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## Lifestyle Risk Behaviours among Adolescents: A Two-Year Longitudinal Study of the Impact of the COVID-19 Pandemic

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Complete List of Authors:	Gardner, Lauren; The University of Sydney, The Matilda Centre for Research Excellence in Mental Health and Substance Use Debenham, Jennifer; The University of Sydney, The Matilda Centre for Research Excellence in Mental Health and Substance Use Newton, Nicola; The University of Sydney, The Matilda Centre for Research Excellence in Mental Health and Substance Use Chapman, Cath; The University of Sydney, The Matilda Centre for Research Excellence in Mental Health and Substance Use Wylie, Fiona; Macquarie University Osman, Bridie; The University of Sydney, The Matilda Centre for Research Excellence in Mental Health and Substance Use Teesson, Maree; The University of Sydney, The Matilda Centre for Research Excellence in Mental Health and Substance Use Champion, Katrina; The University of Sydney, The Matilda Centre for Research Excellence in Mental Health and Substance Use
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3 **Lifestyle Risk Behaviours among Adolescents: A Two-Year Longitudinal Study**  
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5 **of the Impact of the COVID-19 Pandemic**  
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11 Lauren A. Gardner<sup>1</sup>  
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14 Jennifer Debenham<sup>1</sup>  
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16  
17 Nicola C. Newton<sup>1</sup>  
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19  
20 Cath Chapman<sup>1</sup>  
21

22  
23 Fiona Wylie<sup>2</sup>  
24

25  
26 Bridie Osman<sup>1</sup>  
27

28  
29 Maree Teesson<sup>1</sup>  
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31  
32 Katrina E. Champion<sup>1</sup>  
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35  
36 <sup>1</sup>The Matilda Centre for Research Excellence in Mental Health and Substance Use,  
37  
38 University of Sydney, Sydney, Australia

39  
40 <sup>2</sup>Macquarie University, Sydney, Australia  
41

42  
43 Corresponding author: Dr Lauren Gardner, The Matilda Centre, Level 6 Jane Foss Russell  
44  
45 Building, The University of Sydney, NSW, 2006. Email: [lauren.gardner@sydney.edu.au](mailto:lauren.gardner@sydney.edu.au)  
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## Abstract

**Objective:** To examine changes in the prevalence of six key chronic disease risk factors, 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 3000km.

**Participants:** 983 adolescents (baseline  $M_{age}=12.6$ ,  $SD=0.5$ , 54.8% female) 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 ( $PR=1.06$ , 95%  $CI=1.03-1.11$ ), insufficient fruit intake ( $PR=1.50$ , 95%  $CI=1.26-1.79$ ), and alcohol ( $PR=4.34$ , 95%  $CI=2.82-6.67$ ) and tobacco use ( $PR=4.05$ , 95%  $CI=1.86-8.84$ ) increased over the two-year period, with alcohol use increasing more among females ( $PR=2.34$ , 95%  $CI=1.19-4.62$ ). The prevalence of insufficient sleep declined across the full sample ( $PR=0.74$ , 95%  $CI=0.68-0.81$ ); however, increased among females ( $PR=1.24$ , 95%  $CI=1.10-1.41$ ). The prevalence of high sugar-sweetened beverage ( $PR=0.61$ , 95%  $CI=0.64-0.83$ ) and discretionary food consumption ( $PR=0.73$ , 95%  $CI=0.64-0.83$ ) reduced among those subjected to stay-at-home orders, compared to those not in lockdown.

**Conclusion:** Lifestyle risk behaviours are prevalent among adolescents, and they 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 females, are needed.

**Key words:** COVID-19 pandemic, adolescents, physical activity, diet, sleep, recreational screen time, alcohol, tobacco, lifestyle risk behaviours

### **Strengths and limitations of this study**

- This is the first study 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 3000km.
- The prospective design, beginning before the start of the COVID-19 pandemic, and inclusion of participants both in and not in lockdown at follow-up overcomes limitations of previous research (e.g., samples typically being from one city and all in lockdown, and a reliance on retrospective accounts of perceived changes in behaviour).
- Limitations of the research include the reliance on self-report measures, and while the sample was diverse, it was limited to three states and is not representative of the Australian population.

## **Lifestyle Risk Behaviours among Adolescents: A Two-Year Longitudinal Study of the Impact of the COVID-19 Pandemic**

The global spread of COVID-19 and subsequent lockdown measures have presented challenges worldwide. Government responses, such as movement restrictions and school closures, present 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>1-3</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.

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- and long-term health of adolescents.<sup>4-7</sup> These behaviours are common among youth worldwide, with more than 80% of adolescents insufficiently physically active<sup>8</sup> and screen time rapidly increasing.<sup>7,9</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>6,10</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>11,12</sup> which may be the result of increased consumption of discretionary food and sugar-sweetened beverages (SSB) during lockdown periods.<sup>11,13</sup> However, some studies report improvements in dietary behaviours, including less SSB consumption among

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3 Colombian adolescents, higher fruit intake among Italian youth, and higher vegetable intake  
4 among adolescents from Spain, Brazil and Chile.<sup>13 14</sup> Among the few existing Australian  
5 studies, Munasinghe et al.<sup>2</sup> found physical distancing measures implemented in the initial  
6 lockdown period (March-April 2020) were associated with a decline in fast food consumption  
7 among adolescents, but there were no changes in fruit and vegetable consumption. However,  
8 it is unknown whether these changes have been sustained, or whether other dietary  
9 behaviours changed.

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20 The pandemic presents particular challenges for movement behaviours, including  
21 physical activity, sedentary behaviour and sleep. Typically, lockdowns are associated with  
22 lower levels of adolescent physical activity<sup>3 11 13 15 16</sup> and increased screen time, both for  
23 remote learning and recreation, resulting in sedentary lifestyles.<sup>2 3 16 17</sup> However, some  
24 research in Australia<sup>18</sup> and Germany<sup>19</sup> suggests physical activity increased.<sup>19</sup> International  
25 studies also report an increase in adolescent sleep duration during lockdown periods,<sup>11 13</sup> but  
26 higher prevalence of sleep problems, particularly among girls.<sup>20</sup> Similarly, Australian  
27 adolescents perceived an increase in sleep difficulties and had increased sleep disturbance  
28 during the first lockdown.<sup>18</sup> One study<sup>21</sup> reported increased sleep duration among Australian  
29 adolescents who were engaged in remote learning, however another<sup>2</sup> found no changes.

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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>22</sup> reduced among Spanish adolescents,<sup>23</sup> while there was no  
change in alcohol or tobacco use among adolescents from the United States.<sup>24</sup> Further,  
European research suggests a reduction in adolescent tobacco use during the pandemic  
period,<sup>23 25</sup> yet there has been an increase in Uganda.<sup>26</sup> To date, changes in alcohol and  
tobacco use among Australian adolescents have not been examined.



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3 Evidence suggests that the prevalence of the Big 6 varies by gender. For example,  
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5 adolescent females are more likely to be physically inactive, whereas males are more likely to  
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7 engage in high levels of recreational screen time, have a poor diet, and use alcohol and  
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9 tobacco.<sup>8 27-31</sup> However, less is known about whether changes in lifestyle behaviours over the  
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11 pandemic period vary by gender.  
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15 To address these gaps in the literature, this study aims to examine changes in the  
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17 prevalence of the Big 6 among a large, geographically diverse sample of adolescents, from  
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19 before to during the COVID-19 pandemic, and explore whether differences over time are  
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21 associated with gender and lockdown status.  
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## 24 25 **Methods**

### 26 27 **Participants and Procedure**

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29 The sample comprised participants from three Australian states [New South Wales  
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31 (NSW), Queensland (QLD), and Western Australia (WA)], spanning over 3000km, who were  
32  
33 randomly allocated to the control group of the Health4Life Study.<sup>32</sup> Participants with consent  
34  
35 completed self-report assessments in a supervised classroom setting. Only students who  
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37 provided data prior to the beginning of the pandemic (between July-November 2019) and  
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39 during the pandemic (approximately 24-months after baseline, between July and 10<sup>th</sup> October  
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41 2021) were included in this study. During the 2021 data collection period, Australia had strict  
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43 border policies, restricting international travel and mandating hotel quarantine, while state-  
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45 and territory-level border policies for domestic travel varied.<sup>33</sup> Greater Sydney, including the  
46  
47 Central Coast, Shellharbour and Wollongong, were subjected to lockdown restrictions under  
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49 the NSW stay-at-home Public Health Order (e.g.,<sup>34</sup>); the most stringent of which included not  
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51 being permitted to leave the home unless essential (e.g., one person per household to shop for  
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53 food or one hour of exercise per day), movement restricted to a 5km radius of the home,  
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3 closure of all non-essential retail (e.g., hairdressers), home-based work and schooling  
4 requirements, curfews, and mandatory mask wearing, with a high police presence and large  
5 fines enforced for nonadherence. QLD, WA and areas outside of Greater Sydney were not  
6 subjected to extended stay-at-home lockdown restrictions.  
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### 13 **Research Ethics Approval**

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16 Ethical approval was gained from the University of Sydney (2018/882), NSW  
17 Department of Education (SERAP No. 2019006), University of Queensland (2019000037),  
18 Curtin University (HRE2019-0083) and relevant Catholic school committees.<sup>32</sup>  
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### 23 **Patient and Public Involvement**

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26 Patients or the public were not involved in the design, or conduct, or reporting, or  
27 dissemination plans of our research.  
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### 32 **Measures**

#### 33 *Sociodemographic characteristics*

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36 Participants self-reported their age and gender (male, female, non-binary/gender fluid,  
37 missing). A binary “lockdown” variable was created reflecting participants who attended  
38 schools in the Greater Sydney region that were subjected to the stay-at-home Public Health  
39 Order in 2021 and those who were not.<sup>34</sup>  
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#### 47 *Diet*

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50 Dietary intake was assessed using items adapted from the NSW School Physical  
51 Activity and Nutrition Survey (SPANS)<sup>35</sup>. Participants self-reported the number of metric  
52 cups of SSB usually consumed per week or day. A binary variable was created to reflect high  
53 ( $\geq 5$ -6 cups or more/week) and low consumption ( $\leq 4$  cups/week). Participants reported how  
54 often they consume six discretionary food items (hot chips, French fries, wedges or fried  
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3 potatoes; potato crisps or other salty snacks; snack foods e.g., sweet and savoury biscuits,  
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5 cakes, donuts or muesli bars; confectionary; ice cream or ice blocks; and, takeaway meals or  
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7 snacks). High discretionary food consumption was defined as eating any of the items '2 or  
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9 more times/day', or eating at least two of the items '3-4 times/week' or more often.

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12 Participants reported the number of serves of fruit and vegetables consumed per day, and in  
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14 line with the Australian dietary guidelines,<sup>36</sup> insufficient fruit and vegetable consumption was  
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16 defined as <2 serves of fruit and <5 serves of vegetables per day, respectively.

### 17 18 19 ***Physical activity***

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23 A single item was used to assess the number of days over the past week that  
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25 participants engaged in moderate-to-vigorous physical activity for at least 60 minutes.<sup>37</sup> As  
26  
27 per the Australian health guideline, insufficient physical activity was defined as engaging in  
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29 <60 minutes of moderate-to-vigorous physical activity/day.<sup>38</sup>

### 30 31 32 33 ***Recreational screen time***

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36 The International Sedentary Assessment Tool<sup>39</sup> was used to evaluate free time spent  
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38 on a typical weekday and weekend day over the past seven days watching  
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40 television/DVDs/streaming services or using an electronic device. In line with the Australian  
41  
42 health guideline,<sup>38</sup> excessive recreational screen time was defined as >2 hours/day.

### 43 44 45 46 ***Sleep***

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49 The Modified Sleep Habits Survey<sup>40</sup> was used to assess sleep duration. Total sleep  
50  
51 time was calculated by finding the difference between the time participants reported first  
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53 attempting sleep, and the time they woke up in the morning, minus the reported time taken to  
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55 fall asleep from first attempt, with a weighted average sleep duration calculated for school  
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57 and weekend nights. Self-reported bedtime, waketime, and sleep duration have been shown to  
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59 be reliable and valid in adolescent populations.<sup>41 42</sup> As per the Australian guidelines,

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3 insufficient sleep was defined as an average duration outside of 9-11 hours/night for those  
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5 aged 11-13 years, or 8-10 hours/night for those aged 14-17 years.<sup>38</sup>  
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### 8 *Alcohol and Tobacco Use*

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11 Alcohol and tobacco use were measured using two dichotomous (yes/no) items drawn  
12  
13 from previous large scale trials and population based epidemiological surveys:<sup>43 44</sup> “Have you  
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15 had a full standard alcoholic drink in the past 6 months?” and “In the past 6 months, have you  
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17 tried cigarette smoking, even one or two puffs?”  
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### 20 **Statistical Analysis**

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24 Generalized linear mixed models (GLMM) were used to investigate change over time  
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26 in the Big 6. Owing to the high prevalence of outcomes, we used Robust Poisson methods to  
27  
28 generate prevalence ratios (PR) and 95% confidence intervals (CI), to overcome some of the  
29  
30 limitations of reporting odds ratios from logistic regressions, which may appear inflated.<sup>45</sup> All  
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32 models included a random intercept at the student- and school-level, Robust Poisson  
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34 distribution and a log link function, where time is continuous and represents the pre-  
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36 pandemic (2019) and mid-pandemic scores (2021). Group by time interactions were  
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38 estimated to assess change in the prevalence of the Big 6 over time in relation to gender  
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40 (female/male, given the low prevalence of the “non-binary/gender fluid” [.1%] and “prefer  
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42 not to say” [.5%] subgroups) and the presence of lockdown restrictions during the 2021  
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44 survey occasion. All analyses were conducted in Stata V17.<sup>46</sup>  
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## 50 **Results**

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### 52 **Descriptive Statistics**

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56 The sample included 983 students (baseline  $M_{age}=12.6$ ,  $SD=0.5$ , 54.8% female) from  
57  
58 22 schools across NSW, QLD, and WA (see Table 1 for baseline characteristics). At the 2021  
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3 survey occasion, approximately one-third of the sample (32.7%) were under lockdown  
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5 restrictions. Table 2 presents the prevalence of lifestyle risk behaviours over time.  
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11 **Table 1**

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13 *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)

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

<b>Risk Behaviour</b>	<b>Pre-pandemic (2019) n (%)</b>	<b>During the pandemic (2021) n (%)</b>
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 <sup>a</sup> )	549/917 (59.9)	392/885 (44.3)
Excessive recreational screen time ( $> 2$ hrs/day)	825/964 (85.6)	878/925 (93.8)
Insufficient physical activity ( $< 60$ mins 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)

*Note.* SSB=sugar-sweetened beverage, <sup>a</sup> $\leq 13$  years old: 9 to 11 hours/night, 14-17years: 8 to 10 hours/night, MVPA=moderate-to-vigorous physical activity.

### **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 prevalence ratios and confidence intervals detailed in Supplementary 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=0.58-1.18). However, the prevalence was 39% lower in individuals under lockdown (PR=0.61, 95% CI=0.64-0.83) over time, compared to those not in lockdown.

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3 **Discretionary food consumption.** There was no significant change in the prevalence  
4 of high discretionary food consumption over time (PR=0.97, 95% CI=0.86-1.09). However,  
5 the prevalence was 27% lower for individuals living under lockdown (PR=0.73, 95%  
6 CI=0.64-0.83) over time, compared to those not in lockdown.  
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13 **Fruit and vegetable intake.** The prevalence of insufficient fruit intake increased by  
14 50% over time (PR=1.50, 95% CI=1.26-1.79). There were no changes in the prevalence of  
15 insufficient vegetable intake over time (PR=1.01, 95% CI=0.97-1.06), and the presence of  
16 lockdown restrictions was not associated with a change in the prevalence of insufficient fruit  
17 or vegetable intake over time.  
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25 There were no gender-based differences in the prevalence of high SSB consumption,  
26 high discretionary food consumption, or insufficient fruit/vegetable intake over time.  
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### 30 *Sleep*

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33 The prevalence of insufficient sleep decreased by 26% over time (PR=0.74 95%  
34 CI=0.68-0.81). Females reported a higher prevalence of insufficient sleep over time,  
35 compared to males (PR=1.24, 95% CI=1.10-1.41). The presence of lockdown restrictions was  
36 not associated with a change in the prevalence of insufficient sleep over time.  
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### 43 *Recreational screen time*

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46 There was a 6% increase in the prevalence of excessive recreational screen time over  
47 time (PR=1.06, 95% CI=1.03-1.11). Gender and the presence of lockdown restrictions were  
48 not associated with a change in the prevalence of excessive recreational screen time over  
49 time.  
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### 55 *Physical activity*

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3 There was no change in the prevalence of insufficient physical activity over time  
4 (PR=1.03, 95% CI=1.00-1.07). Neither gender nor the presence of lockdown restrictions was  
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6 associated with change in the prevalence of insufficient physical activity over time.  
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### 9 10 *Alcohol use*

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13 The prevalence of past 6-month alcohol use increased by 334% over time (PR=4.34,  
14 95% CI=2.82-6.67). The prevalence of alcohol use increased more in females compared to  
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16 males (PR=2.34, 95% CI=1.19-4.62). The presence of lockdown restrictions was not  
17  
18 associated with change in the prevalence of past 6-month alcohol use over time.  
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### 22 23 *Tobacco use*

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25 The prevalence of past 6-month tobacco use increased by 305% over time (PR=4.05  
26 95% CI=1.86-8.84). Neither gender nor the presence of lockdown restrictions was associated  
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28 with change in the prevalence of past 6-month tobacco use over time.  
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## 32 33 **Discussion**

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35 This study was the first to explore changes in all of the Big 6 lifestyle risk behaviours  
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37 among a large, geographically diverse cohort of adolescents, from before (2019) to during  
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39 (2021) the COVID-19 pandemic, and whether changes varied by gender and lockdown status.  
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41 Over the two-year period, the prevalence of excessive recreational screen time, insufficient  
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43 fruit intake, and alcohol and tobacco use increased, with alcohol use increasing among  
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45 females in particular. The prevalence of insufficient sleep reduced in the overall sample; yet,  
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47 increased among females. Being in lockdown was associated with improvements in SSB  
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49 consumption and discretionary food intake.  
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55 These findings highlight the varied impact of the pandemic across countries. For  
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57 example, consistent with other Australian findings,<sup>2</sup> but in contrast to international research,<sup>11</sup>  
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3 13 the prevalence of discretionary food intake decreased among those in lockdown. Yet in line  
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5 with some international findings,<sup>14</sup> SSB intake reduced among adolescents in lockdown. This  
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7 may reflect increased parental monitoring during lockdown and reduced opportunistic  
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9 exposure to fast food due to not being with friends or commuting to school.<sup>47 48</sup> As such,  
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11 continued parental monitoring beyond the lockdown period and the promotion of healthy  
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13 food options may be beneficial. However, improvements in healthy dietary behaviours were  
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15 not observed. In fact, the prevalence of insufficient fruit intake increased among the full  
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17 sample. This may relate to the higher cost of fresh fruit and vegetables in Australia during the  
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19 pandemic, caused by labour shortages within the farming, wholesale and retail sectors due to  
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21 fewer working holiday makers.<sup>49</sup> These findings support calls for governments to consider  
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23 broader policy-level changes to improve diet, such as taxes and subsidies.<sup>50</sup>  
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29 The finding that sleep duration improved from before to during the pandemic is consistent  
30  
31 with some Australian<sup>21</sup> and international<sup>11 13</sup> studies. This contrasts typical trends over  
32  
33 adolescence<sup>51 52</sup> and was despite an increase in the prevalence of excessive recreational  
34  
35 screen time, which is often considered a primary contributor to poor sleep.<sup>53</sup> It is posited that  
36  
37 the time usually spent getting ready and commuting to school is instead spent getting  
38  
39 additional sleep during periods of lockdown, leading to calls for delayed school start times;<sup>21</sup>  
40  
41 however, we found no differences based on lockdown status to support this. The finding that  
42  
43 insufficient sleep increased among females is consistent with international research reporting  
44  
45 increased sleep disorders among females during the pandemic<sup>20</sup> and may reflect the  
46  
47 association between female pubertal maturation and the emergence of insomnia symptoms.<sup>54</sup>  
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49 Targeted intervention approaches to address sleep among females are needed.  
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55 Notably, in contrast to previous international and Australian research attributing increased  
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57 screen time to lockdown and physical distancing measures,<sup>2 3 16</sup> we found no difference in the  
58  
59 prevalence of excessive recreational screen time between the lockdown and non-lockdown  
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3 groups. This increase may instead reflect general trends of increasing screen time among  
4 adolescents.<sup>9</sup> These findings highlight the value of assessing behaviours amongst adolescents  
5 both in lockdown and not in lockdown in the same period for comparability, and the need for  
6 effective interventions targeting screen time among adolescents.<sup>32</sup>  
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13 Contrasting previous research and typical trends over adolescence,<sup>3 16</sup> the prevalence  
14 of insufficient physical activity did not increase more for those in lockdown. Given data were  
15 from the 2021 lockdown, whereas previous studies focused on the initial lockdown in 2020, it  
16 may be that over time, adolescents have learnt to adapt to the rapidly changing situation and  
17 find other ways to achieve their physical activity goals. It may also be that other forms of  
18 physical activity, such as light and incidental physical activity, have been more severely  
19 impacted.  
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30 Finally, although alcohol and tobacco use increased over time, the prevalence of these  
31 behaviours at the first timepoint, when participants were aged 12, was very low and remained  
32 relatively low 24-months later. This increase is to be expected among adolescents,<sup>55</sup> however,  
33 the greater increase in alcohol use among females was unexpected. Considering this and the  
34 increase in prevalence of insufficient sleep, females may be disproportionately impacted by  
35 the pandemic. This may reflect general patterns of higher prevalence and increasing trends of  
36 mental health problems among adolescent females across the globe,<sup>56 57</sup> which are often  
37 comorbid with poor sleep and substance use; as well as narrowing of the gender gap in  
38 alcohol use among more among recent cohorts.<sup>28 58</sup> Links between these factors are  
39 complex<sup>59</sup> and assessing changes in mental health alongside changes in the Big 6 may be a  
40 useful future research direction.  
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55 Key strengths of this study include having assessment occasions before and during the  
56 pandemic, rather than relying on retrospective accounts of perceived changes in behaviours,  
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3 and a sample comprised of adolescents both in and not in lockdown at follow-up for  
4 comparability. However, we can't rule out the potential impact of other factors, such as  
5 maturation or mental health, that could also be influencing the Big 6. Although the study  
6 builds on previous research that has focused on the early pandemic period, claims about  
7 behavioural shifts across the early and late pandemic periods need to be interpreted with  
8 caution. Other limitations include the reliance on self-report measures, and while the sample  
9 was more diverse than other Australian studies, it is still not representative of the adolescent  
10 population.<sup>7</sup>

## 21 **Conclusion**

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25 Compared to pre-pandemic levels, the prevalence of excessive recreational screen  
26 time, insufficient fruit intake and alcohol/tobacco use increased among adolescents during the  
27 pandemic, while the prevalence of insufficient sleep decreased, regardless of lockdown  
28 status. The lockdown was, however, associated with a decreased prevalence of high SSB and  
29 discretionary food intake, and the prevalence of insufficient sleep and alcohol use increased  
30 more over time among females. Although unchanged, physical inactivity and insufficient  
31 vegetable intake remained highly prevalent, and should be addressed alongside the other risk  
32 behaviours with effective behaviour change interventions.<sup>32</sup> With the pandemic remaining a  
33 continually evolving situation across the world, the impact on health behaviours is also likely  
34 to be dynamic and diverse. Supporting young people to improve or maintain their health  
35 behaviours, regardless of the course of the pandemic, is important, alongside targeted  
36 research and intervention efforts to support groups that may be disproportionately impacted,  
37 such as adolescent females.

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38  
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48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

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## References

1. 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(16) doi: 10.3390/ijerph18168433 [published Online First: 2021/08/28]
2. 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(5):653-61. doi: 10.1016/j.jadohealth.2020.08.008 [published Online First: 2020/10/26]
3. Li SH, Beames JR, Newby JM, et al. The impact of COVID-19 on the lives and mental health of Australian adolescents. *European Child & Adolescent Psychiatry* 2021 doi: 10.1007/s00787-021-01790-x
4. 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 medicine* 2015;12(12):e1001917.
5. Lynch BM, Owen N. Too much sitting and chronic disease risk: steps to move the science forward. *Annals of Internal Medicine* 2015;162(2):146-47.
6. Ezzati M, Riboli E. Behavioral and Dietary Risk Factors for Noncommunicable Diseases. *New England Journal of Medicine* 2013;369(10):954-64. doi: 10.1056/NEJMra1203528
7. Champion\* KE, Chapman\* C, Gardner LA, et al. Lifestyle risks for chronic disease among Australian adolescents: a cross-sectional survey. *Medical Journal of Australia* 2021:(\*equally credited first authors). doi: <https://doi.org/10.5694/mja2.51333>
8. 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&#xb7;6

- 1  
2  
3 million participants. *The Lancet Child & Adolescent Health* 2020;4(1):23-35. doi:  
4  
5 10.1016/S2352-4642(19)30323-2  
6  
7  
8 9. Yang L, Cao C, Kantor ED, et al. Trends in Sedentary Behavior Among the US  
9  
10 Population, 2001-2016. *JAMA* 2019;321(16):1587-97. doi: 10.1001/jama.2019.3636  
11  
12 10. Australian Institute of Health and Welfare. Australia's health 2018. Australia's health  
13 series no. 16 AUS 221. Canberra: AIHW, 2018.  
14  
15 11. Allabadi H, Dabis J, Aghabekian V, et al. Impact of COVID-19 lockdown on dietary and  
16 lifestyle behaviours among adolescents in Palestine. 2020  
17  
18 12. Stavridou A, Kapsali E, Panagouli E, et al. Obesity in Children and Adolescents during  
19 COVID-19 Pandemic. *Children* 2021;8(2):135.  
20  
21 13. Pietrobelli A, Pecoraro L, Ferruzzi A, et al. Effects of COVID-19 Lockdown on Lifestyle  
22 Behaviors in Children with Obesity Living in Verona, Italy: A Longitudinal Study.  
23 *Obesity (Silver Spring)* 2020;28(8):1382-85. doi: 10.1002/oby.22861 [published  
24 Online First: 2020/05/01]  
25  
26 14. Ruiz-Roso MB, de Carvalho Padilha P, Mantilla-Escalante DC, et al. Covid-19  
27 Confinement and Changes of Adolescent's Dietary Trends in Italy, Spain, Chile,  
28 Colombia and Brazil. *Nutrients* 2020;12(6) doi: 10.3390/nu12061807 [published  
29 Online First: 2020/06/21]  
30  
31 15. Bates LC, Zieff G, Stanford K, et al. COVID-19 Impact on Behaviors across the 24-Hour  
32 Day in Children and Adolescents: Physical Activity, Sedentary Behavior, and Sleep.  
33 *Children (Basel)* 2020;7(9) doi: 10.3390/children7090138 [published Online First:  
34 2020/09/20]  
35  
36 16. Reece LJ, Owen K, Foley B, et al. Understanding the impact of COVID-19 on children's  
37 physical activity levels in NSW, Australia. *Health Promotion Journal of Australia*  
38 2021;32(2):365-66. doi: <https://doi.org/10.1002/hpja.436>  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



- 1  
2  
3 17. Lu C, Chi X, Liang K, et al. Moving More and Sitting Less as Healthy Lifestyle  
4 Behaviors are Protective Factors for Insomnia, Depression, and Anxiety Among  
5 Adolescents During the COVID-19 Pandemic. *Psychol Res Behav Manag*  
6 2020;13:1223-33. doi: 10.2147/prbm.S284103 [published Online First: 2020/12/29]  
7  
8  
9  
10  
11  
12 18. Olive L, Sciberras E, Berkowitz TS, et al. Child and parent physical activity, sleep and  
13 screen time during COVID-19 compared to pre-pandemic nationally representative  
14 data and associations with mental health. 2020  
15  
16  
17  
18  
19 19. Schmidt SCE, Anedda B, Burchartz A, et al. Physical activity and screen time of children  
20 and adolescents before and during the COVID-19 lockdown in Germany: a natural  
21 experiment. *Scientific Reports* 2020;10(1):21780. doi: 10.1038/s41598-020-78438-4  
22  
23  
24  
25  
26 20. Fidanci İ, Aksoy H, Yengil Taci D, et al. Evaluation of the effect of the COVID-19  
27 pandemic on sleep disorders and nutrition in children. *International Journal of*  
28 *Clinical Practice* 2021;75(7):e14170. doi: <https://doi.org/10.1111/ijcp.14170>  
29  
30  
31  
32  
33 21. Stone JE, Phillips AJK, Chachos E, et al. In-person vs home schooling during the  
34 COVID-19 pandemic: Differences in sleep, circadian timing, and mood in early  
35 adolescence. *Journal of Pineal Research* 2021;71(2):e12757. doi:  
36 <https://doi.org/10.1111/jpi.12757>  
37  
38  
39  
40  
41  
42 22. Dumas TM, Ellis W, Litt DM. What Does Adolescent Substance Use Look Like During  
43 the COVID-19 Pandemic? Examining Changes in Frequency, Social Contexts, and  
44 Pandemic-Related Predictors. *J Adolesc Health* 2020;67(3):354-61. doi:  
45 10.1016/j.jadohealth.2020.06.018 [published Online First: 2020/07/23]  
46  
47  
48  
49  
50  
51 23. Rogés J, Bosque-Prous M, Colom J, et al. Consumption of Alcohol, Cannabis, and  
52 Tobacco in a Cohort of Adolescents before and during COVID-19 Confinement.  
53 *International Journal of Environmental Research and Public Health*  
54 2021;18(15):7849.  
55  
56  
57  
58  
59  
60

- 1  
2  
3 24. Chaffee BW, Cheng J, Couch ET, et al. Adolescents' Substance Use and Physical  
4  
5 Activity Before and During the COVID-19 Pandemic. *JAMA Pediatrics*  
6  
7 2021;175(7):715-22. doi: 10.1001/jamapediatrics.2021.0541  
8  
9
- 10 25. Benschop A, van Bakkum F, Noijen J. Changing Patterns of Substance Use During the  
11  
12 Coronavirus Pandemic: Self-Reported Use of Tobacco, Alcohol, Cannabis, and Other  
13  
14 Drugs. *Front Psychiatry* 2021;12:633551. doi: 10.3389/fpsy.2021.633551 [published  
15  
16 Online First: 2021/06/15]  
17  
18
- 19 26. Matovu JKB, Kabwama SN, Ssekamatte T, et al. COVID-19 Awareness, Adoption of  
20  
21 COVID-19 Preventive Measures, and Effects of COVID-19 Lockdown Among  
22  
23 Adolescent Boys and Young Men in Kampala, Uganda. *Journal of Community Health*  
24  
25 2021;46(4):842-53. doi: 10.1007/s10900-021-00961-w  
26  
27
- 28 27. Active Healthy Kids Australia. Physical Literacy: Do Our Kids Have All the Tools? The  
29  
30 2016 Active Healthy Kids Australia Report Card on Physical Activity for Children  
31  
32 and Young People. Adelaide, South Australia: Active Healthy Kids Australia., 2016.  
33  
34
- 35 28. Inchley J, Currie D, Vieno A, et al. Adolescent alcohol-related behaviours: trends and  
36  
37 inequalities in the WHO European Region, 2002–2014: observations from the Health  
38  
39 Behaviour in School-aged Children (HBSC) WHO collaborative cross-national study.  
40  
41 Copenhagen: World Health Organization. Regional Office for Europe 2018:viii + 83  
42  
43 p.  
44  
45
- 46 29. Bucksch J, Sigmundova D, Hamrik Z, et al. International Trends in Adolescent Screen-  
47  
48 Time Behaviors From 2002 to 2010. *J Adolesc Health* 2016;58(4):417-25. doi:  
49  
50 10.1016/j.jadohealth.2015.11.014 [published Online First: 2016/02/02]  
51  
52
- 53 30. Centers for Disease Control and Prevention (CDC). 1991-2019 High School Youth Risk  
54  
55 Behavior Survey Data, 2021.  
56  
57  
58  
59  
60

- 1  
2  
3 31. Morley B, Scully M, Niven P, et al. National Secondary Students' Diet and Activity  
4 (NaSSDA) survey, 2012-13. Melbourne: Cancer Council Victoria, 2014.  
5  
6  
7  
8 32. Teesson\* M, Champion\* KE, Newton NC, et al. Study protocol of the Health4Life  
9  
10 Initiative: A cluster randomised controlled trial of an eHealth school-based program  
11 targeting multiple lifestyle risk behaviours among young Australians. *BMJ Open*  
12 2020;10:e035662. doi: doi: 10.1136/bmjopen-2019-035662 \*Equally credited first  
13  
14  
15  
16  
17 authors  
18  
19 33. Bower M, Smout S, Ellsmore S, et al. COVID-19 and Australia's mental health: An  
20 overview of academic literature, policy documents, lived experience accounts, media  
21 and community reports. . Sydney, NSW: Australia's Mental Health Think Tank, 2021.  
22  
23  
24  
25  
26 34. NSW Health. Public Health (COVID-19 Temporary Movement and Gathering  
27 Restrictions) Order 2021 under the Public Health Act 2010. NSW, Australia, 2021.  
28  
29  
30  
31 35. Hardy LL, Mhrshahi S, Drayton BA, et al. NSW Schools Physical Activity and Nutrition  
32 Survey (SPANS) 2015: Full Report. Sydney: NSW Department of Health, 2016.  
33  
34  
35 36. National Health and Medical Research Council. Australian Dietary Guidelines. Canberra:  
36 National Health and Medical Research Council, 2013.  
37  
38  
39  
40 37. Active Healthy Kids Australia. Physical Literacy: Do Our Kids Have All the Tools? The  
41 2016 Report Card on Physical Activity for Children and Young People. Adelaide,  
42 2016.  
43  
44  
45  
46 38. The Australian Government Department of Health. Australian 24-Hour Movement  
47 Guidelines for Children and Young People (5 to 17 years): An Integration of Physical  
48 Activity, Sedentary Behaviour, and Sleep. Canberra: Commonwealth of Australia,  
49 2019.  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 39. Prince SA, LeBlanc AG, Colley RC, et al. Measurement of sedentary behaviour in  
4  
5 population health surveys: a review and recommendations. *PeerJ* 2017;5(12) doi:  
6  
7 10.7717/peerj.4130  
8  
9
- 10 40. Short MA, Gradisar M, Lack LC, et al. Estimating adolescent sleep patterns: parent  
11  
12 reports versus adolescent self-report surveys, sleep diaries, and actigraphy. *Nat Sci*  
13  
14 *Sleep* 2013;5:23-26. doi: 10.2147/NSS.S38369  
15  
16
- 17 41. Golley RK, Maher CA, Matricciani L, et al. Sleep duration or bedtime? Exploring the  
18  
19 association between sleep timing behaviour, diet and BMI in children and  
20  
21 adolescents. *Int J Obes (Lond)* 2013;37(4):546-51. doi: 10.1038/ijo.2012.212  
22  
23 [published Online First: 2013/01/09]  
24  
25
- 26 42. Nascimento-Ferreira MV, Collese TS, de Moraes ACF, et al. Validity and reliability of  
27  
28 sleep time questionnaires in children and adolescents: A systematic review and meta-  
29  
30 analysis. *Sleep Medicine Reviews* 2016;30:85-96. doi: 10.1016/j.smrv.2015.11.006  
31  
32
- 33 43. CDC CfDcAP. National Youth Risk Behavior Survey: U.S. Department of Health and  
34  
35 Human Services, 2019.  
36  
37
- 38 44. Australian Institute of Health and Welfare. National Drug Strategy Household Survey  
39  
40 2016: detailed findings. Canberra: AIHW, 2017.  
41  
42
- 43 45. Deddens J, Petersen M. Approaches for estimating prevalence ratios. *Occupational and*  
44  
45 *environmental medicine* 2008;65(7):501-06.  
46  
47
- 48 46. Stata Statistical Software: Release 17 [program]. College Station: TX: StataCorp LLC,  
49  
50 2021.  
51  
52
- 53 47. Scully M, Morley B, Niven P, et al. Factors associated with frequent consumption of fast  
54  
55 food among Australian secondary school students. *Public Health Nutrition*  
56  
57 2020;23(8):1340-49. doi: 10.1017/S1368980019004208 [published Online First:  
58  
59 2020/03/16]  
60

- 1  
2  
3 48. Haszard JJ, Skidmore PML, Williams SM, et al. Associations between parental feeding  
4 practices, problem food behaviours and dietary intake in New Zealand overweight  
5 children aged 4–8 years. *Public Health Nutrition* 2015;18(6):1036-43. doi:  
6 10.1017/S1368980014001256 [published Online First: 2014/06/23]  
7  
8  
9  
10  
11  
12 49. ABARES. Agricultural Commodities: September quarter 2021  
13  
14  
15 Canberra: Australian Bureau of Agricultural and Resource Economics and Sciences, 2021.  
16  
17  
18 50. Cobiac LJ, Tam K, Veerman L, et al. Taxes and Subsidies for Improving Diet and  
19 Population Health in Australia: A Cost-Effectiveness Modelling Study. *PLoS Med*  
20 2017;14(2):e1002232. doi: 10.1371/journal.pmed.1002232 [published Online First:  
21 2017/02/15]  
22  
23  
24  
25  
26  
27 51. Keyes KM, Maslowsky J, Hamilton A, et al. The Great Sleep Recession: Changes in  
28 Sleep Duration Among US Adolescents, 1991–2012. *Pediatrics* 2015;135(3):460. doi:  
29 10.1542/peds.2014-2707  
30  
31  
32  
33 52. Olds T, Maher C, Blunden S, et al. Normative data on the sleep habits of Australian  
34 children and adolescents. *Sleep* 2010;33(10):1381-88. doi: 10.1093/sleep/33.10.1381  
35  
36  
37  
38 53. Xu F, Adams SK, Cohen SA, et al. Relationship between Physical Activity, Screen Time,  
39 and Sleep Quantity and Quality in US Adolescents Aged 16–19. *Int J Environ Res*  
40  
41  
42  
43  
44  
45 54. Zhang J, Chan NY, Lam SP, et al. Emergence of Sex Differences in Insomnia Symptoms  
46 in Adolescents: A Large-Scale School-Based Study. *Sleep* 2016; 39(8).  
47  
48  
49 <http://europepmc.org/abstract/MED/27091537>  
50  
51  
52 <https://doi.org/10.5665/sleep.6022>  
53  
54  
55 <https://europepmc.org/articles/PMC4945316>  
56  
57  
58 <https://europepmc.org/articles/PMC4945316?pdf=render> (accessed 2016/08/).  
59  
60

- 1  
2  
3 55. Guerin N, White V. ASSAD 2017 Statistics & Trends: Australian Secondary Students'  
4 Use of Tobacco, Alcohol, Over-the-counter Drugs, and Illicit Substances: Cancer  
5 Council Victoria, 2018.  
6  
7  
8  
9  
10 56. Campbell OLK, Bann D, Patalay P. The gender gap in adolescent mental health: A cross-  
11 national investigation of 566,829 adolescents across 73 countries. *SSM - Population*  
12 *Health* 2021;13:100742. doi: <https://doi.org/10.1016/j.ssmph.2021.100742>  
13  
14  
15  
16  
17 57. Högberg B, Strandh M, Hagquist C. Gender and secular trends in adolescent mental  
18 health over 24 years – The role of school-related stress. *Social Science & Medicine*  
19 2020;250:112890. doi: <https://doi.org/10.1016/j.socscimed.2020.112890>  
20  
21  
22  
23  
24 58. Slade T, Chapman C, Swift W, et al. Birth cohort trends in the global epidemiology of  
25 alcohol use and alcohol-related harms in men and women: systematic review and  
26 metaregression. *BMJ Open* 2016;6(10):e011827. doi: 10.1136/bmjopen-2016-011827  
27  
28  
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31 59. Patalay P, Gage SH. Changes in millennial adolescent mental health and health-related  
32 behaviours over 10 years: a population cohort comparison study. *International*  
33 *Journal of Epidemiology* 2019;48(5):1650-64. doi: 10.1093/ije/dyz006  
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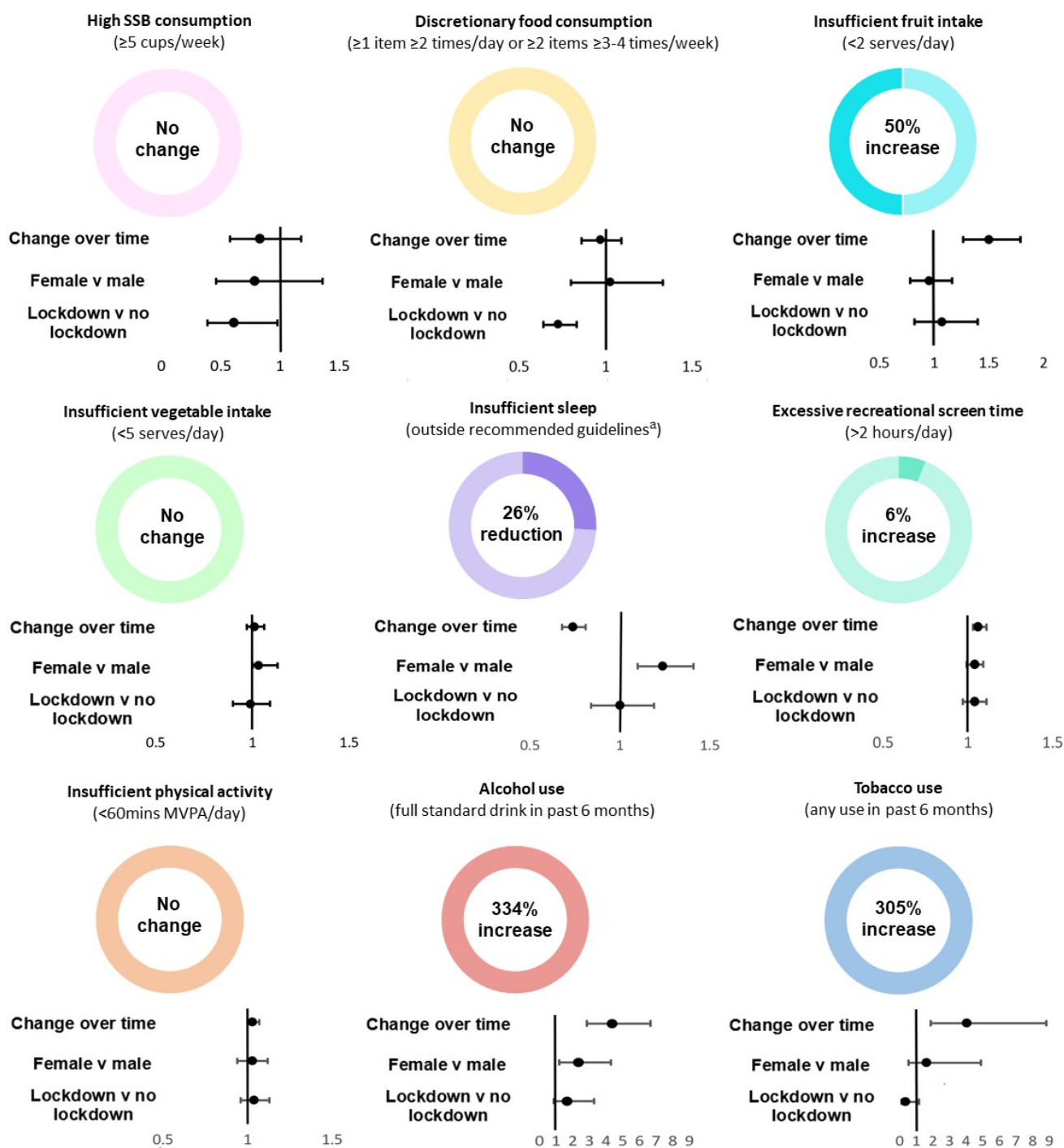
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### Figure Legends

**Figure 1. Change over time in the prevalence of the Big 6 and differences based on lockdown status and gender.**

For peer review only

**Figure 1. Change over time in the prevalence of the Big 6 and differences based on lockdown status and gender.**



*Note.* SSB=sugar-sweetened beverage, <sup>a</sup>≤13 years old: 9 to 11 hours/night, 14-17years: 8 to 10 hours/night, MVPA=moderate-to-vigorous physical activity.



Supplementary Material

eTable 1. Prevalence ratios with 95% confidence intervals for the change in lifestyle risk behaviours over time and by lockdown status and gender

	High SSB intake	High Discretionary food intake	Insufficient fruit intake	Insufficient vegetable intake	Insufficient sleep	Excessive recreational screen time	Insufficient Physical activity	Alcohol use	Tobacco use
<b>Change over time</b>	0.83 (0.58-1.18)	0.97 (0.86-1.09)	1.50** (1.26-1.79)	1.01 (0.97-1.06)	0.74** (0.68-0.81)	1.06** (1.03-1.11)	1.03 (1.00-1.07)	4.34** (2.82-6.67)	4.05** (1.86-8.84)
<b>Lockdown v not</b>	0.61* (0.39-0.98)	0.73** (0.64-0.83)	1.07 (0.82-1.40)	0.99 (0.90-1.09)	1.00 (0.84-1.19)	1.04 (0.97-1.11)	1.04 (0.96-1.13)	1.66 (0.84-3.27)	0.37 (0.12-1.16)
<b>Female v Male</b>	0.79 (0.46-1.36)	1.03 (0.80-1.33)	0.95 (0.78-1.16)	1.03 (1.00-1.13)	1.24** (1.10-1.41)	1.04 (0.99-1.09)	1.03 (0.94-1.12)	2.34* (1.19-4.62)	1.63 (0.55-4.88)

Note. SSB=sugar sweetened beverage, \*Indicates significance at p<0.05; \*\*indicates significance at p<0.001.

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	1, 2, 5
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-10
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7 & 10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	10 10 N/A N/A N/A
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	10 N/A N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	10-11 11 7
Outcome data	15*	Report numbers of outcome events or summary measures over time	10-13

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-13
2			(b) Report category boundaries when continuous variables were categorized	9
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
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9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-13
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11	<b>Discussion</b>			
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13	Key results	18	Summarise key results with reference to study objectives	14-16
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15	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
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17	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
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20	Generalisability	21	Discuss the generalisability (external validity) of the study results	16
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22	<b>Other information</b>			
23	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17-18
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26 \*Give information separately for exposed and unexposed groups.

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29 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

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# BMJ Open

## Lifestyle Risk Behaviours among Adolescents: A Two-Year Longitudinal Study of the Impact of the COVID-19 Pandemic

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-060309.R1
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<b>Primary Subject Heading</b>:	Global health
Secondary Subject Heading:	Public health
Keywords:	COVID-19, Public health < INFECTIOUS DISEASES, EPIDEMIOLOGY

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11 Lauren A. Gardner<sup>1</sup>  
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13  
14 Jennifer Debenham<sup>1</sup>  
15

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17 Nicola C. Newton<sup>1</sup>  
18

19  
20 Cath Chapman<sup>1</sup>  
21

22  
23 Fiona Wylie<sup>2</sup>  
24

25  
26 Bridie Osman<sup>1</sup>  
27

28  
29 Maree Teesson<sup>1</sup>  
30

31  
32 Katrina E. Champion<sup>1</sup>  
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36 <sup>1</sup>The Matilda Centre for Research Excellence in Mental Health and Substance Use,

37  
38 University of Sydney, Sydney, Australia

39  
40 <sup>2</sup>Macquarie University, Sydney, Australia

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42  
43 Corresponding author: Dr Lauren Gardner, The Matilda Centre, Level 6 Jane Foss Russell

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45 Building, The University of Sydney, NSW, 2006. Email: [lauren.gardner@sydney.edu.au](mailto:lauren.gardner@sydney.edu.au)

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## 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 3000km.

**Participants:** 983 adolescents (baseline  $M_{age}=12.6$ ,  $SD=0.5$ , 54.8% female) 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 ( $PR=1.06$ , 95%  $CI=1.03-1.11$ ), insufficient fruit intake ( $PR=1.50$ , 95%  $CI=1.26-1.79$ ), and alcohol ( $PR=4.34$ , 95%  $CI=2.82-6.67$ ) and tobacco use ( $PR=4.05$ , 95%  $CI=1.86-8.84$ ) increased over the two-year period, with alcohol use increasing more among females ( $PR=2.34$ , 95%  $CI=1.19-4.62$ ). The prevalence of insufficient sleep declined across the full sample ( $PR=0.74$ , 95%  $CI=0.68-0.81$ ); however, increased among females ( $PR=1.24$ , 95%  $CI=1.10-1.41$ ). The prevalence of high sugar-sweetened beverage ( $PR=0.61$ , 95%  $CI=0.64-0.83$ ) and discretionary food consumption ( $PR=0.73$ , 95%  $CI=0.64-0.83$ ) reduced among those subjected to stay-at-home orders, compared to those not in lockdown.

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3 **Conclusion:** Lifestyle risk behaviours, particularly excessive recreational screen time, poor  
4 diet, physical inactivity, and poor sleep, are prevalent among adolescents. Young people must  
5 be supported to find ways to improve or maintain their health, regardless of the course of the  
6 pandemic. Targeted approaches to support groups that may be disproportionately impacted,  
7 such as adolescent females, are needed.  
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10  
11 **Key words:** COVID-19 pandemic, adolescents, physical activity, diet, sleep, recreational  
12 screen time, alcohol, tobacco, lifestyle risk behaviours  
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### 25 **Strengths and limitations of this study**

- 26 • A prospective cohort design was used to explore changes in a comprehensive set of  
27 health indicators among adolescents, from before (2019) to during (2021) the  
28 COVID-19 pandemic, and whether changes varied by gender and lockdown status.  
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- 31 • The study included a large (n=983) and geographically diverse sample of adolescents  
32 across three Australian states (New South Wales, Queensland and Western Australia)  
33 spanning over 3000km.  
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- 36 • Limitations of the research include the reliance on self-report measures, and while the  
37 sample was diverse, it is not representative of the Australian population.  
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## **Lifestyle Risk Behaviours among Adolescents: A Two-Year Longitudinal Study of the Impact of the COVID-19 Pandemic**

The global spread of COVID-19 and subsequent lockdown measures have presented challenges worldwide. While disease severity, hospital admissions and deaths have typically been lower among adolescents, compared to 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 through to October 2021 was similar in Australia, the United States and the United Kingdom, 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 (VIC) and New South Wales (NSW), two of the most populous states that saw heightened case numbers during the January 2020-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.

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

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22 Research suggests that COVID-19 has impacted the Big 6, and in turn, the health of  
23 adolescents. For example, youth in Europe and Palestine have gained weight during the  
24 pandemic,<sup>18 19</sup> which may be the result of increased consumption of discretionary food and  
25 sugar-sweetened beverages (SSB) during lockdown periods.<sup>18 20</sup> However, some studies  
26 report improvements in dietary behaviours, including less SSB consumption among  
27 Colombian adolescents, higher fruit intake among Italian youth, and higher vegetable intake  
28 among adolescents from Spain, Brazil and Chile.<sup>20 21</sup> Among the few existing Australian  
29 studies, Munasinghe et al.<sup>3</sup> found physical distancing measures implemented in the initial  
30 lockdown period (March-April 2020) were associated with a decline in fast food consumption  
31 among adolescents, but there were no changes in fruit and vegetable consumption. However,  
32 it is unknown whether these changes have been sustained, or whether other dietary  
33 behaviours changed.

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50 The pandemic presents particular challenges for movement behaviours, including  
51 physical activity, sedentary behaviour and sleep. Typically, lockdowns are associated with  
52 lower levels of adolescent physical activity<sup>4 18 20 22 23</sup> and increased screen time, both for  
53 remote learning and recreation, resulting in sedentary lifestyles.<sup>3 4 23 24</sup> However, some  
54 research in Australia<sup>25</sup> and Germany<sup>26</sup> suggests physical activity increased.<sup>26</sup> International

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3 studies also report an increase in adolescent sleep duration during lockdown periods,<sup>18 20</sup> but  
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5 higher prevalence of sleep problems, particularly among girls.<sup>27</sup> Similarly, Australian  
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7 adolescents perceived an increase in sleep difficulties and had increased sleep disturbance  
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9 during the first lockdown.<sup>25</sup> One study<sup>28</sup> reported increased sleep duration among Australian  
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11 adolescents who were engaged in remote learning, however another<sup>3</sup> found no changes.  
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15 Studies investigating the impact of the pandemic on adolescent alcohol and tobacco  
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17 use have produced mixed findings. For example, alcohol use is reported to have increased  
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19 among Canadian adolescents,<sup>29</sup> reduced among Spanish adolescents,<sup>30</sup> while there was no  
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21 change in alcohol or tobacco use among adolescents from the United States.<sup>31</sup> Further,  
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23 European research suggests a reduction in adolescent tobacco use during the pandemic  
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25 period,<sup>30 32</sup> yet there has been an increase in Uganda.<sup>33</sup> To date, changes in alcohol and  
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27 tobacco use among Australian adolescents have not been examined.  
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32 Evidence suggests that the prevalence of the Big 6 varies by gender. For example,  
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34 adolescent females are more likely to be physically inactive, whereas males are more likely to  
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36 engage in high levels of recreational screen time, have a poor diet, and use alcohol and  
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38 tobacco.<sup>15 34-38</sup> However, less is known about whether changes in lifestyle behaviours over the  
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40 pandemic period vary by gender.  
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45 To address these gaps in the literature, this study aims to examine changes in the  
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47 prevalence of the Big 6 among a large, geographically diverse sample of adolescents, from  
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49 before to during the COVID-19 pandemic, and explore whether differences over time are  
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51 associated with gender and lockdown status.  
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## 54 **Methods**

### 55 **Participants and Procedure**

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3 The sample comprised participants from three Australian states (NSW, QLD, and  
4 WA), spanning over 3000km, who were randomly allocated to the control group of the  
5 Health4Life Study.<sup>39</sup> Participants who provided written consent and had parental consent  
6 (passive, active written, or active verbal, depending on approved procedures for the school  
7 type and region) completed self-report assessments in a supervised classroom setting. Only  
8 students who provided data prior to the beginning of the pandemic (between July-November  
9 2019) and during the pandemic (approximately 24-months after baseline, between July and  
10 10<sup>th</sup> October 2021) were included in this study. During the 2021 data collection period,  
11 Australia had strict border policies, restricting international travel and mandating hotel  
12 quarantine, while state- and territory-level border policies for domestic travel varied.<sup>40</sup>  
13 Greater Sydney, including the Central Coast, Shellharbour and Wollongong, were subjected  
14 to lockdown restrictions under the NSW stay-at-home Public Health Order (e.g.,<sup>41</sup>); the most  
15 stringent of which included not being permitted to leave the home unless essential (e.g., one  
16 person per household to shop for food or one hour of exercise per day), movement restricted  
17 to a 5km radius of the home, closure of all non-essential retail (e.g., hairdressers), home-  
18 based work and schooling requirements, curfews, and mandatory mask wearing, with a high  
19 police presence and large fines enforced for nonadherence. QLD, WA and areas outside of  
20 Greater Sydney were not subjected to extended stay-at-home lockdown restrictions.  
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### 45 **Research Ethics Approval**

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48 Ethical approval was gained from the University of Sydney (2018/882), NSW  
49 Department of Education (SERAP No. 2019006), University of Queensland (2019000037),  
50 Curtin University (HRE2019-0083) and relevant Catholic school committees.<sup>39</sup>  
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### 55 **Patient and Public Involvement**

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3 Patients or the public were not involved in the design, or conduct, or reporting, or  
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5 dissemination plans of our research.  
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## 8 **Measures**

### 10 *Sociodemographic characteristics*

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

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

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3 A single item was used to assess the number of days over the past week that  
4 participants engaged in moderate-to-vigorous physical activity for at least 60 minutes.<sup>44</sup> As  
5 per the Australian health guideline, insufficient physical activity was defined as engaging in  
6 <60 minutes of moderate-to-vigorous physical activity/day.<sup>45</sup>  
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### 13 ***Recreational screen time***

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

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29 The Modified Sleep Habits Survey<sup>47</sup> was used to assess sleep duration. Total sleep  
30 time was calculated by finding the difference between the time participants reported first  
31 attempting sleep, and the time they woke up in the morning, minus the reported time taken to  
32 fall asleep from first attempt, with a weighted average sleep duration calculated for school  
33 and weekend nights. Self-reported bedtime, waketime, and sleep duration have been shown to  
34 be reliable and valid in adolescent populations.<sup>48 49</sup> As per the Australian guidelines,  
35 insufficient sleep was defined as an average duration outside of 9-11 hours/night for those  
36 aged 11-13 years, or 8-10 hours/night for those aged 14-17 years.<sup>45</sup>  
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### 48 ***Alcohol and Tobacco Use***

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

Generalized linear mixed models (GLMM) 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% confidence intervals (CI), to overcome some of the limitations of reporting odds ratios from logistic regressions, which may appear inflated.<sup>52</sup> Prevalence ratios are interpreted as the estimated prevalence of an outcome in one group, compared to another, providing an indication of a change in prevalence, as opposed to risk or odds. All models included a random intercept at the student- and school-level, Robust Poisson distribution and a log link function, where time is continuous and represents the pre-pandemic (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” [.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 V17.<sup>53</sup>

## Results

### Descriptive Statistics

The sample included 983 students (baseline  $M_{\text{age}}=12.6$ ,  $SD=0.5$ , 54.8% female) 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%) were under lockdown restrictions. Table 2 presents the prevalence of lifestyle risk behaviours over time.

**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)

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

Risk Behaviour	Pre-pandemic (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 <sup>a</sup> )	549/917 (59.9)	392/885 (44.3)
Excessive recreational screen time ( $> 2$ hrs/day)	825/964 (85.6)	878/925 (93.8)
Insufficient physical activity ( $< 60$ mins 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)

Note. SSB=sugar-sweetened beverage, <sup>a</sup> $\leq 13$  years old: 9 to 11 hours/night, 14-17years: 8 to 10 hours/night, MVPA=moderate-to-vigorous physical activity.



## 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 prevalence ratios and confidence intervals detailed in Supplementary 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=0.58-1.18). However, the prevalence was 39% lower in individuals under lockdown (PR=0.61, 95% CI=0.64-0.83) over time, compared to 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=0.86-1.09). However, the prevalence was 27% lower for individuals living under lockdown (PR=0.73, 95% CI=0.64-0.83) over time, compared to those not in lockdown.

**Fruit and vegetable intake.** The prevalence of insufficient fruit intake increased by 50% over time (PR=1.50, 95% CI=1.26-1.79). There were no changes in the prevalence of insufficient vegetable intake over time (PR=1.01, 95% CI=0.97-1.06), 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=0.68-0.81). Females reported a higher prevalence of insufficient sleep over time,

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3 compared to males (PR=1.24, 95% CI=1.10-1.41). The presence of lockdown restrictions was  
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5 not associated with a change in the prevalence of insufficient sleep over time.  
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### 8 ***Recreational screen time***

10  
11 There was a 6% increase in the prevalence of excessive recreational screen time over  
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13 time (PR=1.06, 95% CI=1.03-1.11). Gender and the presence of lockdown restrictions were  
14  
15 not associated with a change in the prevalence of excessive recreational screen time over  
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17 time.  
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### 21 ***Physical activity***

22  
23 There was no change in the prevalence of insufficient physical activity over time  
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25 (PR=1.03, 95% CI=1.00-1.07). Neither gender nor the presence of lockdown restrictions was  
26  
27 associated with change in the prevalence of insufficient physical activity over time.  
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### 32 ***Alcohol use***

33  
34 The prevalence of past 6-month alcohol use increased by 334% over time (PR=4.34,  
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36 95% CI=2.82-6.67). The prevalence of alcohol use increased more in females compared to  
37  
38 males (PR=2.34, 95% CI=1.19-4.62). The presence of lockdown restrictions was not  
39  
40 associated with change in the prevalence of past 6-month alcohol use over time.  
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### 45 ***Tobacco use***

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47 The prevalence of past 6-month tobacco use increased by 305% over time (PR=4.05  
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49 95% CI=1.86-8.84). Neither gender nor the presence of lockdown restrictions was associated  
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51 with change in the prevalence of past 6-month tobacco use over time.  
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## 55 **Discussion**

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3 This study was the first to explore changes in all of the Big 6 lifestyle risk behaviours  
4 among a large, geographically diverse cohort of adolescents, from before (2019) to during  
5 (2021) the COVID-19 pandemic, and whether changes varied by gender and lockdown status.  
6  
7 Over the two-year period, the prevalence of excessive recreational screen time, insufficient  
8 fruit intake, and alcohol and tobacco use increased, with alcohol use increasing among  
9 females in particular. The prevalence of insufficient sleep reduced in the overall sample; yet,  
10 increased among females. Being in lockdown was associated with improvements in SSB  
11 consumption and discretionary food intake.  
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22 These findings highlight the varied impact of the pandemic across countries. For  
23 example, consistent with other Australian findings,<sup>3</sup> but in contrast to international research,<sup>18</sup>  
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25 <sup>20</sup> the prevalence of discretionary food intake decreased among those in lockdown. Yet in line  
26 with some international findings,<sup>21</sup> SSB intake reduced among adolescents in lockdown. This  
27 may reflect increased parental monitoring during lockdown and reduced opportunistic  
28 exposure to fast food due to not being with friends or commuting to school.<sup>54 55</sup> As such,  
29 continued parental monitoring beyond the lockdown period and the promotion of healthy  
30 food options may be beneficial. However, improvements in healthy dietary behaviours were  
31 not observed. In fact, the prevalence of insufficient fruit intake increased among the full  
32 sample. This may relate to the higher cost of fresh fruit and vegetables in Australia during the  
33 pandemic, caused by labour shortages within the farming, wholesale and retail sectors due to  
34 fewer working holiday makers.<sup>56</sup> These findings support calls for governments to consider  
35 broader policy-level changes to improve diet, such as taxes and subsidies.<sup>57</sup>  
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52 The finding that sleep duration improved from before to during the pandemic is consistent  
53 with some Australian<sup>28</sup> and international<sup>18 20</sup> studies. This contrasts typical trends over  
54 adolescence<sup>58 59</sup> and was despite an increase in the prevalence of excessive recreational  
55 screen time, which is often considered a primary contributor to poor sleep.<sup>60</sup> It is posited that  
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3 the time usually spent getting ready and commuting to school is instead spent getting  
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5 additional sleep during periods of lockdown, leading to calls for delayed school start times;<sup>28</sup>  
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7 however, we found no differences based on lockdown status to support this. The finding that  
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9 insufficient sleep increased among females is consistent with international research reporting  
10  
11 increased sleep disorders among females during the pandemic<sup>27</sup> and may reflect the  
12  
13 association between female pubertal maturation and the emergence of insomnia symptoms.<sup>61</sup>  
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15 Targeted intervention approaches to address sleep among females are needed.  
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20 Notably, in contrast to previous international and Australian research attributing increased  
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22 screen time to lockdown and physical distancing measures,<sup>3 4 23</sup> we found no difference in the  
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24 prevalence of excessive recreational screen time between the lockdown and non-lockdown  
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26 groups. This increase may instead reflect general trends of increasing screen time among  
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28 adolescents.<sup>16</sup> These findings highlight the value of assessing behaviours amongst  
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30 adolescents both in lockdown and not in lockdown in the same period for comparability, and  
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32 the need for effective interventions targeting screen time among adolescents.<sup>39</sup>  
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37 Contrasting typical trends over adolescence and previous pandemic-research,<sup>4 23</sup> the  
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39 prevalence of insufficient physical activity did not change over time, nor did it increase more  
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41 for those in lockdown. Previous studies have attributed reductions in physical activity during  
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43 the pandemic to government responses, such as the cancellation of organised sport and  
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45 closure of gyms and recreation centres.<sup>1 23</sup> However, given the current data were from the  
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47 2021 lockdown, whereas previous studies focused on the initial lockdown in 2020, it may be  
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49 that over time, adolescents have learnt to adapt to the rapidly changing situation and find  
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51 other ways to achieve their physical activity goals (e.g., replaced organised sport with  
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53 outdoor gym sessions and training). It may also be that other forms of physical activity, such  
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55 as light and incidental physical activity, have been more severely impacted. Future research  
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3 would benefit from assessing how these different forms of physical activities changed  
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5 throughout the pandemic.  
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9 Finally, although alcohol and tobacco use increased over time, the prevalence of these  
10 behaviours at the first timepoint, when participants were aged 12, was very low and remained  
11 relatively low 24-months later. This increase is to be expected among adolescents,<sup>62</sup> however,  
12 the greater increase in alcohol use among females was unexpected. Considering this and the  
13 increase in prevalence of insufficient sleep, females may be disproportionately impacted by  
14 the pandemic. This may reflect general patterns of higher prevalence and increasing trends of  
15 mental health problems among adolescent females across the globe,<sup>63 64</sup> which are often  
16 comorbid with poor sleep and substance use; as well as narrowing of the gender gap in  
17 alcohol use among more among recent cohorts.<sup>35 65</sup> Links between these factors are  
18 complex<sup>66</sup> and assessing changes in mental health alongside changes in the Big 6 may be a  
19 useful future research direction.  
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35 Key strengths of this study include having assessment occasions before and during the  
36 pandemic, rather than relying on retrospective accounts of perceived changes in behaviours,  
37 and a sample comprised of adolescents both in and not in lockdown at follow-up for  
38 comparability. However, we can't rule out the potential impact of other factors, such as  
39 maturation or mental health, that could also be influencing the Big 6. Although the study  
40 builds on previous research that has focused on the early pandemic period, claims about  
41 behavioural shifts across the early and late pandemic periods need to be interpreted with  
42 caution. Other limitations include the reliance on self-report measures, and while the sample  
43 was more diverse than other Australian studies, it is limited to three Australian states and is  
44 therefore not representative of the entire Australian adolescent population.<sup>14</sup>  
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## 58 **Conclusion**

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3 Lifestyle risk behaviours, particularly excessive recreational screen time, poor diet,  
4 physical inactivity, and poor sleep, are prevalent among adolescents and should be addressed  
5 with effective behaviour change interventions.<sup>39</sup> With the pandemic remaining a continually  
6 evolving situation across the world, the impact on health behaviours is also likely to be  
7 dynamic and diverse. Supporting young people to improve or maintain their health  
8 behaviours, regardless of the course of the pandemic, is important, alongside targeted  
9 research and intervention efforts to support groups that may be disproportionately impacted,  
10 such as adolescent females.  
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33 protocol<sup>39</sup> and the Australian New Zealand Clinical Trials Registry  
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47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



## 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(16) doi: 10.3390/ijerph18168433 [published Online First: 2021/08/28]
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(5):653-61. doi: 10.1016/j.jadohealth.2020.08.008 [published Online First: 2020/10/26]
4. Li SH, Beames JR, Newby JM, et al. The impact of COVID-19 on the lives and mental health of Australian adolescents. *European Child & Adolescent Psychiatry* 2021 doi: 10.1007/s00787-021-01790-x
5. Hale T, Angrist N, Goldszmidt R, et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker): Nature Human Behaviour, 2021.
6. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *The Lancet Infectious Diseases* 2020;20(5):533-34. doi: 10.1016/S1473-3099(20)30120-1
7. Hallas L, Hatibie A, Majumdar S, et al. 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 from: <https://covid-19-au.com/> accessed 28/02/2022.

- 1  
2  
3 10. Australian Bureau of Statistics. National, state and territory population. Canberra: ABS,  
4  
5 2021.  
6  
7
- 8 11. Ding D, Rogers K, van der Ploeg H, et al. Traditional and emerging lifestyle risk  
9  
10 behaviors and all-cause mortality in middle-aged and older adults: evidence from a  
11  
12 large population-based Australian cohort. *PLoS medicine* 2015;12(12):e1001917.  
13  
14
- 15 12. Lynch BM, Owen N. Too much sitting and chronic disease risk: steps to move the science  
16  
17 forward. *Annals of Internal Medicine* 2015;162(2):146-47.  
18  
19
- 20 13. Ezzati M, Riboli E. Behavioral and Dietary Risk Factors for Noncommunicable Diseases.  
21  
22 *New England Journal of Medicine* 2013;369(10):954-64. doi:  
23  
24 10.1056/NEJMra1203528  
25
- 26 14. Champion\* KE, Chapman\* C, Gardner LA, et al. Lifestyle risks for chronic disease  
27  
28 among Australian adolescents: a cross-sectional survey. *Medical Journal of Australia*  
29  
30 2021:(\*equally credited first authors). doi: <https://doi.org/10.5694/mja2.51333>  
31  
32
- 33 15. Guthold R, Stevens GA, Riley LM, et al. Global trends in insufficient physical activity  
34  
35 among adolescents: a pooled analysis of 298 population-based surveys with 1&#xb7;6  
36  
37 million participants. *The Lancet Child & Adolescent Health* 2020;4(1):23-35. doi:  
38  
39 10.1016/S2352-4642(19)30323-2  
40  
41
- 42 16. Yang L, Cao C, Kantor ED, et al. Trends in Sedentary Behavior Among the US  
43  
44 Population, 2001-2016. *JAMA* 2019;321(16):1587-97. doi: 10.1001/jama.2019.3636  
45  
46
- 47 17. Australian Institute of Health and Welfare. Australia's health 2018. Australia's health  
48  
49 series no. 16 AUS 221. Canberra: AIHW, 2018.  
50  
51
- 52 18. Allabadi H, Dabis J, Aghabekian V, et al. Impact of COVID-19 lockdown on dietary and  
53  
54 lifestyle behaviours among adolescents in Palestine. 2020  
55
- 56 19. Stavridou A, Kapsali E, Panagouli E, et al. Obesity in Children and Adolescents during  
57  
58 COVID-19 Pandemic. *Children* 2021;8(2):135.  
59  
60

- 1  
2  
3 20. Pietrobelli A, Pecoraro L, Ferruzzi A, et al. Effects of COVID-19 Lockdown on Lifestyle  
4 Behaviors in Children with Obesity Living in Verona, Italy: A Longitudinal Study.  
5  
6 *Obesity (Silver Spring)* 2020;28(8):1382-85. doi: 10.1002/oby.22861 [published  
7  
8 Online First: 2020/05/01]  
9  
10  
11  
12 21. Ruiz-Roso MB, de Carvalho Padilha P, Mantilla-Escalante DC, et al. Covid-19  
13 Confinement and Changes of Adolescent's Dietary Trends in Italy, Spain, Chile,  
14  
15 Colombia and Brazil. *Nutrients* 2020;12(6) doi: 10.3390/nu12061807 [published  
16  
17 Online First: 2020/06/21]  
18  
19  
20  
21 22. Bates LC, Zieff G, Stanford K, et al. COVID-19 Impact on Behaviors across the 24-Hour  
22 Day in Children and Adolescents: Physical Activity, Sedentary Behavior, and Sleep.  
23  
24 *Children (Basel)* 2020;7(9) doi: 10.3390/children7090138 [published Online First:  
25  
26 2020/09/20]  
27  
28  
29  
30 23. Reece LJ, Owen K, Foley B, et al. Understanding the impact of COVID-19 on children's  
31 physical activity levels in NSW, Australia. *Health Promotion Journal of Australia*  
32  
33 2021;32(2):365-66. doi: <https://doi.org/10.1002/hpja.436>  
34  
35  
36  
37 24. Lu C, Chi X, Liang K, et al. Moving More and Sitting Less as Healthy Lifestyle  
38 Behaviors are Protective Factors for Insomnia, Depression, and Anxiety Among  
39  
40 Adolescents During the COVID-19 Pandemic. *Psychol Res Behav Manag*  
41  
42 2020;13:1223-33. doi: 10.2147/prbm.S284103 [published Online First: 2020/12/29]  
43  
44  
45  
46 25. Olive L, Sciberras E, Berkowitz TS, et al. Child and parent physical activity, sleep and  
47 screen time during COVID-19 compared to pre-pandemic nationally representative  
48  
49 data and associations with mental health. 2020  
50  
51  
52  
53 26. Schmidt SCE, Anedda B, Burchartz A, et al. Physical activity and screen time of children  
54 and adolescents before and during the COVID-19 lockdown in Germany: a natural  
55  
56 experiment. *Scientific Reports* 2020;10(1):21780. doi: 10.1038/s41598-020-78438-4  
57  
58  
59  
60

- 1  
2  
3 27. Fidancı İ, Aksoy H, Yengil Taci D, et al. Evaluation of the effect of the COVID-19  
4 pandemic on sleep disorders and nutrition in children. *International Journal of*  
5 *Clinical Practice* 2021;75(7):e14170. doi: <https://doi.org/10.1111/ijcp.14170>  
6  
7  
8  
9  
10 28. Stone JE, Phillips AJK, Chachos E, et al. In-person vs home schooling during the  
11 COVID-19 pandemic: Differences in sleep, circadian timing, and mood in early  
12 adolescence. *Journal of Pineal Research* 2021;71(2):e12757. doi:  
13 <https://doi.org/10.1111/jpi.12757>  
14  
15  
16  
17  
18  
19 29. Dumas TM, Ellis W, Litt DM. What Does Adolescent Substance Use Look Like During  
20 the COVID-19 Pandemic? Examining Changes in Frequency, Social Contexts, and  
21 Pandemic-Related Predictors. *J Adolesc Health* 2020;67(3):354-61. doi:  
22 10.1016/j.jadohealth.2020.06.018 [published Online First: 2020/07/23]  
23  
24  
25  
26  
27  
28 30. Rogés J, Bosque-Prous M, Colom J, et al. Consumption of Alcohol, Cannabis, and  
29 Tobacco in a Cohort of Adolescents before and during COVID-19 Confinement.  
30 *International Journal of Environmental Research and Public Health*  
31 2021;18(15):7849.  
32  
33  
34  
35  
36  
37 31. Chaffee BW, Cheng J, Couch ET, et al. Adolescents' Substance Use and Physical  
38 Activity Before and During the COVID-19 Pandemic. *JAMA Pediatrics*  
39 2021;175(7):715-22. doi: 10.1001/jamapediatrics.2021.0541  
40  
41  
42  
43  
44 32. Benschop A, van Bakkum F, Noijen J. Changing Patterns of Substance Use During the  
45 Coronavirus Pandemic: Self-Reported Use of Tobacco, Alcohol, Cannabis, and Other  
46 Drugs. *Front Psychiatry* 2021;12:633551. doi: 10.3389/fpsy.2021.633551 [published  
47 Online First: 2021/06/15]  
48  
49  
50  
51  
52  
53 33. Matovu JKB, Kabwama SN, Ssekamatte T, et al. COVID-19 Awareness, Adoption of  
54 COVID-19 Preventive Measures, and Effects of COVID-19 Lockdown Among  
55  
56  
57  
58  
59  
60

- 1  
2  
3 Adolescent Boys and Young Men in Kampala, Uganda. *Journal of Community Health*  
4  
5 2021;46(4):842-53. doi: 10.1007/s10900-021-00961-w  
6  
7  
8 34. Active Healthy Kids Australia. Physical Literacy: Do Our Kids Have All the Tools? The  
9  
10 2016 Active Healthy Kids Australia Report Card on Physical Activity for Children  
11  
12 and Young People. Adelaide, South Australia: Active Healthy Kids Australia., 2016.  
13  
14  
15 35. Inchley J, Currie D, Vieno A, et al. Adolescent alcohol-related behaviours: trends and  
16  
17 inequalities in the WHO European Region, 2002–2014: observations from the Health  
18  
19 Behaviour in School-aged Children (HBSC) WHO collaborative cross-national study.  
20  
21 Copenhagen: World Health Organization. Regional Office for Europe 2018:viii + 83  
22  
23 p.  
24  
25  
26 36. Bucksch J, Sigmundova D, Hamrik Z, et al. International Trends in Adolescent Screen-  
27  
28 Time Behaviors From 2002 to 2010. *J Adolesc Health* 2016;58(4):417-25. doi:  
29  
30 10.1016/j.jadohealth.2015.11.014 [published Online First: 2016/02/02]  
31  
32  
33 37. Centers for Disease Control and Prevention (CDC). 1991-2019 High School Youth Risk  
34  
35 Behavior Survey Data, 2021.  
36  
37  
38 38. Morley B, Scully M, Niven P, et al. National Secondary Students' Diet and Activity  
39  
40 (NaSSDA) survey, 2012-13. Melbourne: Cancer Council Victoria, 2014.  
41  
42  
43 39. Teesson\* M, Champion\* KE, Newton NC, et al. Study protocol of the Health4Life  
44  
45 Initiative: A cluster randomised controlled trial of an eHealth school-based program  
46  
47 targeting multiple lifestyle risk behaviours among young Australians. *BMJ Open*  
48  
49 2020;10:e035662. doi: doi: 10.1136/bmjopen-2019-035662 \*Equally credited first  
50  
51 authors  
52  
53  
54 40. Bower M, Smout S, Ellsmore S, et al. COVID-19 and Australia's mental health: An  
55  
56 overview of academic literature, policy documents, lived experience accounts, media  
57  
58 and community reports. . Sydney, NSW: Australia's Mental Health Think Tank, 2021.  
59  
60

- 1  
2  
3 41. NSW Health. Public Health (COVID-19 Temporary Movement and Gathering  
4  
5 Restrictions) Order 2021 under the Public Health Act 2010. NSW, Australia, 2021.  
6  
7
- 8 42. Hardy LL, Mihrshahi S, Drayton BA, et al. NSW Schools Physical Activity and Nutrition  
9  
10 Survey (SPANS) 2015: Full Report. Sydney: NSW Department of Health, 2016.  
11  
12
- 13 43. National Health and Medical Research Council. Australian Dietary Guidelines. Canberra:  
14  
15 National Health and Medical Research Council, 2013.  
16
- 17 44. Active Healthy Kids Australia. Physical Literacy: Do Our Kids Have All the Tools? The  
18  
19 2016 Report Card on Physical Activity for Children and Young People. Adelaide,  
20  
21 2016.  
22  
23
- 24 45. The Australian Government Department of Health. Australian 24-Hour Movement  
25  
26 Guidelines for Children and Young People (5 to 17 years): An Integration of Physical  
27  
28 Activity, Sedentary Behaviour, and Sleep. Canberra: Commonwealth of Australia,  
29  
30 2019.  
31  
32
- 33 46. Prince SA, LeBlanc AG, Colley RC, et al. Measurement of sedentary behaviour in  
34  
35 population health surveys: a review and recommendations. *PeerJ* 2017;5(12) doi:  
36  
37 10.7717/peerj.4130  
38  
39
- 40 47. Short MA, Gradisar M, Lack LC, et al. Estimating adolescent sleep patterns: parent  
41  
42 reports versus adolescent self-report surveys, sleep diaries, and actigraphy. *Nat Sci*  
43  
44 *Sleep* 2013;5:23-26. doi: 10.2147/NSS.S38369  
45  
46
- 47 48. Golley RK, Maher CA, Matricciani L, et al. Sleep duration or bedtime? Exploring the  
48  
49 association between sleep timing behaviour, diet and BMI in children and  
50  
51 adolescents. *Int J Obes (Lond)* 2013;37(4):546-51. doi: 10.1038/ijo.2012.212  
52  
53 [published Online First: 2013/01/09]  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 49. Nascimento-Ferreira MV, Collese TS, de Moraes ACF, et al. Validity and reliability of  
4  
5 sleep time questionnaires in children and adolescents: A systematic review and meta-  
6  
7 analysis. *Sleep Medicine Reviews* 2016;30:85-96. doi: 10.1016/j.smr.2015.11.006  
8  
9
- 10 50. CDC CfDcAP. National Youth Risk Behavior Survey: U.S. Department of Health and  
11  
12 Human Services, 2019.  
13
- 14 51. Australian Institute of Health and Welfare. National Drug Strategy Household Survey  
15  
16 2016: detailed findings. Canberra: AIHW, 2017.  
17  
18
- 19 52. Deddens J, Petersen M. Approaches for estimating prevalence ratios. *Occupational and*  
20  
21 *environmental medicine* 2008;65(7):501-06.  
22  
23
- 24 53. Stata Statistical Software: Release 17 [program]. College Station: TX: StataCorp LLC,  
25  
26 2021.  
27  
28
- 29 54. Scully M, Morley B, Niven P, et al. Factors associated with frequent consumption of fast  
30  
31 food among Australian secondary school students. *Public Health Nutrition*  
32  
33 2020;23(8):1340-49. doi: 10.1017/S1368980019004208 [published Online First:  
34  
35 2020/03/16]  
36  
37
- 38 55. Haszard JJ, Skidmore PML, Williams SM, et al. Associations between parental feeding  
39  
40 practices, problem food behaviours and dietary intake in New Zealand overweight  
41  
42 children aged 4–8 years. *Public Health Nutrition* 2015;18(6):1036-43. doi:  
43  
44 10.1017/S1368980014001256 [published Online First: 2014/06/23]  
45  
46
- 47 56. ABARES. Agricultural Commodities: September quarter 2021  
48  
49 Canberra: Australian Bureau of Agricultural and Resource Economics and Sciences, 2021.  
50  
51
- 52 57. Cobiac LJ, Tam K, Veerman L, et al. Taxes and Subsidies for Improving Diet and  
53  
54 Population Health in Australia: A Cost-Effectiveness Modelling Study. *PLoS Med*  
55  
56 2017;14(2):e1002232. doi: 10.1371/journal.pmed.1002232 [published Online First:  
57  
58 2017/02/15]  
59  
60

- 1  
2  
3 58. Keyes KM, Maslowsky J, Hamilton A, et al. The Great Sleep Recession: Changes in  
4  
5 Sleep Duration Among US Adolescents, 1991–2012. *Pediatrics* 2015;135(3):460. doi:  
6  
7 10.1542/peds.2014-2707  
8  
9
- 10 59. Olds T, Maher C, Blunden S, et al. Normative data on the sleep habits of Australian  
11  
12 children and adolescents. *Sleep* 2010;33(10):1381-88. doi: 10.1093/sleep/33.10.1381  
13  
14
- 15 60. Xu F, Adams SK, Cohen SA, et al. Relationship between Physical Activity, Screen Time,  
16  
17 and Sleep Quantity and Quality in US Adolescents Aged 16–19. *Int J Environ Res*  
18  
19 *Public Health* 2019;16(9):1524.  
20  
21
- 22 61. Zhang J, Chan NY, Lam SP, et al. Emergence of Sex Differences in Insomnia Symptoms  
23  
24 in Adolescents: A Large-Scale School-Based Study. *Sleep* 2016; 39(8).  
25  
26 <http://europepmc.org/abstract/MED/27091537>  
27  
28  
29 <https://doi.org/10.5665/sleep.6022>  
30  
31  
32 <https://europepmc.org/articles/PMC4945316>  
33  
34  
35 <https://europepmc.org/articles/PMC4945316?pdf=render> (accessed 2016/08//).  
36  
37
- 38 62. Guerin N, White V. ASSAD 2017 Statistics & Trends: Australian Secondary Students’  
39  
40 Use of Tobacco, Alcohol, Over-the-counter Drugs, and Illicit Substances: Cancer  
41  
42 Council Victoria, 2018.  
43
- 44 63. Campbell OLK, Bann D, Patalay P. The gender gap in adolescent mental health: A cross-  
45  
46 national investigation of 566,829 adolescents across 73 countries. *SSM - Population*  
47  
48 *Health* 2021;13:100742. doi: <https://doi.org/10.1016/j.ssmph.2021.100742>  
49  
50
- 51 64. Högberg B, Strandh M, Hagquist C. Gender and secular trends in adolescent mental  
52  
53 health over 24 years – The role of school-related stress. *Social Science & Medicine*  
54  
55 2020;250:112890. doi: <https://doi.org/10.1016/j.socscimed.2020.112890>  
56  
57  
58  
59  
60



- 1  
2  
3 65. Slade T, Chapman C, Swift W, et al. Birth cohort trends in the global epidemiology of  
4 alcohol use and alcohol-related harms in men and women: systematic review and  
5  
6  
7  
8  
9  
10 66. Patalay P, Gage SH. Changes in millennial adolescent mental health and health-related  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
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47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60
- behaviours over 10 years: a population cohort comparison study. *International Journal of Epidemiology* 2019;48(5):1650-64. doi: 10.1093/ije/dyz006

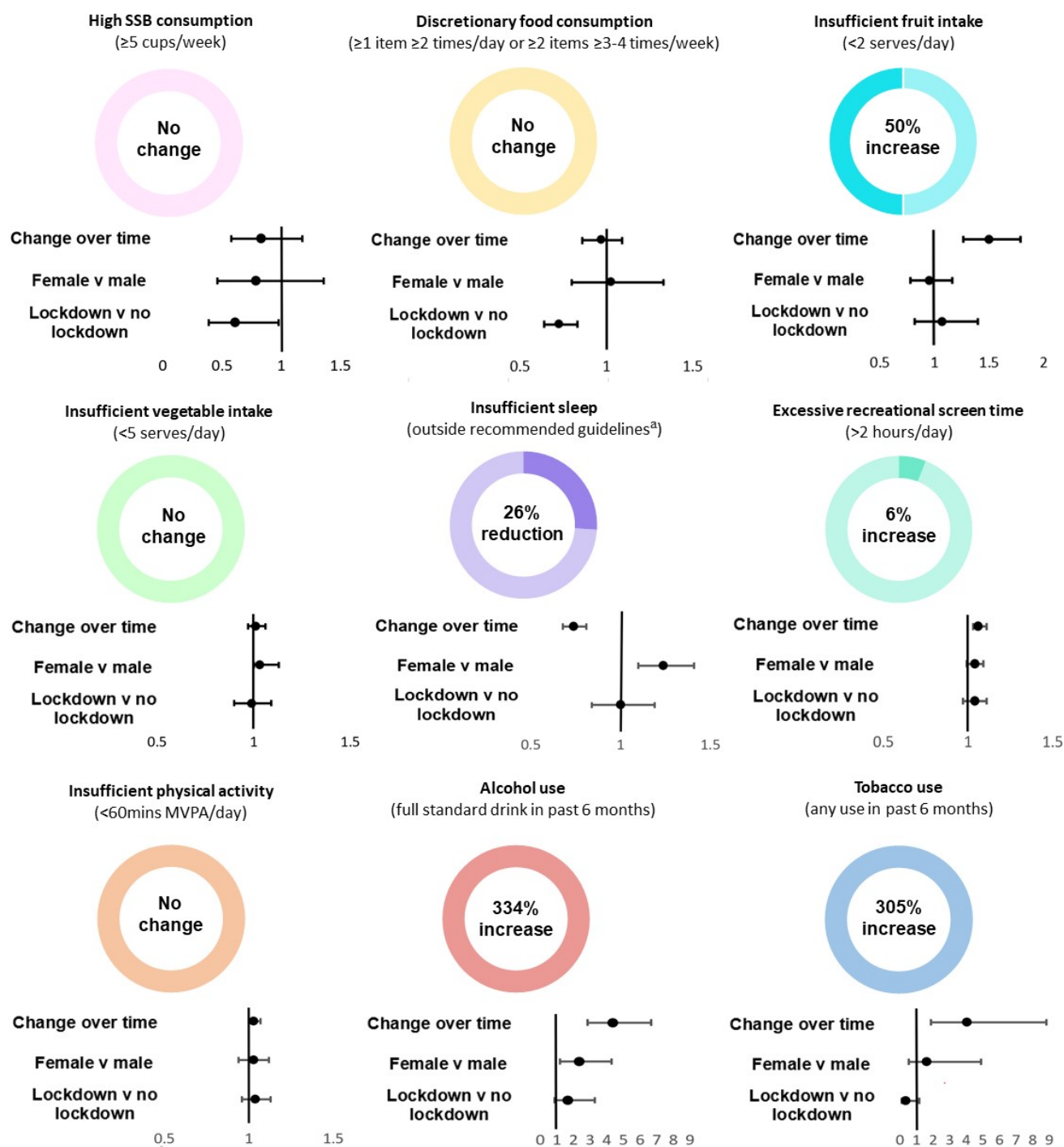
For peer review only

## Figure Legends

**Figure 1. Change over time in the prevalence of the Big 6 and differences based on lockdown status and gender.**

For peer review only

**Figure 1. Change over time in the prevalence of the Big 6 and differences based on lockdown status and gender.**



*Note.* SSB=sugar-sweetened beverage, <sup>a</sup> $\leq 13$  years old: 9 to 11 hours/night, 14-17 years: 8 to 10 hours/night, MVPA=moderate-to-vigorous physical activity.

## Supplementary Material

**eTable 1. Prevalence ratios with 95% confidence intervals for the change in lifestyle risk behaviours over time and by lockdown status and gender**

	High SSB intake	High Discretionary food intake	Insufficient fruit intake	Insufficient vegetable intake	Insufficient sleep	Excessive recreational screen time	Insufficient Physical activity	Alcohol use	Tobacco use
<b>Change over time</b>	0.83 (0.58-1.18)	0.97 (0.86-1.09)	1.50** (1.26-1.79)	1.01 (0.97-1.06)	0.74** (0.68-0.81)	1.06** (1.03-1.11)	1.03 (1.00-1.07)	4.34** (2.82-6.67)	4.05** (1.86-8.84)
<b>Lockdown v not</b>	0.61* (0.39-0.98)	0.73** (0.64-0.83)	1.07 (0.82-1.40)	0.99 (0.90-1.09)	1.00 (0.84-1.19)	1.04 (0.97-1.11)	1.04 (0.96-1.13)	1.66 (0.84-3.27)	0.37 (0.12-1.16)
<b>Female v Male</b>	0.79 (0.46-1.36)	1.03 (0.80-1.33)	0.95 (0.78-1.16)	1.03 (1.00-1.13)	1.24** (1.10-1.41)	1.04 (0.99-1.09)	1.03 (0.94-1.12)	2.34* (1.19-4.62)	1.63 (0.55-4.88)

Note. SSB=sugar sweetened beverage, \*Indicates significance at  $p<0.05$ ; \*\*indicates significance at  $p<0.001$ .

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	1, 2, 5
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-10
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7 & 10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	10 10 N/A N/A N/A
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	10 N/A N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	10-11 11 7
Outcome data	15*	Report numbers of outcome events or summary measures over time	10-13

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-13
2			(b) Report category boundaries when continuous variables were categorized	9
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
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9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-13
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11	<b>Discussion</b>			
12				
13	Key results	18	Summarise key results with reference to study objectives	14-16
14				
15	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
16				
17	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
18				
19				
20	Generalisability	21	Discuss the generalisability (external validity) of the study results	16
21				
22	<b>Other information</b>			
23	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17-18
24				
25				

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.