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Associations of mental health with cardiovascular risk phenotypes and adiposity in adolescence: A cross-sectional community-based study

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Abstract

Objective: Cardiovascular disease and mental illness commonly co-occur in later life, but it is unknown how early these associations arise. We aimed to determine the extent to which: 1) childhood mental health is associated with functional and structural cardiovascular risk phenotypes and adiposity in late childhood/adolescence, and 2) associations between mental health and cardiovascular phenotypes may be explained by differential BMI.

Design: Cross-sectional study. *Setting:* Three longitudinal community-based cohort studies (two enriched for overweight/obesity) in metropolitan Melbourne, Australia, with harmonized follow-up in 2014.

Methods: *Mental Health Exposures:* Emotional and behavioural problems (Strength and Difficulties Questionnaire) and psychosocial health and general wellbeing (Pediatric Quality of Life Inventory, PedsQL) were assessed by self- and parent-proxy report. O*utcomes:* mean arterial pressure, pulse wave velocity, carotid artery intima-media thickness, retinal arteriole-to-venule ratio, waist circumference, % body fat, and BMI z-score. *Analyses:* Multivariable linear regression models, adjusting for age, sex and neighbourhood disadvantage.

Results: Of the 364 participants (mean age 14.7, standard deviation 2.0, years), 30% were overweight and 16% obese. All adiposity indicators were positively associated with higher behavioural/emotional problems and poorer psychosocial health, and negatively associated with better ratings of positive general wellbeing, as reported by parents and children (all pd0.03). However, there was little evidence that cardiovascular functional or structural phenotypes varied by mental health.

Conclusions: By late childhood/adolescence mental health is strongly associated with adiposity, but not with cardiovascular structure or function. This suggests that the known relationship between these constructs may not develop until early or mid-adulthood.

Keywords: child, adolescent, mental health, cardiovascular system, cardiovascular diseases, obesity

What is already known

- Adult mental illnesses, such as bipolar and major depression, are associated with adverse cardiovascular events.
- Both negative and positive aspects of adult mental health are associated with cardiovascular profiles, but it is not known when these associations begin.
- In childhood, higher adiposity is associated with negative mental health but associations with positive mental health are unknown, as are associations of the negative/positive mental health spectrum with cardiovascular changes.

What this study adds

- By mid-adolescence, negative mental health was strongly associated with higher, and positive mental health with lower, adiposity.
- However, neither positive nor negative mental health was associated with functional or structural vascular changes by this age.
- Relationships between these constructs may not develop until adulthood, possibly providing opportunities to prevent cardiovascular disease throughout adolescence.

INTRODUCTION

Cardiovascular disease (CVD) and mental illness are two of the leading contributors to global morbidity.[1] Their frequent co-occurrence in adulthood[1, 2] has led to an appreciation of their shared determinants and underlying biological mechanisms.[3, 4] Since both often originate in childhood and track into adulthood,[5-7] it is plausible that mental health and cardiovascular profiles already co-vary in early life. However, most studies investigating this relationship focus on existing CVD and severe mental illness in late adulthood.[2] By late adulthood disease is overt and the association well established,[8-11] but it is impossible to adequately account for a lifetime of potential confounding factors.[2]

Mental *illnesses* are defined by the presence or absence of a cluster of symptoms according to diagnostic criteria, assessed via clinical interview.[12] In contrast, mental *health* is defined along a continuum[13] and can be assessed via screening surveys by self- or proxy-report, facilitating incorporation in large studies. Typically these measures have focused on the continuum of ill health, with the best possible mental health represented by an absence of negative symptoms. However, the importance of positive mental health is increasingly being recognized and measured in children.[14]

The advent of non-invasive, portable technologies also means that it is now possible to assess intermediate cardiovascular risk phenotypes in community-based studies early in life.[15, 16] Phenotypic measures of vascular structure include measurement of both large arterial parameters via carotid artery intima-media thickness (carotid IMT, a measure of atherosclerotic burden) and the microcirculation via retinal vasculature parameters. Phenotypic measures of vascular function include endothelial function, pulse wave velocity and blood pressure. Many of these parameters are known to track from adolescence into adulthood, where they are predictive of CVD outcomes.[17]

Longitudinal studies in adulthood suggest that mental illness, particularly bipolar, psychosis and schizophrenia, predicts cardiovascular morbidity and mortality.[2, 18] However, the causal directions remain uncertain with shared common determinants and underlying mechanisms likely.[19, 20] In particular, dysfunction of the hypothalamic pituitary axis and heightened inflammation are emerging as important physiological processes in the pathogenesis of both CVD and mental illnesses.[19] These common inflammatory mechanisms are proposed to impact on the endothelial lining of the vascular system,[21, 22] increasing arterial stiffness.

To date, the two studies examining the relationship between mental health and cardiovascular intermediate phenotypes in adolescence have focused on negative mental health symptoms and endothelial dysfunction. Oskia's cross-sectional school-based study of 248 Swedish adolescents reported that girls with symptoms of anger, depression and anxiety had impaired endothelial function, while in boys disruptive behaviour was, perhaps counter-intuitively, associated with *better* vascular function.[23] Tomfohr's longitudinal study of 135 adolescent females reported similar results, showing that when depressive symptoms were worse, so too was endothelial function[24] even after taking into account adiposity and exercise habits. These could be important because clinically obese children have worse cardiovascular [25, 26] as well as psychosocial health.[27, 28] However, it is not yet known whether negative mental health translates into other demonstrable adverse vascular changes at this age. Furthermore, if so it is unknown whether any one element – microvascular structure, macrovascular structure, or functional measures – predates the others.

Positive mental health and cardiovascular phenotypic outcomes have been studied only in adults. In a study of 6,025 Americans aged 26-74 years, those with higher levels of emotional vitality (e.g. energy, positive wellbeing) had reduced risk of developing coronary heart disease during a 15-year follow-up period, even after controlling for multiple cardiovascular and mental health risk factors.[29] Establishing whether positive mental health is associated with cardiovascular risk phenotypes early in life could provide evidence for an early and perhaps causal shared mechanism. Such knowledge could have important implications for prevention of CVD.

Therefore, in this cross-sectional community sample enriched for obesity, we ***aimed*** to determine the extent to which: 1) child mental health, both positive and negative dimensions, are associated with cardiovascular risk phenotypes (functional and structural) and adiposity by late childhood and adolescence, and 2) whether any associations observed between mental health and cardiovascular function/ structure may be explained by differential BMI. We ***hypothesized*** that: 1) positive child mental health (as reported both by parents and children) would be associated with better, and negative mental health with worse, cardiovascular risk phenotypes and adiposity; and 2) accounting for BMI would attenuate these relationships, but independent associations would remain.

MATERIALS AND METHODS

Design/sample

The sample comprised children from Melbourne, Australia, taking part in three harmonized existing community-based cohort intervention trials: PEAS (Parent Education and Support program),[30] LEAP 2 (Live, Eat, And Play 2),[31] and HopSCOTCH (Shared-Care Obesity Trial in Children).[32] Given their robustly null findings with no evidence of intervention effect on adiposity or mental health,[30, 31, 33] the three studies were combined for whole-cohort analyses in a subsequent harmonized wave of follow-up (i.e. this cross-sectional study). This innovative whole-cohort approach was a wise use of resources to address our preliminary research questions.

Briefly, PEAS recruited a birth cohort of 493 first-born infants in the weeks after birth; this cohort was not selected for weight. First time mothers attending Maternal and Child Health centers in the three participating local government areas were invited to take part during the recruitment periods between 1998 and 2000. The PEAS quasi-experimental study initially trialled a 2-year health services intervention concerned with common early infant problems; subsequently, 343 children were re-recruited at age 4 years into the PEAS Kids Growth Study to track growth and anthropometry.[34] The LEAP 2 trial recruited 258 overweight or mildly obese 5-10 year olds in 2009 from a primary care screening survey conducted by 45 general practices (GP) across Melbourne. The trial tested a 4-month brief intervention delivered by GPs to reduce BMI through sustainable nutritional and/or physical activity.[31] The HopSCOTCH trial recruited 119 obese 3-10 year olds in 2009/10 from a screening survey across 22 GPs across Melbourne. The shared-care obesity intervention involved appointments with both GPs and tertiary specialists.[33]

All three studies were approved by The Royal Children's Hospital Ethics in Human Research Committee (PEAS: 28153, HopSCOTCH: 28017, LEAP2: 25006). Parents provided written informed consent, as did children aged over 12 years deemed capable.

Participants

Of the 720 participants in the three cohorts, 643 were invited to participate in the combined follow up in 2014. This included all children who had previously taken part at any previous time point in the LEAP 2 and HopSCOTCH studies, and those who had taken part in the PEAS Kids Growth Study.

Procedures

Data collection ran from February–October 2014. Parents (or caregivers) were sent a postcard informing them of the follow-up. Researchers phoned parents to explain the study, and interested families were mailed an information pack. Families able to attend a 1.5 hour appointment at The Royal Children's Hospital were reimbursed transport costs; for all others, a shorter assessment (minus assessment of cardiovascular structure) was offered at home.

Each assessment involved children and their parents completing a brief survey, which contained questions about the child's mental health and sociodemographic factors. Children then participated in a range of physiological assessments.

Measures

All measures are detailed in Table 1.

Exposure measures: Well-validated screening surveys of child mental health were chosen with parallel child self-report and parent proxy-report versions, given known variability between these respondents. Negative mental health was assessed by emotional and behavioural problems (Strength and Difficulties Questionnaire)[35] and psychosocial health (Pediatric Quality of Life Inventory; PedsQL).[36] Positive mental health was assessed by the PedsQL General Wellbeing Scale.[36] These measures are widely used and detect children at risk of mental illnesses.[35, 36]

Outcome measures: All measures of cardiovascular phenotypes and adiposity were non-invasive. In order to provide an integrated snapshot of cardiovascular health, function (mean arterial pressure, pulse wave velocity) and macrovascular (carotid IMT) and microvascular (retinal arteriole-to-venule ratio) structure were assessed. Adiposity was assessed via measures of waist circumference, % body fat and BMI z-score.

Potential confounders identified a priori included child age, sex, and neighbourhood disadvantage. Socio-Economic Indexes for Areas (SEIFA) disadvantage score was used as a measure of neighbourhood disadvantage. SEIFA is a score derived from Australian Bureau of Statistics census data assigned according to postal code of residence (national mean 1000, standard deviation (SD) 100; lower scores equate to more disadvantage).[37]

Statistical analysis

In order to fit regression models, we examined measures of mental health as "exposures" and those of cardiovascular health and adiposity as "outcomes". However, we acknowledge that the associations described do not imply directionality given the studies cross-sectional nature. Unadjusted and adjusted linear regression models were conducted. Adjusted analyses are presented given the similarity between results.

Model 1 adjusted for child age, sex and neighbourhood disadvantage, while Model 2 further adjusted cardiovascular outcomes for BMI z-score. For ease of interpretation, each mental health measure was standardized internally (by age group <12 or e 12 years given the wide age range and the different norms for each age group (see Table 1)). Thus, regression coefficients represent the difference in cardiovascular measures for each SD unit higher mental health score. All analyses were conducted with Stata 13.0. Rather than conducting multiple test adjustments that increase type II error, we simply suggest caution in interpreting the results.[38]

RESULTS

Sample characteristics (see Table 2)

Of the 643 eligible children, 364 (57%) took part with at least one exposure and one outcome measure available. Retained and non-retained children were comparable in terms of age and sex, but those retained came from less disadvantaged neighbourhoods.

Children ranged from 7–18 years of age, with a slight over-representation of girls (54%). SEIFA scores were almost half a standard deviation higher than the population mean, indicating a relatively advantaged cohort. Reflecting the inclusion of the LEAP and HopSCOTCH cohorts, the sample had higher levels of overweight (30%) and obesity (16%) compared to national estimates (18% and 7%, respectively, all International Obesity TaskForce cut-points).[39] Scores on mental health screening measures were similar to age-appropriate population norms (see Measures, Table 1) and parent proxy-report and child self-report were generally similar.

Associations of mental health with of cardiovascular health and adiposity (Table 3)

Child self-report of mental health

All child self-report mental health measures were strongly associated with adiposity measures (all pd0.003). Thus, BMI z-score, body fat, and waist girth z-score were all higher with worse emotional and behavioural problems and psychosocial health, and lower with better general wellbeing. For example, each SD higher emotional and behavioural problems was associated with a BMI z-score that was 0.15 higher (95% CI 0.05, 0.25, p=0.003) and each SD lower psychosocial health with a BMI z-score that was 0.16 higher (95% CI 0.25, 0.06, p=0.001). Considering positive mental health, each SD higher general wellbeing was associated with a BMI z-score that was 0.26 lower (95% CI -0.34, -0.17, p<0.001).

In contrast, cardiovascular function and structure varied little by children's self-reported mental health. Small associations in Model 1 (adjusted for age, gender and SEIFA) of better general wellbeing with healthier carotid IMT attenuated fully on adjustment for BMI z-score (Model 2).

Parent proxy-report of child mental health

In line with the child self-report, parent proxy-report confirmed the expected associations of child mental health measures with all measures of adiposity (all pd0.05).

Again similar to child self-report, no parent proxy-reported measure of child mental health was associated with cardiovascular structural parameters. However, higher scores for child emotional and behavioural problems were associated with poorer cardiovascular function in terms of higher mean arterial pressure and pulse wave velocity. There was no statistical evidence of associations for psychosocial health or general wellbeing.

DISCUSSION

Mental health, both negative and positive, is strongly cross-sectionally associated with adiposity by late childhood/adolescence. Thus, all indicators of adiposity were higher with more behavioural and emotional problems and lower psychosocial health, and lower with better ratings of positive general wellbeing, whether child mental health was reported by parents or children. However, neither positive nor negative mental health showed associations with functional or structural measures of cardiovascular health by this age.

The association between *negative* mental health and adiposity is well established in adolescence.[28] However, the associations between *positive* mental health (i.e. general wellbeing) and reduced adiposity are novel, while also supported by studies examining more specific aspects of wellbeing. For example, Incledon et al's systematic review[40] showed that higher levels of self-esteem were associated with lower BMI. If this relationship begins in childhood and is indeed protective, then actively targeting positive mental health – in contrast to current policies, which typically focus on reducing negative mental health – could optimize childhood BMI.

Major strengths of this study include its range of both negative and positive mental health measures, multiple direct phenotypic measures of adiposity and cardiovascular structure/function, and multiple informants on the child's mental health. This is a novel approach, as previous studies examining this relationship early in life have typically focused on only one or two cardiovascular measures and one informant.[23, 24] The absence of relationship between the mental health and cardiovascular measures is therefore striking. Coupled with the results of Oskia[23] and Tomfohr[24] discussed in the Introduction, we can infer a possible sequence and timing. By adolescence, mental health is already firmly associated with adiposity and may already be manifesting in detectable endothelial changes, but not yet in readily measurable cardiovascular structural or functional phenotypes. Nonetheless, later in life, strong associations between mental and cardiovascular illness become consistently apparent.[8-11]

Other strengths include the prospective over-representation of overweight and obese participants, which ensures the study does not lack power to detect associations in the overweight/obese ranges. However, the study was not similarly enriched for cardiovascular risk so associations may be evident in a higher risk sample.

In the absence of convincing associations between cardiovascular and mental health, the cross-sectional design is not seen as a limitation because it renders causal direction irrelevant. However, it is for adiposity and mental health as we cannot establish the direction of this association. We also consider some other important limitations. Despite the high harmonization across the three cohorts, their differing recruitment designs and age ranges could have influenced findings and may limit the generalizability to the general community. The relative affluence of the sample is an important limitation given that CVD and mental illness are more prevalent in the more disadvantaged.

The modest sample size may have yielded insufficient power to demonstrate small but real associations, because cardiovascular function and structure variation is subtle at this age. Nonetheless, we note the highly consistent null results for cardiovascular phenotype. The exception is the weak associations of parent-reported child emotional and behavioural problems with mean arterial pressure in Model 2, which we interpret as a likely chance finding and multiple analyses.

We conclude that both negative and positive mental health show well-established associations with adolescent adiposity, but we did not show evidence of associations with cardiovascular function or structure. The consistency in our findings across multiple mental health and cardiovascular measures provides confidence in the null results for cardiovascular phenotype, but requires replication or refutation. Our findings could suggest that the known relationship between these constructs develop at some point beyond mid-adolescence, possibly providing preventive opportunities into early adulthood once lifecourse timing and causal directions are established.

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Table 1: Exposure and outcome measures

Construct	Measure	Additional Information
“Exposures”		
Behavioural and emotional problems	Strengths and Difficulties Questionnaire (SDQ)	A validated 25-item scale for 4-16 year olds that yields four negative subscales (Emotional, Conduct, Hyperactivity and Peer Problems) and one positive subscale (Pro-social behaviour). A Total Difficulties score (20-items) is computed using the four negative subscales and provides an overall measure of behavioural and emotional problems; scores range from 0-40, where higher scores represent more problems.[35] Parent-proxy for all children, self-report for those aged e 12 years. Normative Australian mean 8.96 (SD: 5.62) by child report and 8.18 (SD: 6.06) by parent proxy-report.[41]
Psychosocial Health Related Quality of Life (HQoL)	Pediatric Quality of Life Inventory (PedsQL 4.0) - Psychosocial summary	A validated 23-item measure for 2-18 year olds that yields two summary scores: Psychosocial health (15-items) and physical health (7-items). Scores range from 0 to 100, where higher scores indicate better health. Items are framed in terms of the absence of negative characteristics.[36] For child self-report age-appropriate versions were used. Population norms for healthy children suggest that children self-report poorer psychosocial HQoL at age 13-18 (mean: 81.7 (SD: 14.3), compared to their parent proxy-report (mean: 84.7 (SD: 13.0)).[42]
Quality of Wellbeing	PedsQL 4.0 General Wellbeing scale	The PedsQL General Wellbeing scale (6-item) measure was used to assess happiness, perceived support and optimism about the future. Items are framed from a positive perspective.[43] Scores range from 0 to 100, where higher scores indicate better wellbeing. Standardised scores do not exist.
“Outcomes”		
Adiposity		

Body Mass Index (kg/m^2)	Height: Portable rigid stadiometer (Model IP0955, Invicta, Leicester, UK); measured to nearest 0.1cm. Weight: Calibrated Tanita Digital Body Composition Monitor (BC-351); measured to nearest 0.1kg.	Mean of two height measurements. Weight measured once, wearing light clothing and no shoes or socks. BMI was calculated as weight (kg)/ (height $(m)^2$). BMI z-score was calculated according to the US Centers for Disease Control (CDC) reference values,[44] using the Stata 'zanthro' function and participants were classified as not-overweight, overweight or obese according to age- and sex-specific International Obesity TaskForce cut points.
Body fat (%)	Calibrated Tanita Digital Body Composition Monitor (BC-351); measured to nearest 0.1%.	Body percentage fat was calculated using entered information of the participant's age, sex, body type (standard) and height, and was measured whilst wearing light clothing and no shoes or socks.[45]
Waist girth (cm)	Lufkin Executive Steel Tape (W606PM); measured to nearest 0.1cm.	Mean of two waist measurements.
Cardiovascular function		
Mean arterial pressure (mmHg)	Automated SphygmoCor XCEL device attached to brachial cuff and laptop computer.	Preceded by 7 minutes supine; measured in supine position two to three times and the median used. Radial artery wave-forms were recorded by applanation tonometry using a cuff centred on the right brachial pulse. Waveforms were collected for 5 seconds. Mean arterial pressure was calculated from the peripheral wave-form by the SphygmoCor software using a mathematical transfer function.[46] Higher scores indicate greater arterial stiffness, and subsequent worse cardiovascular health.
Pulse Wave Velocity (m/s)	Automated SphygmoCor XCEL device attached to thigh cuff, tonometer and laptop computer.	Carotid-femoral Pulse Wave Velocity was measured in triplicate. A blood pressure cuff was placed on the participant's right thigh to measure the femoral waveform, and a tonometer was used to detect the right carotid waveform in order to determine transit time. We measured the distances between three points: the sternal notch and carotid pulse in the neck, the sternal notch and the top of the thigh cuff and between the femoral pulse and the top of thigh cuff. On entering data into the Sphygmocor program, travelled distance of the pulse wave is calculated automatically, and pulse wave velocity generated from transit time and distance travelled as outlined in the SphygmoCor XCEL protocol.[47] Higher scores indicate greater

		arterial stiffness, and subsequent worse cardiovascular health.
Cardiovascular structure		
Arteriole to Venule Ratio	Canon non-mydriatic fundus camera, Canon 30D or 60D camera body, Digital Healthcare client software, Singapore 'I' Vessel Assessment (SIVA) software.	Photographs taken in a dark room were centered on the macula and then the optic disc giving four photographs per participant. Photographs were sent for assessment at the Centre for Eye Research Australia, who measured vessel calibre within the area 1-2 disc diameters from the disc margin (zone B) by a trained grader, blinded to participant characteristics. Grading used the semi-automated computer-imaging program SIVA. The revised Knudtson-Parr-Hubbard formula was used to summarize measurements as the AVR.[48] A smaller AVR suggests narrower arterioles (i.e. worse cardiovascular health).
Carotid Intima-Media Thickness (carotid IMT; mm)	Carotid IMT Vividi ultrasound Machine	B-Mode Ultrasound was utilized to capture three images of the carotid artery using a distensibility loop. This involved viewing the artery longitudinally and rotating the probe notch up towards the head. The clearest image of the furthest wall of the artery was analysed. Carotid IMT is a reliable location to examine arterial thickness.[49] Higher values indicate worse cardiovascular health.

Table 2. Sample characteristics

Child Characteristics	Total (N=364) †Mean (SD)
Socio-demographics	
Age (years)	14.7 (2.0)
Male	46.4%
SEIFA disadvantage score	1047.2 (42.8)
Original Study	
PEAS (n)	196
LEAP2 (n)	107
HopSCOTCH (n)	61
Mental health exposures – child self-report	
Emotional and behavioural problems	9.1 (5.6)
Psychosocial health	75.1 (15.1)
Quality of wellbeing	80.4 (14.6)
Mental health exposures – parent proxy-report	
Emotional and behavioural problems	7.1 (5.7)
Psychosocial health	74.7 (16.6)
Quality of wellbeing	83.6 (15.4)
Adiposity	
BMI (kg/m^2)	23.2 (4.3)
BMI z-score	0.85 (0.91)
Body fat (%)	25.4 (10.9)
Waist girth (cm)	75.6 (9.8)
Waist girth z-score	1.4 (1.1)
Cardiovascular measures	
Function	
Mean arterial pressure (mmHg)	81.2 (7.6)
Pulse Wave Velocity (m/s)	4.7 (0.7)
Structure	

‡AVR	0.69 (0.05)
§Carotid IMT	0.47 (0.06)

†Mean (SD) unless specified as a percentage; ‡n=205; §n=196

PEAS: PEAS Kids Growth Study, LEAP 2: Live Eat Play Trial, HopSCOTCH: Shared Care Obesity Trial in Children, n: number, BMI: Body Mass Index, SEIFA: SocioEconomic Indexes for Area, SD: Standard Deviation, AVR: arteriole-to-venule ratio, IMT: intima-media thickness

Table 3. Associations of mental health with cardiovascular phenotypes/adiposity; coefficients represent the change in the outcome for 1 SD unit increase in the exposure.

Outcome variable	Child negative mental health: Emotional and behavioural problems (SD units) (higher score = worse mental health)				Child negative mental health: Psychosocial heath (SD units) (higher score = better mental health)				Child positive mental health: General wellbeing (SD units) (higher score = better mental health)			
	†Model 1		‡Model 2		†Model 1		‡Model 2		†Model 1		‡Model 2	
	B (95% CI)	P	B (95% CI)	P	B (95% CI)	P	B (95% CI)	p	B (95% CI)	p	B (95% CI)	p
CHILD self-reported												
Cardiovascular health												
Mean Art Pressure (mmHg)	0.32 (-0.50, 1.13)	0.45	-0.22 (-1.02, 0.58)	0.59	0.06 (-0.73, 0.86)	0.88	0.33 (-0.47, 1.1)	0.42	-0.03 (-0.77, 0.82)	0.95	0.47 (-0.35, 1.29)	0.26
Pulse Wave Velocity (m/s)	0.04 (-0.04, 0.13)	0.33	0.02 (-0.07, 0.11)	0.69	0.04 (-0.04, 0.13)	0.31	0.06 (-0.03, 0.14)	0.17	0.02 (-0.06, 0.11)	0.60	0.05 (-0.04, 0.13)	0.29
AVR	-0.00 (-0.01, 0.00)	0.26	-0.00 (-0.01, 0.00)	0.41	0.00 (-0.01, 0.01)	0.57	0.00 (-0.01, 0.01)	0.74	-0.00 (-0.1, 0.01)	0.68	-0.00 (-0.01, 0.00)	0.44
Carotid IMT (mm)	0.00 -0.01, 0.01)	0.38	0.00 (-0.01, 0.01)	0.52	-0.01 (-0.02, 0.00)	0.15	-0.01 (-0.01, 0.00)	0.25	-0.01 (-0.02, 0.00)	**0.03**	-0.01 (-0.02, 0.00)	0.08
Adiposity												
BMI z-score	0.15 (0.05, 0.25)	**0.003**	-	-	-0.16 (-0.25, -0.06)	**0.001**	-	-	-0.26 (-0.34, -0.17)	**<0.001**	-	-
Body Fat (%)	1.66 (0.54, 2.78)	**0.004**	-	-	-1.79 (-2.85, -0.73)	**0.001**	-	-	-2.62 (-3.63, -1.61)	**<0.001**	-	-
Waist girth z-score	0.20 (0.08, 0.32)	**0.001**	-	-	-0.21 (-0.32, -0.09)	**<0.001**	-	-	-0.26 (-0.37, -0.15)	**<0.001**	-	-
PARENT-proxy reported												
Cardiovascular health												
Mean Art Pressure (mmHg)	1.04 (0.26, 1.82)	**0.009**	0.79 (-0.00, 1.58)	**0.05**	-0.46 (-1.15, 0.33)	0.26	-0.31 (-1.10, 0.48)	0.44	-0.60 (-1.39, 0.19)	0.13	-0.30 (-1.10, 0.50)	0.46
Pulse Wave Velocity (m/s)	0.09 (-0.0, 0.2)	**0.03**	0.08 (-0.01, 0.16)	0.07	-0.06 (-0.15, 0.19)	0.13	-0.06 (-0.14, 0.03)	0.18	-0.01 (-0.14, 0.03)	0.18	-0.04 (-0.13, 0.04)	0.32
AVR	-0.00 (-0.01, 0.00)	0.20	-0.00 (-0.01, 0.00)	0.29	0.00 (-0.00, 0.01)	0.22	0.00 (-0.00, 0.01)	0.26	0.00 (-0.00, 0.01)	0.82	0.00 (-0.01, 0.01)	0.99

Carotid IMT (mm)	-0.00 (-0.01, 0.01)	0.93	-0.00 (-0.01, 0.01)	0.81	0.00 (-0.01, 0.01)	0.88	0.00 (-0.01, 0.01)	0.80	0.00 (-0.01, 0.01)	0.83	0.01 (-0.01, 0.01)	0.60
Adiposity												
BMI z-score	0.19 (0.99, 0.28)	**<0.001**	-	-	-0.09 (-0.19,-0.00)	**0.05**	-	-	-0.20 (-0.29, -0.11)	**<0.001**	-	-
Body Fat (%)	2.02 (0.97, 3.07)	**<0.001**			-1.27 (-2.3, -0.21)	**0.02**			-2.13 (-3.18, -1.09)	**<0.001**		
Waist girth z-score	0.27 (0.16, 0.38)	**<0.001**	-	-	-0.15 (-0.26, -0.37)	**0.009**	-	-	-0.24 (-0.35, -0.13)	**<0.001**	-	-

†Model 1: Adjusted for child age and sex, and neighbourhood disadvantage; ‡Model 2: Adjusted for Model 1+ BMI z-score. CI: confidence interval, p: p-value, IMT: intima-media thickness, AVR: arteriole-to-venule ratios

Original Article

Associations of mental health with cardiovascular risk phenotypes and adiposity in adolescence: A cross-sectional community-based study

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