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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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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,[1-3] 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.[4-7] These behaviours are common among youth worldwide, with more than 80% of adolescents insufficiently physically active[8] and screen time rapidly increasing.[7 9] The Big 6 contribute significantly to global disease burden and are known predictors of chronic diseases, including cancer, cardiovascular disease and mental disorders.[6 10]

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,[11 12] which may be the result of increased consumption of discretionary food and sugar-sweetened beverages (SSB) during lockdown periods.[11 13] However, some studies report improvements in dietary behaviours, including less SSB consumption among

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

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

Studies investigating the impact of the pandemic on adolescent alcohol and tobacco use have produced mixed findings. For example, alcohol use is reported to have increased among Canadian adolescents,[22] reduced among Spanish adolescents,[23] while there was no change in alcohol or tobacco use among adolescents from the United States.[24] Further, European research suggests a reduction in adolescent tobacco use during the pandemic period,[23 25] yet there has been an increase in Uganda.[26] To date, changes in alcohol and tobacco use among Australian adolescents have not been examined.

Evidence suggests that the prevalence of the Big 6 varies by gender. For example, adolescent females are more likely to be physically inactive, whereas males are more likely to engage in high levels of recreational screen time, have a poor diet, and use alcohol and tobacco.[8 27-31] However, less is known about whether changes in lifestyle behaviours over the pandemic period vary by gender.

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

Methods

Participants and Procedure

The sample comprised participants from three Australian states [New South Wales (NSW), Queensland (QLD), and Western Australia (WA)], spanning over 3000km, who were randomly allocated to the control group of the Health4Life Study.[32] Participants with consent completed self-report assessments in a supervised classroom setting. Only students who provided data prior to the beginning of the pandemic (between July-November 2019) and during the pandemic (approximately 24-months after baseline, between July and 10th October 2021) were included in this study. During the 2021 data collection period, Australia had strict border policies, restricting international travel and mandating hotel quarantine, while state- and territory-level border policies for domestic travel varied.[33] Greater Sydney, including the Central Coast, Shellharbour and Wollongong, were subjected to lockdown restrictions under the NSW stay-at-home Public Health Order (e.g.,[34]); the most stringent of which included not being permitted to leave the home unless essential (e.g., one person per household to shop for food or one hour of exercise per day), movement restricted to a 5km radius of the home,

closure of all non-essential retail (e.g., hairdressers), home-based work and schooling requirements, curfews, and mandatory mask wearing, with a high police presence and large fines enforced for nonadherence. QLD, WA and areas outside of Greater Sydney were not subjected to extended stay-at-home lockdown restrictions.

Research Ethics Approval

Ethical approval was gained from the University of Sydney (2018/882), NSW Department of Education (SERAP No. 2019006), University of Queensland (2019000037), Curtin University (HRE2019-0083) and relevant Catholic school committees.[32]

Patient and Public Involvement

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

Measures

Sociodemographic characteristics

Participants self-reported their age and gender (male, female, non-binary/gender fluid, missing). A binary "lockdown" variable was created reflecting participants who attended schools in the Greater Sydney region that were subjected to the stay-at-home Public Health Order in 2021 and those who were not.[34]

Diet

Dietary intake was assessed using items adapted from the NSW School Physical Activity and Nutrition Survey (SPANS)[35]. Participants self-reported the number of metric cups of SSB usually consumed per week or day. A binary variable was created to reflect high (≥5-6 cups or more/week) and low consumption (≤4 cups/week). Participants reported how often they consume six discretionary food items (hot chips, French fries, wedges or fried

potatoes; potato crisps or other salty snacks; snack foods e.g., sweet and savoury biscuits, cakes, donuts or muesli bars; confectionary; ice cream or ice blocks; and, takeaway meals or snacks). High discretionary food consumption was defined as eating any of the items '2 or more times/day', or eating at least two of the items '3-4 times/week' or more often. Participants reported the number of serves of fruit and vegetables consumed per day, and in line with the Australian dietary guidelines,[36] insufficient fruit and vegetable consumption was defined as <2 serves of fruit and <5 serves of vegetables per day, respectively.

Physical activity

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

Recreational screen time

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

Sleep

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

insufficient sleep was defined as an average duration outside of 9-11 hours/night for those aged 11-13 years, or 8-10 hours/night for those aged 14-17 years.[38]

Alcohol and Tobacco Use

Alcohol and tobacco use were measured using two dichotomous (yes/no) items drawn from previous large scale trials and population based epidemiological surveys:[43 44] "Have you had a full standard alcoholic drink in the past 6 months?" and "In the past 6 months, have you tried cigarette smoking, even one or two puffs?".

Statistical Analysis

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.[45] 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.[46]

Results

Descriptive Statistics

The sample included 983 students (baseline M_{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 (≥5 cups/week)	90/964 (9.3)	72/935 (7.7)
High discretionary food intake (≥1 item ≥2 times/day or ≥2 items ≥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[a])	549/917 (59.9)	392/885 (44.3)
Excessive recreational screen time (>2hrs/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, [a]≤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, compared to males (PR=1.24, 95% CI=1.10-1.41). The presence of lockdown restrictions was not associated with a change in the prevalence of insufficient sleep over time.

Recreational screen time

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

Physical activity

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

Alcohol use

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

Tobacco use

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

Discussion

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

These findings highlight the varied impact of the pandemic across countries. For example, consistent with other Australian findings,[2] but in contrast to international research,[11]

[13] the prevalence of discretionary food intake decreased among those in lockdown. Yet in line with some international findings,[14] SSB intake reduced among adolescents in lockdown. This may reflect increased parental monitoring during lockdown and reduced opportunistic exposure to fast food due to not being with friends or commuting to school.[47 48] As such, continued parental monitoring beyond the lockdown period and the promotion of healthy food options may be beneficial. However, improvements in healthy dietary behaviours were not observed. In fact, the prevalence of insufficient fruit intake increased among the full sample. This may relate to the higher cost of fresh fruit and vegetables in Australia during the pandemic, caused by labour shortages within the farming, wholesale and retail sectors due to fewer working holiday makers.[49] These findings support calls for governments to consider broader policy-level changes to improve diet, such as taxes and subsidies.[50]

The finding that sleep duration improved from before to during the pandemic is consistent with some Australian[21] and international[11 13] studies. This contrasts typical trends over adolescence[51 52] and was despite an increase in the prevalence of excessive recreational screen time, which is often considered a primary contributor to poor sleep.[53] It is posited that the time usually spent getting ready and commuting to school is instead spent getting additional sleep during periods of lockdown, leading to calls for delayed school start times;[21] however, we found no differences based on lockdown status to support this. The finding that insufficient sleep increased among females is consistent with international research reporting increased sleep disorders among females during the pandemic[20] and may reflect the association between female pubertal maturation and the emergence of insomnia symptoms.[54] Targeted intervention approaches to address sleep among females are needed.

Notably, in contrast to previous international and Australian research attributing increased screen time to lockdown and physical distancing measures,[2 3 16] we found no difference in the prevalence of excessive recreational screen time between the lockdown and non-lockdown

groups. This increase may instead reflect general trends of increasing screen time among adolescents.[9] These findings highlight the value of assessing behaviours amongst adolescents both in lockdown and not in lockdown in the same period for comparability, and the need for effective interventions targeting screen time among adolescents.[32]

Contrasting previous research and typical trends over adolescence,[3 16] the prevalence of insufficient physical activity did not increase more for those in lockdown. Given data were from the 2021 lockdown, whereas previous studies focused on the initial lockdown in 2020, it may be that over time, adolescents have learnt to adapt to the rapidly changing situation and find other ways to achieve their physical activity goals. It may also be that other forms of physical activity, such as light and incidental physical activity, have been more severely impacted.

Finally, although alcohol and tobacco use increased over time, the prevalence of these behaviours at the first timepoint, when participants were aged 12, was very low and remained relatively low 24-months later. This increase is to be expected among adolescents,[55] however, the greater increase in alcohol use among females was unexpected. Considering this and the increase in prevalence of insufficient sleep, females may be disproportionately impacted by the pandemic. This may reflect general patterns of higher prevalence and increasing trends of mental health problems among adolescent females across the globe,[56 57] which are often comorbid with poor sleep and substance use; as well as narrowing of the gender gap in alcohol use among more among recent cohorts.[28 58] Links between these factors are complex[59] and assessing changes in mental health alongside changes in the Big 6 may be a useful future research direction.

Key strengths of this study include having assessment occasions before and during the pandemic, rather than relying on retrospective accounts of perceived changes in behaviours,

and a sample comprised of adolescents both in and not in lockdown at follow-up for comparability. However, we can't rule out the potential impact of other factors, such as maturation or mental health, that could also be influencing the Big 6. Although the study builds on previous research that has focused on the early pandemic period, claims about behavioural shifts across the early and late pandemic periods need to be interpreted with caution. Other limitations include the reliance on self-report measures, and while the sample was more diverse than other Australian studies, it is still not representative of the adolescent population.[7]

Conclusion

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

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Author contributions: LG conceptualised the study, with assistance from KC and NN. Acquisition of the data was contributed to by LG, KC, BO, NN, MT, and CC. Analysis and interpretation of data was led by JD and LG. LG led the write up of the manuscript with assistance from JD, FW, and BO. All authors critically revised and approved the final manuscript.

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Data availability statement: Deidentified participant data are available upon reasonable request from the Health4Life Team. Please contact the corresponding author to submit your request. Additional information about the Health4Life Trial is available in the study protocol[32] and the Australian New Zealand Clinical Trials Registry (ACTRN12619000431123).

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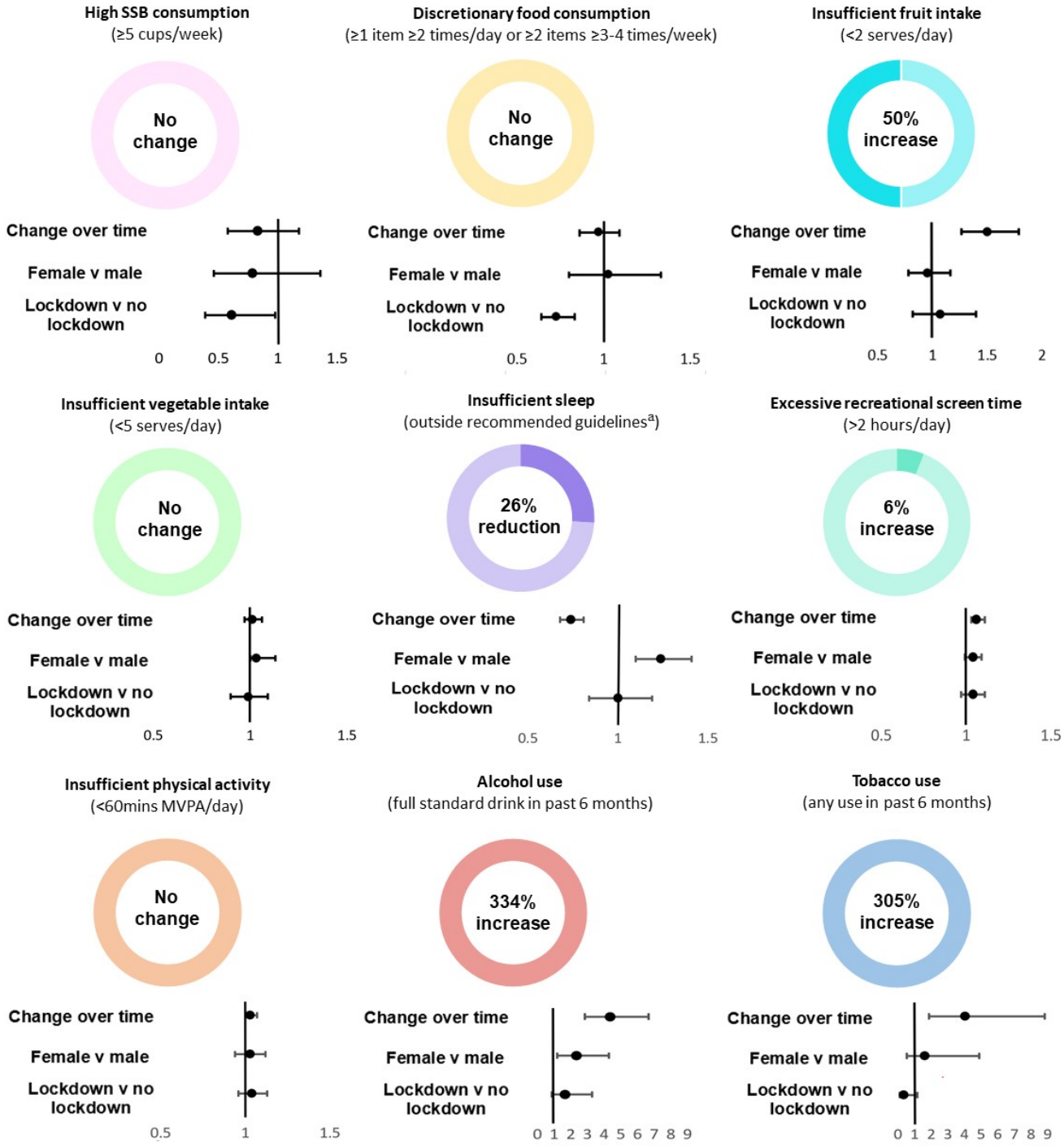
Figure Legends

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

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, [a]≤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
Change over time	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)
Lockdown v not	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)
Female v Male	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
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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

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 (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10-13 9
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14-16
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
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
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
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

*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.

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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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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.

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

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

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,[1] 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,[2-4] 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,[5] 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.[6] However, there can be substantial variation within countries.[7 8] In Australia, for example, stringency index values varied between states and territories by as much as 68 during 2020.[8] 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.[9 10] The Australian context may therefore serve as a case study for understanding the impact of various levels of restrictions on adolescent health behaviours.

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

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,[18 19] which may be the result of increased consumption of discretionary food and sugar-sweetened beverages (SSB) during lockdown periods.[18 20] However, some studies report improvements in dietary behaviours, including less SSB consumption among Colombian adolescents, higher fruit intake among Italian youth, and higher vegetable intake among adolescents from Spain, Brazil and Chile.[20 21] Among the few existing Australian studies, Munasinghe et al.[3] found physical distancing measures implemented in the initial lockdown period (March-April 2020) were associated with a decline in fast food consumption among adolescents, but there were no changes in fruit and vegetable consumption. However, it is unknown whether these changes have been sustained, or whether other dietary behaviours changed.

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

studies also report an increase in adolescent sleep duration during lockdown periods,[18 20] but higher prevalence of sleep problems, particularly among girls.[27] Similarly, Australian adolescents perceived an increase in sleep difficulties and had increased sleep disturbance during the first lockdown.[25] One study[28] reported increased sleep duration among Australian adolescents who were engaged in remote learning, however another[3] found no changes.

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

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

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

Methods

Participants and Procedure

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

Research Ethics Approval

Ethical approval was gained from the University of Sydney (2018/882), NSW Department of Education (SERAP No. 2019006), University of Queensland (2019000037), Curtin University (HRE2019-0083) and relevant Catholic school committees.[39]

Patient and Public Involvement

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

Measures

Sociodemographic characteristics

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

Diet

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

Physical activity

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

Recreational screen time

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

Sleep

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

Alcohol and Tobacco Use

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

Statistical Analysis

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.[52] 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.[53]

Results

Descriptive Statistics

The sample included 983 students (baseline M_{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 (≥5 cups/week)	90/964 (9.3)	72/935 (7.7)
High discretionary food intake (≥1 item ≥2 times/day or ≥2 items ≥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[a])	549/917 (59.9)	392/885 (44.3)
Excessive recreational screen time (>2hrs/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, [a]≤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,

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

Recreational screen time

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

Physical activity

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

Alcohol use

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

Tobacco use

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

Discussion

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

These findings highlight the varied impact of the pandemic across countries. For example, consistent with other Australian findings,[3] but in contrast to international research,[18 20] the prevalence of discretionary food intake decreased among those in lockdown. Yet in line with some international findings,[21] SSB intake reduced among adolescents in lockdown. This may reflect increased parental monitoring during lockdown and reduced opportunistic exposure to fast food due to not being with friends or commuting to school.[54 55] As such, continued parental monitoring beyond the lockdown period and the promotion of healthy food options may be beneficial. However, improvements in healthy dietary behaviours were not observed. In fact, the prevalence of insufficient fruit intake increased among the full sample. This may relate to the higher cost of fresh fruit and vegetables in Australia during the pandemic, caused by labour shortages within the farming, wholesale and retail sectors due to fewer working holiday makers.[56] These findings support calls for governments to consider broader policy-level changes to improve diet, such as taxes and subsidies.[57]

The finding that sleep duration improved from before to during the pandemic is consistent with some Australian[28] and international[18 20] studies. This contrasts typical trends over adolescence[58 59] and was despite an increase in the prevalence of excessive recreational screen time, which is often considered a primary contributor to poor sleep.[60] It is posited that

the time usually spent getting ready and commuting to school is instead spent getting additional sleep during periods of lockdown, leading to calls for delayed school start times;[28] however, we found no differences based on lockdown status to support this. The finding that insufficient sleep increased among females is consistent with international research reporting increased sleep disorders among females during the pandemic[27] and may reflect the association between female pubertal maturation and the emergence of insomnia symptoms.[61] Targeted intervention approaches to address sleep among females are needed.

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

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

would benefit from assessing how these different forms of physical activities changed throughout the pandemic.

Finally, although alcohol and tobacco use increased over time, the prevalence of these behaviours at the first timepoint, when participants were aged 12, was very low and remained relatively low 24-months later. This increase is to be expected among adolescents,[62] however, the greater increase in alcohol use among females was unexpected. Considering this and the increase in prevalence of insufficient sleep, females may be disproportionately impacted by the pandemic. This may reflect general patterns of higher prevalence and increasing trends of mental health problems among adolescent females across the globe,[63 64] which are often comorbid with poor sleep and substance use; as well as narrowing of the gender gap in alcohol use among more among recent cohorts.[35 65] Links between these factors are complex[66] and assessing changes in mental health alongside changes in the Big 6 may be a useful future research direction.

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

Conclusion

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

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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.

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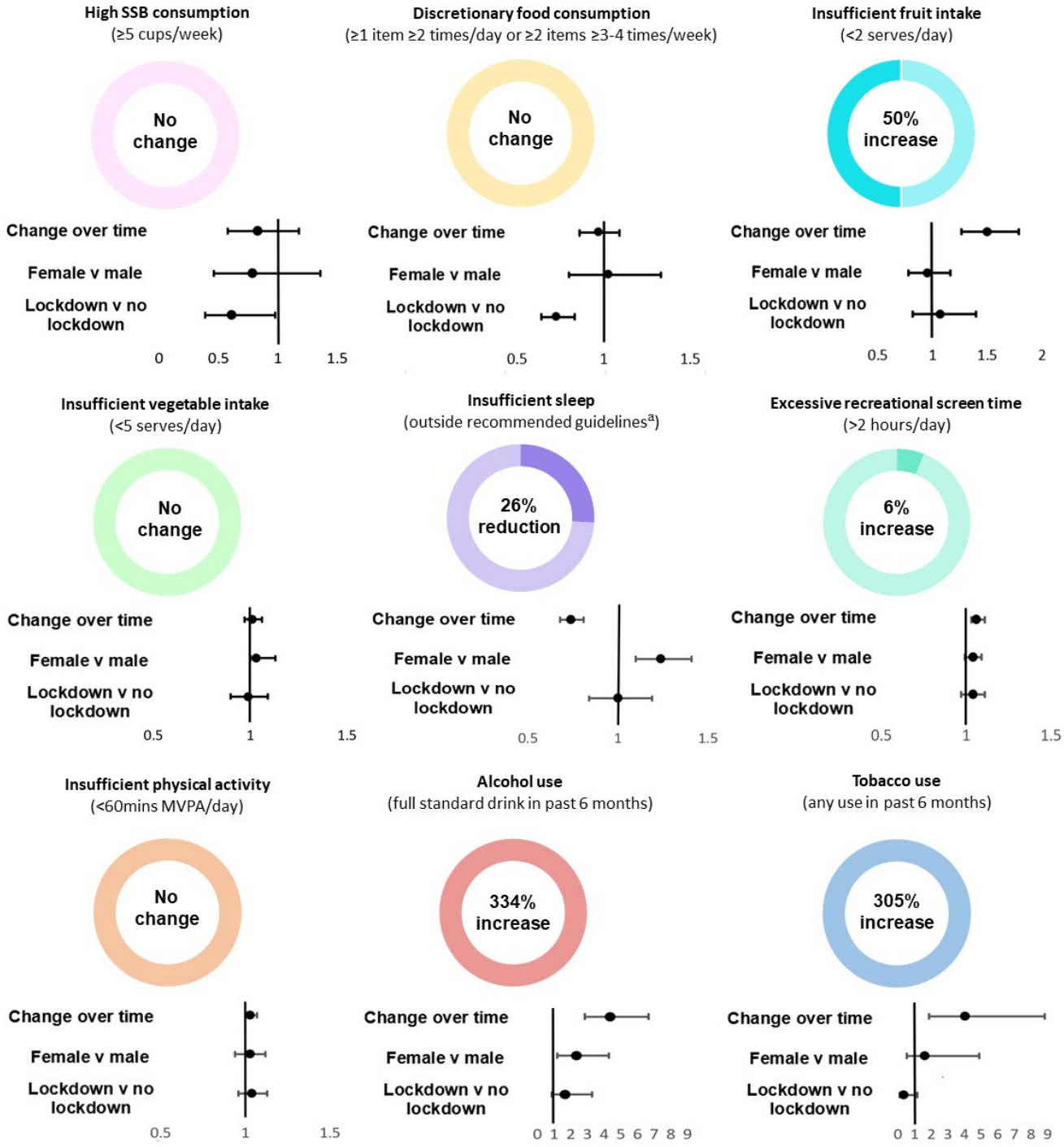

Note. SSB=sugar-sweetened beverage, [a]≤13 years old: 9 to 11 hours/night, 14-17years: 8 to 10 hours/night, MVPA=moderate-to-vigorous physical activity.

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
Change over time	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)
Lockdown v not	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)
Female v Male	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
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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

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 (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10-13 9
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14-16
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
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
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
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

*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.