





# BMJ Open Lifestyle risk behaviours among adolescents: a two-year longitudinal study of the impact of the COVID-19 pandemic

Lauren Anne Gardner <sup>1</sup>, Jennifer Debenham <sup>1</sup>, Nicola Clare Newton,<sup>1</sup> Cath Chapman <sup>1</sup>, Fiona Elizabeth Wylie,<sup>2</sup> Bridie Osman,<sup>1</sup> Maree Teesson,<sup>1</sup> Katrina Elizabeth Champion <sup>1</sup>

**To cite:** Gardner LA, Debenham J, Newton NC, *et al.* Lifestyle risk behaviours among adolescents: a two-year longitudinal study of the impact of the COVID-19 pandemic. *BMJ Open* 2022;**12**:e060309. doi:10.1136/bmjopen-2021-060309

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-060309>).

Received 17 December 2021  
Accepted 04 May 2022



© Author(s) (or their employer(s)) 2022. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

<sup>1</sup>The Matilda Centre for Research Excellence in Mental Health and Substance Use, The University of Sydney, Sydney, New South Wales, Australia  
<sup>2</sup>Department of Psychology, Macquarie University, Sydney, New South Wales, Australia

## Correspondence to

Dr Lauren Anne Gardner;  
[lauren.gardner@sydney.edu.au](mailto:lauren.gardner@sydney.edu.au)

## ABSTRACT

**Objective** To examine changes in the prevalence of six key chronic disease risk factors (the “Big 6”), from before (2019) to during (2021) the COVID-19 pandemic, among a large and geographically diverse sample of adolescents, and whether differences over time are associated with lockdown status and gender.

**Design** Prospective cohort study.

**Setting** Three Australian states (New South Wales, Queensland and Western Australia) spanning over 3000 km.

**Participants** 983 adolescents (baseline  $M_{age}=12.6$ ,  $SD=0.5$ , 54.8% girl) drawn from the control group of the Health4Life Study.

**Primary outcomes** The prevalence of physical inactivity, poor diet (insufficient fruit and vegetable intake, high sugar-sweetened beverage intake, high discretionary food intake), poor sleep, excessive recreational screen time, alcohol use and tobacco use.

**Results** The prevalence of excessive recreational screen time (prevalence ratios (PR)=1.06, 95% CI=1.03 to 1.11), insufficient fruit intake (PR=1.50, 95% CI=1.26 to 1.79), and alcohol (PR=4.34, 95% CI=2.82 to 6.67) and tobacco use (PR=4.05 95% CI=1.86 to 8.84) increased over the 2-year period, with alcohol use increasing more among girls (PR=2.34, 95% CI=1.19 to 4.62). The prevalence of insufficient sleep declined across the full sample (PR=0.74, 95% CI=0.68 to 0.81); however, increased among girls (PR=1.24, 95% CI=1.10 to 1.41). The prevalence of high sugar-sweetened beverage (PR=0.61, 95% CI=0.64 to 0.83) and discretionary food consumption (PR=0.73, 95% CI=0.64 to 0.83) reduced among those subjected to stay-at-home orders, compared with those not in lockdown.

**Conclusion** Lifestyle risk behaviours, particularly excessive recreational screen time, poor diet, physical inactivity and poor sleep, are prevalent among adolescents. Young people must be supported to find ways to improve or maintain their health, regardless of the course of the pandemic. Targeted approaches to support groups that may be disproportionately impacted, such as adolescent girls, are needed.

**Trial registration number** Australian New Zealand Clinical Trials Registry (ACTRN12619000431123)

The global spread of COVID-19 and subsequent lockdown measures have presented

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ A prospective cohort design was used to explore changes in a comprehensive set of health indicators among adolescents, from before (2019) to during (2021) the COVID-19 pandemic, and whether changes varied by gender and lockdown status.
- ⇒ The study included a large (n=983) and geographically diverse sample of adolescents across three Australian states (New South Wales, Queensland and Western Australia) spanning over 3000 km.
- ⇒ Limitations of the research include the reliance on self-report measures, and while the sample was diverse, it is not representative of the Australian population.

challenges worldwide. While disease severity, hospital admissions and deaths have typically been lower among adolescents, compared with adults,<sup>1</sup> government responses, such as movement restrictions and school closures, present further potential health ramifications due to the related changes in lifestyle behaviours. Critically, despite some studies demonstrating the significant physical and mental health consequences of lockdown measures on adolescents,<sup>2–4</sup> research has typically focused on a few select behaviours, rather than a comprehensive set of health indicators. Given the unique presentation of COVID-19 across countries and differing government responses, there is a need to examine health-related changes from a variety of contexts to develop a better understanding of global health.

According to the Oxford COVID-19 Government Response Tracker,<sup>5</sup> the strictness of lockdown restrictions since the first confirmed cases in January 2020 to October 2021 was similar in Australia, the USA and the UK, with average stringency indexes of 60/100, 59/100 and 61/100, respectively,

despite much lower incidence and mortality rates in Australia.<sup>6</sup> However, there can be substantial variation within countries.<sup>7,8</sup> In Australia, for example, stringency index values varied between states and territories by as much as 68 during 2020.<sup>8</sup> The strictest and most extensive lockdown restrictions have been implemented in Victoria and New South Wales (NSW), two of the most populous states that saw heightened case numbers during the January 2020 to October 2021 period, while other Australian states, such as Queensland (QLD) and Western Australia (WA), experienced far fewer cases and restrictions.<sup>9,10</sup> The Australian context may therefore serve as a case study for understanding the impact of various levels of restrictions on adolescent health behaviours.

Previous research has highlighted the importance of six key lifestyle behaviours, including diet, physical activity, sleep, sedentary behaviour (including recreational screen time), alcohol use and smoking—collectively referred to as the ‘Big 6’—for the short-term and long-term health of adolescents.<sup>11–14</sup> These behaviours are common among youth worldwide, with more than 80% of adolescents insufficiently physically active<sup>15</sup> and screen time rapidly increasing.<sup>14,16</sup> The Big 6 contribute significantly to global disease burden and are known predictors of chronic diseases, including cancer, cardiovascular disease and mental disorders.<sup>13,17</sup>

Research suggests that COVID-19 has impacted the Big 6, and in turn, the health of adolescents. For example, youth in Europe and Palestine have gained weight during the pandemic,<sup>18,19</sup> which may be the result of increased consumption of discretionary food and sugar-sweetened beverages (SSB) during lockdown periods.<sup>18,20</sup> However, some studies report improvements in dietary behaviours, including less SSB consumption among Colombian adolescents, higher fruit intake among Italian youth and higher vegetable intake among adolescents from Spain, Brazil and Chile.<sup>20,21</sup> Among the few existing Australian studies, Munasinghe *et al*<sup>5</sup> found physical distancing measures implemented in the initial lockdown period (March–April 2020) were associated with a decline in fast food consumption among adolescents, but there were no changes in fruit and vegetable consumption. However, it is unknown whether these changes have been sustained, or whether other dietary behaviours changed.

The pandemic presents particular challenges for movement behaviours, including physical activity, sedentary behaviour and sleep. Typically, lockdowns are associated with lower levels of adolescent physical activity<sup>4,18,20,22,23</sup> and increased screen time, both for remote learning and recreation, resulting in sedentary lifestyles.<sup>3,4,23,24</sup> However, some research in Australia<sup>25</sup> and Germany<sup>26</sup> suggests physical activity increased.<sup>26</sup> International studies also report an increase in adolescent sleep duration during lockdown periods,<sup>18,20</sup> but higher prevalence of sleep problems, particularly among girls.<sup>27</sup> Similarly, Australian adolescents perceived an increase in sleep difficulties and had increased sleep disturbance during the first lockdown.<sup>25</sup> One study<sup>28</sup> reported increased sleep duration

among Australian adolescents who were engaged in remote learning; however, another<sup>3</sup> found no changes.

Studies investigating the impact of the pandemic on adolescent alcohol and tobacco use have produced mixed findings. For example, alcohol use is reported to have increased among Canadian adolescents,<sup>29</sup> reduced among Spanish adolescents,<sup>30</sup> while there was no change in alcohol or tobacco use among adolescents from the USA.<sup>31</sup> Further, European research suggests a reduction in adolescent tobacco use during the pandemic period,<sup>30,32</sup> yet there has been an increase in Uganda.<sup>33</sup> To date, changes in alcohol and tobacco use among Australian adolescents have not been examined.

Evidence suggests that the prevalence of the Big 6 varies by gender. For example, adolescent girls are more likely to be physically inactive, whereas adolescent boys are more likely to engage in high levels of recreational screen time, have a poor diet, and use alcohol and tobacco.<sup>15,34–38</sup> However, less is known about whether changes in lifestyle behaviours over the pandemic period vary by gender.

To address these gaps in the literature, this study aims to examine changes in the prevalence of the Big 6 among a large, geographically diverse sample of adolescents, from before to during the COVID-19 pandemic, and explore whether differences over time are associated with gender and lockdown status.

## METHODS

### Participants and procedure

The sample comprised participants from three Australian states (NSW, QLD and WA), spanning over 3000 km, who were randomly allocated to the control group of the Health4Life Study.<sup>39</sup> Participants who provided written consent and had parental consent (passive, active written or active verbal, depending on approved procedures for the school type and region) completed self-report assessments in a supervised classroom setting. Only students who provided data prior to the beginning of the pandemic (between July and November 2019) and during the pandemic (approximately 24 months after baseline, between July and 10 October 2021) were included in this study. During the 2021 data collection period, Australia had strict border policies, restricting international travel and mandating hotel quarantine, while state-level and territory-level border policies for domestic travel varied.<sup>40</sup> Greater Sydney, including the Central Coast, Shellharbour and Wollongong were subjected to lockdown restrictions under the NSW stay-at-home Public Health Order<sup>41</sup>; the most stringent of which included not being permitted to leave the home unless essential (eg, one person per household to shop for food or 1 hour of exercise per day), movement restricted to a 5 km radius of the home, closure of all non-essential retail (eg, hairdressers), home-based work and schooling requirements, curfews, and mandatory mask wearing, with a high police presence and large fines enforced for non-adherence. QLD, WA and areas

outside of Greater Sydney were not subjected to extended stay-at-home lockdown restrictions.

### Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

### Measures

#### Sociodemographic characteristics

Participants self-reported their age and gender (male, female, non-binary/gender fluid, missing). A binary 'lockdown' variable was created reflecting participants who attended schools in the Greater Sydney region that were subjected to the stay-at-home Public Health Order in 2021 and those who were not.<sup>41</sup>

#### Diet

Dietary intake was assessed using items adapted from the NSW School Physical Activity and Nutrition Survey.<sup>42</sup> Participants self-reported the number of metric cups of SSB usually consumed per week or day. A binary variable was created to reflect high ( $\geq 5$ –6 cups or more/week) and low consumption ( $\leq 4$  cups/week). Participants reported how often they consume six discretionary food items (hot chips, French fries, wedges or fried potatoes; potato crisps or other salty snacks; snack foods, for example, sweet and savoury biscuits, cakes, doughnuts or muesli bars; confectionary; ice cream or ice blocks; and takeaway meals or snacks). High discretionary food consumption was defined as eating any of the items '2 or more times/day', or eating at least two of the items '3–4 times/week' or more often. Participants reported the number of serves of fruit and vegetables consumed per day, and in line with the Australian dietary guidelines,<sup>43</sup> insufficient fruit and vegetable consumption was defined as  $< 2$  serves of fruit and  $< 5$  serves of vegetables per day, respectively.

#### Physical activity

A single item was used to assess the number of days over the past week that participants engaged in moderate-to-vigorous physical activity for at least 60 min.<sup>44</sup> As per the Australian health guideline, insufficient physical activity was defined as engaging in  $< 60$  min of moderate-to-vigorous physical activity/day.<sup>45</sup>

#### Recreational screen time

The International Sedentary Assessment Tool<sup>46</sup> was used to evaluate free time spent on a typical weekday and weekend day over the past 7 days watching television/DVDs/streaming services or using an electronic device. In line with the Australian health guideline,<sup>45</sup> excessive recreational screen time was defined as  $> 2$  hours/day.

#### Sleep

The Modified Sleep Habits Survey<sup>47</sup> was used to assess sleep duration. Total sleep time was calculated by finding the difference between the time participants reported first attempting sleep, and the time they woke up in the

morning, minus the reported time taken to fall asleep from first attempt, with a weighted average sleep duration calculated for school and weekend nights. Self-reported bedtime, waketime and sleep duration have been shown to be reliable and valid in adolescent populations.<sup>48 49</sup> As per the Australian guidelines, insufficient sleep was defined as an average duration outside of 9–11 hours/night for those aged 11–13 years, or 8–10 hours/night for those aged 14–17 years.<sup>45</sup>

#### Alcohol and tobacco use

Alcohol and tobacco use were measured using two dichotomous (yes/no) items drawn from previous large scale trials and population based epidemiological surveys<sup>50 51</sup>: 'Have you had a full standard alcoholic drink in the past 6 months?' and 'In the past 6 months, have you tried cigarette smoking, even one or two puffs?'

#### Statistical analysis

Generalised linear mixed models were used to investigate change over time in the Big 6. Owing to the high prevalence of outcomes, we used Robust Poisson methods to generate prevalence ratios (PR) and 95% CIs, to overcome some of the limitations of reporting ORs from logistic regressions, which may appear inflated.<sup>52</sup> PR are interpreted as the estimated prevalence of an outcome in one group, compared with another, providing an indication of a change in prevalence, as opposed to risk or odds. All models included a random intercept at the student level and school level, Robust Poisson distribution and a log link function, where time is continuous and represents the prepandemic (2019) and mid-pandemic scores (2021). Group by time interactions were estimated to assess change in the prevalence of the Big 6 over time in relation to gender (female/male, given the low prevalence of the 'non-binary/gender fluid' (0.1%) and 'prefer not to say' (.5%) subgroups) and the presence of lockdown restrictions during the 2021 survey occasion. All analyses were conducted in Stata V.17.<sup>53</sup>

## RESULTS

### Descriptive statistics

The sample included 983 students (baseline  $M_{age}=12.6$ ,  $SD=0.5$ , 54.8% girl) from 22 schools across NSW, QLD and WA (see table 1 for baseline characteristics). At the 2021 survey occasion, approximately one-third of the sample (32.7%) was under lockdown restrictions. Table 2 presents the prevalence of lifestyle risk behaviours over time.

### Changes in lifestyle risk behaviours

Change over time in the prevalence of the Big 6 and differences based on lockdown status and gender are illustrated in figure 1, with PR and CIs detailed in online supplemental table 1.

#### Dietary behaviours

##### SSB consumption

There was no significant change in the prevalence of high SSB consumption over time (PR=0.83 95% CI=0.58



**Table 1** Sample characteristics

Characteristic	n (%)
Gender (n=976)	
Female	535 (54.8)
Male	441 (45.2)
State (n=983)	
New South Wales	451 (45.9)
Queensland	214 (21.8)
Western Australia	318 (32.3)
School type (n=22)	
Independent	14 (63.6)
Catholic	2 (9.1)
Government	6 (27.3)
Country of birth (n=982)	
Australia	842 (85.7)
Other	140 (14.3)

to 1.18). However, the prevalence was 39% lower in individuals under lockdown (PR=0.61, 95% CI=0.64 to 0.83) over time, compared with those not in lockdown.

#### Discretionary food consumption

There was no significant change in the prevalence of high discretionary food consumption over time (PR=0.97, 95% CI=0.86 to 1.09). However, the prevalence was 27% lower for individuals living under lockdown (PR=0.73, 95% CI=0.64 to 0.83) over time, compared with those not in lockdown.

#### Fruit and vegetable intake

The prevalence of insufficient fruit intake increased by 50% over time (PR=1.50, 95% CI=1.26 to 1.79). There were no changes in the prevalence of insufficient vegetable intake over time (PR=1.01, 95% CI=0.97 to 1.06), and the presence of lockdown restrictions was not

associated with a change in the prevalence of insufficient fruit or vegetable intake over time.

There were no gender-based differences in the prevalence of high SSB consumption, high discretionary food consumption or insufficient fruit/vegetable intake over time.

#### Sleep

The prevalence of insufficient sleep decreased by 26% over time (PR=0.74 95% CI=0.68 to 0.81). Girls reported a higher prevalence of insufficient sleep over time, compared with boys (PR=1.24, 95% CI=1.10 to 1.41). The presence of lockdown restrictions was not associated with a change in the prevalence of insufficient sleep over time.

#### Recreational screen time

There was a 6% increase in the prevalence of excessive recreational screen time over time (PR=1.06, 95% CI=1.03 to 1.11). Gender and the presence of lockdown restrictions were not associated with a change in the prevalence of excessive recreational screen time over time.

#### Physical activity

There was no change in the prevalence of insufficient physical activity over time (PR=1.03, 95% CI=1.00 to 1.07). Neither gender nor the presence of lockdown restrictions was associated with change in the prevalence of insufficient physical activity over time.

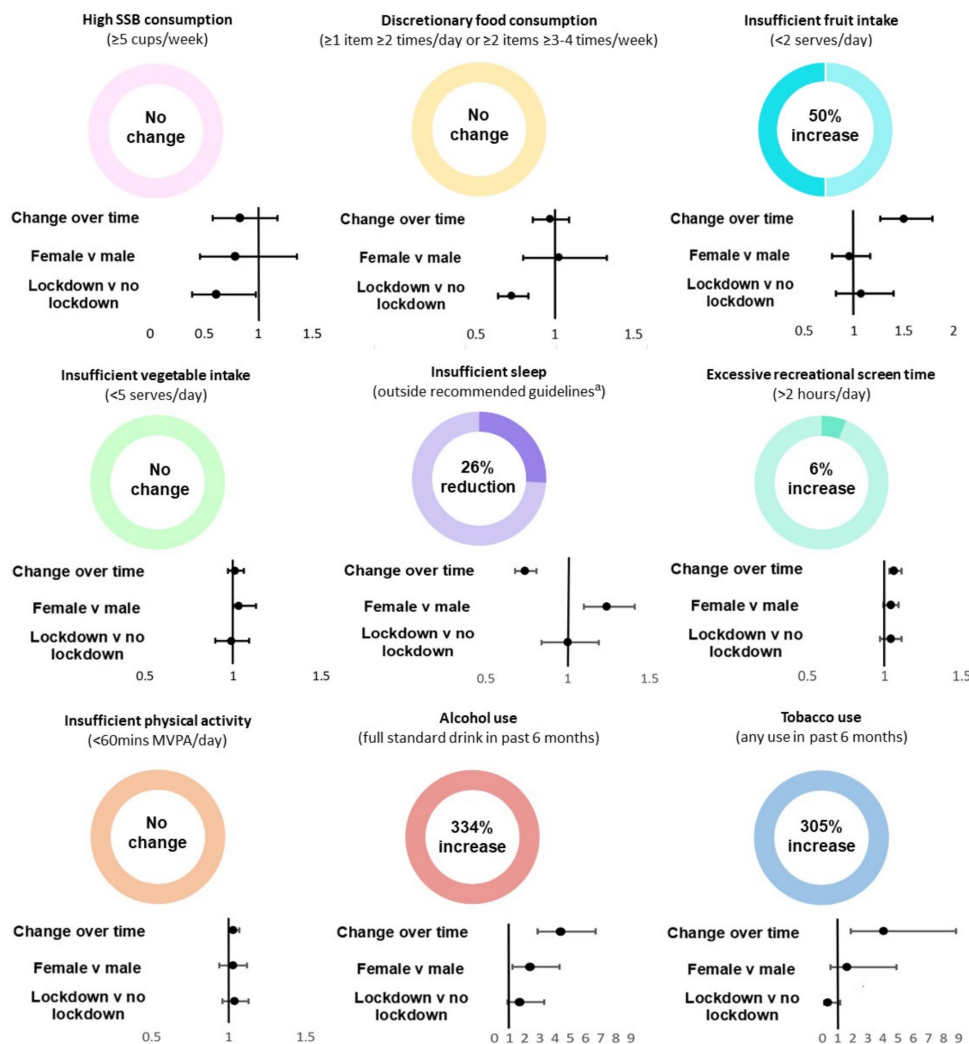
#### Alcohol use

The prevalence of past 6-month alcohol use increased by 334% over time (PR=4.34, 95% CI=2.82 to 6.67). The prevalence of alcohol use increased more in girls compared with boys (PR=2.34, 95% CI=1.19 to 4.62). The presence of lockdown restrictions was not associated with change in the prevalence of past 6-month alcohol use over time.

**Table 2** Prevalence of lifestyle risk behaviours before and during the COVID-19 pandemic

Risk behaviour	Prepandemic (2019), n (%)	During the pandemic (2021), n (%)
High SSB consumption ( $\geq 5$ cups/week)	90/964 (9.3)	72/935 (7.7)
High discretionary food intake ( $\geq 1$ item $\geq 2$ times/day or $\geq 2$ items $\geq 3-4$ times/week)	347/813 (42.7)	360/870 (41.4)
Insufficient fruit intake ( $< 2$ serves/day)	190/960 (19.8)	279/936 (29.8)
Insufficient vegetable intake ( $< 5$ serves/day)	792/958 (82.7)	783/936 (83.7)
Insufficient sleep (outside recommended guidelines*)	549/917 (59.9)	392/885 (44.3)
Excessive recreational screen time ( $> 2$ hours/day)	825/964 (85.6)	878/925 (93.8)
Insufficient physical activity ( $< 60$ min MVPA/day)	757/949 (79.8)	764/931 (82.1)
Alcohol use (full standard drink in past 6 months)	21/940 (2.2)	91/928 (9.8)
Tobacco use (any use in past 6 months)	8/936 (0.9)	32/924 (3.5)

\* $\leq 13$  years old: 9–11 hours/night, 14–17 years: 8–10 hours/night.  
MVPA, moderate-to-vigorous physical activity; SSB, sugar-sweetened beverage.



**Figure 1** Change over time in the prevalence of the Big 6 and differences based on lockdown status and gender. <sup>a</sup>≤13 years old: 9 to 11 hours/night, 14-17 years: 8 to 10 hours/night. MVPA, moderate-to-vigorous physical activity; SSB, sugar-sweetened beverage.

### Tobacco use

The prevalence of past 6-month tobacco use increased by 305% over time (PR=4.05 95% CI=1.86 to 8.84). Neither gender nor the presence of lockdown restrictions was associated with change in the prevalence of past 6-month tobacco use over time.

### DISCUSSION

This study was the first to explore changes in all of the Big 6 lifestyle risk behaviours among a large, geographically diverse cohort of adolescents, from before (2019) to during (2021) the COVID-19 pandemic, and whether changes varied by gender and lockdown status. Over the 2-year period, the prevalence of excessive recreational screen time, insufficient fruit intake and alcohol and tobacco use increased, with alcohol use increasing among girls in particular. The prevalence of insufficient sleep reduced in the overall sample; yet, increased among girls. Being in lockdown was associated with improvements in SSB consumption and discretionary food intake.

These findings highlight the varied impact of the pandemic across countries. For example, consistent with other Australian findings,<sup>3</sup> but in contrast to international research,<sup>18 20</sup> the prevalence of discretionary food intake decreased among those in lockdown. Yet in line with some international findings,<sup>21</sup> SSB intake reduced among adolescents in lockdown. This may reflect increased parental monitoring during lockdown and reduced opportunistic exposure to fast food due to not being with friends or commuting to school.<sup>54 55</sup> As such, continued parental monitoring beyond the lockdown period and the promotion of healthy food options may be beneficial. However, improvements in healthy dietary behaviours were not observed. In fact, the prevalence of insufficient fruit intake increased among the full sample. This may relate to the higher cost of fresh fruit and vegetables in Australia during the pandemic, caused by labour shortages within the farming, wholesale and retail sectors due to fewer working holiday-makers.<sup>56</sup> These findings support calls for governments to consider broader



policy-level changes to improve diet, such as taxes and subsidies.<sup>57</sup>

The finding that sleep duration improved from before to during the pandemic is consistent with some Australian<sup>28</sup> and international<sup>18 20</sup> studies. This contrasts typical trends over adolescence<sup>58 59</sup> and was despite an increase in the prevalence of excessive recreational screen time, which is often considered a primary contributor to poor sleep.<sup>60</sup> It is posited that the time usually spent getting ready and commuting to school is instead spent getting additional sleep during periods of lockdown, leading to calls for delayed school start times<sup>28</sup>; however, we found no differences based on lockdown status to support this. The finding that insufficient sleep increased among girls is consistent with international research reporting increased sleep disorders among girls during the pandemic<sup>27</sup> and may reflect the association between girl pubertal maturation and the emergence of insomnia symptoms.<sup>61</sup> Targeted intervention approaches to address sleep among girls are needed.

Notably, in contrast to previous international and Australian research attributing increased screen time to lockdown and physical distancing measures,<sup>3 4 23</sup> we found no difference in the prevalence of excessive recreational screen time between the lockdown and non-lockdown groups. This increase may instead reflect general trends of increasing screen time among adolescents.<sup>16</sup> These findings highlight the value of assessing behaviours among adolescents both in lockdown and not in lockdown in the same period for comparability, and the need for effective interventions targeting screen time among adolescents.<sup>39</sup>

Contrasting typical trends over adolescence and previous pandemic research,<sup>4 23</sup> the prevalence of insufficient physical activity did not change over time, nor did it increase more for those in lockdown. Previous studies have attributed reductions in physical activity during the pandemic to government responses, such as the cancellation of organised sport and closure of gyms and recreation centres.<sup>1 23</sup> However, given the current data were from the 2021 lockdown, whereas previous studies focused on the initial lockdown in 2020, it may be that over time, adolescents have learnt to adapt to the rapidly changing situation and find other ways to achieve their physical activity goals (eg, replaced organised sport with outdoor gym sessions and training). It may also be that other forms of physical activity, such as light and incidental physical activity, have been more severely impacted. Future research would benefit from assessing how these different forms of physical activities changed throughout the pandemic.

Finally, although alcohol and tobacco use increased over time, the prevalence of these behaviours at the first time-point, when participants were aged 12, was very low and remained relatively low 24 months later. This increase is to be expected among adolescents<sup>62</sup>; however, the greater increase in alcohol use among girls was unexpected. Considering this and the increase in prevalence of insufficient sleep, girls may be disproportionately impacted by the pandemic. This may reflect general patterns of higher

prevalence and increasing trends of mental health problems among adolescent girls across the globe,<sup>63 64</sup> which are often comorbid with poor sleep and substance use; as well as narrowing of the gender gap in alcohol use among more recent cohorts.<sup>35 65</sup> Links between these factors are complex<sup>66</sup> and assessing changes in mental health alongside changes in the Big 6 may be a useful future research direction.

Key strengths of this study include having assessment occasions before and during the pandemic, rather than relying on retrospective accounts of perceived changes in behaviours, and a sample comprised of adolescents both in and not in lockdown at follow-up for comparability. However, we cannot rule out the potential impact of other factors, such as maturation or mental health, that could also be influencing the Big 6. Although the study builds on previous research that has focused on the early pandemic period, claims about behavioural shifts across the early and late pandemic periods need to be interpreted with caution. Other limitations include the reliance on self-report measures, and while the sample was more diverse than other Australian studies, it is limited to three Australian states and is therefore not representative of the entire Australian adolescent population.<sup>14</sup>

## CONCLUSION

Lifestyle risk behaviours, particularly excessive recreational screen time, poor diet, physical inactivity and poor sleep, are prevalent among adolescents and should be addressed with effective behaviour change interventions.<sup>39</sup> With the pandemic remaining a continually evolving situation across the world, the impact on health behaviours is also likely to be dynamic and diverse. Supporting young people to improve or maintain their health behaviours, regardless of the course of the pandemic, is important, alongside targeted research and intervention efforts to support groups that may be disproportionately impacted, such as adolescent girls.

**Twitter** Jennifer Debenham @jennidebenham, Nicola Clare Newton @NickieNewton and Bridie Osman @BridieOsman

**Acknowledgements** The Health4Life Study was led by researchers at the Matilda Centre at the University of Sydney, Curtin University, the University of Queensland, the University of Newcastle, Northwestern University, and UNSW Sydney: MT, NN, F.J. Kay-Lambkin, KC, CC, L.K. Thornton, T. Slade, K.L. Mills, M. Sunderland, J.D. Bauer, B.J. Parmenter, B. Spring, D.R. Lubans, S.J. Ailsop, L. Hides, N.T. McBride, E.L. Barrett, L.A. Stapinski, L. Mewton, L.E. Birrell, C. Quinn and LAG. The authors would like to acknowledge all the research staff who have worked across the study, as well as the schools, students and teachers who participated in this research. The research team also acknowledges the assistance of the New South Wales Department of Education (SERAP 2019006), the Catholic Education Diocese of Bathurst, the Catholic Schools Office Diocese of Maitland-Newcastle, Edmund Rice Education Australia, the Brisbane Catholic Education Committee (373), and Catholic Education Western Australia (RP2019/07) for access to their schools to conduct this research.

**Contributors** LAG conceptualised the study, with assistance from KEC and NCN. Acquisition of the data was contributed to by LAG, KEC, BO, NCN, MT and CC. Analysis and interpretation of data was led by JD and LAG. LAG led the write up of the manuscript with assistance from JD, FEW and BO. All authors critically revised



and approved the final manuscript. LAG is responsible for the overall content as guarantor.

**Funding** The Health4Life Study was funded by the Paul Ramsay Foundation and the Australian National Health and Medical Research Council via Fellowships (KC, APP1120641; MT, APP1078407; and NN, APP1166377) and via a Centre of Research Excellence in the Prevention and Early Intervention in Mental Illness and Substance Use (PREMISE; APP11349009).

**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Ethics approval** This study involves human participants. Ethical approval was gained from the University of Sydney (2018/882), NSW Department of Education (SERAP No. 2019006), University of Queensland (2019000037), Curtin University (HRE2019-0083) and relevant Catholic school committees. Participants gave informed consent to participate in the study before taking part.

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

**Data availability statement** Data are available upon reasonable request.

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

#### ORCID iDs

Lauren Anne Gardner <http://orcid.org/0000-0002-8592-6691>

Jennifer Debenham <http://orcid.org/0000-0002-9596-9484>

Cath Chapman <http://orcid.org/0000-0002-2460-6862>

Katrina Elizabeth Champion <http://orcid.org/0000-0001-8319-9366>

#### REFERENCES

- 1 MCRI COVID-19 Governance Group. *COVID-19 and child and adolescent health*. Victoria, Australia, 2021.
- 2 Caroppo E, Mazza M, Sannella A, et al. Will nothing be the same again?: changes in lifestyle during COVID-19 pandemic and consequences on mental health. *Int J Environ Res Public Health* 2021;18:8433.
- 3 Munasinghe S, Sperandei S, Freebairn L, et al. The impact of physical distancing policies during the COVID-19 pandemic on health and well-being among Australian adolescents. *J Adolesc Health* 2020;67:653–61.
- 4 Li SH, Beames JR, Newby JM, et al. The impact of COVID-19 on the lives and mental health of Australian adolescents. *Eur Child Adolesc Psychiatry* 2021. doi:10.1007/s00787-021-01790-x. [Epub ahead of print: 28 Apr 2021].
- 5 Hale T, Angrist N, Goldszmidt R, et al. A global panel database of pandemic policies (Oxford COVID-19 government response Tracker). *Nat Hum Behav* 2021;5:529–38.
- 6 Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect Dis* 2020;20:533–4.
- 7 Hallas L, Hatibie A, Majumdar S. *Variation in US states' responses to COVID-19 2.0*. Blavatnik School of Government Working Paper, 2020.
- 8 Australian Bureau of Statistics. *State economies and the stringency of COVID-19 containment measures, December quarter 2020*. Canberra, Australia: ABS, 2021.
- 9 COVID-19-AU. COVID-19 in Australia real-time report, 2022. Available: <https://covid-19-au.com/> [Accessed 28 Feb 2022].
- 10 Australian Bureau of Statistics. *National, state and territory population*. Canberra: ABS, 2021.
- 11 Ding D, Rogers K, van der Ploeg H, et al. Traditional and emerging lifestyle risk behaviors and all-cause mortality in middle-aged and older adults: evidence from a large population-based Australian cohort. *PLoS Med* 2015;12:e1001917.
- 12 Lynch BM, Owen N. Too much sitting and chronic disease risk: steps to move the science forward. *Ann Intern Med* 2015;162:146–7.
- 13 Ezzati M, Riboli E. Behavioral and dietary risk factors for noncommunicable diseases. *N Engl J Med Overseas Ed* 2013;369:954–64.
- 14 Champion KE, Chapman C, Gardner LA, et al. Lifestyle risks for chronic disease among Australian adolescents: a cross-sectional survey. *Med J Aust* 2022;216:156–7.
- 15 Guthold R, Stevens GA, Riley LM, et al. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1.6 million participants. *Lancet Child Adolesc Health* 2020;4:23–35.
- 16 Yang L, Cao C, Kantor ED, et al. Trends in sedentary behavior among the US population, 2001–2016. *JAMA* 2019;321:1587–97.
- 17 Australian Institute of Health and Welfare. *Australia's health 2018*. Australia's health series no. 16 AUS 221. Canberra: AIHW, 2018.
- 18 Allabadi H, Dabis J, Aghabekian V. Impact of COVID-19 lockdown on dietary and lifestyle behaviours among adolescents in Palestine. *Dyn Hum Health* 2020;2020:7.
- 19 Stavridou A, Kapsali E, Panagouli E, et al. Obesity in children and adolescents during COVID-19 pandemic. *Children* 2021;8:135.
- 20 Pietrobelli A, Pecoraro L, Ferruzzi A, et al. Effects of COVID-19 Lockdown on lifestyle behaviors in children with obesity living in Verona, Italy: a longitudinal study. *Obesity* 2020;28:1382–5.
- 21 Ruiz-Roso MB, de Carvalho Padilha P, Mantilla-Escalante DC, et al. Covid-19 Confinement and Changes of Adolescent's Dietary Trends in Italy, Spain, Chile, Colombia and Brazil. *Nutrients* 2020;12:1807.
- 22 Bates L, Zieff G, Stanford K, et al. COVID-19 impact on behaviors across the 24-hour day in children and adolescents: physical activity, sedentary behavior, and sleep. *Children* 2020;7:138.
- 23 Reece LJ, Owen K, Foley B, et al. Understanding the impact of COVID-19 on children's physical activity levels in NSW, Australia. *Health Promot J Austr* 2021;32:365–6.
- 24 Lu C, Chi X, Liang K, et al. Moving more and sitting less as healthy lifestyle behaviors are protective factors for insomnia, depression, and anxiety among adolescents during the COVID-19 pandemic. *Psychol Res Behav Manag* 2020;13:1223–33.
- 25 Olive L, Sciberras E, Berkowitz TS. Child and parent physical activity, sleep and screen time during COVID-19 compared to pre-pandemic nationally representative data and associations with mental health 2020.
- 26 Schmidt SCE, Anedda B, Burchartz A, et al. Physical activity and screen time of children and adolescents before and during the COVID-19 lockdown in Germany: a natural experiment. *Sci Rep* 2020;10:21780.
- 27 Fidanci İzzet, Aksoy H, Yengil Taci D, et al. Evaluation of the effect of the COVID-19 pandemic on sleep disorders and nutrition in children. *Int J Clin Pract* 2021;75:e14170.
- 28 Stone JE, Phillips AJK, Chachos E, et al. In-person vs home schooling during the COVID-19 pandemic: differences in sleep, circadian timing, and mood in early adolescence. *J Pineal Res* 2021;71:e12757.
- 29 Dumas TM, Ellis W, Litt DM. What does adolescent substance use look like during the COVID-19 pandemic? Examining changes in frequency, social contexts, and Pandemic-Related predictors. *J Adolesc Health* 2020;67:354–61.
- 30 Rogés J, Bosque-Prous M, Colom J, et al. Consumption of alcohol, cannabis, and tobacco in a cohort of adolescents before and during COVID-19 confinement. *Int J Environ Res Public Health* 2021;18:7849.
- 31 Chaffee BW, Cheng J, Couch ET, et al. Adolescents' substance use and physical activity before and during the COVID-19 pandemic. *JAMA Pediatr* 2021;175:715–22.
- 32 Benschop A, van Bakkum F, Noijen J. Changing patterns of substance use during the coronavirus pandemic: self-reported use of tobacco, alcohol, cannabis, and other drugs. *Front Psychiatry* 2021;12:633551.
- 33 Matovu JKB, Kabwama SN, Ssekamatte T, et al. COVID-19 awareness, adoption of COVID-19 preventive measures, and effects of COVID-19 Lockdown among adolescent boys and young men in Kampala, Uganda. *J Community Health* 2021;46:842–53.
- 34 Active Healthy Kids Australia. *Physical literacy: do our kids have all the tools? the 2016 active healthy kids Australia report card on physical activity for children and young people*. Adelaide, South Australia: Active Healthy Kids Australia, 2016.
- 35 Inchley J, Currie D, Vieno A. *Adolescent alcohol-related behaviours: trends and inequalities in the who European region, 2002–2014*:

- observations from the health behaviour in school-aged children (HBSC) who Collaborative cross-national study. Copenhagen: World Health organization, Regional Office for Europe, 2018: viii. + 83 p.
- 36 Bucksch J, Sigmundova D, Hamrik Z, et al. International trends in adolescent Screen-Time behaviors from 2002 to 2010. *J Adolesc Health* 2016;58:417–25.
  - 37 Centers for Disease Control and Prevention (CDC). 1991–2019 high school youth risk behavior survey data, 2021.
  - 38 Morley B, Scully M, Niven P. *National secondary students' diet and activity (NaSSDA) survey, 2012–13*. Melbourne: Cancer Council Victoria, 2014.
  - 39 Teesson M, Champion KE, Newton NC, et al. Study protocol of the Health4Life initiative: a cluster randomised controlled trial of an eHealth school-based program targeting multiple lifestyle risk behaviours among young Australians. *BMJ Open* 2020;10:e035662.
  - 40 Bower M, Smout S, Ellsmore S. *COVID-19 and Australia's mental health: An overview of academic literature, policy documents, lived experience accounts, media and community reports*. Sydney, NSW: Australia's Mental Health Think Tank, 2021.
  - 41 NSW Health. *Public health (COVID-19 temporary movement and gathering restrictions) order 2021 under the public health act 2010*. NSW, Australia, 2021.
  - 42 Hardy LL, Mihrshahi S, Drayton BA. *Nsw schools physical activity and nutrition survey (spans) 2015: full report*. Sydney: NSW Department of Health, 2016.
  - 43 National Health and Medical Research Council. *Australian dietary guidelines*. Canberra: National Health and Medical Research Council, 2013.
  - 44 Active Healthy Kids Australia. *Physical literacy: do our kids have all the tools? the 2016 report card on physical activity for children and young people*. Adelaide, 2016.
  - 45 The Australian Government Department of Health. *Australian 24-hour movement guidelines for children and young people (5 to 17 years): an integration of physical activity, sedentary behaviour, and sleep*. Canberra: Commonwealth of Australia, 2019.
  - 46 Prince SA, LeBlanc AG, Colley RC, et al. Measurement of sedentary behaviour in population health surveys: a review and recommendations. *PeerJ* 2017;5:e4130.
  - 47 Short MA, Gradisar M, Lack LC, et al. Estimating adolescent sleep patterns: parent reports versus adolescent self-report surveys, sleep diaries, and actigraphy. *Nat Sci Sleep* 2013;5:23–6.
  - 48 Golley RK, Maher CA, Matricciani L, et al. Sleep duration or bedtime? exploring the association between sleep timing behaviour, diet and BMI in children and adolescents. *Int J Obes* 2013;37:546–51.
  - 49 Nascimento-Ferreira MV, Collese TS, de Moraes ACF, et al. Validity and reliability of sleep time questionnaires in children and adolescents: a systematic review and meta-analysis. *Sleep Med Rev* 2016;30:85–96.
  - 50 CDC CfDcAp. *National youth risk behavior survey*. U.S. Department of Health and Human Services, 2019.
  - 51 Australian Institute of Health and Welfare. *National drug strategy household survey 2016: detailed findings*. Canberra: AIHW, 2017.
  - 52 Deddens JA, Petersen MR. Approaches for estimating prevalence ratios. *Occup Environ Med* 2008;65:501–6.
  - 53 StataCorp LLC. *Stata Statistical Software: Release 17 [program]*. College Station: TX: StataCorp LLC, 2021.
  - 54 Scully M, Morley B, Niven P, et al. Factors associated with frequent consumption of fast food among Australian secondary school students. *Public Health Nutr* 2020;23:1340–9.
  - 55 Haszard JJ, Skidmore PML, Williams SM, et al. Associations between parental feeding practices, problem food behaviours and dietary intake in New Zealand overweight children aged 4–8 years. *Public Health Nutr* 2015;18:1036–43.
  - 56 ABARES. *Agricultural commodities: September quarter 2021*. Canberra: Australian Bureau of Agricultural and Resource Economics and Sciences, 2021.
  - 57 Cobiac LJ, Tam K, Veerman L, et al. Taxes and subsidies for improving diet and population health in Australia: a cost-effectiveness modelling study. *PLoS Med* 2017;14:e1002232.
  - 58 Keyes KM, Maslowsky J, Hamilton A, et al. The great sleep recession: changes in sleep duration among US adolescents, 1991–2012. *Pediatrics* 2015;135:460.
  - 59 Olds T, Maher C, Blunden S, et al. Normative data on the sleep habits of Australian children and adolescents. *Sleep* 2010;33:1381–8.
  - 60 Xu F, Adams SK, Cohen SA, et al. Relationship between physical activity, screen time, and sleep quantity and quality in US adolescents aged 16–19. *Int J Environ Res Public Health* 2019;16:1524.
  - 61 Zhang J, Chan NY, Lam SP, et al. Emergence of sex differences in insomnia symptoms in adolescents: a large-scale school-based study. *Sleep* 2016;39:1563–70.
  - 62 Guerin N, White V. *ASSAD 2017 Statistics & Trends: Australian Secondary Students' Use of Tobacco, Alcohol, Over-the-counter Drugs, and Illicit Substances*. Cancer Council Victoria, 2018.
  - 63 Campbell OLK, Bann D, Patalay P. The gender gap in adolescent mental health: a cross-national investigation of 566,829 adolescents across 73 countries. *SSM Popul Health* 2021;13:100742.
  - 64 Högberg B, Strandh M, Hagquist C. Gender and secular trends in adolescent mental health over 24 years - The role of school-related stress. *Soc Sci Med* 2020;250:112890.
  - 65 Slade T, Chapman C, Swift W, et al. Birth cohort trends in the global epidemiology of alcohol use and alcohol-related harms in men and women: systematic review and metaregression. *BMJ Open* 2016;6:e011827.
  - 66 Patalay P, Gage SH. Changes in millennial adolescent mental health and health-related behaviours over 10 years: a population cohort comparison study. *Int J Epidemiol* 2019;48:1650–64.