International Journal of Mental Health and Addiction
https://doi.org/10.1007/s11469-024-01350-9

ORIGINAL ARTICLE

Adolescent Lifestyle Behaviour Modification and Mental Health: Longitudinal Changes in Diet, Physical Activity, Sleep, Screen Time, Smoking, and Alcohol Use and Associations with Psychological Distress

Scarlett Smout[1] · Katrina E. Champion[1] · Siobhan O'Dean[1] · Jillian Halladay[1,2] · Lauren A. Gardner[1] · Nicola C. Newton[1]

Accepted: 7 June 2024

Abstract
This study examines longitudinal behaviour change in six key lifestyle behaviours—sleep, physical activity (PA), sedentary recreational screen time, diet, alcohol use, and tobacco use—and associations with mental health in a large study of Australian adolescents. Change between baseline ($M_{age} = 12.7$, $N = 6{,}639$) and 3-year follow up ($M_{age} = 15.7$, $N = 4445$) was investigated. Generalised linear mixed effects regressions modelled associations between behaviour change and later psychological distress score adjusting for baseline behaviours, baseline psychological distress, social determinants, and school clustering. Changes over time in each of the behaviours were significantly associated with later psychological distress, whereby health-promoting behaviours were associated with reduced psychological distress and vice versa. When all behaviour changes were modelled together, significant effects remained for sleep, PA, vegetable consumption, junk food and SSB consumption, alcohol, and tobacco use. Results highlight the potential benefits of behaviour modification to reduce the progression of psychological distress in adolescence.

Keywords Adolescent · Lifestyle · Health behaviour · Psychological distress · Social determinants of health · Longitudinal studies

L.A Gardner and N.C Newton are joint senior authors.

✉ Scarlett Smout
Scarlett.smout@sydney.edu.au

[1] The Matilda Centre for Research in Mental Health and Substance Use, the University of Sydney, Jane Foss Russell Building G02, Darlington, NSW, Australia

[2] School of Nursing, McMaster University, Hamilton, Canada

Published online: 09 July 2024

Background

Adolescence is a critical developmental period that shapes health outcomes well into adulthood (Sawyer et al., 2012). The peak age of onset for mental disorders occurs in adolescence (at age 14.5), and ~ 50% of all mental disorders emerge before the age of 15 (75% by the age of 25) (Solmi et al., 2022; McGrath et al., 2023). Mental health issues that arise during adolescence typically track into adulthood (Jones, 2013), and mental disorders are the 7th highest cause of disease burden worldwide, which is a rise from 13th in 1990 (GBD 2019 Mental Disorders Collaborators, 2022).

Lifestyle risk and protective factors for chronic disease also typically change substantially in adolescence as more autonomy is gained and, similarly to mental disorders, behavioural patterns established in adolescence often influence behaviours in adulthood (Leger et al., 2012; Telama et al., 2014; Albani et al., 2017; Hayes et al., 2019; Livingston et al., 2020; Gardner et al., 2024). Six key lifestyle factors—moderate-to-vigorous physical activity (PA), sleep, sedentary recreational screen time, diet, alcohol use, and tobacco use—herein referred to as the 'Big 6', are among the leading contributors to burden of disease worldwide (Global Burden of Disease Study, 2023).

A growing body of literature has demonstrated associations between the Big 6 lifestyle behaviours and mental health in adolescence. Studies suggest that mechanisms include physiological mechanisms (e.g. increases in inflammation associated with poor diet worsen mental health (Oddy et al., 2018) and decreases in inflammation associated with PA improve mental health (Kandola et al., 2019)), neurological mechanisms (e.g. impacts on the prefrontal cortex from sleep deprivation (Jamieson et al., 2020) and tobacco use (Jobson et al., 2018) worsen mental health), and psychosocial mechanisms (e.g. cyberbullying and upward social comparison during screen time (Bottino et al., 2015; Seabrook et al., 2016) and social harms from alcohol use (Esmaeelzadeh et al., 2018) worsen mental health). Of the existing research, most studies examine a single behaviour on its own or a subset of two-to-three behaviours and associations with mental health outcomes, but evidence indicates that there are interrelationships between the Big 6 behaviours, suggesting they should be examined together (Fakier & Wild, 2011; Foti et al., 2011; Costigan et al., 2013). There are four recent studies—two from Canada, (Arbour-Nicitopoulos et al., 2012; Dabravolskaj et al., 2023) one from Korea, (Yoo & Kim, 2020) and one from Australia (Smout et al., 2023)—that have examined five or more of the Big 6 within one adolescent cohort. The four studies employed different methodologies and were conducted in cohorts with varying characteristics, limiting comparability of findings. Nevertheless, sleep, screen time and vegetable consumption were consistently associated with mental health outcomes, yet findings for PA, fruit consumption, junk food or SSB consumption, alcohol use, and tobacco use were inconsistent.

There are several key limitations with these studies. Firstly, all except the Australian study only modelled behaviours individually, missing the opportunity to examine how associations may be impacted by adjusting for the remaining behaviours. Secondly, all four studies examined behaviours at a single timepoint; all were cross-sectional except one of Canadian studies, which still only considered baseline behaviours (Arbour-Nicitopoulos et al., 2012; Yoo & Kim, 2020; Dabravolskaj et al., 2023; Smout et al., 2023). This precludes conclusions about the role of behaviour *change*; we cannot discern how improvements in the Big 6 may be associated with mental health outcomes, only how behavioural levels (e.g. serves of vegetables) at one timepoint are associated with mental health at either the same or a later timepoint. In addition, all except the Australian study treated the behaviours categorically, either as meeting/not meeting national guidelines or engaging

in high/moderate/low levels of the behaviours. This precludes realistic, strengths-based conclusions as findings are centred around guidelines or behavioural thresholds that the vast majority of adolescents do not meet (Beal et al., 2019; Guthold et al., 2020; Khan et al., 2021). Finally, there was limited consideration of the social determinants of health across the studies, despite evidence that factors such as gender diversity, relative affluence, and cultural and linguistic diversity can be associated with lifestyle behaviours (Currie et al., 2009; Bishop et al., 2020; Champion et al., 2021) or mental health outcomes (Lund et al., 2018). While some studies did adjust for social determinants including age and sex as covariates, only the Australian study directly examined the associations between social determinants and lifestyle behaviours, and this study was limited by cross-sectional design.

To address these gaps, the present study has three key research questions: (1) What are the patterns of behaviour change in a general population sample of adolescents over 3 years? (2) What relationships do these behaviour changes have with key social determinants? (3) What are the associations between behaviour change and mental health outcomes? To investigate these questions, this study uses a large, longitudinal dataset of Australian adolescents and examines the following: (1) the prevalence and mean changes in the Big 6 between baseline and 3-year follow-up, spanning the first 4 years of secondary school in Australia (year 7 (age ~ 12–13) to year 10 (age ~ 15–16)), (2) associations between social determinants (gender, cultural and linguistic diversity, and family affluence) and behaviour change, and (3) associations between changes in the Big 6 and psychological distress (a general indicator of mental illness), both individually and in a multi-behavioural model, while adjusting for baseline behaviour, baseline psychological distress, and social determinants. Based on the relationships between the Big 6 and mental health observed in the aforementioned studies (Arbour-Nicitopoulos et al., 2012; Bottino et al., 2015; Seabrook et al., 2016; Esmaeelzadeh et al., 2018; Jobson et al., 2018; Oddy et al., 2018; Kandola et al., 2019; Jamieson et al., 2020; Yoo & Kim, 2020; Dabravolskaj et al., 2023; Smout et al., 2023), we hypothesise that an increase in health promoting behaviours will be associated with decreased symptoms of psychological distress, and an increase in health risk behaviours will be associated with increased symptoms of psychological distress.

Methods

Study Design and Procedure

This study uses baseline and 3-year follow-up survey data from the Health4Life cluster randomised controlled trial (RCT), which evaluated the efficacy of an eHealth intervention targeting the Big 6 among Australian secondary school students (Teesson et al., 2020). The trial was pre-registered (ACTRN12619000431123) and had ethical approval (University of Sydney HREC2018/882, University of Queensland 2019000037, Curtin University HRE2019-0083, NSW Department of Education SERAP 2019006, and several Catholic Diocese committees). The published protocol and main outcomes study contain further details on sample size calculations, recruitment procedures and consent procedures (Teesson et al., 2020; Champion et al., 2023). Briefly, 519 independent, public (government-funded), or Catholic schools across New South Wales (NSW), Queensland (QLD), and Western Australia (WA) were approached, with school type based on relevant ethics approval in each State. Schools were identified via the publicly available database My School, with those that had fewer than 30 year 7 students excluded. 85 schools were recruited but 14 schools (distributed between

the states) withdrew, mainly due to lack of time. Seventy-one schools across NSW, QLD, and WA participated in the trial. All year 7 students at participating schools were eligible, but active student consent and either active or passive parental consent (depending on ethics board) was required. Students completed the baseline questionnaire in year 7 in 2019 and 3-year follow up in year 10 in 2022. In Australia, students are aged 12–13 in year 7 and 15–16 in year 10, equivalent in age to grades 7 to 10 in the USA and Canada, and years 8 to 11 in the UK and New Zealand. As reported elsewhere, the Health4Life intervention was found to be no more effective than an active control condition in achieving behaviour change for the Big 6 (Champion et al., 2023; O'Dean et al., 2024). Between-group differences were found immediately post-intervention (7-week follow-up) for psychological distress, (Smout et al., 2024) however effects did not hold beyond this timepoint. As the present study includes only baseline and 3-year follow-up, both the control and intervention group are included to maximise sample size. However, intervention allocation and school cluster are adjusted for in all models (see statistical analysis section).

Measures

Behaviour Change

Physical Activity Change Moderate-to-vigorous PA was measured using a measure recommended by the Active Healthy Kids Australia Research Working Group (Tomkinson et al., 2016). The measure was chosen to facilitate comparison with Australian PA guidelines. Participants are presented with an explanation of moderate-to-vigorous PA ('activity that increases your heart rate and makes you get out of breath some of the time') and are asked to consider a 'typical/usual' week and report how many days (0–7) they engage in at least 60 min of moderate-to-vigorous PA. Change was determined by subtracting year 10 days from year 7 days, resulting in a variable ranging − 7 to 7.

Sleep Change Average nightly sleep duration was measured using the Modified Sleep Habits Survey (Short et al., 2013). Students reported (separately for week nights and weekend nights) the time they usually (1) went to bed (12-h time—am/pm), (2) attempted sleep (12-h time), (3) took to fall asleep (h, min), (4) were awake during the night (h, min), and (5) woke up in the morning (12-h time—am/pm). These items were then used to calculate average hours' sleep per night in the past week (weighted to reflect weeknights and weekend nights). The Sleep Habits Survey has high correlation with sleep journal and actigraphy measurements among adolescents (Wolfson et al., 2003) and studies have demonstrated the validity and accuracy of adolescent self-report bedtime, wake time and sleep duration (Nascimento-Ferreira et al., 2016). Sleep change was determined by subtracting year 10 average hours' sleep from year 7 average hours.

Screen Time Change Recreational screen time was measured using the International Sedentary Assessment Tool (Prince et al., 2017). Participants reflect on a 'typical' week day and 'typical weekend day' and separately report their average daily time spent sitting or lying down while watching television/videos (examples included Netflix and online videos) or using an electronic device (examples included laptop gaming consoles, smartphone). Participants were instructed to only consider free time (i.e. not at school) and not to double count time; if they were watching

videos and scrolling on their phone, they allocated time to one or the other. Both weekend and weekday times were then combined with a weighted average to compute average daily time across the week in hours. Change was determined by subtracting year 10 h from year 7 hours.

Diet Change Four key components of diet—fruit, vegetable, sugar-sweetened beverage (SSB), and discretionary food ('junk food') consumption—were measured using items from the Student Physical Activity and Nutrition Survey (SPANS). For fruit and vegetable intake, participants were presented with visual cues of serving sizes (reflecting National guidelines on fruit and vegetable serving sizes) and asked to report the number of servings they 'usually' have per day. Continuous variables ranging 0–7 were used with 0 representing less than one serve per day and 7 indicating 7 + serves per day. Change was determined by subtracting year 10 average daily serves from year 7 serves, resulting in a variable ranging from − 7 to 7. To report their SSB consumption, students were presented with visual cues on how many cups are contained in typical packaging sizes of beverages and asked to how many cups they consume in a typical week (Supplementary Table 1). Junk food measurement consisted of six variables with different categories of discretionary foods (e.g. 'Confectionary, such as lollies or chocolate', 'Hot chips, French fries, wedges or fried potatoes', etc.), against which students reported how frequently they 'usually' consumed those foods each week (Supplementary Table 2). SSB and junk food have been combined for the present study, with detailed information on how this was operationalised provided in Supplementary Note 1. Briefly, the six junk food variables each had four frequency categories, so the scale was summed to a total score out of 24. The SSB variable was converted to four frequency categories, a total score out of 4. The junk and SSB total scores were summed to a combined 'Junk and SSB score' out of 28 and the change score was calculated by subtracting year 10 score from year 7 score.

Alcohol and Tobacco Change Binary variables were utilised to capture alcohol and tobacco use. Binary measures were chosen due to the low prevalence of alcohol and tobacco use among year 7 students (12–13 years) (Champion et al., 2021). For alcohol, participants reported whether they had consumed a full standard alcoholic drink in the past 6 months. To help students discern a full standard drink, they were shown a chart that indicated the number of standard drinks in a range of different alcohol types and sizes. Tobacco measurement used an item from the Youth Risk Behavior Survey (YRBS), whereby participants reported whether they had smoked a cigarette ('even one or two puffs') in the last 6 months (Brener et al., 2013). Change variables were determined by comparing year 7 response to year 10 response and were categorised as (1) no change, (2) 'yes' in year 7 but 'no' in year 10, and (3) 'yes' in year 10 but 'no' in year 7. Those who reported no change were not split into categories of yes at both timepoints or no at both timepoints, despite likely differences in year 10 mental health between these groups, as our research question was interested in behaviour change.

Psychological Distress

The Kessler 6-item scale (K6) is a measure of psychological distress with predictive ability to identify common mental disorders among adolescents, including major depressive disorder, generalised anxiety disorder, and bipolar disorder (Ferro, 2019). The K6 measured prior-four-week psychological distress symptoms such as nervousness, hopelessness, restlessness, and worthlessness and asked students to report the portion of time they experienced these symptoms from 'all of the time' to 'none of the time' (Kessler et al., 2002). This K6 is scored out of a possible range of 0–24, with scores ≥ 13 indicating high psychological distress (Kessler

et al., 2011; Mewton et al., 2016). High psychological distress on the K6 is not disorder-specific, instead indicating a 'probable serious mental illness' (Kessler et al., 2011). The K6 is widely used and has demonstrated good internal consistency and predictive validity in adolescents (Kessler et al., 2011; Mewton et al., 2016; Ferro, 2019).

Social Determinants

Gender The two-step approach to categorising gender was used, whereby gender identity and sex assigned at birth are combined to recognise transgender and gender diverse participants whose gender identity does not match their sex assigned at birth (Kidd et al., 2022). Students reported their gender identity, with four options: 'male', 'female', 'non-binary/gender fluid', 'different identity', and 'prefer not to say' (ACON, 2021). Sex at birth options were 'male', 'female', and 'prefer not to say'. After performing the two-step method, the final gender variable consisted of four categories: (1) cisgender male (male-identifying and assigned male sex at birth), (2) cisgender female (female-identifying and assigned female at birth), (3) transgender/non-binary/gender diverse (different gender identity to sex assigned at birth), and (4) prefer not to say (prefer not to say indicated for either identity or sex assigned at birth). Year 10 (3-year follow-up) gender was the covariate used.

Cultural and Linguistic Diversity (CALD) CALD participants were those who reported being born in a non-English speaking country and/or indicated primarily speaking a language other than English at home, as recommended in a recent review (Pham et al., 2021).

Socioeconomic Status As parent or carers' income, education and other socioeconomic indicators are often unknown by children and adolescents, the Family Affluence Scale III (FASIII) was used to identify relative family affluence (Torsheim et al., 2016 Sep 1). The FASIII asks students to report against indicators of familial wealth that young people are likely to know (e.g. number of computers, number of bathrooms in home) as a proxy for familial socioeconomic status. It has demonstrated good test–retest reliability ($r = 0.9$) and strong correlation with parental report (Torsheim et al., 2016). A ridit transformation is then applied to the summed score, which converts the sample scores to a normal distribution, representing a participant's relative family affluence position *within* the overall sample. This ridit score is then recoded into low relative affluence (0–0.2), middle relative affluence (0.2–0.8), and high relative affluence (0.8–1) categories. Year 7 family affluence categories are used in descriptive statistics and models.

Australian National Guidelines

Some results are compared to Australian national health guidelines, which are summarised in Table 1.

Statistical Analysis

All analyses were conducted in R Studio version 2022.12.0 + 353. Descriptive analyses determined the sample characteristics and mean scores and prevalence of the Big 6 behaviours and psychological distress, as well as mean change at the overall sample

Table 1 Australian national health guidelines

Behaviour	Australian national health guideline
Moderate-to-vigorous PA	At least 60 min each day of moderate to vigorous physical activity (Australian Government Department of Health and Aged Care, 2021).
Sleep	Children aged 5 to 13 years should get 9 to 11 h of uninterrupted sleep (Australian Government Department of Health and Aged Care, 2021). Young people aged 14 to 17 years should get 8 to 10 h of uninterrupted sleep (Australian Government Department of Health and Aged Care, 2021).
Screen time	No more than 2 h of sedentary recreational screen time per day (Australian Government Department of Health and Aged Care, 2021).
Fruit consumption	At least 2 servings of vegetables per day (National Health and Medical Research Council, 2013).
Vegetable consumption	At least 5 servings of vegetables per day (National Health and Medical Research Council, 2013).
Junk food and SSB intake	Limit intake of foods and drinks containing saturated fat, added salt, and added sugars (National Health and Medical Research Council, 2013).
Alcohol use	Children and people under 18 years of age should not drink alcohol (National Health and Medical Research Council, 2020).
Tobacco use	No health guideline but purchasing cigarettes is illegal for anyone under the age of 18

level and in subgroups for each of the three social determinant covariates. The social determinant subgroup differences in mean change scores were examined with t-tests (for CALD status) and one-way ANOVAs (for gender and family affluence), while the differences on categorical measures (alcohol and tobacco) were examined with chi-square tests. The 'tableone' package was used for all descriptive analyses and subgroup tests (Yoshida et al., 2020).

Mixed effects regressions were used to model the association between change in each of the behaviours and psychological distress. Models adjusted for baseline behaviour and baseline psychological distress to determine the role of behaviour change, over-and-above the influence of participants' starting point for health behaviours or psychological distress. Models also adjusted for gender, affluence and CALD status and included a random effect of school, to account for the clustered nature of the dataset. Four types of mixed effects regressions were tested; linear mixed effects regressions, and—as the K6 symptom score variable is essentially a count of symptoms and their frequency and has a left skewed distribution—three generalised linear mixed effects approaches (Poisson, negative binomial type I, and negative binomial type II) (Green, 2021). Model fit statistics (AIC and BIC) were compared to guide model selection. Negative binomial type I regressions offered superior fit for all models. These were performed using the R package 'glmmTMB' (Brooks et al., 2017). First, single behaviours and their relationship with psychological distress were modelled. Next, a multi-behavioural model was analysed, which included all health behaviours to identify any unique associations with psychological distress, over-and-above the other behaviours. The multi-behavioural model was checked for multi-collinearity using the variable inflation factor (VIF) from the 'performance' package (Lüdecke et al., 2021). A VIF < 5 indicates a low correlation of that predictor with other predictors (Lüdecke et al., 2021). Attrition analysis examined baseline characteristics by follow-up status, using a t-test for continuous variables (psychological distress, moderate-to-vigorous PA, sleep, screen time, fruit, vegetable, and junk food/SSB) and a binomial logistic regression for alcohol and tobacco use.

Table 2 Characteristics of the sample

	Year 7 (baseline)	Year 10 (36-month follow-up)
Participant, *N*	6639	4445
Age mean (SD)	12.65 (0.50)	15.71 (0.64)
Gender, *N* (%)		
Cisgender male	3271 (49.5)	2109 (47.9)
Cisgender female	3185 (48.2)	2035 (46.2)
Transgender/non-binary/gender diverse	51 (0.8)	142 (3.2)
Prefer not to say	105 (1.6)	119 (2.7)
Relative family affluence, *N* (%)		
Low	909 (15.1)	571 (14.0)
Middle	3510 (58.4)	2426 (59.3)
High	1595 (26.5)	1092 (26.7)
Cultural and linguistically diverse, *N* (%)		
Non-CALD	5809 (87.8)	3907 (88.2)
CALD	808 (12.2)	525 (11.8)

Results

Participant Characteristics

As summarised in Table 2, 6639 participants completed baseline in year 7 ($M_{age} = 12.7$, 49.5% male, 48.2% female, 0.8% gender-diverse) and 4,445 completed 3-year follow-up in Year 10 ($M_{age} = 15.7$, 47.9% male, 46.2% female, 3.2% gender-diverse). Attrition analysis (Supplementary Table 3) showed that, compared to those who completed follow-up in year 10, those who only completed the baseline questionnaire had significantly higher baseline psychological distress, higher baseline PA, lower baseline sleep, higher baseline screen time, and higher baseline junk food/SSB. There were no significant differences by baseline fruit and vegetable consumption. Those who reported drinking alcohol or smoking a cigarette at baseline were less likely to complete follow-up.

Table 3 presents descriptive statistics for the Big 6 behaviours. By year 10, the sample averaged 11% less moderate-to-vigorous PA, 8% less sleep, 10% more screen time, 17% less fruit consumption, 4% less vegetable consumption, and 2% more junk food/SSB consumption. In year 10, 29.9% of participants had consumed a full standard drink and 7.9% of participants had smoked a cigarette in the past 6 months, compared to year 7 prevalence of 2.9% and 1.5%, respectively. Mean psychological distress scores increased over time, with 23.8% of participants meeting the threshold for probable mental illness in year 10, compared to 14.1% in year 7. The portion of the sample adhering to National guidelines decreased between years 7 and 10 for all behaviours aside from sleep, likely due to the sleep guidelines changing from 9 to 11 h per night for 12–13-year-olds to 8–10 h for 14–17-year-olds.

Table 4 shows the descriptive statistics for mean change in behaviours between year 7 and year 10, overall and by social determinant subgroups, in addition to tests of significance for each social determinant. Cisgender females and gender diverse participants had significantly larger decreases in physical activity than cisgender males. There were no significant differences in sleep changes by gender. Gender diverse participants had

Table 3 Descriptive statistics on the Big 6 and psychological distress

	Year 7 (baseline)	Year 10 (36-month follow-up)	Year 7 adherence to Australian Guidelines, *n* (%)	Year 10 adherence to National Guidelines, *n* (%)
n	6639	4445	6639	4445
Continuous Big 6 variables	Mean (SD)		*N* (%)	
Days of moderate-to-vigorous PA in past week	4.25 (2.03)	3.80 (2.13)	1428 (22.3)	725 (17.0)
Hours of sleep	8.52 (1.49)	7.83 (1.31)	2327 (38.7)	1965 (49.1)
Hours of screen time	5.58 (3.96)	6.15 (4.11)	912 (14.1)	391 (9.2)
Daily fruit serves	2.54 (1.55)	2.10 (1.49)	4674 (75.8)	2658 (63.8)
Daily vegetable serves	2.71 (1.64)	2.60 (1.56)	853 (13.7)	458 (11.0)
Score on junk food and drink measure	7.18 (4.42)	7.32 (4.59)	n/a	
Categorical Big 6 variables	*N* (%)		*N* (%)	
Full standard drink past 6 months				
Yes	181 (2.9)	1263 (29.9)	6164 (97.1)	2962 (70.1)
No	6164 (97.1)	2962 (70.1)		
Smoked a cigarette past 6 months				
Yes	97 (1.5)	334 (7.9)	6208 (98.5)	3878 (92.1)
No	6208 (98.5)	3878 (92.1)		
Psychological distress (%)	Mean (SD)		n/a	
Psychological distress	6.86 (5.40)	8.42 (6.39)		
High psychological distress (probable mental illness)	*N* (%)			
Yes	886 (14.1)	997 (23.8)		
No	5391 (85.9)	3196 (76.2)		

Table 4 Mean change between year 7 and year 10, overall and by subgroup for each social determinant covariate

	Overall	Gender						Cultural and linguistic diversity			Relative family affluence			
		Cisgender male	Cisgender female	Gender diverse	Prefer not to say	All genders sig. test, *p* val	Cisgender only sig. test, *p* val	Non-CALD	CALD	Sig. test, *p* val	Low	Middle	High	Sig. test, *p* val
Continuous variables: mean (SD)														
Moderate-to-vigorous PA change—days per week	−0.38 (2.40)	0.00 (2.45)	−0.74 (2.23)	−0.86 (2.52)	−0.20 (2.84)	<0.001	<0.001	−0.40 (2.38)	−0.24 (2.59)	0.164	−0.42 (2.57)	−0.35 (2.36)	−0.37 (2.34)	0.816
Sleep change—hours	−0.73 (1.64)	−0.71 (1.67)	−0.74 (1.56)	−0.78 (2.13)	−0.81 (1.81)	0.864	0.514	−0.73 (1.62)	−0.66 (1.73)	0.388	−0.70 (1.74)	−0.73 (1.58)	−0.73 (1.69)	0.931
Screen time change—hours	0.79 (4.48)	0.70 (4.80)	0.74 (3.89)	2.14 (5.47)	1.08 (5.91)	0.003	0.757	0.82 (4.44)	0.58 (4.74)	0.269	0.86 (4.79)	0.77 (4.39)	0.70 (4.34)	0.79
Fruit change—daily serves	−0.40 (1.63)	−0.32 (1.68)	−0.48 (1.50)	−0.35 (2.05)	−0.50 (2.02)	0.024	0.002	−0.38 (1.59)	−0.53 (1.89)	0.053	−0.44 (1.70)	−0.37 (1.60)	−0.38 (1.67)	0.738
Vegetables change—daily serves	−0.09 (1.75)	−0.01 (1.80)	−0.14 (1.64)	−0.40 (1.92)	−0.49 (2.09)	0.003	0.023	−0.09 (1.73)	−0.12 (1.87)	0.713	−0.08 (1.86)	−0.08 (1.69)	−0.08 (1.80)	0.999
Junk food and SSB change—units	0.31 (4.89)	0.26 (5.20)	0.30 (4.33)	0.89 (5.49)	0.08 (6.47)	0.569	0.802	0.38 (4.84)	−0.18 (5.18)	0.028	0.24 (5.31)	0.32 (4.72)	0.35 (5.00)	0.923

Table 4 (continued)

	Overall	Gender						Cultural and linguistic diversity			Relative family affluence			
		Cisgender male	Cisgender female	Gender diverse	Prefer not to say	All genders sig. test, *p* val	Cisgender only sig. test, *p* val	Non-CALD	CALD	Sig. test, *p* val	Low	Middle	High	Sig. test, *p* val
Categorical variables: *n* (%)														
Consumed a full standard drink in the past 6 months														
No change	2892 (70.7)	1430 (74.4)	1282 (67.4)	88 (66.2)	70 (65.4)	<0.001	<0.001	2482 (68.8)	404 (84.5)	<0.001	413 (75.5)	1631 (70.3)	709 (68.8)	0.004
Drink to no drink	30 (0.7)	15 (0.8)	6 (0.3)	5 (3.8)	4 (3.7)			25 (0.7)	5 (1.0)		8 (1.5)	12 (0.5)	9 (0.9)	
No drink to drink	1171 (28.6)	476 (24.8)	613 (32.2)	40 (30.1)	33 (30.8)			1101 (30.5)	69 (14.4)		126 (23.0)	678 (29.2)	313 (30.4)	
Smoked a cigarette in the past 6 months														
No change	3724 (91.8)	1747 (92.0)	1754 (92.6)	110 (84.0)	90 (86.5)	<0.001	<0.001	3272 (91.4)	445 (94.5)	0.019	482 (89.6)	2137 (92.3)	946 (92.1)	0.114
Smoke to no smoke	30 (0.7)	23 (1.2)	3 (0.2)	2 (1.5)	2 (1.9)			24 (0.7)	5 (1.1)		8 (1.5)	14 (0.6)	6 (0.6)	
No smoke to smoke	304 (7.5)	128 (6.7)	138 (7.3)	19 (14.5)	12 (11.5)			283 (7.9)	21 (4.5)		48 (8.9)	164 (7.1)	75 (7.3)	

significantly larger increases in screen time than their cisgender peers. Cisgender females and gender diverse participants had significantly larger decreases in fruit and vegetable consumption but there were no significant gender differences in changes in junk food and SSB consumption. Changes in alcohol and tobacco use were both significantly associated with gender; 28.6% of cisgender males changed from not drinking to drinking, compared to 32.2% of females and 30.1% of gender diverse participants. Of cisgender males, 6.7% changed from not smoking to smoking, compared to 7.3% of females and 14.9% of gender diverse participants.

CALD status was significantly associated with junk food and SSB score, alcohol use and tobacco use but none of the other variables (Table 4). CALD participants had less harmful changes across these categories—their junk food score rose by less than non-CALD participants, a lower proportion of CALD participants went from not drinking to drinking, and a lower proportion of CALD participants went from not smoking to smoking, compared to non-CALD participants.

There were no significant differences between relative family affluence groups for any of the variables except alcohol use (Table 4). The low affluence group had the lowest proportion of participants who changed from not drinking to drinking, followed by middle affluence, then high affluence.

Associations Between Behaviour Change and Psychological Distress

Table 5 presents the results from single behaviour models exploring each Big 6 behaviour change (change from year 7 to year 10) and year 10 psychological distress score, after adjusting for social determinants and year 7 behaviour and year 7 psychological distress.

Table 5 Main output from single and multi-behavioural models

Model	Single behaviour models—negative binomial type I models main output	Multi-behavioural model—negative binomial type I model main output
Moderate-to-vigorous PA change	expβ 0.97(0.96, 0.98), $p < 0.001$	expβ 1.01(1.01, 1.02), $p < 0.001$
Sleep change	expβ 0.91(0.90, 0.93), $p < 0.001$	expβ 0.96(0.95, 0.98), $p < 0.001$
Screen time change	expβ 1.02(1.02, 1.03), $p < 0.001$	expβ 1.01(1.00, 1.02), $p < 0.001$
Fruit change	expβ 0.96(0.94, 0.98), $p < 0.001$	expβ 0.98(0.96, 0.99), p 0.008
Vegetables change	expβ 0.96(0.94, 0.98), $p < 0.001$	expβ 1(0.98, 1.02), p 0.84
Junk and SSB change	expβ 1.02(1.02, 1.03), $p < 0.001$	expβ 0.99(0.98, 1.00), p 0.029
Alcohol change		
No change	—	—
Drink to no drink	expβ 0.98(0.71, 1.37), p 0.92	expβ 1.1(0.77, 1.57), p 0.6
No drink to drink	expβ 1.17(1.11, 1.23), $p < 0.001$	expβ 1.13(1.07, 1.20), $p < 0.001$
Tobacco change		
No change	—	—
Smoke to no smoke	expβ 0.79(0.52, 1.21), p 0.28	expβ 0.95(0.64, 1.40), p 0.8
No smoke to smoke	expβ 1.36(1.26, 1.47), $p < 0.001$	expβ 1.26(1.14, 1.39), $p < 0.001$

All models adjust for baseline psychological distress and baseline behaviour level as well as gender, relative affluence, CALD status. Models have a random effect of school. Full model output for each model available in Supplementary Tables 4-11

The full model outputs are available in Supplementary Tables 4–10. For each increase of one day per week in moderate-to-vigorous PA between year 7 and year 10, year 10 K6 score decreased by 3% (expβ 0.97 [0.96,0.98], $p < 0.001$). For each added hour of sleep, year 10 K6 score decreased by 9% (expβ 0.91 [0.90,0.93], $p < 0.001$). For each added hour of screen time, year 10 K6 score increased by 2% (expβ 1.02 [1.02,1.03], $p < 0.001$). For each added daily serve of fruit, year 10 K6 score decreased by 4% (expβ 0.96 [0.94,0.98], $p < 0.001$). For each added daily serve of vegetables, year 10 K6 score decreased by 4% (expβ 0.96 [0.94,0.98], $p < 0.001$). For each one unit increase in junk food, year 10 K6 score increased by 2% (expβ 1.02 [1.02,1.03], $p < 0.001$). Uptake of alcohol use between year 7 and year 10 was associated with a 17% increase in K6 score (expβ 1.17 [1.11,1.23], $p < 0.001$). Changing from non-smoking in year 7 to smoking in year 10 was associated with a 36% increase in K6 score (expβ 1.36 [1.26,1.47], $p < 0.001$). To illustrate these findings further, model-predicted year 10 K6 scores based on levels of behaviour change are presented in Supplementary Table 13.

The multi-behavioural model (see Table 5), includes all behaviour change variables, meaning that change in each behaviour adjusts for changes in the other behaviours. Changes in moderate-to-vigorous PA and fruit consumption were no longer statistically significant predictors of psychological distress in this model and the remaining effects decreased in magnitude compared to the single behaviour models. An hour increase in sleep was associated with 4% lower psychological distress (expβ 0.96 [0.95,0.98], $p < 0.001$), while an hour increase in screen time was associated with a 1% increase in psychological distress (expβ 1.01 [1.01,1.02], $p < 0.001$). An increase of one vegetable serve per day was associated with 2% lower psychological distress (expβ 0.98 [0.96,0.99], p 0.008), and a one unit increase in junk food/SSB was associated with a 1% increase in psychological distress (expβ 1.01 [1.00,1.02], $p < 0.001$). Uptake of drinking between year 7 and year 10 was associated with a 13% increase in K6 score (expβ 1.13 [1.07,1.20], $p < 0.001$). Changing from non-smoking in year 7 to smoking in year 10 (even a puff, in the prior 6 months) was associated with a 26% increase in K6 score (expβ 1.26 [1.14,1.39], $p < 0.001$). There was low collinearity between the variables in the full model (Supplementary Table 12).

Discussion

This study analysed a large dataset of Australian adolescents to examine the patterns of behaviour change across six key lifestyle behaviours (moderate-to-vigorous PA, sleep, sedentary recreational screen time, diet (fruit, vegetables, junk food and SSB), alcohol use, and tobacco use), and associations with psychological distress over a 3-year period. To our knowledge, this is the first study to examine the relationship between lifestyle behaviours and adolescent mental health with inclusion of all Big 6 behaviours and a focus on behaviour *change* as the predictor, rather than behavioural levels at a single timepoint (Fakier & Wild, 2011; Foti et al., 2011; Costigan et al., 2013). Change was measured between year 7 (mean age 12.7) to year 10 (mean age 15.7); the first four years of secondary school in Australia.

Overall, the sample reported a decrease in health-promoting behaviours (moderate-to-vigorous PA, sleep, fruit, and vegetables) and an increase in health risk behaviours (screen time, junk food and SSB, alcohol use and tobacco use) over the three years. This is consistent with other epidemiological studies that demonstrate a decline throughout adolescence in physical activity, (Telama et al., 2014) sleep, (Leger et al., 2012) sedentary recreational

screen time, (Hayes et al., 2019) and diet quality, (Albani et al., 2017) and an increase in prevalence of alcohol and tobacco use (Keyes et al., 2019; Livingston et al., 2020; Feb; Gardner et al., 2023). Mean psychological distress score and the prevalence of high psychological distress also increased over the study period, in line with literature suggesting rising mental ill-health and onset of mental disorders in the adolescent period (Solmi et al., 2022). However, the present study adds significantly to the field with findings that increases in health-promoting behaviours (moderate-to-vigorous PA, sleep, fruit, and vegetables) were each associated with lower psychological distress, and increases in health risk behaviours (screen time, junk food and SSB, alcohol use, and tobacco use) were each associated with higher psychological distress. When modelled together in a multi-behavioural model, the magnitude of effects reduced slightly but remained statistically significant for sleep, physical activity, vegetable consumption, junk food and SSB consumption, alcohol use, and tobacco use. This suggests that each of these behaviour changes has unique effects, over-and-above the effects of changes in other behaviours, indicating that there may be additive mental health benefits of interventions targeting these lifestyle behaviours simultaneously. While no other studies have examined the association between behaviour *change* in the Big 6 and mental health outcomes, four studies have examined the association between behavioural *levels* (in five or more of the Big 6) and mental health outcomes (Arbour-Nicitopoulos et al., 2012; Yoo & Kim, 2020; Dabravolskaj et al., 2023; Smout et al., 2023). These studies utilised different methodologies cohorts with varying characteristics so findings regarding the relationship between PA, fruit consumption, junk food or SSB consumption, alcohol use, and tobacco use and mental health outcomes, were inconsistent. However, sleep, screen time and vegetable consumption were consistently found to be associated with mental health outcomes, congruous with findings from the present study (Arbour-Nicitopoulos et al., 2012; Yoo & Kim, 2020; Dabravolskaj et al., 2023 Apr 17; Smout et al., 2023).

Many countries have national health guidelines for physical activity, screen time, fruit and vegetable consumption, and sleep, including Australia. However, studies show that many adolescents do not meet these guidelines (Beal et al., 2019; Guthold et al., 2020; Khan et al., 2021). Indeed, the present study found that the proportion of students meeting guidelines dropped between year 7 and year 10 (with the exception of sleep, due to a reduction in recommended sleep for older adolescents). By year 10, most participants were not meeting guidelines for moderate-to-vigorous PA, sleep, screen time, and vegetable consumption. This low adherence to guidelines, coupled with our findings that even small positive behaviour changes are associated with incremental improvements in mental health, suggest that messaging focussing on the benefits of making positive changes (rather than solely on the benefits of meeting aspirational guidelines) may offer a more strengths-based and realistic adolescent health promotion approach.

Social Determinants, Behaviour Change, and Mental Health

When examining the relationship between lifestyle behaviours and mental health, it is essential to consider and adjust for the influence of social determinants that may influence both lifestyle behaviours and mental health outcomes (Currie et al., 2009; Lund et al., 2018; Bishop et al., 2020; Champion et al., 2021). Yet, to our knowledge, no other studies have reported gender, cultural, and socioeconomic differences in behaviour change for all the Big 6 in the one cohort of adolescents. In the present study, gender was significantly associated with change in all behaviours except sleep and junk food consumption.

Compared to cisgender males, cisgender females and gender diverse participants had larger decreases in health-promoting behaviours (reductions in fruit consumption, vegetable consumption, and moderate-to-vigorous PA) and larger increases in health risk behaviours (alcohol and tobacco uptake). Gender diverse young people had a substantially higher increase in screen time than their cisgender peers. Findings suggest the need to consider targeting and/or tailoring content in adolescent health behaviour change interventions to ensure they resonate and are effective for female and gender diverse adolescents (Marmot, 2013). Further, a substantial body of literature has demonstrated a growing gender gap in adolescent mental health (Campbell et al., 2021). Findings from the present study suggest that reducing the deterioration in health behaviours among adolescent girls and gender diverse young people may offer an intervention target to reduce this gap. Indeed, one study has identified physical activity as a likely mediator between gender and mental health (Halliday et al., 2019). However, further longitudinal research considering all Big 6 is needed to further investigate their role as contributors to the gender gap in adolescent mental health.

Cultural and linguistic diversity was associated with behaviour change for junk food, alcohol use and tobacco use; CALD participants had substantially lower increases in these health risk behaviours compared to non-CALD participants. For example, 31% of non-CALD participants went from not drinking to drinking compared to only 14% of CALD participants. This is consistent with findings from another longitudinal Australian study that found lower rates of alcohol use among adolescents who primarily spoke a language other than English at home compared to those from English-speaking families, and the authors theorised that parenting styles more common in families speaking a language other than English may be protective (Ghayour-minaie et al., 2019). There are no studies reporting differences in cigarette use between CALD and non-CALD adolescents in Australia, however rates of smoking in CALD adults are substantially lower than non-CALD adults (AIHW, 2023). Future research could further examine the protective mechanisms for health behaviour change among CALD adolescents to investigate whether these behaviour change patterns are protective of mental health for CALD adolescents.

Family socioeconomic affluence was not significantly associated with behaviour change for any behaviour except alcohol uptake, where lower affluence participants had a lower prevalence of changing from not drinking in year 7 to drinking in year 10. However, this is likely attributable to higher prevalence of year 7 alcohol use among lower affluence participants (Champion et al., 2021). Research has demonstrated a socioeconomic gradient to mental health, whereby those experiencing lower affluence generally have poorer mental health outcomes (Alegría et al., 2018). The absence of evidence in the present study for a relationship between socioeconomic affluence and behaviour change suggests that other forces make a more substantial contribution to the socioeconomic discrepancies in mental health outcomes, however further research in representative samples is needed to examine this further.

Further Implications and Opportunities for Future Research

All behaviour change models adjusted for participants' baseline behaviour and psychological distress score, suggesting that—regardless of where an adolescent starts in terms of their behaviour or mental health—increasing health-promoting behaviours and reducing health risk behaviours may make a difference to their levels of psychological distress. However, further research using causal methodology is needed to confirm this. In addition,

some studies suggest that health behaviour change and mental health share common predictors, such as self-efficacy, self-control, and emotion regulation (Paxton et al., 2010; Aparicio et al., 2016; Gilbert et al., 2022). In our study, observed improvements in psychological distress may be due to the inherent benefits of behaviour changes (for example through social, neurological, or biological mechanisms), or due to the shared predictors required to make positive behaviour change and improve mental health. Relatedly, the observed magnitudes of effect for alcohol and tobacco use were large, especially considering the thresholds for endorsing use were small (at least one full standard drink or puff of a cigarette in the prior 6 months). It is unlikely that that these observed associations are wholly due to direct causal impacts of alcohol or tobacco use on psychological distress (through social, biological, or neurological mechanisms). Instead, they are likely attributable to a complex interplay of these mechanisms and the impact of shared risk factors for adolescent substance use and mental ill-health, such as personality factors, (Mackie et al., 2011) peer factors, and family factors (Barnes et al., 2009). Further, bi-directional relationships have been demonstrated for many of the Big 6. For example, sleep disturbances are both a symptom of mental ill-health and a predictor of mental ill-health (Kortesoja et al., 2020). While we adjusted for baseline behavioural level and psychological distress to somewhat address this, future research using causal methodologies is needed to determine the directionality of these relationships.

Strengths and Limitations

This study examines the largest Australian adolescent sample in which the Big 6 and psychological distress have been measured to date. Due to its size, it includes a substantial number of gender- and culturally diverse participants, enabling the inclusion and comparison of these groups. It has a closely population-representative gender split and distribution of participants between the three included States that span the west-to-east coasts of the Australian continent. However, the sample is not population-representative and as such, findings may not be generalisable to all Australian adolescents. In addition, despite thorough follow-up procedures and strong retention, findings may have been biased by attrition; participants who did not complete follow-up in year 10 had a higher mean baseline psychological distress, and significantly different baseline levels of moderate-to-vigorous PA, sleep, screen time, junk food/ SSB, alcohol use, and tobacco smoking. Measures of the Big 6 and psychological distress were self-report, introducing the possibility of self-report bias; however, participants were assured of the confidentiality of their responses, all measures were externally developed, and most measures have demonstrated strong psychometric properties. E-cigarette use or 'vaping' became more prevalent among Australian adolescents during the study period, yet was only measured in Year 10, precluding the examination of vaping behaviour change in the present study (Gardner et al., 2023). The COVID-19 pandemic may have influenced the findings of this study. Evidence shows that the pandemic was associated with changes in adolescent lifestyle behaviours (Gardner et al., 2022) and mental health (Bower et al., 2023). While data was collected in 2019 and late 2022 (on either side of the lockdowns and restrictions in Australia), it is possible that pandemic-related impacts outlasted the removal of restrictions and influenced results, yet we cannot discern this from our study. Finally, the present study comprises longitudinal analyses examining change in all Big 6, which adds to extant literature examining a single behaviour or employing cross-sectional and prospective methodologies. However, the methodology employed cannot determine the causal relationships between the Big 6 and mental health.

Conclusion

This study complements existing evidence that throughout adolescence there is a general decrease in health-promoting behaviours (moderate-to-vigorous PA, sleep, fruit, and vegetables) and an increase in health risk behaviours (screen time, junk food and SSB, alcohol use, and tobacco use). We found differences in the magnitude of behaviour change by gender and cultural and linguistic diversity, highlighting the need for tailoring and targeting of behaviour change interventions to ensure their acceptability and efficacy for different groups of adolescents. Changes over time in each of the Big 6 were significantly associated with year 10 psychological distress, with health-promoting behaviours associated with reduced psychological distress and vice versa. When all Big 6 behaviour changes were modelled together, statistically significant effects remained for sleep, physical activity, vegetable consumption, junk food and SSB consumption, alcohol use, and tobacco use, highlighting the potential benefits of targeting positive behaviour change across multiple domains simultaneously. Findings from this study suggest the importance of addressing the Big 6 through research, policy, and practice, as a potential mechanism to improve adolescent mental health.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11469-024-01350-9.

Acknowledgements The Health4Life study was led by researchers at the Matilda Centre at the University of Sydney, Curtin University, the University of Queensland, the University of Newcastle, Northwestern University, and UNSW Sydney: Teesson, M., Newton, N.C, Kay-Lambkin, F.J., Champion, K.E., Chapman, C., Thornton, L.K., Slade, T., Mills, K.L., Sunderland, M., Bauer, J.D., Parmenter, B.J., Spring, B., Lubans, D.R., Allsop, S.J., Hides, L., McBride, N.T., Barrett, E.L., Stapinski, L.A., Mewton, L., Birrell, L.E., & Quinn, C & Gardner, L.A. The authors would like to acknowledge the schools, students, and teachers who participated in this research and all research staff who have worked across the study (Osman, B., Hunter, E., McCann, K., Ellem, R., Catakovic, A., Whife, J., Stewart, C.).

Author Contribution SS led the development of this article. LAG and NCN share senior authorship. All authors were involved in conceptualization. KEC and NCN secured funding for this study. KEC led the development of the Health4Life cRCT. SS, SO, LAG, and KEC led data curation. Data were directly accessed and verified by SS, KEC, SO, JH, and LAG. SS developed the methodology and conducted formal analysis with support from SO. KEC and LAG were responsible for ethics and governance and overall trial administration with oversight from NCN. NCN, KEC, and LAG provided PhD supervision to SS. SS wrote the original manuscript, and all authors were involved in review. All authors had full access to the data in the study, and all had final responsibility for the decision to submit for publication.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions. The Health-4Life study was funded by the Paul Ramsay Foundation and the Australian National Health and Medical Research Council via Fellowships (KEC, APP1120641, and NCN, APP1166377) and via a Centre of Research Excellence in the Prevention and Early Intervention in Mental Illness and Substance Use (PREMISE; APP11349009). KC is funded by a University of Sydney Horizon Fellowship. JH is funded by a Canadian Institutes for Health Research Banting Postdoctoral Fellowship. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. NCN is a Director of Climate Schools Pty Ltd and OurFutures Institute Ltd.

Data availability De-identified participant data will be made available to researchers on request to Dr Katrina Champion (katrina.champion@sydney.edu.au) and with appropriate reason when accompanied by study protocol and analysis plan. Data will be shared after the approval of a proposal by a committee of the current research team with a signed data access agreement.

Declarations

Ethics Approval All procedures followed were in accordance with the ethical standards of the responsible committees on human experimentation (University of Sydney HREC2018/882, University of Queensland

2019000037, Curtin University HRE2019-0083, NSW Department of Education SERAP 2019006, and several Catholic Diocese committees).

Informed Consent As detailed in methods, informed consent was obtained from all patients for being included in the study.

Conflict of Interest The authors declare no competing interests.

References

ACON. (2021). Recommended Community Indicators for Research [Internet]. Available from: https://www.acon.org.au/what-we-are-here-for/policy-research/#recommended-sexuality-and-gender-indicators. Accessed 3 May 2024

AIHW. (2023). Alcohol, tobacco & other drugs in Australia. *Priority populations: People from culturally and linguistically diverse backgrounds [Internet]. Canberra: AIHW; 2023*. Available from: https://www.aihw.gov.au/reports/alcohol/alcohol-tobacco-other-drugs-australia/contents/population-groups-of-interest/people-from-culturally-and-linguistically-diverse. Accessed 3 May 2024

Albani, V., Butler, L. T., Traill, W. B., & Kennedy, O. B. (2017). Fruit and vegetable intake: Change with age across childhood and adolescence. *British Journal of Nutrition, 117*(5), 759–765. https://doi.org/10.1017/S0007114517000599

Alegría, M., NeMoyer, A., Falgàs Bagué, I., Wang, Y., & Alvarez, K. (2018). Social determinants of mental health: Where we are and where we need to go. *Current Psychiatry Reports, 20*(11), 95. https://doi.org/10.1007/s11920-018-0969-9

Aparicio, E., Canals, J., Arija, V., Henauw, S. D., & Michels, N. (2016). The role of emotion regulation in childhood obesity: Implications for prevention and treatment. *Nutrition Research Reviews, 29*(1), 17–29. https://doi.org/10.1017/S0954422415000153

Arbour-Nicitopoulos, K. P., Faulkner, G. E., & Irving, H. M. (2012). Multiple health-risk behaviour and psychological distress in adolescence. *Journal of Canadian Academy of Child and Adolescent Psychiatry, 21*(3), 171–178.

Australian Government Department of Health and Aged Care. 24-hour movement guidelines – children and young people (5 to 17 years) [Internet]. Australian Government Department of Health and Aged Care. Australian Government Department of Health and Aged Care; 2021 [cited 2023 Dec 24]. Available from: https://www.health.gov.au/topics/physical-activity-and-exercise/physical-activity-and-exercise-guidelines-for-all-australians/for-children-and-young-people-5-to-17-years

Barnes, G. E., Mitic, W., Leadbeater, B., & Dhami, M. K. (2009). Risk and protective factors for adolescent substance use and mental health symptoms. *Canadian Journal of Community Mental Health, 28*(1), 1–15.

Beal, T., Morris, S. S., & Tumilowicz, A. (2019). Global patterns of adolescent fruit, vegetable, carbonated soft drink, and fast-food consumption: A meta-analysis of global school-based student health surveys. *Food and Nutrition Bulletin, 40*(4), 444–459. https://doi.org/10.1177/0379572119848287

Bishop, A., Overcash, F., McGuire, J., & Reicks, M. (2020). Diet and physical activity behaviors among adolescent transgender students: School survey results. *Journal of Adolescent Health, 66*(4), 484–490. https://doi.org/10.1016/j.jadohealth.2019.10.026

Bottino, S. M. B., Bottino, C., Regina, C. G., Correia, A. V. L., & Ribeiro, W. S. (2015). Cyberbullying and adolescent mental health: Systematic review. *Cadernos De Saúde Pública, 31*, 463–475.

Bower, M., Smout, S., Donohoe-Bales, A., O'Dean, S., Teesson, L., Boyle, J., et al. (2023) A hidden pandemic? An umbrella review of global evidence on mental health in the time of COVID-19. Front Psychiatry. 14. https://doi.org/10.3389/fpsyt.2023.1107560

Brener, N. D., Kann, L., Shanklin, S., Kinchen, S., Eaton, D. K., Hawkins, J., et al. (2013). Methodology of the youth risk behavior surveillance system—2013. *Morbidity and Mortality Weekly Report. Surveillance Summaries, 62*(1), 1–20.

Brooks, M. E., Kristensen, K., Van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, A., et al. (2017). glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *R J., 9*(2), 378–400.

Campbell, O. L. K., Bann, D., & Patalay, P. (2021). The gender gap in adolescent mental health: A cross-national investigation of 566,829 adolescents across 73 countries. *SSM - Popul Health, 1*(13), 100742. https://doi.org/10.1016/j.ssmph.2021.100742

Champion, K. E., Chapman, C., Gardner, L. A., Sunderland, M., Newton, N. C., Smout, S., Thornton, L. K., Hides, L., McBride, N., Allsop, S. J., Mills, K., Kay-Lambkin, F., Teesson, M., Slade, T., & team† the H. (2021). Lifestyle risks for chronic disease among Australian adolescents: A cross-sectional survey. *Medical Journal of Australia, 216*(3).

Champion, K. E., Newton, N. C., Gardner, L. A., Chapman, C., Thornton, L., Slade, T., Sunderland, M., Hides, L., McBride, N., O'Dean, S., Kay-Lambkin, F., Allsop, S., Lubans, D. R., Parmenter, B., Mills, K., Spring, B., Osman, B., Ellem, R., Smout, S., … Mewton, L. (2023). Health4Life eHealth intervention to modify multiple lifestyle risk behaviours among adolescent students in Australia: A cluster-randomised controlled trial. *The Lancet Digital Health, 5*(5), e276–e287. https://doi.org/10.1016/S2589-7500(23)00028-6

Costigan, S. A., Barnett, L., Plotnikoff, R. C., & Lubans, D. R. (2013). The health indicators associated with screen-based sedentary behavior among adolescent girls: A systematic review. *Journal of Adolescent Health, 52*(4), 382–392. https://doi.org/10.1016/j.jadohealth.2012.07.018

Currie, C., Zanotti, C., Morgan, A., Currie, D., De Looze, M., Roberts, C., et al. (2009). Social determinants of health and well-being among young people. *Health Behav Sch-Aged Child HBSC Study Int Rep from., 2010*, 271.

Dabravolskaj, J., Veugelers, P. J., Amores, A., Leatherdale, S. T., Patte, K. A., & Maximova, K. (2023). The impact of 12 modifiable lifestyle behaviours on depressive and anxiety symptoms in middle adolescence: Prospective analyses of the Canadian longitudinal COMPASS study. *International Journal of Behavioral Nutrition and Physical Activity, 20*(1), 45. https://doi.org/10.1186/s12966-023-01436-y

Esmaeelzadeh, S., Moraros, J., Thorpe, L., & Bird, Y. (2018). Examining the association and directionality between mental health disorders and substance use among adolescents and young adults in the U.S. and Canada—A systematic review and meta-analysis. *J Clin Med, 7*(12), 543.

Fakier, N., & Wild, L. G. (2011). Associations among sleep problems, learning difficulties and substance use in adolescence. *Journal of Adolescence, 34*(4), 717–726. https://doi.org/10.1016/j.adolescence.2010.09.010

Ferro, M. A. (2019). The psychometric properties of the Kessler Psychological Distress Scale (K6) in an epidemiological sample of Canadian youth. *Can J Psychiatry Rev Can Psychiatr., 64*(9), 647–657. https://doi.org/10.1177/0706743718818414

Foti, K. E., Eaton, D. K., Lowry, R., & McKnight-Ely, L. R. (2011). Sufficient sleep, physical activity, and sedentary behaviors. *American Journal of Preventive Medicine, 41*(6), 596–602. https://doi.org/10.1016/j.amepre.2011.08.009

Gardner, L. A., Debenham, J., Newton, N. C., Chapman, C., Wylie, F. E., Osman, B., et al. (2022). Lifestyle risk behaviours among adolescents: A two-year longitudinal study of the impact of the COVID-19 pandemic. *British Medical Journal Open, 12*(6), e060309. https://doi.org/10.1136/bmjopen-2021-060309

Gardner, L. A., O'Dean, S., Champion, K. E., Stockings, E., Rowe, A., Teesson, M., et al. (2023). Prevalence, patterns of use, and socio-demographic features of e-cigarette use by Australian adolescents: A survey. *Medical Journal of Australia, 219*(7), 332–334.

Gardner, L. A., Stockings, E., Champion, K. E., Mather, M., & Newton, N. C. (2024). Alcohol initiation before age 15 predicts earlier hazardous drinking: A survival analysis of a 7-year prospective longitudinal cohort of Australian adolescents. *Addiction, 119*(3), 518–529. https://onlinelibrary.wiley.com/doi/abs/10.1111/add.16376doi:10.1111/add.16376

GBD 2019 Mental Disorders Collaborators. Global, regional, and national burden of 12 mental disorders in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Psychiatry. 2022;9(2):137–50. https://doi.org/10.1016/S2215-0366(21)00395-3

Ghayour-minaie, M., King, R. M., Skvarc, D. R., Satyen, L., & Toumbourou, J. W. (2019). Family, cultural diversity, and the development of Australian adolescent substance use. *Australian Psychologist, 54*(5), 382–390. https://doi.org/10.1111/ap.12391

Gilbert, W., Bureau, J. S., Poellhuber, B., Guay, F,. (2022) Educational contexts that nurture students' psychological needs predict low distress and healthy lifestyle through facilitated self-control. Curr Psychol [Internet]. 2022 Nov 22 [cited 2023 May 3]. https://doi.org/10.1007/s12144-022-04019-510.1007/s12144-022-04019-5

Global Burden of Disease Study. GBD cause and risk summaries [Internet]. The Lancet. [cited 2023 Nov 8]. Available from: https://www.thelancet.com/gbd/summaries

Green, J. A. (2021). Too many zeros and/or highly skewed? A tutorial on modelling health behaviour as count data with Poisson and negative binomial regression. *Health Psychology and Behavioral Medicine, 9*(1), 436–455. https://doi.org/10.1080/21642850.2021.1920416

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1· 6 million participants. *Lancet Child Adolesc Health., 4*(1), 23–35.

Halliday, A. J., Kern, M. L., & Turnbull, D. A. (2019). Can physical activity help explain the gender gap in adolescent mental health? A cross-sectional exploration. *Mental Health and Physical Activity, 16*, 8–18.

Hayes, G., Dowd, K. P., MacDonncha, C., & Donnelly, A. E. (2019). Tracking of physical activity and sedentary behavior from adolescence to young adulthood: A systematic literature review. *Journal of Adolescent Health, 65*(4), 446–454. https://doi.org/10.1016/j.jadohealth.2019.03.013

Jamieson, D., Broadhouse, K. M., Lagopoulos, J., & Hermens, D. F. (2020). Investigating the links between adolescent sleep deprivation, fronto-limbic connectivity and the Onset of Mental Disorders: A review of the literature. *Sleep Medicine, 66*, 61–67. https://doi.org/10.1016/j.sleep.2019.08.013

Jobson, C. L. M., Renard, J., Szkudlarek, H., Rosen, L. G., Pereira, B., Wright, D. J., et al. (2018). Adolescent nicotine exposure induces dysregulation of mesocorticolimbic activity states and depressive and anxiety-like prefrontal cortical molecular phenotypes persisting into adulthood. *Cerebral Cortex, 29*(7), 3140–3153. https://doi.org/10.1093/cercor/bhy179

Jones, P. B. (2013). Adult mental health disorders and their age at onset. *British Journal of Psychiatry, 202*(s54), s5-10. https://doi.org/10.1192/bjp.bp.112.119164

Kandola, A., Ashdown-Franks, G., Hendrikse, J., Sabiston, C. M., & Stubbs, B. (2019). Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity. *Neuroscience and Biobehavioral Reviews, 1*(107), 525–539. https://doi.org/10.1016/j.neubiorev.2019.09.040

Kessler, R. C., Andrews, G., Colpe, L. J., Hiripi, E., Mroczek, D. K., Normand, S. L. T., et al. (2002). Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychological Medicine, 32*(6), 959–976. https://doi.org/10.1017/s0033291702006074

Kessler, R. C., Green, J. G., Gruber, M. J., Sampson, N. A., Bromet, E., Cuitan, M., et al. (2011). Screening for serious mental illness in the general population with the K6 screening scale: Results from the WHO World Mental Health (WMH) survey initiative. *International Journal of Methods in Psychiatric Research, 20*(1), 62–62. https://doi.org/10.1002/mpr.333

Keyes, K. M., Rutherford, C., & Miech, R. (2019). Historical trends in the grade of onset and sequence of cigarette, alcohol, and marijuana use among adolescents from 1976–2016: Implications for "Gateway" patterns in adolescence. *Drug and Alcohol Dependence, 1*(194), 51–58. https://doi.org/10.1016/j.drugalcdep.2018.09.015

Khan, A., Lee, E. Y., & Tremblay, M. S. (2021). Meeting 24-h movement guidelines and associations with health related quality of life of Australian adolescents. *Journal of Science and Medicine in Sport, 24*(5), 468–473. https://doi.org/10.1016/j.jsams.2020.10.017

Kidd, K. M., Sequeira, G. M., Rothenberger, S. D., Paglisotti, T., Kristjansson, A., Schweiberger, K., et al. (2022). Operationalizing and analyzing 2-step gender identity questions: Methodological and ethical considerations. *Journal of the American Medical Informatics Association, 29*(2), 249–256. https://doi.org/10.1093/jamia/ocab137

Kortesoja, L., Vainikainen, M. P., Hotulainen, R., Rimpelä, A., Dobewall, H., Lindfors, P., et al. (2020). Bidirectional relationship of sleep with emotional and behavioral difficulties: A five-year follow-up of Finnish adolescents. *Journal of Youth and Adolescence, 49*(6), 1277–1291. https://doi.org/10.1007/s10964-020-01203-3

Leger, D., Beck, F., Richard, J. B., & Godeau, E. (2012). Total sleep time severely drops during adolescence. *PLoS ONE, 7*(10), e45204. https://doi.org/10.1371/journal.pone.0045204

Livingston, M., Holmes, J., Oldham, M., Vashishtha, R., & Pennay, A. (2020). Trends in the sequence of first alcohol, cannabis and cigarette use in Australia, 2001–2016. *Drug and Alcohol Dependence, 1*(207), 107821. https://doi.org/10.1016/j.drugalcdep.2019.107821

Lüdecke, D., Ben-Shachar, M. S., Patil, I., Waggoner, P., Makowski, D. (2021). Performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software, 6*(60).

Lund, C., Brooke-Sumner, C., Baingana, F., Baron, E. C., Breuer, E., Chandra, P., et al. (2018). Social determinants of mental disorders and the Sustainable Development Goals: A systematic review of reviews. *Lancet Psychiatry, 5*(4), 357–369. https://doi.org/10.1016/S2215-0366(18)30060-9

Mackie, C. J., Castellanos-Ryan, N., & Conrod, P. J. (2011). Personality moderates the longitudinal relationship between psychological symptoms and alcohol use in adolescents. *Alcoholism, Clinical and Experimental Research, 35*(4), 703–716. https://doi.org/10.1111/j.1530-0277.2010.01388.x

Marmot, M. (2013). Fair society healthy lives. In *Inequalities in health*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199931392.003.0019

McGrath, J. J., Al-Hamzawi, A., Alonso, J., Altwaijri, Y., Andrade, L. H, Bromet, EJ., et al. (2023). Age of onset and cumulative risk of mental disorders: A cross-national analysis of population surveys from 29 countries. Lancet Psychiatry [Internet]. 2023 Jul 30 [cited 2023 Aug 9];0(0). Available from: https://www.thelancet.com/journals/lanpsy/article/PIIS2215-0366(23)00193-1/fulltext10.1016/S2215-0366(23)00193-1

Mewton, L., Kessler, R. C., Slade, T., Hobbs, M. J., Brownhill, L., Birrell, L., et al. (2016). The psychometric properties of the Kessler Psychological Distress Scale (K6) in a general population sample of adolescents. *Psychological Assessment, 28*(10), 1232–1242. https://doi.org/10.1037/pas0000239

Nascimento-Ferreira, M. V., Collese, T. S., de Moraes, A. C. F., Rendo-Urteaga, T., Moreno, L. A., & Carvalho, H. B. (2016). Validity and reliability of sleep time questionnaires in children and adolescents: A systematic review and meta-analysis. *Sleep Medicine Reviews, 30*, 85–96. https://doi.org/10.1016/j.smrv.2015.11.006

National Health and Medical Research Council. Australian Dietary Guidelines. Canberra: National Health and Medical Research Council; 2013.

National Health and Medical Research Council. (2020). *Australian guidelines to reduce health risks from drinking alcohol*. National Health and Medical Research Council, Commonwealth of Australia.

O'Dean, S., Sunderland, M., Newton, N., Gardner, L., Teesson, M., Chapman, C., ... & Champion, K. (2024). The Health4Life e-health intervention for modifying lifestyle risk behaviours of adolescents: Secondary outcomes of a cluster randomised controlled trial. *Medical Journal of Australia*, *220*(8), 417–424.

Oddy, W. H., Allen, K. L., Trapp, G. S. A., Ambrosini, G. L., Black, L. J., Huang, R. C., et al. (2018). Dietary patterns, body mass index and inflammation: Pathways to depression and mental health problems in adolescents. *Brain, Behavior, and Immunity, 1*(69), 428–439. https://doi.org/10.1016/j.bbi.2018.01.002

Paxton, R. J., Motl, R. W., Aylward, A., & Nigg, C. R. (2010). Physical activity and quality of life—The complementary influence of self-efficacy for physical activity and mental health difficulties. *International Journal of Behavioral Medicine, 17*(4), 255–263. https://doi.org/10.1007/s12529-010-9086-9

Pham, T. T. L., Berecki-Gisolf, J., Clapperton, A., O'Brien, K. S., Liu, S., & Gibson, K. (2021). Definitions of culturally and linguistically diverse (CALD): A literature review of epidemiological research in Australia. *International Journal of Environmental Research and Public Health, 18*(2). https://doi.org/10.3390/ijerph18020737

Prince, S. A., LeBlanc, A. G., Colley, R. C., & Saunders, T. J. (2017). Measurement of sedentary behaviour in population health surveys: A review and recommendations. *PeerJ, 5*, e4130.

Sawyer, S. M., Afifi, R. A., Bearinger, L. H., Blakemore, S. J., Dick, B., Ezeh, A. C., et al. (2012). Adolescence: A foundation for future health. *The Lancet., 379*(9826), 1630–1640. https://doi.org/10.1016/S0140-6736(12)60072-5

Seabrook, E. M., Kern, M. L., & Rickard, N. S. (2016). Social networking sites, depression, and anxiety: A systematic review. *JMIR Ment Health., 3*(4), e5842.

Short, M. A., Gradisar, M., Lack, L. C., Wright, H. R., & Chatburn, A. (2013). Estimating adolescent sleep patterns: Parent reports versus adolescent self-report surveys, sleep diaries, and actigraphy. *Nat Sci Sleep., 12*(5), 23–26. https://doi.org/10.2147/NSS.S38369

Smout, S., Gardner, L. A., Newton, N., & Champion, K. E. (2023). Dose–response associations between modifiable lifestyle behaviours and anxiety, depression and psychological distress symptoms in early adolescence. *Australian and New Zealand Journal of Public Health, 47*(1), 100010. https://doi.org/10.1016/j.anzjph.2022.100010

Smout, S., Champion, K. E., O'Dean, S., Teesson, M., Gardner, L. A., & Newton, N. C. (2024). Anxiety, depression and distress outcomes from the Health4Life intervention for adolescent mental health: A cluster-randomized controlled trial. *Nature Mental Health*, 1–10.

Solmi, M., Radua, J., Olivola, M., Croce, E., Soardo, L., Salazar de Pablo, G., et al. (2022). Age at onset of mental disorders worldwide: large-scale meta-analysis of 192 epidemiological studies. *Mol Psychiatry, 27*(1), 281–95. https://doi.org/10.1038/s41380-021-01161-7

Teesson, M., Champion, K. E., Newton, N. C., Kay-Lambkin, F., Chapman, C., Thornton, L., Slade, T., Sunderland, M., Mills, K., & Gardner, L. A. (2020). Study protocol of the Health4Life initiative: A cluster randomised controlled trial of an eHealth school-based program targeting multiple lifestyle risk behaviours among young Australians. *BMJ Open, 10*(7), e035662.

Telama, R., Yang, X., Leskinen, E., Kankaanpää, A., Hirvensalo, M., Tammelin, T., et al. (2014). Tracking of physical activity from early childhood through youth into adulthood. *Medicine and Science in Sports and Exercise, 46*(5), 955–962. https://doi.org/10.1249/mss.0000000000000181

Tomkinson, G., Schranz, N., Olds, T., Boyd, R., Evans, J., Gomersall, S., Hardy, L., Hesketh, K., Lubans, D., & Ridgers, N. (2016). Physical literacy: Do our kids have all the tools? The 2016 active healthy kids australia report card on physical activity for children and young people. *Active Healthy Kids Australia*. https://doi.org/10.4226/78/57AAD6BD49165

Torsheim, T., Cavallo, F., Levin, K. A., Schnohr, C., Mazur, J., Niclasen, B., et al. (2016). Psychometric validation of the Revised Family Affluence Scale: A latent variable approach. *Child Indicators Research, 9*(3), 771–784. https://doi.org/10.1007/s12187-015-9339-x

Wolfson, A. R., Carskadon, M. A., Acebo, C., Seifer, R., Fallone, G., Labyak, S. E., et al. (2003). Evidence for the validity of a sleep habits survey for adolescents. *Sleep, 26*(2), 213–216. https://doi.org/10.1093/sleep/26.2.213

Yoo, H., & Kim, N. (2020). Factors associated with lifestyle habits and mental health problems in Korean adolescents: The Korea National Health and Nutrition Examination Survey 2017–2018. *International Journal of Environmental Research and Public Health, 17*(24), 9418. https://doi.org/10.3390/ijerph17249418

Yoshida, K., Bohn, J., & Yoshida, M. K. (2020). *Package 'tableone'*. R foundation for statistical computing, Vienna, Austria (30 November 2016).