Cardiometabolic health markers among Aboriginal adolescents from the Next Generation Youth Wellbeing Cohort Study

Christopher D. McKay,[1]* Lina Gubhaju,[1] Alison J. Gibberd,[1] Bridgette J. McNamara,[1] Emily Banks,[2] Peter Azzopardi,[3,4] Robyn Williams,[5] Sandra Eades[1]

[1]Melbourne School of Population and Global Health, The University of Melbourne, Australia
[2]Centre for Public Health Data and Policy, National Centre for Epidemiology and Population Health, College of Health & Medicine, Australian National University, Australia
[3]Murdoch Children's Research Institute, Australia
[4]Telethon Kids Institute, Australia
[5]Curtin Medical School, Curtin University, Australia

Submitted: 25 April 2023; Revision requested: 28 November 2023; Accepted: 11 February 2024

Abstract

Objective: The objective of this study was to investigate cardiometabolic health markers among Aboriginal adolescents aged 10–24 years and relationships with age, gender, and body composition.

Methods: Baseline data (2018–2020) from the Next Generation Youth Wellbeing Cohort Study (Western Australia, New South Wales, and Central Australia) on clinically assessed body mass index, waist/height ratio, blood pressure, glycated haemoglobin (HbA1c), total and high-density lipoprotein cholesterol, total/high-density lipoprotein cholesterol ratio, and triglycerides were analysed.

Results: Among 1100 participants, the proportion with individual health markers within the ideal range ranged from 59% for total cholesterol to 91% for HbA1c. Four percent had high blood pressure, which was more common with increasing age and among males; 1% had HbA1c indicative of diabetes. Healthier body composition (body mass index and waist/height ratio) was associated with having individual health markers in the ideal range and with an ideal cardiometabolic profile.

Conclusions: Most Aboriginal adolescents in this study had cardiometabolic markers within the ideal range, though markers of high risk were present from early adolescence. Ideal health markers were more prevalent among those with healthy body composition.

Implications for public health: Specific screening and management guidelines for Aboriginal adolescents and population health initiatives that support maintenance of healthy body composition could help improve cardiometabolic health in this population.

Key words: Australian Aboriginal and Torres Strait Islander Peoples, adolescent health, protective factors, cardiometabolic risk factors, body composition

Introduction

The Aboriginal and Torres Strait Islander population in Australia is characterised by a young age profile, with about 30% of the population falling into the adolescent age range,[1] defined in this article as 10–24 years.[2] Adolescence is a time of important biological and social changes, with the health and behaviours established during this period becoming the foundation for adult health.[3] Therefore, prioritising adolescent health now could provide the next leap forward in chronic disease prevention for the coming generation of Aboriginal and Torres Strait Islander adults. There have been substantial improvements in prevention of cardiovascular disease (CVD) and metabolic disorders such as diabetes among adults over the last two decades; however, cardiometabolic diseases are still leading causes of overall morbidity and mortality and of health inequities for Aboriginal and Torres Strait Islander people.[4] Among Aboriginal children and adolescents, type 2 diabetes mellitus incidence appears to be rising, indicating a growing health issue in this age group thought to be related to the childhood obesity epidemic.[5–7]

While there are national data on body weight among Aboriginal and Torres Strait Islander adolescents from the past decade, there is a need for better data on other biological markers of cardiometabolic health, such as blood pressure, blood glucose, and lipids. Current data are limited to the young adult subgroup (aged 18–24 years)[8,9] or

*Correspondence to: Christopher D. McKay, Melbourne School of Population and Global Health, The University of Melbourne, Melbourne, VIC 3010, Australia; e-mail: christopher.mckay@anu.edu.au.

Aust NZ J Public Health. 2024; Online; https://doi.org/10.1016/j.anzjph.2024.100139

come from localised studies.[10–12] An expanded evidence base would help determine if current clinical guidelines are sufficient for adolescents, including the age at which screening commences to identify high risk individuals.[13,14] It would also inform future research into the potential determinants of cardiometabolic risk at this age and preventive health approaches.[15] Population data that provide insights into the maintenance of cardiometabolic health markers within an ideal range during this stage of life would also align with strengths-based approaches to Aboriginal and Torres Strait Islander health.[16]

This study aimed to quantify the distribution of cardiometabolic health markers, including blood pressure, glycated haemoglobin (HbA1c), and lipids, among a cohort of Aboriginal adolescents aged 10–24 years and investigate how ideal cardiometabolic health markers relate to age, gender, and body composition. The term Aboriginal is used in this study as the preferred term of the communities participating in the Next Generation Youth Wellbeing Cohort Study (NextGen).

Methods

Participants

NextGen has been described in detail previously.[17] Participants were recruited by Aboriginal-led community-based researcher teams in Western Australia (WA), New South Wales (NSW), and the Central Australia (CA) region of the Northern Territory from March 2018 to March 2020. Eligible participants self-identified as Aboriginal and/or Torres Strait Islander, were aged between 10 and 24 years, and provided personal consent (with caregiver consent required for those aged under 16 years). Due to the difficulties of engaging this hard-to-reach population group, pragmatic recruitment strategies were used based around the established relationships of the community-based researchers.[18] The researchers recruited participants via personal and community networks (including through Aboriginal community centres, sporting clubs, and youth centres), employment of Aboriginal youth peer recruiters, community events, word of mouth, secondary schools (small numbers in NSW only), and social media promotion. Participants were invited to complete a health and wellbeing survey and a clinical assessment of cardiometabolic health markers. Recruitment took place across a mix of urban, regional, and remote areas. Using Australian Bureau of Statistics Indigenous Regions,[19] the locations recruitment predominately occurred were the following: in WA, the Perth and South-Western WA regions; in NSW, the North-Eastern NSW, NSW Central and North Coast, Riverina—Orange, and Sydney—Wollongong regions; and in CA, the Alice Springs region. The nature of recruitment means individuals from outside these regions may also have participated.

Of the 1126 participants who completed the NextGen clinical assessment, 11 were missing data on all study variables, and a further 15 were excluded for being pregnant, having an eating disorder, having a congenital condition known to impact body composition, or not identifying as female or male (excluded due to small numbers to preserve privacy and allow for presentation of data by gender). This left 1100 participants included in the present study.

Data collection

Height, weight, and waist circumference (WC) were measured during the clinical assessment. WC was measured twice, and if there was a variation greater than 0.5 cm between consecutive measurements, a third was taken. Average WC was then calculated. Systolic blood pressure (SBP) and diastolic blood pressure and (DBP) were measured using an automated blood pressure monitor (Omron HEM-907, Omron Healthcare Co., Kyoto, Japan). After giving participants 5 minutes to relax, three measurements were taken with 2–3 minutes between each. Average SBP and DBP were calculated from the second and third measures. Non-fasting point-of-care finger-prick blood tests were used to measure levels of HbA1c, and blood lipids (total cholesterol, high-density lipoprotein cholesterol [HDL-c], total/HDL-c ratio, and triglycerides) using the Cobas b101 instrument (Roche Diagnostics International, Rotkreuz, Switzerland). Participants and caregivers were provided with feedback, including advice to follow-up with their local health service in the following cases: body mass index (BMI) was underweight or obese; SBP ≥125 mmHg; HbA1c ≥6.0%; total cholesterol >5.0 mmol/L; total/HDL-c ratio >4.5; or triglycerides >2.0 mmol/L. Data cleaning methods are described in Supplementary Material.

Measures

The primary outcome variables were blood pressure, HbA1c, total cholesterol, HDL-c, total/HDL-c ratio, triglycerides, and the ideal cardiometabolic profile. Categories were formed using thresholds that would allow for comparisons with other Aboriginal studies[11,20] and to align with the *National guide to a preventive health assessment for Aboriginal and Torres Strait Islander people*.[14] 'Ideal' categories represent the lowest-risk category for each outcome. Blood pressure categories were defined as ideal (SBP <120 mmHg and DBP <80 mmHg [<120/80]), borderline (SBP: ≥120 and <140 mmHg or DBP: ≥80 and <90 mmHg [≥120/80 − <140/90]), high (SBP ≥140 mmHg, or DBP ≥ 90 mmHg [≥140/90]). HbA1c categories were ideal (<6.0% [42 mmol/mol]), borderline (≥6.0–<6.5% [48 mmol/mol]), or high risk (≥6.5%). Total cholesterol was categorised as ideal (<4.0 mmol/L), borderline (≥4.0–7.5 mmol/L), or high risk (≥7.5 mmol/L). HDL-c was ideal (≥1.0 mmol/L), or low (<1.0 mmol/L), and ideal total/HDL-c ratio was <4.5. Thresholds for triglycerides were defined according to guidelines for non-fasting samples,[21] as ideal (<2.0 mmol/L), or elevated (≥2.0 mmol/L). In addition, age- and sex-specific blood pressure thresholds for children and adolescents,[22] and an expanded range for borderline HbA1c (≥5.7% [39 mmol/mol]–<6.5%),[23] were investigated in supplementary results. For regression analyses, binary outcome variables were created where the ideal category was the outcome of interest, relative to the other categories combined. The ideal cardiometabolic profile was defined as having each of ideal blood pressure, ideal HbA1c, ideal triglycerides, and ideal cholesterol (where ideal cholesterol was defined as all three cholesterol measures inside the ideal range).

The measures of body composition—BMI and waist/height ratio (WHtR)—were calculated from measured height, weight and average WC. BMI was categorised using the World Health Organization classifications for adults[24] and the International Obesity Taskforce age- and sex-specific cut-offs for those aged under 18 years.[25,26] The International Obesity Taskforce cut-offs align with the World Health Organization classifications at 18 years of age. BMI categories were 'underweight', 'healthy', 'overweight', or 'obese'. A binary variable was created combining underweight and healthy as 'low BMI', representing healthier weight and overweight and obese as

'high BMI'. High WHtR was defined as ≥0.5,[27,28] consistent with previous studies involving Aboriginal adolescents.[29] Other variables included age group (10–14; 15–19; 20–24), gender (female; male), and recruitment region (WA; NSW; CA).

Statistical analysis

Histograms of continuous outcome measures were produced, and the median and interquartile range were calculated. Frequencies and proportions of individuals in each outcome category were calculated and presented by age, gender, and body composition. Supplementary data are also provided by recruitment region and for an 18–24 years subgroup. Robust Poisson regression was undertaken to calculate prevalence ratios (PRs) for ideal health markers by age, gender, and body composition. Supplementary analyses were undertaken for high-risk categories of blood pressure and HbA1c. A generalised estimating equations framework with an exchangeable correlation structure was used to account for clustering within families. To control for potential confounding, regression models quantifying associations with age were adjusted for gender, and vice versa, and those calculating associations with body composition were adjusted for age, gender, and recruitment region.

As most variables were subject to missing data, sensitivity analyses using multiple imputation were undertaken to assess potential bias and precision of estimates. A chained equations method was used via Stata's *mi impute chained* command,[30] with all study variables included and 100 datasets imputed. Weight, average WC, and the first SBP and DBP measures were used as auxiliary variables. Estimates were pooled according to Rubin's rules.[31]

Analyses were conducted in Stata 16.0.

Results

Participant characteristics

The median age was 14.5 years (54% 10–14 years; 32% 15–19 years; and 14% 20–24 years), with 56% being female participants and 63% recruited in WA (Table 1). The median BMI was 22 kg/m^2, with 8% being underweight, 48% healthy, 24% overweight, and 20% obese. Median WHtR was 0.47, and 64% had low WHtR (<0.5). The distribution of BMI and WHtR in this cohort by age, gender, and region has been published previously.[32]

Table 1: Participant characteristics (n=1100).

	%	(n)[a]
Age (years), median (IQR)	14.5	(12.1–18.0)
Age group		
10–14 years	53.9	(593)
15–19 years	31.6	(348)
20–24 years	14.5	(159)
Gender		
Female	56.2	(618)
Male	43.8	(482)
Recruitment region		
Western Australia	62.5	(688)
New South Wales	30.0	(330)
Central Australia	7.5	(82)
BMI (kg/m2), median (IQR)	22.0	(18.9–26.8)
BMI category		
Underweight	8.4	(88)
Healthy	47.7	(499)
Overweight	23.6	(247)
Obese	20.3	(213)
WHtR, median (IQR)	0.47	(0.42–0.53)
WHtR category		
Low (<0.5)	64.2	(667)
High (≥0.5)	35.8	(372)

Abbreviations: BMI = body mass index; IQR = interquartile range; WHtR = waist/height ratio.
[a]Categories for BMI and WHtR do not sum to total sample size (1100) due to missing data.

Missing data

The proportion of missing data ranged from 5% for BMI to 66% for the lipid measures (Supplementary Table S1), with 26% of participants having complete data for all outcomes. Those with missing outcome data were younger than those with complete data (Supplementary Table S2). NSW participants were the least likely to have a complete set of outcomes, and participants from CA were the most likely; however, NSW participants were most likely to have blood pressure measured.

Distribution of cardiometabolic health markers

Histograms for continuous outcome measures are included in Supplementary Material (Figure S1). For each individual cardiometabolic marker, a majority were in the ideal range (**Figure 1**A); ideal HbA1c was the most common (91%, n=594), and ideal total cholesterol was the least (59%, n=222). Four per cent (n=33) had high blood pressure (≥140/90 mmHg) (Supplementary Table S3), and 1% (n=6) had high HbA1c (≥6.5%, data included with 'borderline' category). There were no individuals with high total cholesterol (≥7.5 mmol/L). Among the 289 participants with data for all cardiometabolic measures, 23% had an ideal health profile (all four of blood pressure, HbA1c, cholesterol, and triglycerides in the ideal range), the majority (64%) had 2–3 components in the ideal range, and 2% had no markers in the ideal range (Supplementary Figure S2).

When the age- and sex-specific classifications for blood pressure were used, the proportion of 10-14-year olds with borderline/high blood pressure was higher (21% *vs.* 16%, Supplementary Table S4). When the expanded range for borderline HbA1c was used, the total proportion with borderline/high HbA1c more than doubled (19% *vs.* 9%).

Associations with age, gender, and body composition

Age

The proportion of participants with ideal blood pressure declined with increasing age group, from 84% in the 10–14 years group, to 45% among those aged 20–24 years (Figure 1B). This trend remained after adjusting for gender (Table 2). High blood pressure was about 10 times higher in the oldest age group than in the youngest (11% *vs.* 1%, adjusted PR [aPR]: 9.86 [95% confidence interval {CI}: 3.25–29.95], Supplementary Tables S3 and S5). Ideal total/HDL-c ratio was less common among the oldest age group than in the youngest (67% *vs.* 91%, adjusted PR [aPR]: 0.74 [95% CI: 0.61–0.90]). For each of the other health markers, except HbA1c, 20- to 24-year-old participants were less likely to be in the ideal range than 10- to 14-year olds, but the confidence intervals for aPRs included the null.

Figure 1: Proportion of NextGen participants within the ideal range for blood pressure (BP, n=811), glycated haemoglobin (HbA1c, n=651), total cholesterol (Tot-c, n=377), high-density lipoprotein cholesterol (HDL-c, n=374), total/HDL-c (Tot/HDL-c, n=372), triglycerides (TG, n=373) and ideal cardiometabolic profile (Profile, n=289), overall (Panel A) and by age (Panel B), gender (Panel C), body mass index (BMI, Panel D), and waist/height ratio (WHtR, Panel E). Abbreviation: NextGen = Next Generation Youth Wellbeing Cohort Study.

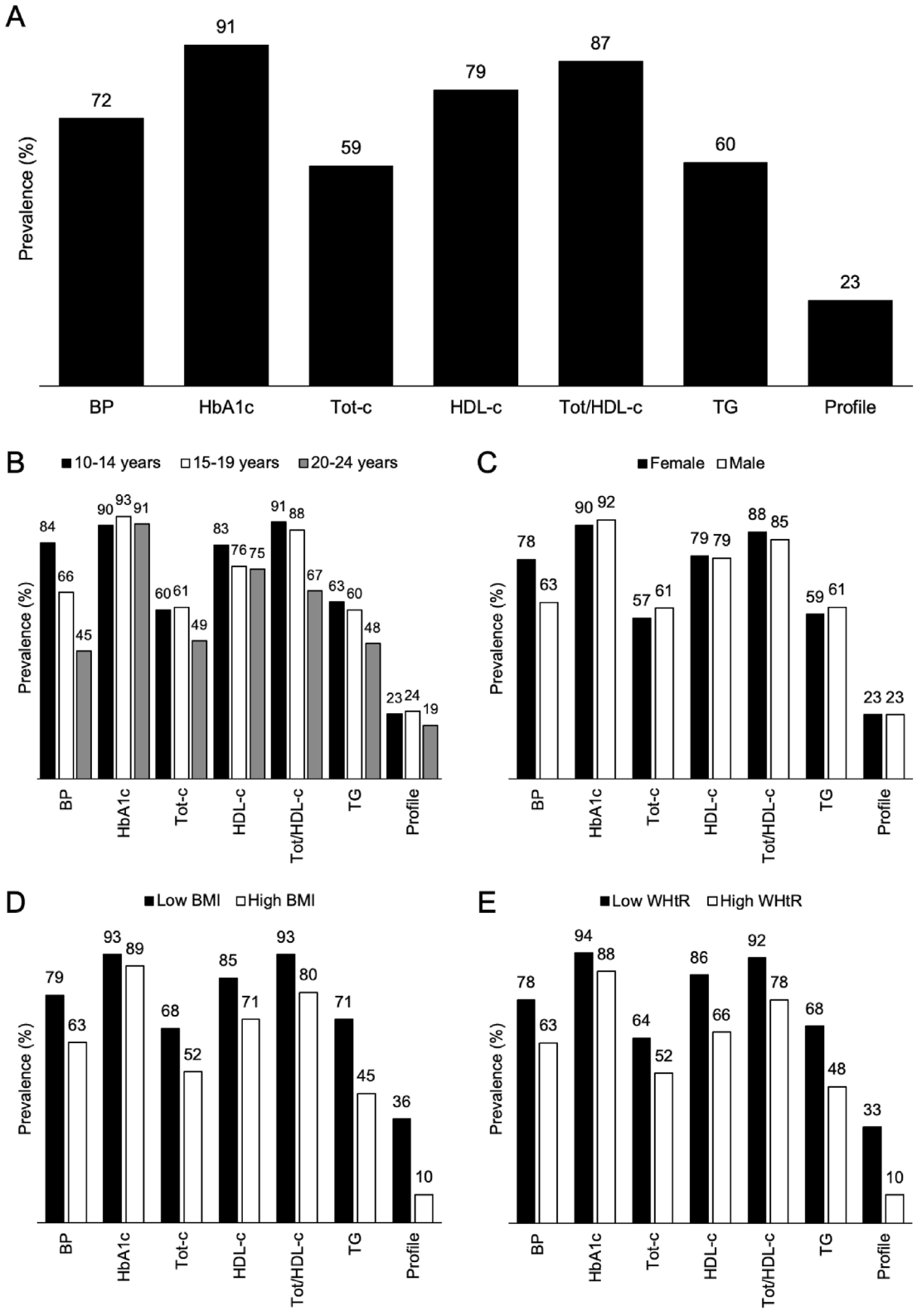

Table 2: Associations of ideal cardiometabolic health markers with age, sex, body mass index and waist/height ratio among NextGen participants from complete-records analyses.

Variable	Blood pressure		HbA1c		Total cholesterol		HDL-c		Total/HDL-c		Triglycerides		Ideal health profile	
	aPR	(95% CI)	aPR	(95% CI)	aPR	(95% CI)	aPR	(95% CI)	aPR	(95% CI)	aPR	(95% CI)	aPR	(95% CI)
Age group[a]														
10–14 years	Ref		Ref		Ref		Ref		Ref		Ref		Ref	
15–19 years	0.76	(0.69–0.84)	1.04	(0.99–1.10)	1.03	(0.86–1.23)	0.91	(0.81–1.02)	0.96	(0.90–1.04)	0.95	(0.80–1.14)	1.01	(0.64–1.58)
20–24 years	0.53	(0.44–0.64)	1.01	(0.95–1.09)	0.82	(0.61–1.11)	0.90	(0.76-1.07)	0.74	(0.61–0.90)	0.75	(0.54–1.03)	0.79	(0.40–1.57)
Gender[b]														
Female	Ref		Ref		Ref		Ref		Ref		Ref		Ref	
Male	0.77	(0.70–0.84)	1.01	(0.97–1.06)	1.07	(0.90–1.26)	0.98	(0.88–1.09)	0.97	(0.89–1.05)	1.03	(0.87–1.23)	0.98	(0.65–1.47)
BMI[c]														
High	Ref		Ref		Ref		Ref		Ref		Ref		Ref	
Low	1.20	(1.09–1.31)	1.05	(1.01–1.10)	1.27	(1.07–1.50)	1.20	(1.07–1.35)	1.15	(1.06–1.25)	1.59	(1.30–1.93)	3.76	(2.18–6.46)
WHtR[c]														
High	Ref		Ref		Ref		Ref		Ref		Ref		Ref	
Low	1.18	(1.07–1.30)	1.08	(1.03–1.14)	1.19	(0.98–1.43)	1.30	(1.14–1.48)	1.16	(1.06–1.27)	1.41	(1.16–1.72)	3.39	(1.95–5.89)

See Supplementary Table S3 for category frequencies and proportions.
Abbreviations: aPR = adjusted prevalence ratio; BMI = body mass index; CI = confidence interval; HbA1c = glycated haemoglobin; HDL-c = high-density lipoprotein cholesterol; Ideal health profile = each of the other individual health markers in the ideal range.
[a]adjusted for gender.
[b]adjusted for age.
[c]adjusted for age, gender and recruitment region.

Gender

Ideal blood pressure was less common among males than among females (63% *vs.* 78%, aPR: 0.77 [0.70–0.84]) (Figure 1C), with males having more than double the proportion of high blood pressure (5.8% *vs.* 2.7%, aPR: 2.59 [1.28–5.27]). Gender was not associated with any other outcomes.

Body composition

For all outcomes, participants with low BMI and WHtR were more likely to fall within the ideal range, relative to those with high BMI and WHtR (Figures 1D and 1E). Adjusted PRs for the individual outcomes ranged from a 1.05-fold (95% CI: 1.01–1.10) and 1.08-fold (1.03–1.14) increased prevalence of ideal HbA1c for low BMI and WHtR, respectively, to a 1.59-fold (1.30–1.93) and 1.41-fold (1.16–1.72) increased prevalence of ideal triglycerides. For ideal cardiometabolic health profile, low BMI and WHtR were associated with a 3.76-fold (2.18–6.46) and 3.39-fold (1.95–5.89) increased prevalence relative to high BMI and WHtR, respectively. For the high-BMI and high-WHtR groups, there was about double the proportion, or greater, of participants within the elevated risk categories of blood pressure, HbA1c, HDL-c, and total/HDL-c ratio, compared to the low-BMI and low-WHtR groups.

Sensitivity analyses

Results from the imputed dataset were consistent with the primary analyses (Supplementary Table S6), except for ideal cardiometabolic health profile, where there were substantial variations in some associations. This included a clearer association with age, with ideal cardiometabolic profile less common at 20–24 years than 10–14 years. Associations between body composition and ideal cardiometabolic profile were attenuated in the imputed dataset, though they remained strong and in the same direction.

Discussion

Cross-sectional data from this cohort of Aboriginal adolescents indicate that a majority had BMI below overweight/obese, a WC less than half their height, and each of the other individual cardiometabolic health markers within the ideal range. Looking at the overall cardiometabolic health profile, most adolescents had at least three of blood pressure, HbA1c, cholesterol, and triglycerides within the ideal range, and about a quarter had all ideal markers. However, there was a small proportion of individuals with high blood pressure indicative of hypertension, and HbA1c indicative of diabetes, with high blood pressure increasing with increasing age group and being more common among males. The presence of these risk markers, and the substantial proportion of participants with lipid measures outside the ideal range, may have implications for screening and management of cardiometabolic risk among Aboriginal adolescents. Having individual health markers in the ideal range, and having an ideal cardiometabolic profile, was more likely for participants with healthier BMI and WHtR.

We contribute new population data about the distribution of cardiometabolic health markers among Aboriginal adolescents. Although NextGen sampling methods mean these data may not reflect true population prevalence, they represent some of the only data available for this population group, with national data typically available only for Aboriginal people aged 18 years and

above. As such, the results complement the existing national data,[8,9,20] filling gaps for younger adolescents, and can be compared and potentially synthesised with limited data from other studies.[15,33]

Our findings indicate that markers of increased cardiometabolic risk are present right across the age of adolescence in this population group, which may have implications for screening and management. Borderline/high HbA1c was present from early adolescence and was more common among those with high BMI, which is consistent with an urban NSW study.[11] These findings support recent type 2 diabetes mellitus guidelines for Aboriginal adolescents, which advise assessment of HbA1c using a point-of-care test from 10 years of age when obesity or other risk factors are present,[23] and annual screening of everyone aged 15 years and over.[34] Our study is the first to report prevalence data using the HbA1c cut-offs for 'at risk of diabetes' in these new guidelines (≥5.7%–<6.5%). Previously, HbA1c ≥6.0% has been used to define 'at risk',[8,11,35] though this was not a formal classification. Our results indicate up to about 20% of participants in this study could require clinical follow-up based on HbA1c ≥5.7%, double the proportion within the previously used threshold, and this could have important implications for healthcare resourcing.

Increased high blood pressure with increasing age group suggests adolescence is an important life phase for early intervention or identification of risk with respect to blood pressure. Furthermore, our results and other data indicate males should be a priority group for CVD prevention strategies.[9,15] While blood pressure is assessed as part of the Medicare Benefits Schedule–funded Aboriginal and Torres Strait Islander Peoples Health Assessment (Medicare Benefits Schedule Item 715) for people aged 15 years and above (the 'adult assessment'),[36] available annually, there is no formal guidance for clinicians on how measures should be interpreted and inform management for people under 18 years of age.[13,14] Blood pressure is not assessed in the 'child assessment' (under 15 years of age), yet our results indicate that earlier assessment may help detect adolescents at risk of hypertension. Furthermore, the national goal to increase uptake of these assessments among adolescents is not on track, with only 24% of 15- to 24-year olds receiving one in 2020–2021.[37] Greater efforts to improve access to health assessments and clearer guidelines on adolescent hypertension are needed.

As with blood pressure, there are currently no specific clinical guidelines for lipids among adolescents under 18 years or for assessing overall cardiometabolic health using multiple health markers. For adults, blood pressure and lipids are recommended to be considered in the context of absolute CVD risk, though the absolute CVD risk framework is not designed for use before 30 years of age,[13] meaning that there is no clear assessment framework for adolescents. International evidence has linked abnormal lipids during adolescence to increased risk of CVD in adulthood,[38] and atherosclerosis becomes more severe with the increasing number of cardiometabolic risk markers present in adolescence and young adulthood.[39] Therefore, lipids may be an important contributor to cardiometabolic risk among Aboriginal adolescents requiring further investigation. In the Northern Territory-based Aboriginal birth cohort, subclinical atherosclerosis at 18 years of age was associated with having the metabolic syndrome (a clustering of cardiometabolic risk markers) during childhood and adolescence, yet the extent of atherosclerosis was reduced for those who had it only during childhood.[40] This highlights the potential gains from identifying high-risk individuals during adolescence, as well as reducing the prevalence of risk markers in the population.

Addressing gaps in clinical guidance for Aboriginal adolescents, ideally through specific guidelines for this population group, would support screening and management of cardiometabolic risk.

The associations between body composition and cardiometabolic health markers reveal the potential for health improvements across the population through maintenance of healthy weight during adolescence. The National Obesity Strategy 2022–2032 provides a good foundation for action, with a national target to reduce overweight and obesity among children and adolescents (2–17 years) by at least 5%.[41] However, considering the prevalence of overweight and obesity rising among Aboriginal adolescents,[8,9] reversing the trend will require urgent and focussed efforts. Past mainstream initiatives to reduce childhood obesity have not managed to engage Aboriginal young people in an equitable way.[42] Aboriginal-designed and -led community-based approaches that account for social and cultural determinants of health are likely to be crucial to engagement and success,[16,42] as will further research be into factors associated with healthy body composition.[32] Targets for ideal cardiometabolic health markers across the life course, such as those in the United States,[43] could help with evaluating the impact of preventive health strategies on cardiometabolic health in the population.

The strengths of this study are the data from the first Aboriginal cohort established across the full adolescent age range of 10–24 years, sampled from diverse regions across Australia and objective measurement of multiple cardiometabolic health markers. As such, the NextGen cohort is a unique data source on cardiometabolic health among Aboriginal adolescents. The involvement of Aboriginal communities and organisations in the NextGen study and the information exchange with the research team will ensure findings from the study can inform community-based approaches to preventive health. Findings will be particularly applicable to the communities involved in the study, though the diversity of the cohort means they are likely to be more broadly useful.

There are also some important limitations to our findings. The lack of randomised sampling methods means prevalence estimates should not be interpreted as representative. We used adult cut-offs for categorising cardiometabolic markers, which may not be ideal for an adolescent cohort, though validated reference ranges and cut-offs for Aboriginal adolescents are not currently available. International age-specific classifications for blood pressure and new HbA1c thresholds for adolescents were used to obtain supplementary results for comparison. The categories we used in the primary results have the advantage of aligning with the preventive health-assessment guidelines for Aboriginal populations[14] and allow direct comparison with other cohorts. Data resulting from future follow-up of the NextGen cohort, as well as other Aboriginal cohorts, could contribute to defining categories in adolescence that most accurately predict future cardiometabolic outcomes. NextGen used methods of measuring cardiometabolic markers that were the most practical for a broadly focussed epidemiological study. Point-of-care finger-prick blood tests have been found to be appropriate, reliable, and accurate, including for Aboriginal and adolescent populations.[44,45] They are also now recommended for use in screening HbA1c in adolescence.[23] Missing data had the potential to introduce bias into our study, particularly for lipid outcomes, although consistent results were seen in sensitivity analyses using multiple imputation.

Conclusions

Most Aboriginal adolescents had individual cardiometabolic health markers in the ideal range, associated with healthier BMI and WHtR, though markers of elevated risk were present across the adolescent age range. Specific screening and management guidelines for high-risk Aboriginal adolescents and population health initiatives that support maintenance of healthy body composition could help prevent cardiometabolic disease in the next generation of Aboriginal adults.

Conflicts of interest

The authors have no competing interests to declare.

Funding

NextGen was funded by the National Health and Medical Research Council of Australia (grant number 1089104). C.D.M. was supported by an Australian Government Research Training Program Scholarship. EB is supported by a National Health and Medical Research Council of Australia Investigator Grant (2017742).

Ethical approval

Ethics approvals were granted by the Central Australian Aboriginal Human Research Ethics Committee (16-398), Western Australian Aboriginal Health Ethics Committee (719), Aboriginal Health and Medical Research Council of NSW Ethics Committee (1255-17), and the University of Melbourne Medicine and Dentistry Human Ethics Sub-Committee (1851155). NextGen is Aboriginal-led, and the research team and governance committee are each comprised of Aboriginal and non-Aboriginal members. This study included three Aboriginal authors (CDM, RW, and SE). Feedback on the study design and interpretation of results was obtained through engagement with Aboriginal members of the governance committee and community-based teams.

Acknowledgements

We acknowledge the Aboriginal Custodians where the Next Generation Youth Wellbeing Cohort Study (NextGen) took place, including the Arrernte, Awabakal, Bidjigal, Darkinjung, Dharug, Gadigal, Gamilaraay, Gumbaynggirr, Noongar and Wiradjuri peoples. We thank the Aboriginal community members who participated in NextGen, without whose support the study would not have been possible. The authors would also like to acknowledge the support from our community partners including Central Australian Aboriginal Congress, Derbarl Yerrigan Health Service, South West Aboriginal Medical Service, Awabakal Medical Service, Mingaletta Aboriginal and Torres Strait Islander Corporation, Miimi Aboriginal Corporation, Tamworth Regional Youth Centre and Orange City Council Community Services. We acknowledge fellow NextGen study investigators.

Author ORCIDs

Christopher D. McKay https://orcid.org/0000-0002-1430-0480

References

1. Australian Bureau of Statistics. *Estimates of Aboriginal and Torres Strait Islander Australians, June 2021: ABS;* 2022 [cited 2023 March 22]. Available from: https://www.abs.gov.au/ausstats/abs@.nsf/mf/3238.0.55.001.
2. Sawyer SM, Azzopardi PS, Wickremarathne D, Patton GC. The age of adolescence. *Lancet Child Adolescent Health* 2018;**2**(3):223–8.
3. Sawyer SM, Afifi RA, Bearinger LH, Blakemore S-J, Dick B, Ezeh AC, et al. Adolescence: a foundation for future health. *Lancet* 2012;**379**(9826):1630–40.
4. Australian Institute of Health and Welfare. *Australian Burden of Disease Study: impact and causes of illness and death in Aboriginal and Torres Strait Islander people 2018. Canberra, Australia*. 2022. Report No.: Cat. no. BOD 32.
5. Craig ME, Femia G, Broyda V, Lloyd M, Howard NJ. Type 2 diabetes in indigenous and non-indigenous children and adolescents in New South Wales. *Med J Aust* 2007;**186**(10):497–9.
6. Haynes A, Kalic R, Cooper M, Hewitt JK, Davis EA. Increasing incidence of type 2 diabetes in Indigenous and non-Indigenous children in Western Australia, 1990–2012. *Med J Aust* 2016;**204**(8):303.
7. Titmuss A, Davis EA, O'Donnell V, Wenitong M, Maple-Brown LJ, Haynes A, et al. Youth-onset type 2 diabetes among First Nations young people in northern Australia: a retrospective, cross-sectional study. *Lancet Diabetes Endocrinol* 2022;**10**(1):11–3.
8. Australian Bureau of Statistics. *Australian Aboriginal and Torres Strait Islander Health Survey: updated results, 2012–13*. Canberra, Australia: Australian Bureau of Statistics; 2014. Report No.: Cat. no. 4727.0.55.006.
9. Australian Bureau of Statistics. *National Aboriginal and Torres Strait Islander Health Survey, 2018-19*. Canberra, Australia: Australian Bureau of Statistics; 2019. Report No.: Cat. no. 4715.0.
10. Larkins N, Teixeira Pinto A, Banks E, Gunasekera H, Cass A, Kearnes J, et al. Blood pressure among Australian Aboriginal children. *J Hypertens* 2017;**35**(9):1801–7.
11. Riley T, Lovett R, Banks E, Thandrayen J, Sherriff S, Muthayya S, et al. Markers of chronic disease risk in a cohort of Aboriginal children: findings from the study of environment on Aboriginal Resilience and Child Health (SEARCH). *Aust N Z J Publ Health* 2021;**45**(6):637–42.
12. Sjöholm P, Pahkala K, Davison B, Juonala M, Singh GR. Early life determinants of cardiovascular health in adulthood. The Australian Aboriginal Birth Cohort study. *Int J Cardiol* 2018;**269**:304–9.
13. Agostino JW, Wong D, Paige E, Wade V, Connell C, Davey ME, et al. Cardiovascular disease risk assessment for Aboriginal and Torres Strait Islander adults aged under 35 years: a consensus statement. *Med J Aust* 2020;**212**(9):422–7.
14. National Aboriginal Community Controlled Health Organisation and The Royal Australian College of General Practitioners. *National guide to a preventive health assessment for Aboriginal and Torres Strait Islander people*. 3rd ed. East Melbourne, Vic: RACGP; 2018.
15. McKay CD, O'Bryan E, Gubhaju L, McNamara B, Gibberd AJ, Azzopardi P, et al. Potential determinants of cardio-metabolic risk among Aboriginal and Torres Strait Islander Children and Adolescents: a systematic review. *Int J Environ Res Publ Health* 2022;**19**(15):9180.
16. Australian Government Department of Health. *National Aboriginal and Torres Strait Islander Health Plan 2021–2031*. Canberra, Australia: Department of Health; 2021.
17. Gubhaju L, Banks E, Ward J, D'Este C, Ivers R, Roseby R, et al. 'Next Generation Youth Well-being Study:' understanding the health and social well-being trajectories of Australian Aboriginal adolescents aged 10–24 years: study protocol. *BMJ Open* 2019;**9**(3):e028734.
18. Williams R, Eades F, Davis K, Whitby J, McKay C, Gubhaju L, et al., Developing the "Moorditj Moort Boodja (Solid Family and Country) on the ground community relational framework for Aboriginal research engagement" in Western Australia: the Next Generation Aboriginal Youth Wellbeing Cohort Study. Alternative Int J Indigenous Peoples. in press.
19. Australian Bureau of Statistics. *Indigenous regions: Australian Statistical Geography Standard (ASGS) edition 3*. ABS; 2021 [cited 2023 November 21]. Available from: https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/indigenous-structure/indigenous-regions.
20. Calabria B, Korda RJ, Lovett RW, Fernando P, Martin T, Malamoo L, et al. Absolute cardiovascular disease risk and lipid-lowering therapy among Aboriginal and Torres Strait Islander Australians. *Med J Aust* 2018;**209**(1):35–41.
21. Nordestgaard BG, Langsted A, Mora S, Kolovou G, Baum H, Bruckert E, et al. Fasting is not routinely required for determination of a lipid profile: clinical and laboratory implications including flagging at desirable concentration cut-points—a joint consensus statement from the European Atherosclerosis Society and European Federation of Clinical Chemistry and Laboratory Medicine. *Eur Heart J* 2016;**37**(25):1944–58.
22. Flynn JT, Kaelber DC, Baker-Smith CM, Blowey D, Carroll AE, Daniels SR, et al. Clinical practice guideline for screening and management of high blood pressure in children and adolescents. *Pediatrics* 2017;**140**(3):e20171904.
23. Peña AS, Curran JA, Fuery M, George C, Jefferies CA, Lobley K, et al. Screening, assessment and management of type 2 diabetes mellitus in children and adolescents: Australasian Paediatric Endocrine Group guidelines. *Med J Aust* 2020;**213**(1):30–43.

24. WHO Consultation on Obesity. *Obesity: preventing and managing the global epidemic*. Geneva, Switzerland: Report of a WHO consultation; 2000.
25. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; **320**(7244):1240–3.
26. Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ* 2007; **335**(7612):194.
27. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. *Nutr Res Rev* 2010;**23**(2):247–69.
28. Khoury M, Manlhiot C, McCrindle BW. Role of the waist/height ratio in the cardiometabolic risk assessment of children classified by body mass index. *J Am Coll Cardiol* 2013;**62**(8):742–51.
29. Hardy LL, MacNiven R, Esgin T, Mihrshahi S. Cross-sectional changes in weight status and weight related behaviors among Australian children and Australian Indigenous children between 2010 and 2015. *PLoS One* 2019;**14**(7):e0211249.
30. White IR, Royston P, Wood AM. Multiple imputation using chained equations: issues and guidance for practice. *Stat Med* 2011;**30**(4):377–99.
31. Rubin DB. *Multiple imputation for nonresponse in surveys*. New York, NY: Wiley; 1987.
32. McKay CD, Gubhaju L, Gibberd AJ, McNamara BJ, Macniven R, Joshy G, et al. Health behaviours associated with healthy body composition among Aboriginal adolescents in Australia in the 'Next Generation: youth Well-being study'. *Prev Med* 2023;**175**:107715.
33. O'Bryan E, McKay CD, Eades S, Gubhaju L, Pearson O, Kerr JA, et al. Cardiometabolic risk markers for aboriginal and Torres Strait Islander children and youths: a systematic review of data quality and population prevalence. *Int J Environ Res Publ Health [Internet]* 2023;**20**(13).
34. Wong J, Ross GP, Zoungas S, Craig ME, Davis EA, Donaghue KC, et al. Management of type 2 diabetes in young adults aged 18–30 years: ADS/ADEA/APEG consensus statement. *Med J Aust* 2022;**216**(8):422–9.
35. d'Emden MC, Shaw JE, Jones GR, Cheung NW. Guidance concerning the use of glycated haemoglobin (HbA1c) for the diagnosis of diabetes mellitus. *The Medical Journal of Australia* 2015;**203**(2):89–90.
36. Australian Government Department of Health. Medicare Benefits Schedule - Item 715 Canberra: Department of Health; [cited 2023 April 24]. Available from: http://www9.health.gov.au/mbs/fullDisplay.cfm?type=item&q=715.
37. Australian Institute of Health and Welfare. *Tracking progress against the implementation plan goals for the Aboriginal and Torres Strait Islander Health Plan 2013–2023*. AIHW; 2021 [cited 2023 November 23]. Available from: https://www.aihw.gov.au/reports/indigenous-australians/tracking-progress-against-ipg-2013-2023/contents/adolescent-youth-health-domain/goal-13.
38. Kavey R-EW, 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**(11):1562–6.
39. Berenson GS, Srinivasan SR, Bao W, Newman WP, Tracy RE, Wattigney WA. Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. *N Engl J Med* 1998;**338**(23):1650–6.
40. Juonala M, Singh GR, Davison B, Van Schilfgaarde K, Skilton MR, Sabin MA, et al. Childhood metabolic syndrome, inflammation and carotid intima-media thickness. The Aboriginal Birth Cohort Study. *Int J Cardiol* 2016;**203**:32–6.
41. Commonwealth of Australia. *The National Obesity Strategy 2022-2032*. Canberra, Australia: Health Ministers Meeting; 2022.
42. Sherriff S, Baur L, Lambert M, Dickson M, Eades S, Muthayya S. Aboriginal childhood overweight and obesity: the need for Aboriginal designed and led initiatives. *Public Health Research & Practice* 2019;**29**(4): e2941925.
43. Lloyd-Jones DM, Allen NB, Anderson CAM, Black T, Brewer LC, Foraker RE, et al. Life's essential 8: updating and enhancing the American Heart Association's construct of cardiovascular health: a presidential advisory from the American Heart Association. *Circulation* 2022;**146**(5):e18–43.
44. Barrett SC, Huffman FG, Johnson P. Validation of finger-prick testing of fasting blood glucose, total cholesterol, and HbA1c in adolescents. *Point Care* 2011;**10**(2).
45. Marley JV, Oh MS, Hadgraft N, Singleton S, Isaacs K, Atkinson D. Cross-sectional comparison of point-of-care with laboratory HbA1c in detecting diabetes in real-world remote Aboriginal settings. *BMJ Open* 2015;**5**(3):e006277.

Appendix A Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.anzjph.2024.100139.