Castilla-La Mancha co-financed by the European Social Fund (2020-PREDUCLM-16746).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

The Clinical Research Ethics Committee of the Cuenca Health Area approved the study protocol.

EQUITY, DIVERSITY AND INCLUSION STATEMENT

Our research team is committed to promote diversity, equity and inclusion in our clinical work, research and training programmes. We understand the impact that systemic inequalities and biases can have in the research process, and we are taking steps to address these challenges.

PATIENT CONSENT STATEMENT

After obtaining the approval of the director of each school, and after informing parents, written approval was requested for their children's participation. Moreover, the schoolchildren were asked to collaborate with informative talks held class by class.

ORCID

Irene Sequí-Domínguez https://orcid.org/0000-0001-8981-4331
Vicente Martínez-Vizcaíno https://orcid.org/0000-0001-6121-7893

REFERENCES

1. World Health Organization. Noncommunicable Diseases Country Profiles 2018. World Health Organization; 2018. https://apps.who.int/iris/handle/10665/274512. Licencia: CC BY-NC-SA 3.0 IGO
2. Kavey REW, Daniels SR, Lauer RM, Atkins DL, Hayman LL, Taubert K. American Heart Association guidelines for primary prevention of atherosclerotic cardiovascular disease beginning in childhood. Circulation. 2003;107:1562-6. doi:10.1161/01.CIR.0000061521.15730.6E
3. Newman WP, Freedman DS, Voors AW, et al. Relation of serum lipoprotein levels and systolic blood pressure to early atherosclerosis. N Engl J Med. 1986;314:138-44. doi:10.1056/NEJM198601163140302
4. Berenson GS, Srinivasan SR, Bao W, Newman WP 3rd, Tracy RE, Wattigney WA. Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart study. N Engl J Med. 1998;338:1650-6. doi:10.1056/NEJM199806043382302
5. Mahoney L, Burns T, Stanford W, et al. Coronary Risk Factors Measured in Childhood and Young Adult Life Are Associated with Coronary Artery Calcification in Young Adults: the Muscatine Study. J Am Coll Cardiol. 1996;27(2):277-84.

6. McGill HC, McMahan CA. Determinants of atherosclerosis in the young. Am J Cardiol. 1998;82:30-6. doi:10.1016/S0002-9149(98)00720-6
7. Jacobs DRJ, Woo JG, Sinaiko AR, et al. Childhood cardiovascular risk factors and adult cardiovascular events. N Engl J Med. 2022;386:1877-88. doi:10.1056/NEJMoa2109191
8. Twisk JWR. Applied Longitudinal Data Analysis for Epidemiology: A Practical Guide. Cambridge University Press; 2013. doi:10.1017/CBO9781139342834
9. Martínez-Vizcaíno V, Solera Martínez M, Salcedo Aguilar F, et al. Validity of a single-factor model underlying the metabolic syndrome in children: a confirmatory factor analysis. Am Diabetes Assoc. 2010;33:1370-2. doi:10.2337/dc09-2049
10. Jiang X, Srinivasan SR, Bao W, Berenson GS. Association of fasting insulin with blood pressure in young individuals. The Bogalusa Heart study. Arch Intern Med. 1993;153:323-8.
11. Manolio TA, Savage PJ, Burke GL, et al. Association of fasting insulin with blood pressure and lipids in young adults: the CARDIA study. Arterioscler Thromb Vasc Biol. 1990;10:430-6. doi:10.1161/01.ATV.10.3.430
12. Orchard TJ, Becker DJ, Bates M, Kuller LH, Drash AL. Plasma insulin and lipoprotein concentrations: an atherogenic association? Am J Epidemiol. 1983;118:326-37. doi:10.1093/OXFORDJOURNALS.AJE.A113639
13. Burke GL, Webber LS, Srinivasan SR, Radhakrishnamurthy B, Freedman DS, Berenson GS. Fasting plasma glucose and insulin levels and their relationship to cardiovascular risk factors in children: Bogalusa Heart study. Metabolism. 1986;35:441-6. doi:10.1016/0026-0495(86)90135-6
14. Rönnemaa T, Knip M, Lautala P, et al. Serum insulin and other cardiovascular risk indicators in children, adolescents and young adults. Ann Med. 1991;23:67-72. doi:10.3109/07853899109147933
15. Bao WH, Srinivasan SR, Wattigney WA, Berenson GS. Persistence of multiple cardiovascular risk clustering related to syndrome-x from childhood to young adulthood - the Bogalusa-HEART-study. Arch Intern Med. 1994;154:1842-7.
16. Bao W, Srinivasan SR, Berenson GS. Persistent elevation of plasma insulin levels is associated with increased cardiovascular risk in children and young adults. The Bogalusa heart study. Circulation. 1996;93:54-9. doi:10.1161/01.cir.93.1.54
17. Myers J, McAuley P, Lavie CJ, Despres JP, Arena R, Kokkinos P. Physical activity and cardiorespiratory fitness as major markers of cardiovascular risk: their independent and interwoven importance to health status. Prog Cardiovasc Dis. 2015;57:306-14. doi:10.1016/J.PCAD.2014.09.011
18. Poitras VJ, Gray CE, Borghese MM, et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. Appl Physiol Nutr Metab. 2016;41:S197-239.
19. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour 54.
20. Organization WH. Global Status Report on Physical Activity 2022: executive summary. World Health Organization; 2022.
21. Roman-Viñas B, Zazo F, Martínez-Martínez J, Aznar-Laín S, Serra-Majem L. Results from Spain's 2018 report card on physical activity for children and youth. J Phys Act Health. 2018;15:S411-2. doi:10.1123/JPAH.2018-0464
22. Tudor-Locke C, Craig CL, Beets MW, et al. How many steps/day are enough? For children and adolescents. Int J Behav Nutr Phys Act. 2011;8:1-14. doi:10.1186/1479-5868-8-78/FIGURES/1
23. Nayor M, Chernofsky A, Spartano NL, et al. Physical activity and fitness in the community: the Framingham Heart study. Eur Heart J. 2021;42:4565-75. doi:10.1093/EURHEARTJ/EHAB580
24. Leger L, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. J Sports Sci. 1988;6:93-101. doi:10.1080/02640418808729800
25. Tanner JM, Davies PSW. Clinical longitudinal standards for height and height velocity for north American children. J Pediatr. 1985;107:317-29. doi:10.1016/S0022-3476(85)80501-1
26. Hayes A. Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach. Guildford Publications; 2017.
27. Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research. Conceptual, strategic, and statistical considerations. J Pers Soc Psychol. 1986;51:1173-82. doi:10.1037/0022-3514.51.6.1173
28. Janssen I, LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010;7:1-16. doi:10.1186/1479-5868-7-40/
29. Guinhouya BC, Hubert H. Insight into physical activity in combating the infantile metabolic syndrome. Environ Health Prev Med. 2011;16:144-7. doi:10.1007/s12199-010-0185-7
30. García-Artero E, Ortega FFB, Ruiz JRJ, et al. Lipid and metabolic profiles in adolescents are affected more by physical fitness than physical activity (AVENA study). Rev Esp Cardiol. 2007;60:581-8. doi:10.1157/13107114
31. Brage S, Wedderkopp N, Ekelund U, et al. Features of the Metabolic Syndrome Are Associated with Objectively Measured Physical Activity and Fitness in Danish Children: the European Youth Heart Study (EYHS). Am Diabetes Assoc. 2004;27:2141-8. doi:10.2337/diacare.27.9.2141
32. Eisenmann JC, Wickel EE, Welk GJ, Blair SN. Relationship between adolescent fitness and fatness and cardiovascular disease risk factors in adulthood: the aerobics center longitudinal study (ACLS). Am Heart J. 2005;149:46-53. doi:10.1016/j.ahj.2004.07.016
33. Bailey DP, Boddy LM, Savory LA, Denton SJ, Kerr CJ. Associations between cardiorespiratory fitness, physical activity and clustered cardiometabolic risk in children and adolescents: the HAPPY study. Eur J Pediatr. 2012;171:1317-23. doi:10.1007/S00431-012-1719-3
34. Franklin BA, Eijsvogels TMH, Pandey A, Quindry J, Toth PP. Physical activity, cardiorespiratory fitness, and cardiovascular health: a clinical practice statement of the ASPC part I: bioenergetics, contemporary physical activity recommendations, benefits, risks, extreme exercise regimens, potential maladaptations. Am J Prev Cardiol. 2022;12:100424. doi:10.1016/j.ajpc.2022.100424

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Sequí-Domínguez I, Martínez-Vizcaíno V, Rodríguez-Gutiérrez E, Bizzozero-Peroni B, Martinez-Madrid V, Prada de Medio E, et al. Association of daily steps on lipid and glycaemic profiles in children: The mediator role of cardiorespiratory fitness. Acta Paediatr. 2024;113:296–302. https://doi.org/10.1111/apa.17035