Cardiometabolic health in adolescence and its association with educational outcomes

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ABSTRACT

Aim To explore the association of selected cardiometabolic biomarkers and metabolic syndrome (MetS) with educational outcomes in adolescents from Chile.

Methods Of 678 participants, 632 (52% males) met criteria for the study. At 16 years, waist circumference (WC), systolic blood pressure, triglycerides (TG), high-density lipoprotein and glucose were measured. A continuous cardiometabolic risk score (zMetS) using indicators of obesity, lipids, glucose and blood pressure was computed, with lower values denoting a healthier cardiometabolic profile. MetS was diagnosed with the International Diabetes Federation/American Heart Association/National Heart, Lung, and Blood Institute joint criteria. Data on high school (HS) graduation, grade point average (GPA), college examination rates and college test scores were collected. Data were analysed controlling for sociodemographic, lifestyle and educational confounders.

Result zMetS, WC, TG and homeostatic model assessment of insulin resistance at 16 years were negatively and significantly associated with the odds of completing HS and taking college exams. Notably, for a one-unit increase in zMetS, we found 52% (OR: 0.48, 95% CI 0.227 to 0.98) and 39% (OR: 0.61, 95% CI 0.28 to 0.93) reduction in the odds of HS completion and taking college exams, respectively. The odds of HS completion and taking college exams in participants with MetS were 37% (95% CI 0.14 to 0.98) and 33% (95% CI 0.15 to 0.79) that of participants with no cardiometabolic risk factors. Compared with adolescents with no risk factors, those with MetS had lower GPA (515 vs 461 points; p=0.002; Cohen's *d*=0.55). Adolescents having the MetS had significantly lower odds of passing the mathematics exam for college compared with peers with no cardiometabolic risk factors (OR: 0.49; 95% CI 0.16 to 0.95).

Conclusion In Chilean adolescents, cardiometabolic health was associated with educational outcomes.

INTRODUCTION

The presence of cardiometabolic risk factors (CMRF), such as obesity, insulin resistance (IR) or high lipid levels, in adolescents has been associated with the early onset of non-communicable chronic diseases (ie, type 2 diabetes and coronary heart disease).[1] Cardiometabolic abnormalities are a major public health concern worldwide because they lead to high financial costs, increased morbimortality and poorer quality of life.[2] Despite sustained preventive efforts at national and local levels, the prevalence of CMRFs continues to increase among younger age populations.[3] According to a national survey, in Chile, 30% of male and 26% of female schoolchildren have abdominal obesity. The prevalence is greater in children aged 6–13, in urban compared with rural areas, and from low to middle socioeconomic status (SES) compared with those in higher SES.[4] A longitudinal study conducted in the country found that 9.5% of adolescents aged 16–17 years had metabolic syndrome (MetS)[5] and 17% had IR.[6] In children aged 10–15 years, the prevalence of MetS and IR was 7.3% and 25.6%, respectively.[7] In both studies, low high-density lipoprotein (HDL) cholesterol and abdominal obesity were the most frequent MetS components, whereas hyperglycaemia was the least common.[5–7]

Other implications of the increased prevalence of CMRFs in children and youth are less clear. The MetS, a cluster of risk factors including increased blood pressure, high blood sugar, excess body fat around the waist and abnormal cholesterol or triglyceride (TG) levels, is known to adversely affect cognition in adults.[8 9] Some interventions targeted at reducing individual MetS components have resulted in positive cognitive changes.[10–12] IR has been related to impaired synaptic plasticity and memory performance due to atrophy of dendritic arbours of differentiated GABAergic neurons.[10 13–15] However, very few studies have explored these relationships in children and adolescents and even fewer have investigated the potential effects on educational outcomes. A growing body of evidence suggests that biological factors such as diet, physical activity (PA) and nutritional status affect knowledge acquisition, learning and achievement of school goals.[16–21] Consequently, several public health agencies have recognised that educational attainment is inter-related with health behaviours and, thus, this relationship has long-term consequences for youth, adults and the society as a whole.[22 23] Here, we explored the association of the MetS and its components to several educational outcomes in adolescents from Chile, to examine the hypothesis that increased cardiometabolic risk relates to poorer academic results. If cardiometabolic health affects academic results, there would be implications for public health and education policies. Such findings would provide schools and parents with an important incentive to encourage cardiometabolic health in adolescents.

METHODS

Study design and population

We studied 678 participants aged 16 years living in urban Santiago (Chile), from low to middle

SES families, who were part of a follow-up study beginning in infancy. The infants, recruited at 4 months, were healthy, full-term singletons and weighing ≥3 kg at birth. They were assessed for developmental outcomes in infancy, 5, 10 and 16 years.[24] At 16 years, they were also assessed for obesity risk and the presence of CMRFs.[5] Of the 678 participants, 632 (93%) enrolled in high school (HS) and were eligible for this study. Informed and written consent was provided according to the norms for Human Experimentation, Code of Ethics of the World Medical Association.

Educational outcomes

The academic outcomes measured were HS grade point average (GPA), the likelihood of HS completion, the likelihood of taking college entrance examinations and passing those exams. In Chile, completion of secondary education is around the age of 18. Data on GPA and HS completion were obtained from publicly available records. Following the Ministry of Education criteria, GPA was transformed into standardised scores (ranging from 210 to 825), and adjusted by type of secondary education. Data on college examination rates and performance in the mandatory language and mathematics tests were derived from publicly available information from the Assessment and Measurement Department of the University of Chile, which administers the tests for college entrance on behalf of the Ministry of Education. Although the exams for college admission are non-mandatory for HS graduates, more than 85% of Chilean HS graduates take them and, thus, are considering plans for future schooling.[25] The cut-off for passing the college entrance examinations is 450 points.

Cardiometabolic assessments and diagnosis of cardiometabolic risk

Adolescents were assessed at 16 years during the fourth wave of the longitudinal research study, which took place in 2009–2013. A research physician used standardised procedures to measure the waist circumference (WC) with non-elastic flexible tape (SECA 201, Seca) and recorded to 0.1 cm. Measurements were taken twice, with a third measurement if the difference between the first two exceeded 1.0 cm. Fifteen minutes after the anthropometric examination, and before other physical evaluations, systolic and diastolic blood pressure (SBP and DBP) were measured three times on the non-dominant arm using a standard mercury sphygmomanometer; the average value was used for analyses. Fasting serum total glucose (Gli), total cholesterol, TG, HDL and insulin were assessed after a 12-hour overnight fast. Radioimmunoassay (DCP Diagnostic Products) was used for insulin determination. Gli was measured with enzymatic-colorimetric test (QCA) and cholesterol profile was determined with dry analytical methodology (Vitros, Johnson & Johnson, Clinical Diagnostics). Homeostatic model assessment of insulin resistance (HOMA-IR) was estimated (HOMA-IR=[Gli mg/dL*insulin μUI]/405). A continuous score representing a composite CMRF profile was computed. The methodology of the zMetS score calculation was previously published.[26] It was computed by standardising the residuals (z-scores) of WC, SBP, HDL, TG and Gli by regressing them according to sex. Because HDL is inversely related to MetS risk, its reciprocal was used. We obtained a continuous, normally distributed cardiometabolic risk z-score, expressed in SDs, by averaging these five values. A lower zMetS indicates a healthier cardiometabolic profile. Finally, the following CMRFs were identified based on the International Diabetes Federation/American Heart Association/National Heart, Lung, and Blood Institute joint definition[27]: abdominal obesity (WC ≥80 and 90 cm in females and males, respectively), high blood arterial pressure (SBP ≥130 mm Hg, DBP ≥85 mm Hg), hypertriglyceridaemia (TG ≥150 mg/dL), low HDL (≤50 and ≤40 mg/dL in females and males, respectively) and fasting hyperglycaemia (Gli ≥100 mg/dL). Participants with ≥3 risk factors were categorised as having MetS.

Other covariates

Anthropometric measurements

Standardised procedures were used to measure height to the nearest 0.1 cm, using a Holtain stadiometer, and weight to the nearest 0.1 kg, using a scale (SECA 703, Seca). Measurements were taken twice, with a third measurement if the difference between the first two exceeded 0.3 kg for weight and 0.5 cm for height. Body mass index (BMI) was calculated and weight status was evaluated according to the 2007 WHO growth standards.

Socioeconomic status

In health research, parental education has been often used as a proxy for SES.[28] Thus, in our analysis, both maternal and paternal education acted as indirect indicators of the socioeconomic background of participants. In infancy, participant's parents reported the highest schooling level they had been enrolled in, and the highest grade they completed at that level. Five educational categories were defined: (1) no education completed, (2) first level (primary school), (3) secondary level (9th–10th), (4) secondary level (11th–12th), and (5) postsecondary non-tertiary education. We merged these categories into two: incomplete secondary education (1+2+3) and complete secondary education or higher (4+5).

Lifestyle assessment

Diet quality and PA have been associated with academic outcomes in studies conducted in Chile,[17–20] therefore, they could be confounders for the association of cardiometabolic health with academic results. To assess diet at 16 years, we used a validated food frequency questionnaire,[29 30] which was administered to all participants at the time of the anthropometric examination. The frequency of food consumption was assessed by a multiple response grid; participants were asked to estimate how often a particular food/beverage was consumed. Categories ranged from 'never' to '7-times a week'. The electronic version of the Chilean Food Composition Tables/Database was used to assess the quality of food composition.[31] Foods were classified as high in saturated fats and sugars, high in sugars although low in saturated fats, and nutrient-rich foods. We assigned adjustment weights to each food item conditioned to its nutritional quality. A continuous score ranging from 0 to 10 was computed adjusting the frequency of food consumption to the nutritional quality, with higher scores representing healthier dietary habits. Cut-offs for the Chilean adolescent population identified participants having unhealthy, unhealthy-to-fair, or healthy diets. We approached PA accounting for the number of weekly hours devoted to physical education (PE) and extracurricular sports. To measure this, we used a questionnaire that was validated in a previous study using accelerometers in both elementary and high schoolers.[32] Participants reporting ≤90 min of weekly scheduled PA, which is the mandatory time for school-based PE in Chile, were considered to be physically inactive.

Type of secondary education
In Chile, secondary education includes academic HS, vocational training schools and adult schools. Data on the type of secondary education attended by participants were retrieved from publicly available records at the Ministry of Education.

Data analysis

All variables were checked for normality of distribution (Shapiro-Wilk test) before the analysis. WC, SBP, DBP, HOMA-IR, TG and HDL were normalised by natural logarithm transformation. Statistical analysis was performed on transformed data. We present untransformed data here. Analysis of variance and Pearson's χ^2 test were used for comparison of anthropometric and cardiometabolic variables. To examine the association of cardiometabolic biomarkers (exposure) with: (1) the odds of HS completion (outcome), (2) taking exams for college, and (3) passing the college entrance exams, we conducted logistic regressions with continuous predictor variables. For each biomarker, two models were estimated. Model 1 was unadjusted. Model 2 was adjusted for sex, weight status, SES, nutritional quality of diet, PA, type of secondary education and school grades at 16 years. A further logistic analysis was conducted to estimate the odds and 95% CI for the association of HS completion, taking exams for college entrance and passing those exams with the number of CMRFs. Again, the first model was unadjusted, and a second model included weight status as covariate along with SES, nutritional quality of diet, PA, type of secondary education and school grades at 16 years. Data were analysed using Stata for Windows V.15.0 (College Station, TX, USA).

RESULTS

Of the 678 adolescents, 632 (93%) enrolled in HS and met criteria for the study. Comparisons of those who were enrolled in HS and those who were not showed no differences in age, sex, BMI, weight status, number of CMRFs, SBP, DBP, HOMA-IR, TG and HDL at 16 years. However, those who did not enrol in HS had higher WC, Gli and zMetS, were more likely to have unhealthy diets and their mothers were less likely to have completed secondary education compared with those who enrolled in HS (see online supplementary table S1).

Our final sample was on average 16.8 (SD: 0.3) years old, 52% males and 48% females, of whom 79% had at least one CMRF and 8.8% had MetS. In addition, 38% were either overweight or obese. The mean GPA was 481 (SD: 92; ranging from 269 to 795), 90.2% completed HS, 61% took the examination for college admission and 53% passed the mandatory language and mathematics tests (table 1). The mean age of participants at HS completion was 18.5 years (SD: 0.5).

We observed a negative and significant association between the number of CMRFs in adolescence and GPA (figure 1). The *post hoc analysis* revealed that adolescents with MetS at 16 years had lower GPA scores than those without the condition. Compared with adolescents with no CMRF, those with MetS had significantly lower GPA (515 vs 461 points; p=0.002; Cohen's *d*=0.55).

After accounting for other confounders, we found a negative association between the odds of HS completion and the following cardiometabolic biomarkers: WC, Gli, HOMA-IR, TG and zMetS. A positive association was found between HS completion of and serum HDL. Notably, a one-unit or 1 SD increase in the zMetS related to 52% reduction in the odds of completing HS (OR: 0.48, 95% CI 0.22 to 0.92). Similarly, a one-unit increase in HOMA-IR was associated with a 20% reduction in the odds of completing HS (OR: 0.80, 95% CI 0.63 to 0.92) in this sample. A similar pattern was observed when the outcome was the likelihood of taking college entrance examinations. The odds of completing HS were negatively related to WC, HOMA-IR, TG and zMetS, and positively related to HDL. As in the previous result, the greatest reduction in the odds of HS completion was related to higher zMetS and HOMA-IR (table 2).

Table 1 Descriptive statistics of participants in the sample (n=632)

	Mean or n	(SD) or percentage
Chronological age		
Age (years)	16.8	(0.3)
Age at school completion (years) (n=571)	18.5	(0.8)
Sex		
Males	330	52.2%
Females	302	47.8%
Cardiometabolic profile		
WC (cm)	80.9	(11.1)
SBP (mm Hg)	111.6	(10.5)
DBP (mm Hg)	69.0	(7.1)
Gli (mg/dL)	88.4	(8.9)
TG (mg/dL)	87.4	(49.1)
HDL (mg/dL)	40.3	(10.6)
zMetS (SD)	−0.02	(0.5)
HOMA-IR	1.78	(1.3)
Cardiometabolic risk factors at 16 years		
None	136	21.4%
1	286	45.3%
2	155	24.6%
Metabolic syndrome	51	8.7%
Anthropometric profile at 16 years		
BMI (z-score) (SD)	0.64	(1.1)
Overweight (BMIz >1 SD)	155	24.5%
Obese (BMIz >2 SD)	86	13.6%
Academic profile		
High school grade point average (GPA)*	481.1	(92.3)
School grades at 16 years	469.2	(87.1)
Completed high school	571	90.1%
College entrance exams (n=570)	387	61.3%
Passed language exam (n=388)	204	52.6%
Passed math exam (n=388)	218	56.2%
Socioeconomic background		
Mother: incomplete secondary education	212	33.5%
Father: incomplete secondary education	176	27.9%
Lifestyles at 16 years		
Healthy diet	171	27.7%
Physically active	119	18.8%
Type of secondary education		
Academic	179	28.3%
Vocational	330	52.2%
Adult	123	19.5%

*GPA and school grades at 16 years expressed as standardised score (scale 210–825), according to the Ministry of Education (Chile).
BMI, body mass index; DBP, diastolic blood pressure; HDL, high-density lipoprotein; HOMA-IR, homeostatic model assessment of insulin resistance; SBP, systolic blood pressure; TG, triglyceride; WC, waist circumference.

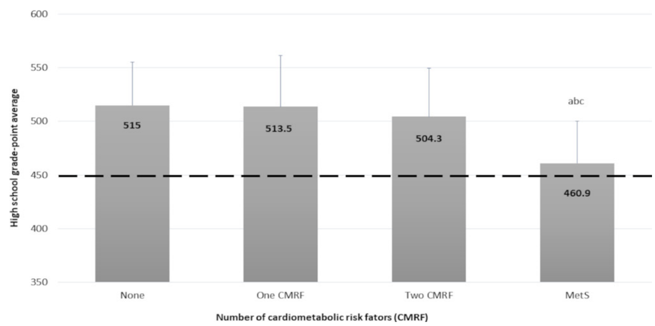

Figure 1 Association between number of cardiometabolic risk factors at 16 years and high school grade point average in Chilean adolescents (n=632). Cardiometabolic risk factors (CMRF) include: abdominal obesity (WC >80 and >90 cm in females and males, respectively); raised blood pressure (systolic BP ≥130 mm Hg or diastolic BP ≥85 mm Hg); fasting plasma glucose ≥100 mg/dL; raised TG level (≥150 mg/dL); and reduced HDL cholesterol (<40 and <50 mg/dL in males and females, respectively). High school GPA expressed as score, according to the Ministry of Education (Chile). (abc) Significantly different from the group having none (a), one (b), and two (c) cardiometabolic risk factors. GPA scores were adjusted for sociodemographic, lifestyle and educational confounders. Error bars are 95% CI (upper limit). Cut-off for passing the college entrance exams is 450 points (dotted red line), with scores ranging from 210 to 825. BP, blood pressure; GPA, grade point average; HDL, high-density lipoprotein; MetS, metabolic syndrome; TG, triglyceride; WC, waist circumference.

Table 3 shows the results for the association between the number of CMRFs with the likelihood of HS completion and taking college entrance examinations. The odds of HS completion decreased as the number of CMRFs increased, though the association was significant only in participants having two (OR: 0.47, 95% CI 0.22 to 0.98) or ≥3 risk factors (OR: 0.37, 95% CI 0.14 to 0.98). The odds of taking college entrance examinations was negatively associated with higher number of CMRFs. A significant association was found only in participants with MetS (OR: 0.33, 95% CI 0.15 to 0.79).

The likelihood of passing the college entrance examinations was also decreased as the number of CMRFs increased (table 4). These associations were significant only for the results of the mathematics test. These results showed that having MetS decreased the likelihood of passing the test by approximately 50% compared with the absence of CMRF (OR: 0.49, 95% CI 0.16 to 0.95). Furthermore, the associations remained significant when sociodemographic, lifestyle and other educational covariates were taken into account.

DISCUSSION

Our findings confirmed the important relationship between cardiometabolic health in adolescence and relevant educational outcomes: school completion, GPA, taking college entrance examinations and passing the mandatory mathematics college entrance examination. The results show that these relationships were independent of sex, parental education, weight status, type of school, school grades at 16 years and lifestyles. Notably, the findings show that composite cardiometabolic risk and HOMA-IR were importantly associated with higher risk for dropping out of school and lower likelihood of taking college entrance exams. Other cardiometabolic biomarkers related to poor academic performance were WC and HDL. It is worth noting that abdominal obesity and low HDL are highly prevalent in youth, and largely due to unhealthy dietary habits and inadequate time for exercise. Although low HDL has consistently shown high prevalence in relation to other MetS components, it is not usually targeted by primary prevention programmes. Prevention of cardiovascular risk in children and adolescents focuses on management of excess weight and high TG.[33]

Although our findings were based on functional measures of cognitive performance, they are consistent with the existing literature, which shows that elevated cardiometabolic risk is related to increased risk of impaired cognition, memory and executive function in adults.[8–10 15] Moreover, cognitive changes have been observed even at levels of risk that would be considered subclinical according to current diagnostic conventions but may be important enough to interfere with memory, attention, reasoning and planning.[34] All these domains have been linked to school performance.[35]

Possible biological explanations for our results may be persistent inflammation and oxidative stress observed in cardiometabolic dysfunction. The release of proinflammatory cytokines (ie, tumour necrosis factor-α, high-sensitivity C-reactive protein and interleukin-1β) is thought to induce synaptic pruning, leading to impaired neuroplasticity and structural brain changes that negatively affect cognition.[36 37] During inflammation, some cytokines activate

Table 2 Estimated association between selected cardiometabolic markers (exposure) and educational outcomes in HS in Chilean adolescents

	High school completion				Taking college exams†			
	Model 1		Model 2		Model 1		Model 2	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Metabolic syndrome z-score	0.48*	0.29 to 0.86	0.48*	0.22 to 0.92	0.62**	0.42 to 0.87	0.61*	0.28 to 0.93
Waist circumference	0.96*	0.93 to 0.98	0.98*	0.931 to 0.98	0.97*	0.95 to 0.99	0.97*	0.93 to 0.99
Systolic blood pressure	0.99	0.96 to 1.04	0.98	0.96 to 1.01	0.99	0.97 to 1.01	0.99	0.98 to 1.03
Diastolic blood pressure	0.98	0.97 to 1.07	0.99	0.95 to 1.03	0.97	0.95 to 1.01	0.99	0.95 to 1.02
Glycaemia (mg/dL)	0.97*	0.94 to 0.98	0.97*	0.94 to 0.99	0.97	0.95 to 1.002	0.98	0.95 to 1.007
HOMA-IR	0.83*	0.68 to 0.99	0.80*	0.63 to 0.92	0.81*	0.68 to 0.96	0.86*	0.73 to 0.98
Triglycerides (mg/dL)	0.99*	0.97 to 0.99	0.99*	0.97 to 0.99	0.99**	0.98 to 0.99	0.99**	0.98 to 0.99
HDL (mg/dL)	1.05*	1.02 to 1.09	1.05*	1.008 to 1.09	1.03*	1.002 to 1.05	1.03*	1.01 to 1.06

Model 1 was unadjusted. Model 2 was adjusted for weight status categories (overweight and obesity), sex, parental education, lifestyles (diet and exercise), type of secondary education (vocational, adult) and school grades at 16 years.
*p<0.05; **p<0.01; ***p<0.001.
†In the sample, 571 out of 632 participants completed high school and met criteria for taking exams for higher education.
HDL, high-density lipoprotein; HOMA-IR, homeostatic model assessment of insulin resistance; HS, high school.

Table 3 Estimated association of number of cardiometabolic risk factors (exposure) with high school completion and taking exams for college in Chilean adolescents

	High school completion				Taking college exams†			
	Model 1		Model 2		Model 1		Model 2	
	OR	95% CI	aOR	95% CI	OR	95% CI	aOR	95% CI
One CMRF	0.83	0.47 to 1.46	0.76	0.41 to 1.40	0.94	0.52 to 1.81	0.95	0.39 to 2.29
Two CMRFs	0.61**	0.32 to 0.83	0.47*	0.22 to 0.98	0.87	0.42 to 1.79	0.80	0.37 to 1.75
Metabolic syndrome	0.46**	0.21 to 0.87	0.37*	0.14 to 0.98	0.35**	0.17 to 0.74	0.33*	0.15 to 0.79

Reference category: Adolescents with no cardiometabolic risk factors. Model 1 is unadjusted. Model 2 is adjusted for sociodemographic covariates (sex and family educational background), lifestyles (diet and exercise), type of secondary education (vocational, adult) and school grades at 16 years.
*p<0.05; **p<0.01; ***p<0.001.
†In the sample, 571 out of 632 participants completed high school and met criteria for taking exams for higher education.
aOR, adjusted OR; CMRF, cardiometabolic risk factor.

a persistent inflammatory response, which is particularly damaging to the hippocampal region, the part of the brain that is responsible for learning and memory.[37] Moreover, the brain is more vulnerable to oxidative stress than other body organs. Evidence has shown that impaired learning and memory are associated with oxidative damage to the hippocampus.[38 39] Some studies showed that oxidative stress is involved in a type of programmed cell death that is dependent on iron and characterised by the accumulation of lipid peroxides; this ferroptosis is activated by the failure of antioxidant defences. In addition, neurons that are degraded through ferroptosis release lipid metabolites that are harmful to surrounding neurons, thus causing neuroinflammation.[39] Likewise, other studies show that obesity determines a range of behaviours that may affect students' performance (ie, classroom behaviour, attendance and dropout rates, and academic adjustment).[40 41] This might be mediated by the impact of obesity on self-esteem, school satisfaction and school connectedness.[42]

Our findings suggest that paediatric prevention to minimise the risk of cardiometabolic disorders may be a realistic method of advancing students' performance. In a previous study, 15-year-old Chilean students underperformed the Organization for Economic Cooperation and Development average in mathematics, reading and science.[43] Evidence shows that students who fail to reach the baseline level of performance in these areas have difficulties with academic readiness, persistence and completion of higher education.[44] Thus, our results may provide the groundwork for the active involvement of educational agencies in health advancement. In addition, unlike many sociodemographic determinants of educational results, most health-related determinants are modifiable factors.

We provide results that support the existence of a positive link between cardiometabolic health and academic achievement. We tested this relationship by accounting for confounding factors, such as sex, SES (including both parents' education), type of school, quality of diet and time allocation for exercise. Subsequent studies should also account for socioemotional factors (ie, students' motivation and how future oriented an adolescent is). Additionally, we tested these relationships using functional measures of cognition and we focused on adolescents. Also, our results may serve to reinforce efforts to develop active and preventive policies for cardiometabolic risk in children and adolescents, in particular measures supporting healthy diets and PA. Last, we provide findings that may be useful for countries undergoing nutritional and epidemiological transitions where obesity-associated cardiovascular risk is rising. Yet, several limitations should be considered. Because our sample consisted of adolescents from low to middle SES, we are not able to extrapolate these results to the overall population of Chilean adolescents. Although a limitation, this bias makes our findings particularly relevant. The prevalence of CMRFs is higher in adolescents of low to middle SES according to nationally conducted studies. Also, adolescents from these SES levels are more exposed to risk factors for cardiometabolic disorders, that is, unhealthy dietary habits and sedentary behaviour. Second, although observational designs are more realistic

Table 4 Estimated association of number of cardiometabolic risk factors (exposure) with passing the language and mathematics college admission tests (outcomes) in Chilean adolescents

	College entrance exam: language†				College entrance exam: mathematics†			
	Model 1		Model 2		Model 1		Model 2	
	OR	95% CI	aOR	95% CI	OR	95% CI	aOR	95% CI
One CMRF	0.89	0.53 to 1.50	0.91	0.51 to 1.62	0.64	0.37 to 1.11	0.68	0.38 to 1.52
Two CMRFs	0.82	0.46 to 1.46	0.83	0.40 to 1.71	0.58	0.22 to 1.32	0.52	0.25 to 1.10
Metabolic syndrome	0.67	0.11 to 1.18	0.70	0.25 to 2.15	0.41*	0.07 to 0.72	0.49*	0.16 to 0.95

Reference category: Adolescents with no cardiometabolic risk factors. Model 1 is unadjusted. Model 2 is adjusted for sociodemographic covariates (sex and family background), lifestyles (diet and exercise), type of secondary education (vocational, adult) and school grades at 16 years. Cut-off point for passing the college entry exams is 450 points, with scores ranging from 210 to 825.
*p<0.05; **p<0.01; ***p<0.001.
†In the sample, 385 participants out of 571 who had HS completed took exams for higher education.
aOR, adjusted OR; CMRF, cardiometabolic risk factor; HS, high school.

than experimental methods, causality cannot be established in this study. Crossover or randomised controlled trials should be conducted to confirm causal relationship between cardiometabolic risk beginning early in life and its impact on educational attainment. Third, although we accounted for the effect of important confounders (ie, parental education, lifestyles), we were not able to consider other key influences. Due to data constraint the effect of mental health conditions was not included in the study. The impact of cardiometabolic disorders on memory and cognition might be confounded by the coexistence of mental health problems such as depression, anxiety and substance-related disorders.

What is already known on this subject

- Despite sustained preventive efforts, the prevalence of cardiometabolic risk factors continues to increase among younger age populations.
- Cardiometabolic risk is known to affect cognition in adults. Very few studies have explored these relationships in younger age populations and even few have investigated the impact on educational outcomes.

What this study adds

- After controlling sociodemographic, lifestyle and educational covariates, we found that composite cardiometabolic risk and homeostatic model assessment of insulin resistance were importantly associated with higher risk for dropping out of school and lower likelihood of taking college entrance exams. Other cardiometabolic disease biomarkers related to poor academic performance were waist circumference and high-density lipoprotein (HDL) cholesterol. Abdominal obesity and low HDL are highly prevalent in youth.
- Our findings may provide schools and parents with an important incentive to encourage cardiometabolic health in adolescents and support the importance of schools as points of entry for health promotion.

Contributors Conceptualisation: PCB and RB. Methodology: PCB and RB. Formal analysis: PCB. Investigation: PCB, RB, SG. Data curation: PCB. Writing-original draft preparation: PCB. Writing-review and editing: EB, SG, RB. Supervision: RB. Project administration: EB. Funding acquisition: SG, RB, PCB.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval All procedures performed in the participants were in accordance with the ethical standards of the institutional review boards of the University of Michigan, the Institute of Nutrition and Food Technology (University of Chile), the University of California San Diego, and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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