



# BMJ Open Family history of non-communicable diseases and associations with weight and movement behaviours in Australian school-aged children: a prospective study

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## ABSTRACT

**Objective** To assess differences in weight status and movement behaviour guideline compliance among children aged 5–12 years with and without a family history of non-communicable diseases (NCDs).

**Design** Prospective.

**Setting and participants** Women born between 1973 and 1978 were recruited to the Australian Longitudinal Study on Women's Health (ALSWH) via the database of the Health Insurance Commission (now Medicare; Australia's universal health insurance scheme). In 2016–2017, women in that cohort were invited to participate in the Mothers and their Children's Health Study and reported on their three youngest children (aged <13 years). Data from children aged 5–12 years (n=4416) were analysed.

**Measures** Mothers reported their children's height and weight, used to calculate body mass index (kg/m<sup>2</sup>), physical activity, screen time and sleep. In the 2015 ALSWH Survey, women reported diagnoses and family history of type 2 diabetes, heart disease and hypertension. Logistic regression models determined differences between outcomes for children with and without a family history of NCDs.

**Results** Boys with a family history of type 2 diabetes had 30% (95% CI: 0.51%–0.97%) and 43% lower odds (95% CI: 0.37%–0.88%) of meeting the sleep and combined guidelines, respectively, and 40% higher odds (95% CI: 1.01%–1.95%) of being overweight/obese. Girls with a family history of hypertension had 27% lower odds (95% CI: 0.57%–0.93%) of meeting the screen time guidelines. No associations were observed for family history of heart disease.

**Conclusions** Children who have a family history of type 2 diabetes and hypertension may be at risk of poorer health behaviours from a young age. Mothers with a diagnosis or a family history of these NCDs may need additional support to help their children develop healthy movement behaviours and maintain healthy weight.

## INTRODUCTION

Overweight/obesity,<sup>1</sup> physical inactivity,<sup>2</sup> sedentary behaviour (eg, television viewing)<sup>3</sup> and poor sleep<sup>4</sup> are among the

## Strengths and limitations of this study

- Data from the Mothers and their Children's Health Study were drawn from a nationally representative sample from the Australian Longitudinal Study on Women's Health.
- A large sample was included in analyses.
- Paternal data were not collected and hence could not be included in analyses.
- Child outcomes (height, weight, physical activity, screen time and sleep) were proxy-reported by mothers and may be subject to reporting biases.

leading risk factors for development of non-communicable diseases (NCDs) in adults. These risk factors track from childhood to adulthood,<sup>5–7</sup> with emerging evidence suggesting that physical activity, sedentary behaviour and sleep (collectively referred to as 'movement behaviours') are associated with cardiovascular risk factors even in children.<sup>8–10</sup> As such, governments internationally have developed evidence-based guidelines for these behaviours in children, which are designed to optimise their health and development. Australia was one of the first countries to develop 24-hour movement guidelines, which integrate physical activity, sedentary behaviour and sleep.<sup>11</sup> These guidelines suggest that children aged 5–17 years should: accumulate at least 60 min per day of moderate to vigorous intensity physical activity (MVPA); limit sedentary recreational screen time to no more than 2 hours per day; and have 9–11 hours of sleep (for those aged 5–13 years) and 8–10 hours of sleep (for those aged 14–17 years) per night.<sup>11</sup>

Evidence suggests that fewer than 15% of Australian children, and just 7% of children worldwide, meet the combined MVPA, screen

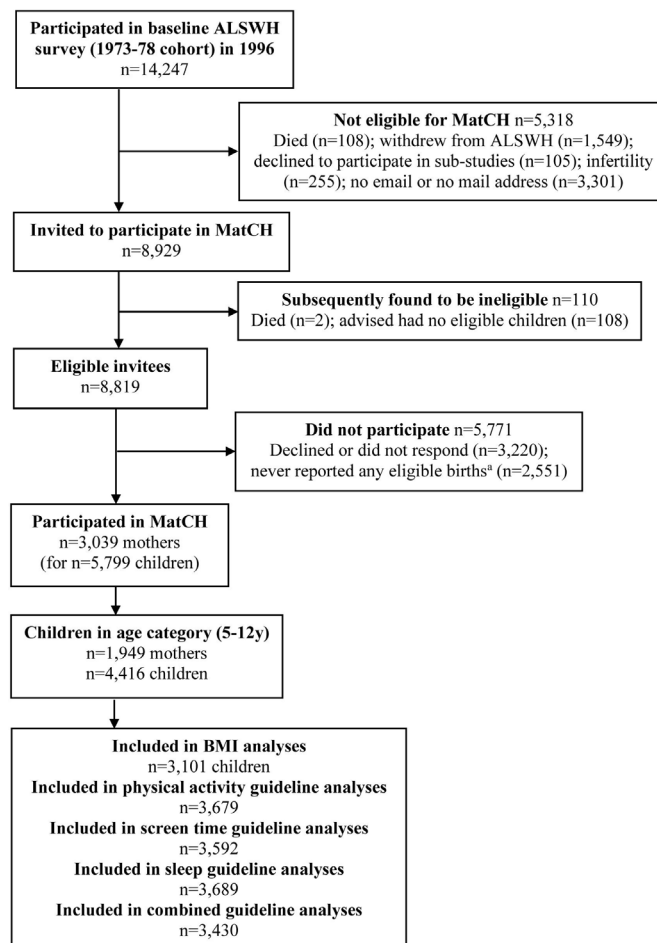
time and sleep guidelines,<sup>12</sup> with boys more likely to meet guidelines than girls.<sup>13</sup> Public health efforts to improve compliance with movement behaviours need to focus on those most at risk. Given that disease risk runs in families, children from these families could be even more at risk for the development of NCDs. For example, parental diabetes, obesity and metabolic syndrome predict type 2 diabetes risk in adults,<sup>14</sup> and parental cardiovascular disease predicts future offspring events in adults, particularly men.<sup>15</sup> Additionally, paternal history of kidney disease, heart failure and hypertension has been associated with obesity in children,<sup>16</sup> while parents' own cardiovascular biomarkers (such as body mass index (BMI), skin folds, blood pressure and serum cholesterol) are associated with their children's cardiovascular biomarkers.<sup>17 18</sup>

If children with a family history of NCDs have poorer lifestyle behaviours in childhood, they are at an even higher risk of developing NCDs themselves, potentially through an inherited genetic profile and exacerbated by lifestyle behaviours. Children with a family history of NCDs could be an important group to target in behavioural interventions to improve movement behaviours. To our knowledge, no studies have examined whether family history of NCDs is associated with children's movement behaviours. Therefore, the aim of this study was to determine whether a family history of type 2 diabetes, heart disease or hypertension is associated with physical activity, sedentary behaviour, sleep and weight status in boys and girls.

## METHODS

### Recruitment and participants

Data were drawn from the Australian Longitudinal Study on Women's Health (ALSWH) and the Mothers and their Children's Health Study (MatCH; <https://www.alswh.org.au/match>), a substudy of the ALSWH. Details of both the ALSWH<sup>19–21</sup> and MatCH<sup>22</sup> have been previously reported. Briefly, the ALSWH includes three random samples of women born between 1973–1978, 1946–1951 and 1921–1926 recruited via the database of the Health Insurance Commission (now Medicare; Australia's universal health insurance scheme). Women in the 1973–1978 cohort were surveyed by postal questionnaires or online surveys in 1996, 2000, 2003, 2006, 2009, 2012 and 2015. In 2016–2017, all of the women in this cohort were invited to participate in MatCH (excluding those who were deceased, had withdrawn from the study, asked not to be contacted about substudies or had reported infertility). To be eligible for inclusion, women had to have at least one biological child who was currently living with them at least part of the time, and was aged under 13 years on the date they completed the MatCH survey. Eligible mothers who consented to take part completed postal or online questionnaires and were asked to report on their three youngest children. Of the 8929 women invited to participate in MatCH, 3039 mothers provided information on 5799 children. The present study focused on primary (elementary) aged children and hence used data



**Figure 1** Participant flow chart. ALSWH, Australian Longitudinal Study on Women's Health; BMI, body mass index; MatCH, Mothers and their Children's Health Study.

only from children aged 5–12 years ( $n=4416$ ). Children aged <5 years were not included given: (1) the relatively small sample of children in this age group compared with those aged 5–12 years ( $n=1383$ ), making comparisons between the groups difficult; and (2) that 24-hour movement guidelines differ for children aged 0–5 years.<sup>23</sup> We conducted complete case analysis for each of the outcomes of interest; the final analytical sample included 3101 for child weight status and 3679, 3591, 3689 and 3430 for compliance with the physical activity, screen time, sleep and combined guidelines, respectively (see figure 1).

### Measures and data management

#### Outcome variables

Outcome variables, drawn from MatCH, were child weight status and compliance with physical activity, screen time and sleep guidelines. Mothers reported their child's height (cm) and weight (kg), which were used to calculate BMI ( $\text{kg}/\text{m}^2$ ). Child BMI categories were determined using age-specific and sex-specific international cut-off points,<sup>24</sup> and collapsed into underweight/healthy weight and overweight/obese. Compliance with physical activity guidelines was assessed by parent-reported number of

days in a typical week (0–7) the child achieved  $\geq 60$  min of MVPA<sup>11</sup> (adapted from Prochaska *et al*<sup>25</sup>). Screen time (single item including any time spent watching/using screen-based equipment, such as television, computers, tablets, mobile phones and electronic games; excluding for school work) on week and weekend days over the past month was parent-reported as hours and minutes per day<sup>26</sup>; usual daily screen time was weighted as:  $((\text{weekday} \times 5) + (\text{weekend} \times 2)) / 7$ . Children were classified as meeting the screen time guideline if they had  $\leq 2$  hours per day on an average day.<sup>11</sup> Usual sleep time was parent-reported as hours per night during the past week, with children classified as meeting the sleep guideline if they had  $\geq 9$  and  $\leq 11$  hours of sleep.<sup>11</sup> Children were classified as meeting the combined guidelines if they met all three individual guidelines.

### Explanatory variables

In the 2015 survey, women in the 1973–1978 cohort of the ALSWH reported whether they had a diagnosis of non-insulin dependent (type 2) diabetes, heart disease or hypertension. They also reported whether they had a family history (ie, mother, father or siblings) of the same NCDs. Children were classified as having a family history of these diseases if their mother had either a diagnosis or family history.

### Covariates

In the ALSWH Survey, women reported their highest education level (collapsed into: year 10 or equivalent; year 12, trade, certificate, apprenticeship or diploma; and tertiary education) and their date of birth. They reported the date of birth and sex of their child/ren in the MatCH Survey. The Accessibility/Remoteness Index of Australia (ARIA) Plus was used to classify participants as living in a major city, regional or remote area from their postcode given at the time of the 2015 ALSWH Survey.

### Data analysis

Analyses were performed in Stata V.15.0 (StataCorp, Texas, USA). Descriptive statistics were used to characterise the sample; unpaired t-tests and  $\chi^2$  tests were used to determine differences in characteristics between boys and girls. Logistic regression models were used to determine differences between outcomes (ie, weight status and meeting physical activity, screen time, sleep and combined guidelines) for children with and without a family history of lifestyle disease, adjusting for potential covariates and clustering by family. Analyses were stratified by sex of the child.

### Sensitivity analyses

We conducted sensitivity analyses additionally controlling for mothers' own risk factors for NCDs (ie, maternal BMI, physical activity and sitting) as potential confounders. In the 2015 ALSWH Survey, women reported their own height and weight (used to calculate BMI ( $\text{kg}/\text{m}^2$ )), their MVPA in the last week (using the Active Australia Survey<sup>27</sup>); divided by 7 to give average minutes/day, and their usual

time sitting down on week and weekend days; weighted as:  $((\text{weekday} \times 5) + (\text{weekend} \times 2)) / 7$ . Mean values for each of these variables were: BMI  $26.0 \pm 5.7 \text{ kg}/\text{m}^2$ ; MVPA  $55.4 \pm 66.1 \text{ min}/\text{day}$  and sitting  $339.6 \pm 160.7 \text{ min}/\text{day}$ . We did not control for these potential confounders in the main analyses because they were reported at different points in time to the child outcomes (ie, child outcomes were reported in 2016–2017, while maternal BMI, physical activity and sitting were reported in 2015) and may have varied over time.<sup>28 29</sup>

### Missing data

Missing value percentages for the outcome variables were 22.0% (child BMI), 5.6% (physical activity guideline compliance), 7.2% (screen time guideline compliance), 5.2% (sleep guideline compliance) and 12.2% (compliance with combined guidelines). For the explanatory variables, missing value percentages were 9.3% (family history of type 2 diabetes), 9.4% (family history of heart disease) and 8.8% (family history of hypertension). For covariates, missing value percentages were 9.6% (maternal education) and 0.3% (ARIA Plus); there were no missing values for maternal or child age. The only difference between the final analytical sample and the full sample was that mothers in the analytical sample were slightly older compared with mothers in the full sample (40.6 years compared with 40.3 years; see online supplemental table 1).

### Patient and public involvement

There was no patient or public involvement in any phase of this study, including the development of the research question, the analysis and the conclusions.

## RESULTS

Maternal and child characteristics are shown in table 1. Mothers in this study had a mean age of 40 years. Just over half reported a family history of hypertension, with around one-quarter reporting a family history of type 2 diabetes and heart disease. Few mothers reported diagnoses of NCDs: 4% reported a diagnosis of hypertension and less than 1% reported diagnoses of type 2 diabetes or heart disease (combined with mothers' family history to create the child's family history). Children had a mean age of 8 years and just under half were girls. The majority of children (86%) met the sleep guideline, 65% met the screen time guideline, 18% met the physical activity guideline, 11% met the combined guidelines and 15% were classified as overweight/obese. A greater proportion of boys than girls met the physical activity guideline and combined guidelines, while a greater proportion of girls met the screen time guideline. There were no differences in family history of NCDs (mothers' own diagnoses and their family history) between boys and girls.

Figures 2 and 3 present the results of the logistic regression analyses of associations of family history of type 2 diabetes, heart disease and hypertension with guideline

**Table 1** Maternal and child characteristics\*, n (%) unless otherwise noted

	Total sample (n=3819)†	Boys (n=1965)†	Girls (n=1854)†	P value‡
<b>Maternal characteristics (n=1670)</b>				
Age (years), mean (SD)	40.6 (1.5)	40.6 (1.5)	40.5 (1.5)	0.5
<b>Highest education level</b>				
Year 10 or equivalent	75 (4.5)	39 (4.5)	36 (4.5)	0.98
Year 12, trade, certificate, apprenticeship or diploma	596 (35.7)	294 (33.8)	302 (37.8)	0.08
Tertiary	999 (59.8)	538 (61.8)	461 (57.7)	0.09
<b>Family history of NCDs</b>				
Type 2 diabetes	394 (23.6)	208 (23.9)	186 (23.3)	0.77
Heart disease	431 (25.8)	226 (26.0)	205 (25.7)	0.89
Hypertension	867 (51.9)	451 (51.8)	416 (52.1)	0.91
<b>Diagnoses of NCDs</b>				
Type 2 diabetes	15 (0.9)	6 (0.7)	9 (1.1)	0.34
Heart disease	8 (0.5)	6 (0.7)	2 (0.3)	0.19
Hypertension	65 (3.9)	39 (4.5)	26 (3.3)	0.2
<b>Child characteristics (n=3819)</b>				
Age (years), mean (SD)	8.4 (2.2)	8.4 (2.2)	8.4 (2.2)	0.2
<b>Weight status</b>				
Healthy weight	2630 (84.8)	1387 (85.4)	1243 (84.2)	0.33
Overweight/obese	471 (15.2)	237 (14.6)	234 (15.8)	0.33
<b>Guideline compliance</b>				
Physical activity	658 (17.9)	411 (21.7)	247 (13.8)	<0.0001
Screen time	2348 (65.4)	1151 (61.9)	1197 (69.1)	<0.0001
Sleep	3179 (86.2)	1657 (87.2)	1522 (85.1)	0.07
Combined	322 (11.3)	201 (13.3)	121 (9.0)	<0.0001
<b>Family history of NCDs (mothers' own diagnoses and their family history)</b>				
Type 2 diabetes	881 (23.1)	463 (23.6)	418 (22.6)	0.46
Heart disease	996 (26.1)	523 (26.6)	473 (25.1)	0.43
Hypertension	1969 (51.5)	1005 (51.2)	963 (51.9)	0.62

\*Maternal and child characteristics are presented for the full analytical sample, that is, those with BMI or guideline compliance (physical activity, screen time, sleep and combined guidelines) outcome data.

†Sample sizes are for the child sample.

‡P value for differences between boys and girls.

BMI, body mass index; NCDs, non-communicable diseases.

compliance and overweight/obesity for boys and girls, respectively. Boys with a family history of type 2 diabetes had 40% higher odds of being classified as overweight/obese. They had 30% and 43% lower odds of meeting the sleep and combined guidelines, respectively. Conversely, girls had 27% lower odds of meeting the screen time guideline if they had a family history of hypertension. No associations were observed between family history of heart disease and the odds of meeting the guidelines or overweight/obesity for either boys or girls.

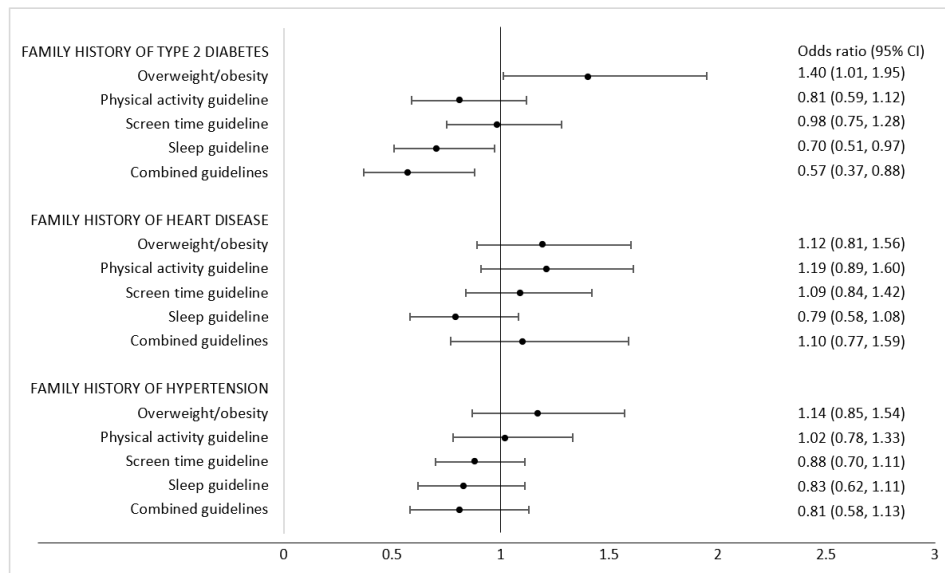
### Sensitivity analyses

In general, associations reduced in magnitude when controlling for additional potential confounders in sensitivity analyses (see online supplemental table 2).

For boys, associations of family history of type 2 diabetes with weight status and compliance with the sleep guideline were no longer statistically significant. However, the association between family history of type 2 diabetes and compliance with the combined guidelines remained. For girls, the association between family history of hypertension and compliance with the screen time guideline was no longer statistically significant.

### DISCUSSION

In the present study we examined whether weight status and compliance with the Australian child and adolescent 24-hour movement guidelines differed for children with

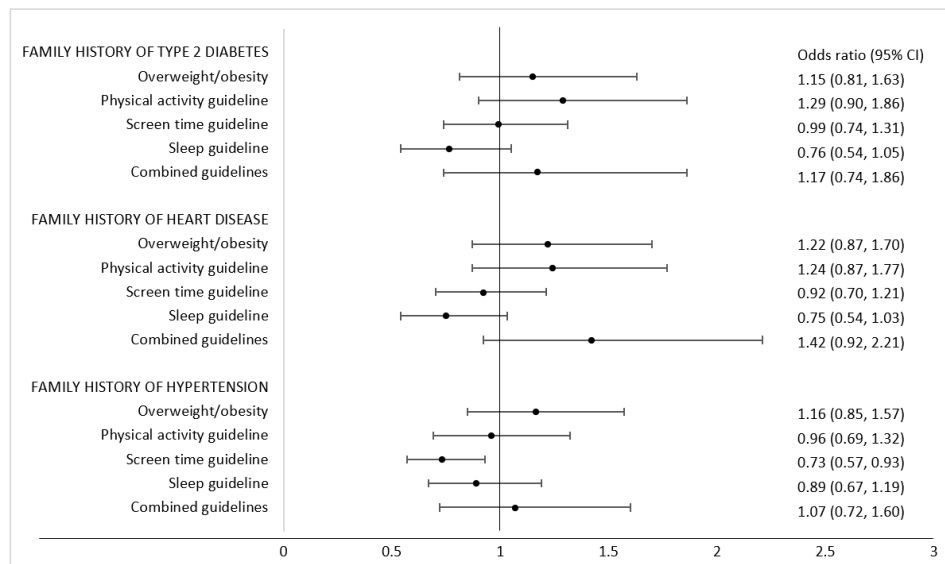


**Figure 2** Odds of meeting guidelines and overweight/obesity for boys with family history of non-communicable diseases, adjusted for maternal age, maternal education, remoteness, child age and clustering by family.

and without a family history of NCDs. Findings suggest that a family history type 2 diabetes is associated with lower odds of children complying with guidelines and higher odds of overweight/obesity for boys, while family history of hypertension is associated with lower odds of children complying with guidelines for girls. To our knowledge, this is the first study to investigate whether family history of NCDs is associated with children’s obesity-related movement behaviours.

Family history of type 2 diabetes was associated with reduced odds of meeting the sleep guideline for boys. This is not the first evidence of association between NCD risk and sleep. Evidence has shown that children with sleep disordered breathing experience significant

changes in blood pressure and heart rate during obstructive events, with similar magnitudes to levels reported in adults, which may contribute to the development of hypertension.<sup>30</sup> Previous studies have shown that children with type 2 diabetes may also have other comorbidities, including sleep disorders,<sup>31 32</sup> and treatment recommendations for youth-onset type 2 diabetes suggest increasing sleep duration (among numerous other lifestyle modifications).<sup>32</sup> Knutson *et al*<sup>33</sup> suggest that in adults chronic partial sleep loss, that can occur as a result of sleep disorders, may increase the risk of obesity and type 2 diabetes through multiple pathways, including excessive food intake and decreased energy expenditure as a result of insulin resistance and a



**Figure 3** Odds of meeting guidelines and overweight/obesity for girls with family history of non-communicable diseases, adjusted for maternal age, maternal education, remoteness, child age and clustering by family.



dysregulation of the neuroendocrine control of appetite. There is also evidence of the existence of familial sleep disorders, whereby sleep traits are genetically influenced; although environmental factors can impact the duration and intensity of sleep.<sup>34</sup> Collectively, this suggests that there may be multiple, complex pathways through which family history of NCDs, particularly type 2 diabetes, may relate to children's sleep.

In addition to sleep, boys also had lower odds of meeting the combined guidelines and higher odds of being classified as overweight/obese if they had a family history of type 2 diabetes. Two of the biggest known risk factors for type 2 diabetes in children are overweight/obesity and family history of type 2 diabetes.<sup>35</sup> Potentially, the two are inter-related, in that children with a family history of type 2 diabetes are exposed to a range of risk factors (for example, an 'obesogenic' home environment), are less likely to meet 24-hour movement guidelines, and are more likely to be classified as overweight/obese. However, the direction of influence for these factors is currently unclear. In a large ( $n > 6000$ ), international sample of children aged 9–11 years, meeting the combined guidelines was shown to be associated with a lower BMI z-score.<sup>12</sup> In adults, there is evidence of a graded increase in self-reported obesity for those with average, moderate and high risk of type 2 diabetes (based on family history),<sup>36</sup> suggesting that family history is important in the development of obesity. Further research is required to investigate how these behaviours and risk factors might be inter-related, the direction of the associations and the potential pathways through which family history of type 2 diabetes influences child outcomes. Regardless, findings suggest that lifestyle interventions, focusing on increasing physical activity, decreasing screen time and optimising sleep, should be promoted in children at risk for the development of type 2 diabetes, that is, those with a family history of type 2 diabetes.

We also found that girls had lower odds of meeting the screen time guideline if they had a family history of hypertension. Although previous research investigating associations between family history of hypertension and children's behaviours is lacking, there is some evidence that family history of hypertension may affect children's own health. For example, a study of children aged 6–10 years with non-elevated waist circumference in Mexico found that maternal family history of hypertension was associated with high blood pressure, hyperglycaemia, hypertriglyceridaemia and low HDL cholesterol in the children.<sup>37</sup> Given that both high screen time and BMI are associated with cardiometabolic risk factors in children,<sup>8 38 39</sup> it may be that children's screen time mediates the association between family history of hypertension and children's cardiometabolic risk factors (eg, high blood pressure, hyperglycaemia). Children with a family history of hypertension, when placed in these unfavourable 'environments' (eg, high levels of screen time), may have a stronger physiological response compared with children without a family history.

Within the current study, 18% of children met the physical activity guideline, 65% met the screen time guideline, 86% met the sleep guideline and 11% met the combined guidelines. A previous study examining adherence to the guidelines, across countries participating in the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE), reported that 55%, 35%, 80% and 15% of children from Australia aged 9–11 years met the physical activity, screen time, sleep and combined guidelines, respectively.<sup>12</sup> Differences between the two studies in estimates of children meeting the physical activity and screen time guidelines are likely due to measurement differences. In the current study, physical activity guideline compliance was maternal-reported as number of days the child achieved  $\geq 60$  min of MVPA per day, with mothers asked to exclude school physical education classes, while the ISCOLE used accelerometers to objectively assess MVPA, which captures time across the whole day. Additionally, compliance with recreational screen time guidelines was based on maternal-reported data (and potentially underestimated) in the current study, but based on self-report data from the child in ISCOLE. This is important given that school-aged children tend to self-report greater duration of screen time than their parents report they engage in.<sup>40</sup> Potentially different associations may have been observed with different measures of physical activity and screen time. Future studies should consider including objective measures of physical activity, in particular, and asking children to self-report their screen time.

In the current study, the proportion of mothers with diagnoses of NCDs was very low (likely due to the young age of the included mothers), and hence contributed little to the child's family history of diseases. This may explain why few associations were observed, given that parents tend to be the strongest influence on a child's behaviour.<sup>41 42</sup> In sensitivity analyses, we adjusted for maternal risk factors for NCDs (ie, BMI, MVPA and sitting) as potential confounders, with associations generally reducing in magnitude. This suggests that maternal risk factors for NCDs may be associated with children's outcomes. This may also be important in terms of parental modelling of behaviours, which is an important influence on children's behaviours.<sup>42</sup> In addition, data on common precursors to NCDs, such as elevated blood pressure, were not collected in the current study and hence could not be included in analyses. Finally, we were not able to examine whether paternal diagnoses or family history of NCDs were associated with children's guideline compliance and weight status, and hence only examined half of the 'picture' in terms of children's family history.

A further limitation of MatCH is the low response rate of 34%. However, among women known to be mothers, based on data provided in ALSWH, the response rate was 48%. In addition, recruitment for MatCH was limited to ALSWH participants with children under the age of 13 years, meaning that the cohort of mothers were restricted to between 25 and 43 years of age. This may

have introduced bias given that socioeconomic, health and family characteristics of women who give birth at a young age, and the impact on their children's outcomes, differ to women who give birth at later ages.<sup>43</sup> Finally, the sample may not be representative of the general population; 15% of the current sample of children were classified as overweight/obese, compared with 24% of children aged 5–14 years Australia-wide.<sup>44</sup> Strengths of MatCH are the large sample size, drawn from a nationally representative sample of women from the ALSWH, including those in rural and remote areas.

## CONCLUSION

Findings from this study show that family history of NCDs, particularly type 2 diabetes and hypertension, may be risk factors for children's weight status (boys only) and obesity-related movement behaviours. Further research is required to determine whether there is a potential inter-generational transfer of lifestyle disease risk, and through which pathway this might occur. However, findings suggest that mothers with a family history of NCDs may need additional support to help their children develop healthy movement behaviours and to maintain healthy weight.

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**Contributors** KLD conceptualised and designed the current study, carried out the analyses, drafted the initial manuscript, and reviewed and revised the manuscript. KDH conceptualised and designed the current study, provided input into the data collection instruments and critically reviewed the manuscript for important intellectual content. AT and JS conceptualised and designed the current study, and critically reviewed the manuscript for important intellectual content. KM provided input to study design and critically reviewed the manuscript for important intellectual content. GM conceptualised and designed the overall study (MatCH), designed the data collection instruments, coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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**Competing interests** None declared.

**Patient consent for publication** Not required.

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**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available upon reasonable request. ALSWH and MatCH data are available free of charge to bona fide researchers. Information on the process and conditions of access, along with the request forms, can be found on the ALSWH website (<http://www.alswh.org.au>).

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