Prevalence of noncommunicable diseases and developmental conditions in 5014 Australian adolescents, and their correlations with diet, other lifestyle behaviours and mental health

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Abstract

Objective: Amongst Australian youth, there is currently a lack of understanding of the prevalence of noncommunicable diseases and developmental conditions and links with modifiable lifestyle behaviours, mental health and other socio-demographics. This paper aims to address this gap.

Methods: Australian adolescents (N = 5014, Mage=14.7, SD=0.80) completed a self-report survey assessing noncommunicable diseases/developmental conditions, sex, socio-economic status (SES), lifestyle behaviours and mental health. Multivariable logistic regressions were used to estimate the associations between these variables. The moderating effects of sex and SES were investigated by including interaction terms in each regression model.

Results: 45.6% adolescents reported ≥1 noncommunicable disease/developmental condition. Being female, consuming more sugar-sweetened beverages, ultra-processed foods, or alcohol, participating in more screen time, having depression, anxiety or psychological distress were each associated with higher rates of having at least one disease/condition ($p<0.01$). Sex and SES significantly moderated the associations between some lifestyle behaviours and eight diseases/conditions were examined.

Conclusion: Australian adolescents experience considerable rates of noncommunicable diseases and developmental conditions, highlighting the significance of this public health issue.

Implications for public health: Links with lifestyle behaviours and mental health highlight their potential importance in public health to assist with prevention and treatment of these common and emerging noncommunicable diseases and developmental conditions in adolescents.

Key words: disease, developmental, adolescent, diet, lifestyle behaviors, mental health

Objective

There is increasing recognition that a large proportion of Australian adolescents are living with noncommunicable diseases and developmental conditions.[1] Noncommunicable diseases such as diabetes or chronic respiratory disease are among the leading causes of death worldwide; these can be debilitating, being a significant burden physically and economically.[2] Adolescence is a period where the onset of many noncommunicable diseases and developmental conditions can occur, affecting the physical and mental well-being of sufferers. As such, the common and emerging noncommunicable diseases or developmental conditions that are recognised currently or are developing as the most impactful are of primary interest. The most common noncommunicable diseases in adolescents are atopic conditions such as asthma, eczema, food allergies and hay fever. Prevalence of these conditions has been rising worldwide since the 1980s,[3] with particularly high prevalence in westernised countries.[4] Asthma specifically is the number one cause of hospitalisation in adolescents outside of injuries.[4] Developmental condition is an umbrella term for a group of disorders that can affect physical, cognitive, language and/or behavioural functioning,[5] rates of common developmental conditions such as attention-deficit/

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hyperactivity disorder (ADHD) or autism have also been increasing. The onset of irritable bowel syndrome (IBS) is most common during adolescence[6,7] impacting the physical, educational and social lives of sufferers.[8] These conditions, alongside further emerging noncommunicable diseases, described as those rising in incidence within adolescents, such as type 1 (T1D) and type 2 diabetes (T2D),[9,10] significantly impact quality of life and can predispose an individual to further burden of disease or disability.

Each of these common and emerging noncommunicable diseases or developmental conditions are associated with systemic inflammation, while this relationship can be either cause or effect depending on the underlying aetiology, it is important to note that additional inflammation can exacerbate symptoms. Public health campaigns and research have predominantly focused on addressing noncommunicable diseases in adults, when prevalence is highest and they have caused oxidative stress for elongated periods of time, resulting in further cell damage, disability or even mortality.[11] Such conditions often co-occur with mental health problems as well as unhealthy lifestyle behaviours, which in turn are understood to increase the risk for common mental health problems as well as diseases or developmental conditions.[11] In adolescents, significant physical and psychological adaptations, and poor lifestyle behaviour habits are commonly adopted during this time, making this a key period for prevention and intervention efforts. Yet, to our knowledge, there is no research assessing the associations between multiple lifestyle behaviours, mental health and socio-demographics with noncommunicable diseases or developmental condition prevalence in an Australian adolescent cohort.

Lifestyle behaviours such as dietary intake, exercise, tobacco smoking and alcohol intake are linked to chronic disease incidence in adults,[11] and emerging associations include poor mental health, sleep and sedentary recreational screen time.[11,12] Furthermore, some socio-demographics are understood to predispose an individual to specific conditions, for example, those from lower socio-economic status (SES) have a higher risk of asthma,[13] ADHD[14] and T2D,[15] likely determined by a variety of environmental and behavioural exposures. Males are predisposed to higher rates of autism[16] or ADHD,[1] whilst females have higher rates of IBS[17] and hay fever,[18] predominantly due to genetic factors such as differing hormones. Additionally, IBS and asthma severity have been known to increase with poor mental health or lifestyle behaviours[6,19,20] making them ideal candidates for targeted public health strategies.

There is a lack of evidence assessing associations between multiple lifestyle behaviours, mental health and socio-demographics with these common and emerging diseases/conditions in adolescents, an important gap in the literature, as this reflects an individual's whole lifestyle. Most worldwide research only evaluates one-to-two health or mental health behaviours with a singular noncommunicable disease or developmental condition, generally in small cohorts. Clarifying prevalence and furthering our knowledge of associations with these common and emerging conditions, at an age where there is an opportunity to intervene, may equip us with the information to inform future public health attempts and research on causality, as well as treatment strategies to mitigate some of the negative outcomes or even prevent their onset.

This study aims to address the gaps in research by using a large sample of Australian adolescents to: 1) Determine overall and specific prevalence of a wide range of common and emerging noncommunicable diseases and developmental conditions (i.e. IBS, asthma, eczema, chronic fatigue, hay fever, food allergies, T2D, T1D, ADD/ADHD and autism/Asperger's); 2) determine overall and specific prevalence of these conditions separately for males and females and different SES; 3) analyse associations between lifestyle behaviours (dietary intake, physical activity, sleep, screen time, tobacco and alcohol use) and mental health (psychological distress, depression and anxiety) with noncommunicable diseases, developmental conditions and related severity when controlling for sex and SES; and 4) assess whether these associations differ depending on sex and SES.

Methods

Participants

Participants were adolescents taking part in the 'Health4Life' health behaviour change cluster randomised controlled trial (RCT) among 71 schools across three Australian states (New South Wales, Queensland and Western Australia).[21,22] All adolescents aged 11-13 years, who were fluent in English, attending participating schools and had parental consent were eligible to participate. As a part of this trial baseline data were collected from 6639 consenting participants between June and December of 2019, further information on consent rates have been published previously.[21] This trial followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines. Data for this study came from a follow up assessment via an online self-report survey administered in class, which was completed in 2021 by 5014 participants. The Health4Life study resulted in no changes in participant outcomes between intervention and control groups, as a result participants within the trial were treated as one cohort.

Measures

Measures validated for use among adolescents were used where possible. Full details of all measures and their cited origins are available in the supplementary material, briefly summarised below.

Sociodemographics

Participants were asked to report their sex assigned at birth; SES was assessed using the Family Affluence Scale (FAS-III).[23]

Lifestyle behaviours

Four areas of dietary intake were assessed, including ultra-processed food (UPF), fruit, vegetable and sugar-sweetened beverages (SSB) intake. A single item assessed both alcohol use *'Have you had a full standard alcoholic drink in the past 6 months?'* (*'No'/'Yes'*) and tobacco use *'In the past 6 months, have you tried cigarette smoking, even one or two puffs?'* (*'No'/'Yes'*). Screen time was assessed by time (hours/minutes) spent engaging in sedentary recreational screen time per day over an average week. Sleep durations were measured by average sleep per night (hours/minutes) over an average week. Physical activity (PA) assessed moderate-to-vigorous physical activity (MVPA) time per day/week.

Mental health

Psychological distress was assessed using questions derived from the strengths and difficulties questionnaire (SDQ),[24] a score of $\leq$17 indicates having psychological distress. From responses to the patient health questionnaire (PHQ),[25] categorical (mild, moderate, moderately severe or severe) depression scores were calculated. From responses to the patient-reported outcomes measurement information system for anxiety (PROMIS-A),[26] categorical (mild, moderate or severe) anxiety scores were calculated.

Noncommunicable diseases and developmental conditions

The noncommunicable disease and developmental condition diagnoses questions asked participants to report on the presence/absence of the most prevalent and impactful noncommunicable diseases and developmental conditions, as identified by the literature, that occur in adolescence, including IBS, asthma, eczema, chronic fatigue, hay fever, food allergies, T2D, T1D, ADD/ADHD and autism/Asperger's. A binary '≥1 common/emerging condition' variable was calculated if one or more disease/condition was reported to account for susceptible multi-morbidity between diseases/conditions. Participants with IBS or asthma responded to additional severity questions, including the IBS severity scale (IBS-SSS)[19] from which we calculated a binary score *('none/mild'* and *'moderate'/severe')*. The asthma severity scale[27] assessed the frequency of asthma attacks in the past 12 months and the persistence of symptoms between attacks in the past 12 months' producing binary scores (*'less than 1 per month'/'1 per month'* and *'1 per week'/'1 per day'; 'none'/'wheezing'* and *'wheezing and shortness of breath'/'activities limited by shortness of breath')*. The final asthma severity question asked, 'have you had any hospitalisation for asthma in the past 12 months' (*'No'/'Yes'*).

Statistical analysis

A data analysis plan was pre-registered prior to beginning analysis[28] and followed without deviation throughout the analysis. R packages were used to conduct all data cleaning and statistical analysis (*'lmtest'*[29] and *'interactions'*[30]). The sample characteristics were examined using descriptive statistics, prevalence estimates and standard errors were estimated using a cluster-robust sandwich estimate to account for clustering of students in each school. Prevalence for ≥1 common/emerging conditions, each of the noncommunicable diseases or developmental conditions, and IBS and asthma severity were also estimated separately by sex and SES. Significant differences between sex and SES groups were determined using logistic regression. A correlation matrix was used to determine multi-collinearity between lifestyle behaviours, mental health, sex and SES variables, finding depression, anxiety and psychological distress variables to be moderately correlated (r values= 0.55-0.65) (Supplementary Table S8). Separate multivariable logistic regressions were then used to individually estimate the associations between UPF, SSB, fruit, vegetables, exercise, sleep, screen time, alcohol and tobacco use, psychological distress, depression, anxiety with noncommunicable diseases or developmental conditions or IBS and asthma severity, controlling for sex at birth and SES. Associations were considered significant at a $p<0.01$ and odds ratios with 99% confidence intervals (99%CI) were estimated.

Additional moderation analyses on each of the multivariable logistic regressions were conducted by including interaction terms between each of the lifestyle behaviours or mental health covariates with sex and SES, separately. Statistically significant interaction terms were identified ($p<0.01$) and the associations were graphed separately for each level of the moderator. Further robustness analysis was run to generate E-values based on significant associations, these define the minimum strength of an association on the odds ratios that an unmeasured confounder would need to have with the outcome and the predictor to fully explain away a specific predictor-outcome association.

Missing data analysis

To investigate the impact of attrition on outcomes, a binary variable was created representing those present at baseline-only versus those who completed one or more follow-up surveys. T-tests were used to investigate differences between missing lifestyle behaviours and mental health conditions on baseline continuous variables. Binary and multinomial logistic regressions were used for dichotomous and categorical variables, respectively, both finding no variance in characteristics between those with or without missing data. Furthermore, missing data in this sample equated to <7.3% of the total sample (n=5014), which aligns with the description of a 'small missing' group[31] whose potential impact on the missing data is likely to be negligible.[32] As such, listwise deletion was used when dealing with missing data.

Results

A total of 5014 participants completed the self-report cross-sectional survey (Mage=14.68 SDage=0.82), there was an even split of sex and most participants were from upper SES and major cities (Table 1 for more information). Included in the main analysis were 4651 participants who reported on at least one noncommunicable disease or developmental condition or 'no diseases or conditions'. The total number of participants included specifically any individual analysis conducted on the '≥1 common/emerging condition' was 3691, to account for only the common and emerging chronic diseases and developmental conditions of interest or 'no diseases or conditions'.

Descriptives

The rates of individual lifestyle behaviours and mental health measures are presented in Table 1. Overall, 45.6% (Table S1) of adolescents reported having at least one of the ten noncommunicable diseases or developmental conditions of interest. The specific prevalence of each condition is presented in Supplementary Table S1, of the noncommunicable diseases hay fever (23.2%) and asthma (15.1%) were the most prevalent and T2D (1.0%) was the least prevalent. ADHD/ADD (9.4%) was the most prevalent developmental condition. The severity of conditions IBS and asthma is reported in Supplementary Table S1. Of note, 52% of those with IBS were experiencing moderate/severe IBS severity. Of those with asthma, 51% had shortness of breath or activities limited by shortness of breath between asthma attacks, and 13% were hospitalised by asthma in the last 12 months.

Rates varied between sexes, with 53.5% of females reporting having ≥1 common/emerging disease/condition compared to 45.5% of males ($p<0.001$) (Table 1). Specifically, females had higher odds of having eczema (OR=1.96, 99%CI: 1.51-2.54), food allergies (OR=1.50, 99%CI: 1.15-1.97), hay fever (OR=1.36, 99%CI: 1.08-1.72) and more persistent asthma symptoms (OR=2.04, 99%CI: 1.23-3.38), compared to males; whilst females had lower odds of having ADHD/ADD (OR=0.73, 99%CI: 0.55-0.98), autism/Asperger's (OR=0.73, 99%CI: 0.55-0.98), T1D (OR=0.25, 99%CI: 0.10-0.59) and T2D (OR=0.12, 99%CI: 0.03-0.48) compared to males (Table 2).

Multi-variable logistic regressions

Noncommunicable diseases and developmental conditions

In the multi-variable logistic regression models (Table 2) having ≥1 common/emerging condition was associated with consuming more SSB (OR=1.08, 99%CI: 1.01-1.15), UPF (OR=1.03, 99%CI: 1.01-1.06) or alcohol (OR=1.39, 99%CI: 1.08-1.79), participating in more screen time (OR=1.02, 99%CI: 1.00-1.04), having severe rates of depression (OR=2.98, 99%CI: 1.96-4.53), severe anxiety (OR=2.69, 99%CI: 1.85-

Table 1: Descriptive statistics of participants split by those having at least one common and emerging noncommunicable diseases or developmental conditions and those without.

	Descriptive statistics			
Variable	**All participants, n = 5,014[a]**	**No common/ emerging condition, n = 2,008[a]**	**≥1 common/emerging condition, n = 1,683[a]**	***p*-value[b]**
Sex assigned at birth				<0.001
Male	2,481 (49.5%)	1,048 (52.2%)	765 (45.5%)	
Female	2,465 (49.2%)	939 (46.8%)	898 (53.5%)	
Prefer not to say	62 (1.2%)	21 (1.0%)	17 (1.0%)	
Unknown	6	0	3	
Age (years)	14.68 (0.82)	14.68 (0.67)	14.68 (0.94)	0.846
Unknown	7	0	4	
Socio-economic status[c]				0.822
Lower 20%	671 (14.6%)	279 (14.9%)	222 (14.3%)	
Middle 40%	1,711 (37.2%)	699 (37.4%)	581 (37.3%)	
Upper 40%	2,223 (48.3%)	889 (47.6%)	754 (48.4%)	
Unknown	409	141	126	
Regionality				0.141
Major city	4,547 (90.7%)	1,838 (91.5%)	1,516 (90.1%)	
Inner/outer regional	467 (9.3%)	170 (8.5%)	167 (9.9%)	
UPF intake	6.12 (4.44)	5.73 (3.71)	6.47 (5.02)	<0.001
Unknown	688	140	125	
Servings of fruit per day	2.15 (1.01)	2.20 (0.95)	2.13 (1.04)	0.143
Unknown	393	51	32	
Servings of vegetables per day	2.78 (1.20)	2.77 (1.14)	2.76 (1.18)	0.908
Unknown	268	1	2	
Cups of SSB per week	1.05 (1.32)	0.98 (1.18)	1.06 (1.37)	0.044
Unknown	259	2	2	
Number of days per week engaging in PA[d]	4.00 (2.11)	4.08 (2.08)	3.98 (2.10)	0.146
Unknown	294	5	8	
Screen time per day (h)	6.79 (5.40)	6.30 (4.49)	6.97 (5.92)	<0.001
Unknown	281	24	35	
Sleep per night (h)	8.56 (1.30)	8.56 (1.21)	8.56 (1.30)	0.982
Unknown	394	97	103	
Alcoholic drink in the last 6 mo				<0.001
No	3,952 (84.0%)	1,736 (86.6%)	1,380 (82.1%)	
Yes	750 (16.0%)	269 (13.4%)	300 (17.9%)	
Unknown	312	3	3	
Cigarette in the last 6 mo				0.298
No	4,763 (98.7%)	1,927 (99.1%)	1,608 (98.7%)	
Yes	61 (1.3%)	17 (0.9%)	21 (1.3%)	
Unknown	190	64	54	
Psychological distress				<0.001
No	3,605 (77.5%)	1,691 (84.3%)	1,247 (74.2%)	
Yes	1,047 (22.5%)	314 (15.7%)	434 (25.8%)	
Unknown	362	3	2	
Depression severity				<0.001
None/minimal	2,234 (48.4%)	1,101 (55.2%)	768 (46.1%)	
Mild depression	1,115 (24.1%)	495 (24.8%)	387 (23.2%)	
Moderate depression	641(13.9%)	233 (11.7%)	235 (14.1%)	
Moderately severe depression	346 (7.5%)	103 (5.2%)	144 (8.6%)	
Severe depression	282 (6.1%)	62 (3.1%)	131 (7.9%)	
Unknown	396	14	18	
Anxiety severity				<0.001
None/slight	3,068 (66.6%)	1,476 (74.3%)	1,055 (63.7%)	
Mild	483 (10.5%)	189 (9.5%)	181(10.9%)	
Moderate	748 (16.2%)	255 (12.8%)	283 (17.1%)	
Severe anxiety	306 (6.6%)	67 (3.4%)	137 (8.3%)	
Unknown	409	21	27	

[a]n (%); Mean (SD)
[b]Pearson's Chi-squared test; Welch Two Sample t-test
[c]Relative socio-economic status within this cohort
[d]Moderate to vigorous physical activity for at least 60 minutes a day

Table 2: Multivariable logistic regressions to estimate the associations between lifestyle behaviours/mental health and individual common and emerging diseases/conditions, whilst controlling for sex at birth and SES, including E-values for significant associations only.

Variables	≥1 common/ emerging condition (n=3691)		Irritable bowel syndrome (n=4651)		Asthma (n=4651)		Eczema (n=4651)		Type 2 diabetes (n=4651)		Chronic fatigue (n=4651)		Hay fever (n=4651)		Food allergies (n=4651)		ADD/ADHD (n=4651)		Autism/Asperger's (n=4651)		Type 1 diabetes (n=4651)	
	OR[a]	99%CI[b]	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI
Sex – Female[c]	1.31**	1.08-1.58	0.70	0.45-1.09	0.90	0.75-1.09	1.96**	1.51-2.54	0.12**	0.03-0.48	0.88	1.54	1.36**	1.08-1.72	1.50**	1.15-1.97	0.73*	0.55-0.98	0.73*	0.55-0.98	0.25**	0.10-0.59
E-value	**1.95**						**2.15**		**16.15**				**1.61**		**2.37**		**2.08**		**2.08**		**7.46**	
UPFs	1.03**	1.01-1.06	1.14**	1.10-1.18	1.04**	1.02-1.06	1.04**	1.01-1.07	1.19**	1.13-1.25	1.15**	1.10-1.20	1.02*	1.00-1.69	1.03*	1.00-1.07	1.06**	1.03-1.09	1.10**	1.06-1.14	1.18**	1.12-1.23
E-value	**1.21**		**1.54**		**1.24**		**1.16**		**1.67**		**1.57**		**1.11**		**1.21**		**1.31**		**1.43**		**1.64**	
SSB	1.08*	1.01-1.15	1.45**	1.17-1.81	1.13**	1.04-1.23	1.02	0.90-1.16	1.68**	1.35-2.08	1.48**	1.24-1.76	1.03	0.94-1.13	1.08	0.96-1.22	1.18**	1.08-1.29	1.28**	1.10-1.50	1.52**	1.26-1.84
E-value	**1.37**		**2.26**		**1.51**				**2.75**		**2.32**						**1.64**		**1.88**		**2.41**	
Alcoholic drink <6 mo - Yes[d]	1.39**	1.08-1.79	6.91**	4.28-11.16	1.45**	1.12-1.87	1.49*	1.04-2.14	13.18**	5.52-31.4	4.73**	2.62-8.56	1.36*	1.04-1.77	1.43*	1.01-2.03	2.63**	1.94-3.55	2.74**	1.81-4.16	6.09**	3.26-11.37
E-value	**2.13**		**13.3**		**2.26**		**1.74**		**25.85**		**8.93**		**1.61**		**2.21**		**4.7**		**4.92**		**11.66**	
Tobacco <6 mo – Yes[e]	1.35	0.58-3.12	13.55**	7.55-24.30	2.64**	1.85-3.75	1.86*	1.13-3.07	29.58**	12.18-71.83	8.94**	4.47-17.88	1.88**	1.39-2.54	1.74*	1.07-2.83	5.49**	3.71-8.14	4.98**	2.80-8.86	16.42**	7.09-38.02
E-value			**26.59**		**4.72**		**2.07**		**58.66**		**17.37**		**2.08**		**2.87**		**10.45**		**9.43**		**32.33**	
Screen time	1.02**	1.00-1.04	1.14**	1.11-1.18	1.03**	1.01-1.05	1.03*	1.00-1.06	1.13**	1.08-1.18	1.10**	1.06-1.14	1.00	0.99-1.02	1.03**	1.00-1.06	1.06**	1.04-1.08	1.07**	1.05-1.11	1.11**	1.06-1.15
E-value	**1.16**		**1.54**		**1.21**		**1.14**		**1.51**		**1.43**				**1.21**		**1.31**		**1.34**		**1.46**	
Sleep	1.00	0.92-1.09	0.77*	0.61-0.96	0.95	0.86-1.05	0.98	0.86-1.12	0.64**	0.46-0.89	0.68**	0.54-0.85	0.96	0.89-1.04	0.99	0.88-1.12	0.90	0.79-1.02	0.91	0.74-1.12	0.73	0.53-1.01
E-value			**1.92**						**2.5**		**2.3**											
Physical activity	0.98	0.95-1.02	0.85	0.72-1.00	1.01	0.95-1.07	0.96	0.91-1.01	0.82	0.66-1.01	0.83*	0.71-0.97	1.02	0.98-1.05	0.99	0.93-1.06	0.93	0.87-1.01	0.82**	0.72-0.92	0.88	0.73-1.05
E-value											**1.7**								**1.74**			
Psychological distress – Yes[f]	1.85**	1.46-2.34	3.94**	2.25-6.89	1.70**	1.34-2.16	1.29*	1.00-1.66	10.87**	5.13-23.01	7.82**	4.43-13.78	1.47**	1.17-1.84	1.72**	1.33-2.24	3.46**	2.68-4.46	4.33**	2.68-6.97	7.86**	3.95-15.61
E-value	**3.1**		**7.34**		**2.79**		**1.53**		**21.23**		**15.12**		**1.72**		**2.83**		**6.38**		**8.13**		**15.2**	
Depression - None	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Mild[g]	1.08	0.86-1.35	1.03	0.44-2.39	1.18	0.88-1.59	1.08	0.81-1.43	0.86	0.17-4.21	1.70	0.66-4.34	1.19	0.94-1.49	0.99	0.71-1.38	1.70**	1.18-2.44	1.51	0.78-2.94	0.60	0.14-2.45
E-value																	**2.79**					
Moderate[g]	1.37*	1.06-1.79	2.05	0.87-4.85	1.33	0.97-1.83	0.88	0.58-1.20	3.04	0.75-12.33	3.92**	1.59-9.62	1.34**	1.03-1.76	1.29	0.84-1.99	2.15**	1.42-3.26	1.83	0.87-3.82	2.47	0.92-6.59
E-value	**2.08**										**7.3**		**1.58**				**3.72**					
Moderately severe[g]	1.87**	1.31-2.66	2.87	0.94-8.72	1.82**	1.27-2.60	1.17	0.77-1.77	5.66*	1.38-23.07	7.80**	3.06-19.85	1.31	0.92-1.86	1.53	0.98-2.40	4.54**	2.89-7.13	4.86**	2.58-9.16	2.63	0.79-8.75
E-value	**3.15**		**5.19**		**3.04**		**1.38**		**10.8**		**15.08**		**1.55**		**2.43**		**8.55**		**9.19**		**4.7**	
Severe[g]	2.98**	1.96-4.53	11.13**	5.19-23.83	2.65**	1.75-4.02	1.87*	1.08-3.23	24.4	8.03-74.59	18.30**	6.83-49.01	1.81**	1.25-2.63	1.86*	1.02-3.38	6.41**	3.86-10.64	5.76**	2.87-11.56	13.80**	5.51-34.58
E-value	**5.41**		**21.75**		**4.74**		**2.08**				**36.09**		**2.03**		**3.12**		**12.3**		**11**		**27.09**	
Anxiety - None	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Mild[h]	1.31	0.92-1.88	2.16	0.78-5.99	1.40*	1.01-1.91	1.24	0.78-1.97	3.76	5.99-23.69	3.39	0.92-12.47	1.35*	1.02-1.78	1.33	0.84-2.09	1.51	0.90-2.53	2.59**	1.35-4.96	2.21	0.48-9.99
E-value					**2.15**								**1.6**						**4.62**			
Moderate[h]	1.47**	1.11-1.94	3.54**	1.85-6.78	1.33*	1.02-1.73	0.84	0.60-1.19	7.69**	2.40-24.62	5.00**	2.06-12.17	1.22	0.98-1.52	1.70**	1.23-2.35	2.83**	2.06-3.89	3.59**	1.91-6.75	4.45**	1.65-11.99

(continued)

TABLE 2. Continued

Variables	≥1 common/ emerging condition (n=3691)		Irritable bowel syndrome (n=4651)		Asthma (n=4651)		Eczema (n=4651)		Type 2 diabetes (n=4651)		Chronic fatigue (n=4651)		Hay fever (n=4651)		Food allergies (n=4651)		ADD/ADHD (n=4651)		Autism/Asperger's (n=4651)		Type 1 diabetes (n=4651)	
	OR[a]	99%CI[b]	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI	OR	99%CI
E-value	2.3		6.54		1.99				14.86		9.47				2.79		5.11		6.64		8.37	
Severe[h]	2.69**	1.85-3.91	15.68**	7.95-30.92	2.39**	1.48-3.86	2.14**	1.36-3.39	45.04**	1.40-144.29	24.85**	9.48-65.16	1.65**	1.13-2.43	2.23**	1.47-3.38	5.30**	3.50-8.03	7.66**	4.17-14.06	18.72**	6.82-51.32
E-value	4.82		30.85		4.21		2.29		89.58		49.19		1.89		3.89		10.07		14.8		36.93	

* P<0.01
** P<0.001
[a]Odds ratios
[b]99% Confidence intervals
[c]These results are compared to males
[d]These results are compared to those who have not drank alcohol in the past 6 months
[e]These results are compared to those who have not smoked tobacco in the past 6 months
[f]These results are compared to those who do not have psychological distress
[g]These results are compared to those with no depression
[h]These results are compared to those with no anxiety

3.91) or reporting psychological distress (OR=1.85, 99%CI: 1.46-2.34). Non-significant multi-variable logistic regression models can be found in Table S2.

IBS, asthma, eczema, chronic fatigue, hay fever, food allergies, T2D, T1D, ADHD/ADD and autism/Asperger's were each individually associated with increased UPF intake, having drank alcohol or smoked tobacco, or having psychological distress, more severe anxiety and depression. The strongest associations found that the odds of T2D were higher in those who smoked tobacco (OR=29.58, 99%CI: 12.18-71.83), drank alcohol (OR=13.18, 99%CI: 5.52-31.4) or with severe anxiety (OR=45.04, 99%CI: 1.40-144.29) and that the odds of chronic fatigue were higher in those with severe depression (OR=18.30, 99% CI: 6.83-49.01). All diseases/conditions apart from hay fever were also significantly associated with higher screen time. T2D, Chronic fatigue and autism were each significantly associated with almost all of the lifestyle behaviours or mental health conditions.

Noncommunicable diseases IBS and asthma severity

Of the adolescents with IBS, those who drank alcohol (OR=6.44, 99% CI: 1.68-24.56) or smoked tobacco (OR=12.03, 99%CI: 2.29-63.11) had increased odds of having more severe IBS symptoms than those who did not (Table S5).

Of the adolescents with asthma, between the severity measures of higher frequency of asthma attacks, more persistent asthma symptoms in the past 12 months and having been hospitalised for asthma in the past 12 months, there were associations with all lifestyle behaviours and mental health measures other than PA. The odds of more frequent asthma attacks were higher in those who had smoked (OR=5.53, 99%CI: 2.25-13.59), odds of more persistent asthma symptoms were higher in those who had severe depression (OR=2.98, 99%CI: 1.39-6.36) and odds of being hospitalised for asthma in the past 12 months were higher in those who had smoked (OR=6.48, 99% CI: 2.43-17.29), have severe depression (OR=13.78, 99%CI: 4.79-39.67) or anxiety (OR=8.61, 99%CI: 3.11-23.77) (Table S5).

Sex and SES moderations of noncommunicable diseases and developmental conditions

Looking at the sex moderation analysis, associations between having ≥1 common/emerging condition, IBS, asthma, eczema, chronic fatigue, hay fever, food allergies, T2D with some lifestyle behaviours or mental health measures were significantly moderated by sex (Table S3, **Figure 1** & Figure S1). The strongest associations found that of all the adolescents who drank alcohol (OR=0.17, 99%CI: 0.05-0.63) or had severe anxiety (OR=0.15, 99%CI: 0.02-0.93), females had lower odds of having chronic fatigue in comparison to males (Table S3, **Figure 1**). Secondly, of all of those with severe anxiety (OR=0.12, 99% CI: 0.03-0.50) or severe depression (OR=0.21, 99%CI: 0.04-0.97) females had decreased odds of having IBS in comparison to males (Table S3, Figure 1).

Looking at the SES moderation analysis, SES only moderated associations between chronic fatigue, food allergies, T2D, autism/ Asperger's and some of the lifestyle behaviours and mental health measures (Table S4). The strongest associations found that of all those adolescents with mild anxiety, those from low SES had higher rates of T2D compared to those from high SES (OR= 0.54, 99%CI: 0.28-1.03) (Table S4). Secondly, of all those adolescents consuming less vegetables or participating in less PA, those from high SES had higher

rates of autism/Asperger's than those from low SES (vegetable OR=0.93, 99%CI: 0.88-0.97; PA OR=0.93, 99%CI: 0.88-0.97) (Table S4).

Sex and SES moderations of noncommunicable diseases IBS and asthma severity

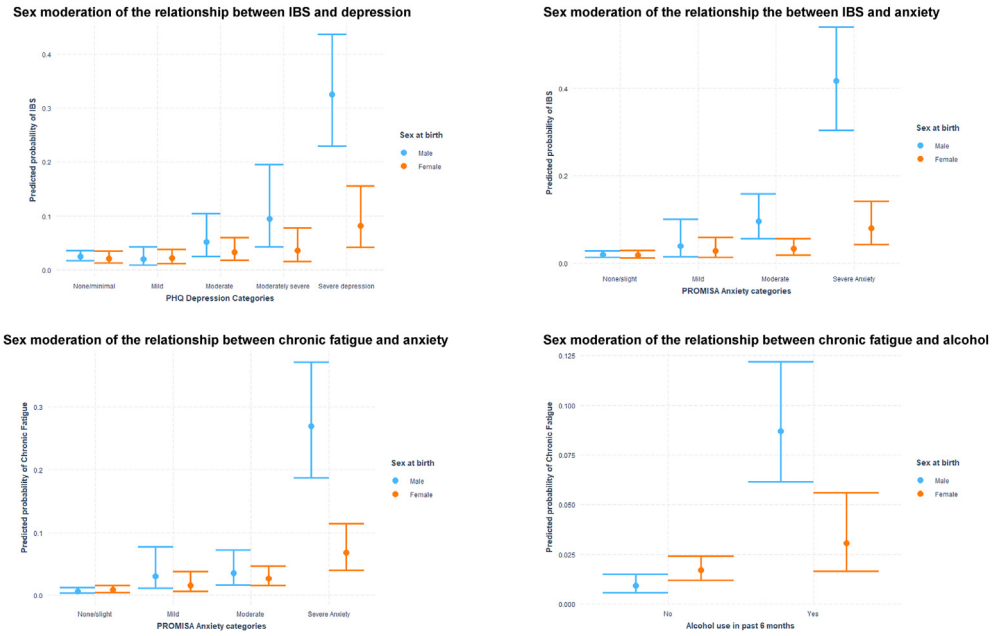
Looking at the sex moderation analysis, associations between IBS and asthma severity and SSB intake, depression and anxiety were significantly moderated by sex (Table S6). The strongest associations found that of all the adolescents who consumed more SSB, females had lower odds of more severe IBS in comparison to males (OR=0.51, 99%CI: 0.27-0.93) (Table S6). Secondly, of all of those who had severe depression, females had lower odds of frequent asthma attacks in comparison to males (OR=0.09, 99%CI: 0.00-0.92), and of those who had severe anxiety, females had decreased odds of being hospitalised by asthma in the past 12 months in comparison to males (OR=0.03, 99%CI: 0.00-0.25) (Table S7). There were no significant SES moderations with the severity of IBS and asthma.

Discussion

This study aimed to determine the prevalence of and associations between noncommunicable diseases and developmental conditions and related severity with lifestyle behaviours and mental health in a large cohort of adolescents, it also aimed to assess whether these associations differed depending on sex and SES. In the current study, almost half of the adolescents reported having at least one noncommunicable disease or developmental condition, highlighting the significance of this public health issue amongst adolescents. Asthma, hay fever, eczema, food allergies and ADHD were the most prevalent diseases/conditions. According to the Australian National Health Survey 2020-2021,[33] 11.7% of 15-17 year olds had asthma, the slightly higher rate in this sample (15.1%) may be due to the high proportion living in a metropolitan area, which is known to correlate with a higher risk of asthma compared to those living in a regional area.[13] The prevalence of hay fever (23.3%), food allergies (10.1%) and ADD/ADHD (9.4%) aligned with the rates found in recent Australian literature,[33–35] however, our sample reported a lower prevalence of eczema (10.6%).[36] Of concern, adolescents that have IBS and asthma were reporting severe symptomology; this proves problematic during adolescence, as it can result in reduced physical activities and impacts to mental health,[6,8,20] which can further induce a continuous cycle of inflammation. The common atopic diseases, such as hay fever, eczema, food allergies and persistent asthma symptoms were more prevalent in females. In line with the literature, males had higher rates of the developmental conditions ADHD[1] and autism/Asperger's[16] and reported higher rates of T1D[37] and T2D.

Poor lifestyle behaviours of tobacco, alcohol, or high UPF intake and poor mental health measures of psychological distress, moderately-severe depression and severe anxiety were significantly associated with every noncommunicable disease or developmental condition measured. The strong associations found between tobacco and alcohol and these noncommunicable diseases and developmental conditions could be in part explained by both behaviours being less normative in Australian adolescents; therefore, it is increasingly seen as an indicator of severity of physical and mental health across the board, much like other externalising conditions.[38] UPF intake in adolescents has been increasing, and its association with poor health outcomes is supported by a growing body of evidence, highlighting its detrimental effect on cardiometabolic and inflammatory markers contributing to chronic disease prevalence.[39] Literature suggests there is an independent bi-directional relationship between UPF and mental health conditions,[40] making it understandable for these two variables to be significantly associated with noncommunicable diseases/developmental conditions in tandem. Poor mental health can inhibit an inflammatory response[41] and dysregulation of the hypothalamic-pituitary-adrenal axis (HPA) altering hormonal balance.[42] This can contribute to the onset of disease and vice versa,

Figure 1: Sex moderation analysis of multi-variable logistic regressions interaction graphs of the strongest significant associations



which could help justify the strongest associations found between psychological distress, moderate-to-severe anxiety and depression with each one of the noncommunicable diseases and developmental conditions measured. Finally, participating in more screen time was associated with all diseases/conditions apart from hay fever. Screen time usage is currently at an all-time high in adolescents, known to coincide with adverse health outcomes such as weight status, depression, poor physical activity and social support.[43] Overall findings illustrate those adolescents with noncommunicable diseases or developmental conditions are generally in worse physical and mental health than their peers, outlining their vulnerability and the demand for targeted interventions. Multiple health behaviour change public health efforts and programs should consider specifically emphasising tobacco, alcohol and UPF avoidance and improving mental health to best assist with prevention and treatment of these common and emerging diseases/conditions.

Examination of the associations with noncommunicable disease severity contributes to a greater understanding of this bilateral relationship, offering potential insights that could help to inform alleviation or minimisation of symptoms. The association between asthma severity and almost all lifestyle behaviours and mental health measures (Table S5) contributes important knowledge from Australian data. Linkages between poor mental health, lifestyle behaviours and asthma severity have previously been established in the UK, Taiwan, Canada, Sweden and USA.[20] Risk-taking behaviours such as alcohol or tobacco use have been associated with worse asthma outcomes such as poorer health, medication adherence or symptom control,[44] whilst a pro-inflammatory diet (high in UPFs, SSB, low in fruit and vegetables) has been linked to worsened asthma prevalence and symptomology.[44,45] Simultaneously, some studies suggest having a chronic condition at a young age could be the driver for more risky lifestyle behaviours or poorer mental health,[20] whilst there are mixed findings that some types of medication to treat asthma, such as corticosteroids, may itself be the reason for worsened mental health. Overall, whilst there are clear associations, the direction of relationships are speculatory and further longitudinal research is required to examine causal relationships.

Critically, we found that males disproportionately had more associations with noncommunicable diseases or developmental conditions than females when their lifestyle behaviours or mental health were worse. Males reporting poor mental health were found to have the strongest relationships with the most noncommunicable diseases (Table S3, Figure 1 & Figure S1) (≥1 common/emerging condition, IBS, asthma and asthma severity, eczema, chronic fatigue, hay fever, food allergies). One explanation for this could be due to research showing that males generally have lower rates of mental health issues than females, possibly caused by underreporting due to cultural stigma or failure to seek help,[46] therefore males reporting poor mental health could potentially represent a greater marker of severity. Other poor lifestyle behaviours such as drinking alcohol or tobacco use were also strongly associated with higher prevalence of noncommunicable diseases compared to females. The increase in testosterone males experience during adolescence could inhibit more impulsive or sensation-seeking behaviour,[47] or increased susceptibility to adhere to peer pressure.[48] These findings highlight that compared to females, males who drank alcohol or smoked tobacco had higher odds of chronic fatigue, asthma and IBS, whether it is a cause or effect of a noncommunicable disease, making these behaviours important to target in public health messaging and future prevention programs.

Although there is evidence of SES disparities in health, there were minimal significant interactions in this sample, which could be in part explained by our cohort being generally from higher SES. Many associations were centred around dietary intake, as both high UPF and low SES are both independent risk factors for chronic fatigue[49,50] it is unsurprising that our findings of adolescents eating higher UPF were more likely to report chronic fatigue if they were from low SES compared to their high SES counterparts. However, of interest was the higher rates of food allergies and autism/Asperger's in those from high SES when vegetable intake and PA was lower when compared to those from low SES. When assessing relationships with autism/Asperger's consideration needs to be given to SES. Individuals from lower SES cohorts may be underdiagnosing autism/Asperger's due to lack of resources or awareness. This has been reported elsewhere as a contributing factor for increased diagnoses in higher SES.[51,52]

Limitations

This research was broadly exploratory and designed for hypothesis generation, having the limitation of increased potential for spurious associations to be found. Precautions to minimise this risk by conducting further robustness analyses to generate E-values and focussing only on those associations meeting a minimum strength of E-value association. Secondly, potential bias can occur when using self-report data. However, the prevalence of poor lifestyle behaviours, mental health, noncommunicable diseases and developmental conditions in this study were similar to, or higher than, recent Australian government data, adding confidence to the findings. The third limitation of this study is the cross-sectional study design, which limits our ability to establish causal relationships. The usage of listwise deletion for missing data analysis was chosen due to a lack of difference in baseline characteristics between those with or without missing data; however, assuming that data are missing at random can increase the potential for bias if participant characteristics make some participants more likely to have missing data than others. Finally, whilst our sample spanned across three Australian states, most of the participants were from urban areas and generally from higher SES backgrounds, meaning the sample was not nationally representative.

Conclusion

In a large cohort of Australian adolescents, nearly half reported having one or more noncommunicable diseases or developmental conditions, which can impact current physical and mental health and potentially contribute to future disease or disability. Whilst this cross-sectional analysis cannot depict the causal effect of lifestyle behaviours, mental health, and socio-demographics on condition prevalence, these associations highlight the important inter-relationship signifying the need for a whole lifestyle approach to help with future public health prevention and treatment attempts. Finally, understanding if these associations are moderated by sex is vital to better understand differences between males and females' experiences and ultimately help to better guide future public health efforts. Further research is needed using longitudinal data to obtain an improved understanding of causal relationships and further inform future public health messaging.

Conflicts of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Dr Bridie Osman was funded by The Paul Ramsay Foundation and declares that the funder had no involvement in this study. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethics

Ethical approval for the study was provided by the Human Research Ethics Committees of the University of Sydney (2018/882), Curtin University (HRE2019-0083), the University of Queensland (2019000037), and relevant school sector ethics committees. This trial was prospectively registered (ACTRN12619000431123).

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Appendix A Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.anzjph.2025.100225.