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Exploring the Link between Adolescent Mental Wellbeing and Non-Communicable Disease Risk: Evidence from a Cross-sectional Study Using Objective Indicators in Indonesia

Karly I. Cini[1-3*], Nisaa R. Wulan[1], Dorothea Dumuid[4], Alifah Nurjannah Triputri[5], Iffat Abbsar[2,6], Luo Li[2,3], Diandra A. Priambodo[2,7], Grace E. Sameve[8], Artha Camellia[8], Kate L. Francis[2,3], Susan M. Sawyer[2,3], George C. Patton[2,3], Ansariadi Ansariadi[5], Peter S. Azzopardi[1-3,9]

[1]Global Adolescent Health Group, Maternal Child and Adolescent Health Program, Burnet Institute, Melbourne, Australia.
[2]Centre for Adolescent Health, Murdoch Children's Research Institute, Melbourne, Australia.
[3]Department of Paediatrics, Faculty of Medicine, Dentistry, and Health Sciences, University of Melbourne, Melbourne, Australia.
[4]Alliance for Research in Exercise, Nutrition and Activity (ARENA), Allied Health & Human Performance, University of South Australia, Australia.
[5]Centre for Epidemiology and Population Health Studies, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia.
[6]Faculty of Medicine, Nursing and Health Sciences, Monash University, Melbourne, Australia.
[7]Faculty of Medicine, University of Indonesia, Jakarta, Indonesia.
[8]UNICEF Indonesia, Jakarta, Indonesia.
[9]Adolescent Health and Wellbeing Program, Telethon Kids Institute, Adelaide, South Australia, Australia.

Abstract

Although adolescence marks the onset of many risk factors for non-communicable diseases (NCDs)—including cardiovascular diseases, cancers, diabetes, chronic respiratory conditions, and mental disorders—these are often only considered in relation to adult health. There is limited insight into how various NCD risk factors co-occur and how they may influence mental wellbeing during adolescence. This study investigates how common these risks are, how they cluster, and how they are connected to mental wellbeing among adolescents in Indonesia—a nation with a youthful demographic and rising rates of NCDs. The study involved 1,331 adolescents aged 16–18 years from secondary schools in Jakarta (n = 609) and South Sulawesi (n = 722). Risk factors across five key domains—adiposity, physical inactivity, poor diet, substance use, and high levels of sedentary behavior—were assessed using a combination of objective measurements and self-reported data. In Jakarta, additional biomedical indicators such as blood glucose, cholesterol, triglycerides, and blood pressure were also evaluated. Mental wellbeing was measured using three criteria: psychological distress, overall quality of life

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Corresponding author: Karly I. Cini
E-mail: karly.cini@mcri.edu.au

(QoL), and QoL related to physical function. Multivariable linear regression models were used to examine associations between multiple risk factors and wellbeing outcomes, adjusting for factors such as province, sex, socioeconomic status, and religion. Clustering of NCD risk factors was widespread, with 58.9% (95% CI: 53.7–63.9) of participants showing three or more concurrent risks. Adolescents with at least one NCD risk were more prone to report psychological distress, with this association being strongest among those spending extensive time on sedentary activities like video gaming and computer use. A greater accumulation of risk factors corresponded with reduced psychological wellbeing and lower scores in both overall and physical function QoL. In the Jakarta subgroup, psychological distress was notably linked to elevated blood glucose and reduced HDL levels, while a higher count of physiological risk markers was associated with poorer physical function QoL. Findings indicate that both individual and combined NCD risk factors are strongly associated with lower mental wellbeing in Indonesian adolescents, even when controlling for potential confounders.

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Introduction

Non-communicable diseases (NCDs)—including cancer, cardiovascular disease, diabetes, chronic respiratory conditions, and mental disorders—now account for approximately 70% of the global disease burden [1, 2]. Although these conditions were historically associated with high-income nations, current data show that the majority—75% of all NCD-related deaths and 85% of premature deaths (ages 30–69)—occur in low- and middle-income countries (LMICs) [1]. In Indonesia alone, NCDs were responsible for over 42 million deaths in 2019, representing more than 74% of total mortality, despite many of these being preventable [1, 2]. These diseases often share modifiable behavioural risk factors—such as tobacco use, harmful alcohol consumption, physical inactivity, unhealthy diets, and exposure to air pollution—as well as clinical indicators like obesity, elevated blood pressure, hyperglycaemia, and dyslipidaemia [3]. Indonesian data point to a rapid increase in both NCDs and their associated risks, with considerable variation across age, sex, and provincial lines, underscoring the urgent need for preventive strategies [4–6].

Although NCDs lead to greater mortality and disability in adulthood, adolescence is the life stage during which many of these risk factors first emerge. This presents a critical window for prevention efforts [7, 8]. Given that most NCDs are incurable and long-lasting, prevention becomes central to managing the overall disease burden. A life course approach to prevention is now widely advocated [7, 9, 10]. However, adolescent-specific prevention strategies often emphasize long-term benefits, which may not align with the neurodevelopmental profile of adolescents, who are more responsive to interventions with immediate effects on their own wellbeing [8]. Therefore, beyond long-term health outcomes, investing in adolescent NCD prevention may also yield short-term improvements in quality of life and mental wellbeing.

Current research increasingly shows that NCD risk factors are already widespread among adolescents [11, 12]. Some evidence from high-income countries suggests that individual risks—such as limited physical activity, excessive sedentary behaviour, consumption of sugary drinks, and exposure to air pollution—negatively affect adolescents' mental health [13–15] and health-related quality of life (QoL) [16]. However, this body of evidence is limited in LMIC contexts. More research is needed to explore how combinations of multiple risk factors—known as co-occurring risks—may influence adolescents' current wellbeing and QoL. This question is particularly relevant for countries like Indonesia, where policymakers are just beginning to grapple with the growing impact of NCDs.

Materials and Methods

This study was designed to assess the prevalence, co-occurrence, and sociodemographic patterns of NCD risk factors among adolescents in Jakarta and South Sulawesi, Indonesia. It also examines how these risk factors relate to adolescents' current wellbeing and quality of life. In the Jakarta sample, we additionally report on the prevalence of cardio-metabolic biomarkers including raised blood pressure, elevated glycated haemoglobin (HbA1c), high triglyceride levels, and reduced High-density Lipoprotein (HDL) cholesterol. Furthermore, we investigate the associations between these biological indicators and adolescents' quality of life and wellbeing.

The research utilized a cross-sectional design that included a representative, school-based survey, physical measurements, and biomarker assessments in a subsample. This project emerged from a broader international collaboration between Indonesia and Australia, involving researchers and clinicians based in Jakarta, Makassar, and Melbourne. Given the sensitive focus of the study, substantial community engagement was prioritized. Community meetings were conducted at key stages—early during study planning and again prior to the start of data collection. Full methodological details are available in a separate publication [17].

Study setting and population

The research took place in two Indonesian provinces: Jakarta, characterized by dense urban development, and South Sulawesi, which encompasses urban, peri-urban, and rural zones. These provinces were purposefully chosen to reflect contrasting geographical and socio-economic contexts [17]. The target population consisted of adolescents aged 16 to 18 who had been enrolled in school at any time during the preceding 90 days.

Sampling strategy, eligibility, and participant recruitment

For detailed procedures regarding sampling and recruitment, refer to the published protocol [17]. In summary, a multi-level sampling approach was applied. Twelve schools were randomly selected from each province, and within each school, one class from each of grades 10, 11, and 12 was chosen. All students in these selected classes were eligible to participate, provided they fulfilled the study's criteria. A total of 2,509 students were given consent forms for their parents or guardians to sign. Of these, 1,337 students returned the forms (53.2%), including 611 (48.3%) from Jakarta and 726 (58.3%) from South Sulawesi. Adolescents were also required to provide their own informed assent prior to participating in any part of the study.

Data collection procedure

Fieldwork was conducted between February and April 2018. Each participant completed a digital survey via tablet during one class session. Anthropometric data were collected immediately afterward in a subsequent session. In Jakarta, the protocol also included biomarker collection, with participants seated and at rest during sampling. The entire process took roughly two hours per student, and all data collection for each school was finalized within a single day.

Anthropometric measurements

Body weight was recorded once using Seca 877 electronic scales, precise to 100 grams. Height was measured using a Shorrboard portable stadiometer. Two readings were taken, and a third measurement was done if the height readings differed by more than 0.5 cm. Waist circumference was measured using a SECA 201 tape, and if two measurements differed by more than 1.0 cm, a third was taken for accuracy.

Biomarker assessment

Biological data collected included triglycerides, high-density lipoprotein (HDL) cholesterol, and glycated haemoglobin A1C (HbA1c). Blood samples were obtained via venipuncture by qualified phlebotomists who followed standard safety protocols. Participants were non-fasting, and collection occurred in each school's first-aid station. Blood pressure was measured using an Omron HEM-6121 automated wrist monitor. Two readings were taken at one-minute intervals, and a third was added if systolic pressure differed by more than 10 mmHg or diastolic by over 6 mmHg. Biomarker collection was restricted to Jakarta due to ethical and logistical barriers preventing appropriate follow-up of clinically significant findings in South Sulawesi [17]. If a student's results indicated potential health risks, a notification letter was sent to their parent or guardian with information on the findings and a recommendation to seek medical advice [17].

Measures

To assess general psychological distress, the study utilized the 10-item Kessler Psychological Distress Scale (K10). This tool underwent a two-phase adaptation: first, it was translated into Bahasa Indonesia and culturally adjusted, followed by formal validation through clinician-administered assessments using the Mini International Neuropsychiatric Interview for Children and Adolescents (MINI-Kid) [18].

General quality of life was evaluated using the Youth Quality of Life Instrument–Short Form (YQoL-SF), which contains 15 items. Physical function, as part of health-related quality of life, was measured separately through the 8-item Physical Function subscale of the Pediatric Quality of Life Inventory (PedsQL). A full list of variables—outcome indicators, predictors, and their operational definitions—can be found in **Table 1**.

Key socio-demographic characteristics included in the analysis were: province (Jakarta or South Sulawesi), age group (16, 17, or 18 years), and sex (participants could choose Male, Female, or indicate 'other' and specify their gender identity). Additional factors included school grade (10, 11, or 12), self-rated family socio-economic status (ranging from average to very well off vs. below average to not at all well off), religious affiliation (Muslim or other groups including Christianity, Hinduism, Buddhism, or no religion), and current living arrangement (either with parents or stepparents, or with others such as grandparents, peers, or in a dormitory setting).

Table 1. Overview of Measures

Measure Name, Source	Description	Definition and Interpretation
Wellbeing Outcomes		
Psychological Distress (Kessler 10, K10) [19]	10-item scale measuring psychological distress in adolescents over the past 4 weeks.	Scores range from 0–40, calculated as the sum of all 10 items. Higher scores reflect greater distress.

General Quality of Life (Youth Quality of Life Instrument-Short Form, YQoL-SF) [20]	5-item multidimensional tool assessing quality of life in adolescents aged 11–18, using a 10-point Likert scale.	Scores are converted to a 0–100 scale, with higher scores indicating better quality of life. The score is the mean of recoded items.
Health-related Quality of Life (Pediatric Quality of Life Inventory Physical Function Sub-scale, PedsQL-PF) [21]	8-item scale evaluating physical ability and symptoms over the past 30 days, using a 5-point Likert scale.	Scores are converted to a 0–100 scale, with higher scores indicating better quality of life. The score is the mean of recoded items.
Risk Factors (All dichotomized, 1 = risk criteria met)		
Adiposity Domain		
High Body Mass Index (BMI)	2 items. BMI calculated from average height and weight (kg/m²). Age-sex-adjusted BMI Z-score using WHO 2007 reference [22, 23].	Risk defined as BMI Z-score > +1 SD (overweight per WHO).
High Waist Circumference	1 item. Average waist circumference from two closest measurements.	Risk defined as ≥ 90 cm (males) or ≥ 80 cm (females) [24].
Substance Use Domain		
Tobacco Use (Adapted from Global Youth Tobacco Survey, GYTS) [25]	2 items. Questions on current cigarette smoking and frequency.	Risk defined as smoking cigarettes weekly or more.
Alcohol Use (Adapted from YRBSS) [26]	2 items. Questions on lifetime and past 30-day alcohol use frequency.	Risk defined as ≥ 1 alcoholic drink in the past 30 days.
Physical Inactivity Domain		
Lack of Daily Moderate to Vigorous Physical Activity (Adapted from HBSC) [27, 28]	1 item. Question on frequency and duration of physical activity in the past week, per WHO guidelines for ages 11–17 [29].	Risk defined as < 60 minutes of moderate to vigorous activity daily.
Lack of Vigorous Physical Activity (Adapted from HBSC) [27, 28]	1 item. Question on frequency of vigorous physical activity in the past month.	Risk defined as vigorous activity < twice per week.
Sedentary Domain		
High Sedentary Activity (TV) (Adapted from HBSC) [27, 28]	1 item. Question on average time spent watching TV.	Risk defined as > 2 hours of TV per day.
High Sedentary Activity (Gaming) (Adapted from HBSC) [27, 28]	1 item. Question on average time spent on laptops or video games.	Risk defined as > 2 hours of gaming/computer use per day.
Unhealthy Diet Domain		
Insufficient Fruit and Vegetable Intake (Adapted from HBSC) [27, 28]	2 items. Questions on weekly fruit and vegetable consumption.	Risk defined as consuming fruits or vegetables less than daily.
Increased Sweets or Soft Drink Intake (Adapted from HBSC) [27, 28]	2 items. Questions on weekly sweets and soft drink consumption.	Risk defined as consuming sweets or soft drinks at least daily.
Risk Count		
Co-occurring Risk Exposure	Count of risk domains with ≥ 1 risk present (from 5 domains).	Range 0–5. Higher score indicates more co-occurring risks. Binary variable: ≥ 3 domains.
Biomarkers (All dichotomized, 1 = risk criteria met, based on International Diabetes Federation criteria [17, 24])		
Raised Triglycerides	1 item. Triglyceride levels from biomarker assays.	Risk defined as ≥ 1.7 mmol/L [24].
Reduced HDL Cholesterol	1 item. HDL cholesterol levels from biomarker assays.	Risk defined as HDL < 1.03 mmol/L (males) or < 1.29 mmol/L (females) [24].

Raised Blood Pressure	2 items. Average systolic and diastolic blood pressure.	Risk defined as ≥ 90th percentile (ages 16–17) or systolic ≥ 130 mmHg or diastolic ≥ 85 mmHg (age 18) [30, 31].
Raised HbA1c	1 item. HbA1c percentage from biomarker assays.	Risk defined as HbA1c ≥ 5.7% [24].
Biomarker Risk Count		
Co-occurring Biomarker Exposure	Count of biomarkers with risk present (from 5 biomarkers: high waist circumference, high triglycerides, low HDL, high BP, high blood sugar).	Range 0–5. Higher score indicates more risk biomarkers. Binary variable: ≥ 3 risk biomarkers.

Data management and analysis

Descriptive statistics for participant characteristics and wellbeing measures (psychological distress, YQoL, and PedsPF) were calculated without weighting, presenting categorical variables as counts and percentages, and continuous variables as means with standard deviations (SD). To account for the complex sampling design of the school-based survey, post-stratification inverse probability weights were applied. Weighted population prevalence estimates and corresponding 95% confidence intervals (CIs) were computed for dichotomized individual risk factors (based on self-report, anthropometric measures, and biomarkers) as well as for co-occurring risk factors. For continuous measures of co-occurring risk counts, weighted means and SDs were calculated.

Socio-demographic variables—including sex, province, family socioeconomic status (SES), and living situation—were dichotomized. Using population-weighted prevalence data disaggregated by these variables, risk ratios (RR) for each risk factor were estimated. Poisson regression models with robust error variance were used to calculate relative risks and 95% CIs, with statistical significance set at $p < 0.05$.

Associations between individual and combined NCD risk factors and wellbeing outcomes were examined using generalized linear regression models for the entire sample, as well as separately by sex. Within the Jakarta subsample, relationships between individual and clustered biomarkers and wellbeing outcomes were assessed overall and by sex. Separate regression analyses were conducted for each wellbeing indicator, adjusting for significant covariates: province, sex, family SES, and religious affiliation. For sex-specific models, adjustments excluded sex but included province, family SES, and religious affiliation. Statistical significance was defined as $p < 0.05$. All data preparation and analyses were performed using STATA SE version 18.0.

Results and Discussion

Participant characteristics

A total of 1,331 adolescents attending school participated in this study, with 722 from South Sulawesi and 609 from Jakarta. Six participants from the initial 1,337 were excluded due to missing essential demographic data (sex and age). The median age was 17 years (mean = 16.7, SD = 0.71), and females represented just over half of the sample (n = 735, 55.2%). No participants identified their gender as 'other.' Approximately half of the adolescents reported family socioeconomic status as below average. The majority identified as Muslim (93.9%), and nearly 80% lived with their parents or stepparents **(Table 2)**.

Table 2. Pa and Pi value of standard and novel ligands

	Female (n = 735)		**Male (n = 596)**		**Total (N = 1331)**	
	n	**(%)**	**n**	**(%)**	**N**	**(%)**
Province						
Jakarta	348	(47.3)	261	(43.8)	609	(45.8)
South Sulawesi	387	(52.7)	335	(56.2)	722	(54.2)
Age in years						
16	389	(52.9)	239	(40.1)	628	(47.2)
17	261	(35.5)	257	(43.1)	518	(38.9)
18	85	(11.6)	100	(16.8)	185	(13.9)
Grade at School						
Year 10	236	(32.1)	159	(26.7)	395	(29.7)
Year 11	262	(35.6)	234	(39.3)	496	(37.3)
Year 12	237	(32.2)	203	(34.1)	440	(33.1)

Family Socio-Economic Status, self-report						
SES Average or higher	342	(48.0)	282	(50.4)	624	(49.1)
SES Below average	370	(52.0)	277	(49.6)	647	(50.9)
Missing	23		37		60	
Living Situation						
Live with parents or stepparents	575	(80.4)	453	(77.8)	1,028	(79.3)
Live with others (grandparents, friends, others)	140	(19.6)	129	(22.2)	269	(20.7)
Missing	20		14		34	
Religion type						
Muslim	713	(97.1)	533	(89.9)	1,246	(93.9)
Christianity, Buddhism, Hinduism, or None	21	(2.9)	60	(10.1)	81	(6.1)
Missing	1		3		4	
OUTCOMES, Mean (SD)	M	(SD)	M	(SD)	M	(SD)
K10 Psychological Distress, Total 0–40	13.9	(7.2)	11.4	(6.5)	12.8	(7.0)
Missing	52		63		115	
PedsQL-Physical Functioning, Mean 0–100	74.2	(15.5)	81.2	(15.3)	77.3	(15.8)
Youth Quality of Life-Short Form, Mean 0–100	63.9	(19.6)	68.4	(20.8)	65.9	(20.3)

Distribution of risk behaviours

Self-reported risk factors

The leading risk behaviours reported were low levels of physical activity—specifically daily moderate-to-vigorous physical activity (MVPA)—and insufficient intake of fruits and vegetables **(Table 3)**. Over half of the adolescent participants (58.9%, 95% CI: 53.7–63.9) faced risks spanning three or more areas, with males showing a higher prevalence (65.4%, 95% CI: 59.0–71.3) compared to females (53.6%, 95% CI: 47.8–59.4), as detailed in **Table 3**. **Figure 1** depicts the distinct patterns of risk factor combinations. The pairing of poor diet and physical inactivity was the most frequently occurring two-factor cluster. Among clusters involving three or more risk domains, the combination of diet, physical inactivity, and excessive sedentary behaviour was the most prevalent, followed by the cluster adding adiposity to these three.

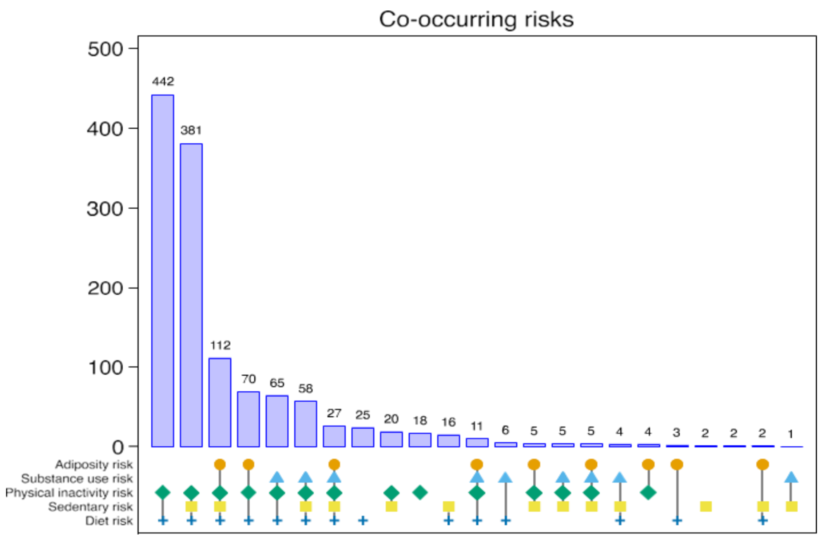

Figure 1. Risk factor co-occurrence across the full sample, by risk domain, sorted by frequency. Note: The groups are exclusive of each other, the icons indicate which risk domains adolescents were exposed to, and the number indicates the number of people in each group

Table 3. Weighted estimates for NCD risk factors and biomarkers, by sex. Estimate is weighted population prevalence, unles otherwise noted

Domain	Individual risk factor	Female	Male	Total
		n/N, estimate, (95%CI)	n/N, estimate, (95%CI)	n/N, estimate, (95%CI)

Adiposity	High BMI	117/ 735	15.9%	(12.7,19.7)	117/ 596	19.7%	(14.4,26.3)	234/1331	17.6%	(14.0,21.8)
	High waist	96/ 735	13.0%	(9.1,18.2)	63/ 596	10.6%	(6.5,16.7)	159/1331	11.9%	(8.8,15.9)
Substance use	Smoking	6/ 625	1.0%	(0.5, 2.1)	141/ 436	32.3%	(23.6,42.5)	147/1061	13.9%	(8.6,21.7)
	Alcohol use	8/ 707	1.2%	(0.6, 2.5)	71/ 568	12.6%	(4.9,28.7)	80/1275	6.3%	(2.4,15.2)
Physical inactivity	Inadequate MVPA	707/ 735	96.1%	(94.8,97.2)	547/ 595	91.9%	(89.4,93.8)	1254/1330	94.2%	(93.0,95.2)
Sedentary	Inadequate VPA	480/ 735	65.3%	(59.8,70.4)	207/ 595	34.7%	(30.2,39.5)	687/1330	51.6%	(46.3,56.9)
	Excess TV	261/ 728	35.9%	(30.2,42.1)	179/ 590	30.3%	(24.7,36.5)	440/1318	33.4%	(28.7,38.4)
	Excess gaming	150/ 662	22.6%	(17.9,28.1)	210/ 546	38.4%	(31.2,46.1)	359/1209	29.7%	(24.7,35.3)
Diet	Lack of fruit or veg	670/ 735	91.1%	(88.3,93.3)	536/ 596	89.9%	(86.2,92.7)	1206/1331	90.6%	(88.3,92.4)
	Excess sweets/ soft drink	232/ 735	31.6%	(27.5,36.1)	152/ 596	25.5%	(21.4,30.1)	385/1331	28.9%	(25.6,32.4)
Co-occurring risk count (0–5)a		735	2.6 (0.72)	(2.5, 2.7)	596	2.9 (0.92)	(2.7, 3.1)	1331	2.7 (0.83)	(2.6, 2.9)
Co-occurring binary (≥ 3 risks)		394/ 735	53.6%	(47.8,59.4)	390/ 596	65.4%	(59.0,71.3)	784/1331	58.9%	(53.7,63.9)
Biomarkers (Jakarta only)										
	High waist circumference	74/ 374	19.7%	(12.7,29.4)	50/ 306	16.4%	(9.6,26.5)	124/ 680	18.2%	(12.4,25.8)
	Reduced HDL	194/ 284	68.2%	(55.5,78.7)	86/ 224	38.1%	(26.2,51.6)	279/ 509	54.9%	(46.4,63.1)
	Raised triglycerides	46/ 284	16.1%	(11.1,22.8)	62/ 224	27.7%	(19.9,37.1)	108/ 509	21.2%	(15.6,28.1)
	Raised blood glucose	11/ 284	3.9%	(1.3,11.6)	14/ 225	6.0%	(2.8,12.3)	25/ 510	4.8%	(2.1,10.6)
	Raised blood pressure	25/ 374	6.7%	(3.3,13.2)	39/ 303	12.7%	(7.1,21.7)	64/ 677	9.4%	(5.1,16.6)
Co-occurring risk count (0–5)a		284	1.1 (0.94)	(0.9, 1.4)	225	1.0 (1.02)	(0.8, 1.3)	510	1.1 (0.99)	(0.9, 1.3)
Co-occurring binary (≥ 3 risks)	High BMI	21/284	7.3%	(2.8,17.8)	19/225	8.3%	(4.0,16.6)	39/510	7.7%	(3.6,15.9)

NB: Population N will differ for each risk, as participants could skip survey questions if they chose
MVPA Moderate to Vigorous Physical Activity, VPA Vigorous Physical Activity, TV Television, HDL High Density Lipoprotein
a Weighted mean (standard deviation)

Biomarkers

Among adolescents from Jakarta, the most frequently detected biomarker abnormality was low HDL cholesterol, affecting 54.9% (95% CI: 46.4 to 63.1) of participants. Elevated triglycerides, raised blood glucose (suggesting prediabetes), and increased blood pressure were observed more often in males than in females. In contrast, females showed higher prevalence of both low HDL cholesterol and greater waist circumference. Overall, 7.7% (95% CI: 3.6 to 15.9) of this subgroup exhibited multiple cardiometabolic risk factors simultaneously, with an average count of 1.1 (SD = 0.99).

Socio-demographic variations

Significant sex-related disparities appeared in several risk behaviours **(Figure 2)**. The rate of tobacco smoking was markedly higher among males at 32.3%, compared to just 1% in females, corresponding to a risk ratio (RR) of 0.03 (95% CI: 0.01–0.07). Alcohol consumption was also far more common in males, approximately ten times higher than females (RR 0.09, 95% CI: 0.03–0.29). Females were nearly twice as likely to not engage in sufficient vigorous physical activity compared to males (65.3% versus 34.7%; RR 1.88, 95% CI: 1.64–2.16).

Comparing by province, adolescents in Jakarta exhibited higher prevalence of increased BMI (RR 0.40, 95% CI:

0.27–0.61), enlarged waist circumference (RR 0.29, 95% CI: 0.17–0.51), insufficient daily moderate-to-vigorous physical activity (RR 0.95, 95% CI: 0.93–0.98), and prolonged sedentary behaviour (RR 0.63, 95% CI: 0.52–0.76) compared to their peers in South Sulawesi. Those identifying with higher socio-economic status had significantly greater likelihoods of elevated BMI (RR 0.70, 95% CI: 0.54–0.91), larger waist circumference (RR 0.64, 95% CI: 0.50–0.82), and alcohol use (RR 0.40, 95% CI: 0.16–0.98) than adolescents from lower socio-economic backgrounds. Living arrangements—whether with parents or others—did not show strong links with any measured risk factors.

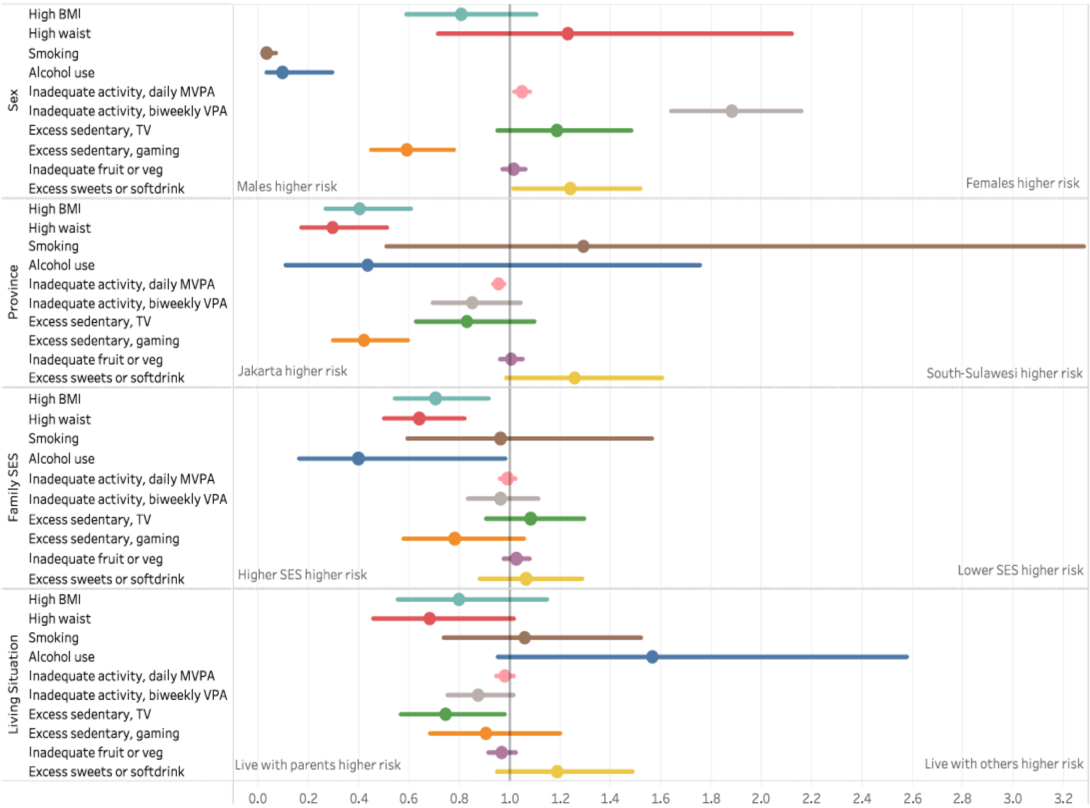

Figure 2. Risk ratios for population weighted prevalence of NCD risk factors, by socio-demographic factors, bars indicate 95%CI's

Primary outcomes: mental wellbeing indicators

The average psychological distress score across all participants was 12.8 (SD = 7). As shown in **Table 2**, females had notably higher distress scores than males. When examining general quality of life (QoL), scores were largely comparable between sexes. However, males reported better physical functioning QoL, with an average score of 81.2 (SD = 15.3), compared to females, who averaged 74.2 (SD = 15.5).

Links between individual NCD risk factors and wellbeing measures

relationships between NCD risk exposures and wellbeing indicators. Generally, adolescents exposed to these risk factors exhibited lower average scores for physical functioning and general QoL, alongside elevated psychological distress scores. Psychological distress showed significant correlations with eight out of ten risk factors assessed. Physical functioning QoL was associated with five risk factors, while four were linked to general QoL. Excessive TV watching, however, did not significantly relate to any of the wellbeing outcomes. Analysis by sex revealed similar trends: both males and females with NCD risks had reduced physical functioning and general QoL scores, along with increased psychological distress. Interestingly, more risk factors correlated with psychological distress in males than in females.

Focusing on biomarkers measured solely in Jakarta, reduced HDL cholesterol and raised blood glucose correlated with higher psychological distress scores **(Table 5)**. Consistent with the overall sample, high waist circumference was connected to lower physical functioning QoL. There were no clear links between biomarkers and general QoL. When considering sex differences, reduced HDL was significantly associated with psychological distress among females, whereas in males, high waist circumference was linked to diminished physical functioning QoL.

Table 4. Wellbeing outcomes by individual and co-occurring NCD risk factors, in adolescents

		Psychological distress (scale: 0–40)		Physical function quality of life (scale: 0–100)		Youth general quality of life (scale: 0–100)	
NCD risks[a] in Jakarta and South Sulawesi							
		Mean Diff	**95% CI**	**Mean Diff**	**95% CI**	**Mean Diff**	**95% CI**
Adiposity	High BMI	1.04*	(0.2, 1.9)	−4.05*	(−6.3, −1.8)	−1.08	(−4.4, 2.2)
	High waist	1.29	(−0.0, 2.6)	−3.65*	(−6.7, −0.6)	−1.19	(−4.8, 2.4)
Substance use	Smoking	1.50*	(0.1, 3.0)	−2.77	(−7.3, 1.8)	−5.46*	(−10.7, −0.3)
	Alcohol use	2.04*	(0.1, 3.9)	−0.54	(−4.8, 3.7)	−3.49	(−9.2, 2.2)
Physical inactivity	Inadequate MVPA	2.35*	(0.6, 4.1)	−5.56*	(−10.1, −1.1)	−12.63*	(−16.7, −8.6)
	Inadequate vigorous PA	0.87*	(0.1, 1.7)	−6.46*	(−8.9, −4.0)	−3.54*	(−6.0, −1.1)
Sedentary	Excess TV	−0.05	(−0.9, 0.8)	−0.29	(−2.3, 1.8)	2.59	(−0.1, 5.2)
	Excess gaming	2.21*	(0.9, 3.5)	−3.04*	(−5.7, −0.4)	0.90	(−2.3, 4.1)
Diet	Inadequate fruit or veg	1.79*	(0.8, 2.8)	−2.83	(−6.1, 0.5)	−5.96*	(−9.6, −2.3)
	Excess sweets/ soft drink	0.92*	(0.1, 1.7)	−0.11	(−2.0, 1.8)	1.00	(−1.3, 3.3)
		Coeff	95% CI	Coeff	95% CI	Coeff	95% CI
Co-occurring NCD risk count[b]		1.40*	(1.0, 1.8)	−2.54*	(−3.7, −1.4)	−1.68*	(−3.1, −0.3)

NB: Each regression analysis accounted for covariates that showed significant associations, including province, sex, family socioeconomic status, and religious affiliation.

[a] NCD risks are binary outcomes where the reference category is the absence of the risk factor, as defined in **Table 1**

[b] Co-occurring risk counts for NCD risks are continuous measures

* Indicates P value: $p < 0.05$

Table 5. Wellbeing outcomes by individual and co-occurring risk biomarkers, in adolescents

	Psychological distress (scale: 0–40)		Physical function quality of life (scale: 0–100)		Youth general quality of life (scale: 0–100)	
Biomarkers[a] in Jakarta	**Mean Diff**	**95% CI**	**Mean Diff**	**95% CI**	**Mean Diff**	**95% CI**
Reduced HDL	1.18*	(0.1, 2.2)	−1.47	(−5.0, 2.0)	−1.56	(−3.7, 0.6)
Raised triglycerides	−0.55	(−1.9, 0.8)	−0.70	(−5.0, 3.6)	0.43	(−3.9, 4.8)
Raised blood glucose	3.55*	(0.7, 6.4)	−9.68	(−19.7, 0.3)	−0.98	(−8.0, 6.0)
Raised blood pressure	−0.18	(−2.9, 2.5)	1.46	(−2.4, 5.3)	2.94	(−1.5, 7.4)
High waist	1.25	(−0.4, 2.9)	−4.22*	(−7.8, −0.6)	−0.40	(−4.4, 3.6)
	Coeff	95% CI	Coeff	95% CI	Coeff	95% CI
Co-occurring biomarker count[b]	0.51	(−0.3, 1.3)	−1.43*	(−2.4, −0.5)	−0.02	(−1.6, 1.5)

NB: Each regression analysis accounted for covariates that showed significant associations, including province, sex, family socioeconomic status, and religious affiliation.

[a] Biomarkers are binary outcomes where the reference category is the absence of the risk factor, as defined in **Table 1**

[b] Co-occurring risk counts for biomarkers are continuous measures

* Indicates P value: $p < 0.05$

Relationship between co-occurring risks and wellbeing

The link between exposure to multiple simultaneous NCD risk factors and indicators of wellbeing, including psychological distress and quality of life, was apparent **(Table 4)**. After adjusting for significant covariates such as province, sex, family socioeconomic status, and religious affiliation, adolescents experiencing multiple risks had notably higher average psychological distress scores. Specifically, the regression model showed that each additional risk factor corresponded to an increase of 1.40 points (95% CI: 1.0 to 1.8) in the mean psychological distress score. Similarly, exposure to a greater number of co-occurring risks was related to lower quality of life scores even after controlling for all relevant covariates. Each additional risk factor was linked with a decline of 2.54 points (95% CI: −3.7 to −1.4) in physical function QoL and a reduction of 1.68 points (95% CI: −3.1 to −0.3) in general QoL.

When analyzing the data separately by sex, these patterns remained consistent. For males, a one-unit increase in the number of risk factors was associated with a 1.14-point (95% CI: 0.5 to 1.8) rise in psychological distress, while for females the increase was 1.74 points (95% CI: 1.2 to 2.2). Correspondingly, the physical functioning score decreased by 2.45 points (95% CI: −4.1 to −0.8) in males and by 2.82 points (95% CI: −4.8 to −0.9) in females for each additional risk factor. Notably, the decline in general QoL related to co-occurring risks reached statistical significance only among males.

Regarding co-occurring cardiometabolic risk biomarkers measured in Jakarta, no strong associations were found with any wellbeing outcomes overall **(Table 5)**. However, there was some indication that an increase in biomarker count was linked to reduced physical function QoL, with a one-unit rise in biomarker number corresponding to a 1.43-point (95% CI: −2.4 to −0.5) decrease in the mean physical function score. Sex-specific analyses showed differences: males displayed a similar negative association between biomarker count and physical functioning, whereas in females, each additional biomarker was associated with a 1.04-point (95% CI: 0.2 to 1.9) increase in psychological distress. For females, no significant relationship was observed between biomarker count and physical functioning QoL.

This study represents the first investigation of its kind focused on Indonesian adolescents. Our findings reveal a clear and significant link between key NCD risk factors and current indicators of mental wellbeing within this unique sample. Psychological distress was connected to all examined risk domains, while physical functioning quality of life (QoL) showed associations with adiposity, physical inactivity, and excessive sedentary behaviour. General QoL was related to substance use, physical inactivity, and diet. Adolescents with risk factors spanning multiple domains demonstrated higher average psychological distress scores, a measure known for its effectiveness in detecting depression and anxiety within this population [18]. Furthermore, an increase in the number of co-occurring risk factors corresponded with reductions in quality of life across both physical functioning and general QoL scales. These results suggest that targeting NCD risk factors could positively influence adolescents' mental health and wellbeing in the present, rather than solely benefiting their health in adulthood.

The observed patterns highlight an important relationship between adolescents' current wellbeing and their exposure to common NCD risks, particularly the cumulative number of co-occurring risks. Interestingly, this pattern was not observed within our subsample assessing multiple cardiometabolic risk biomarkers. This aligns with findings from another study involving young adults that evaluated biomarkers such as fasting glucose, triglycerides, low HDL cholesterol, blood pressure, and waist circumference, which found only a weak correlation between waist circumference and psychological distress [32]. This context may help interpret our findings, suggesting that the behavioural and social aspects of these risks—like smoking habits, dietary choices, and physical activity levels—may be more closely linked to adolescent wellbeing than biological markers such as blood lipid profiles. While the biological measures assessed here are certainly relevant to wellbeing, other mediating factors are likely involved. A recent meta-analysis of cohort studies exploring the connection between clustered metabolic risks and depressive symptoms reported consistent associations in Western populations but not in Asian populations [33]. Additionally, a population-based study on adults with diabetes found that depressive symptoms were more strongly related to the subjective experience of diabetic symptoms than to glycaemic control as measured by HbA1c levels [34]. Therefore, although the link between co-occurring biomarkers and mental wellbeing may be less evident in our adolescent sample, the significant association between broader NCD risks and mental wellbeing is both novel and important. Further research is necessary to clarify the directionality of these relationships, which could offer valuable opportunities for preventing ill health.

In recent years, there has been increasing advocacy for incorporating major NCD risk factors into public health strategies aimed at preventing and managing common mental disorders [35, 36]. Many of these risk factors are modifiable, and while their individual-level impact on mental health may not rival that of major determinants such as adverse childhood experiences or poly-victimisation, their collective influence at the population level—and across multiple disease outcomes—should not be underestimated [37, 38]. Previous research has produced mixed results; systematic reviews by Wu *et al.* [16] and Hoare *et al.* [13, 39] identified links between various NCD risk factors and health-related quality of life (HRQOL) and depressive symptoms, respectively, but also raised concerns about study quality and representativeness [16, 39]. Our cross-sectional findings reinforce the presence of an association between NCD risks and adolescent wellbeing. Future intervention studies targeting NCD risk factors could benefit from including measures of wellbeing as potential short-term outcomes, alongside long-term goals such as reducing the likelihood of developing NCDs later in life or decreasing disability related to these diseases [40]. Demonstrating improvements in immediate wellbeing might provide stronger motivation for adolescents to engage in preventative behaviours than emphasizing benefits that manifest only in the distant future. Given the mixed evidence from earlier studies and the robust associations identified here, further research is essential to unpack the complex interplay of these factors during this critical developmental period.

Socio-demographic factors—at the individual, household, and societal levels—are frequently emphasized in the literature as playing a key role in the mechanisms that explain the strong connection between mental wellbeing, non-communicable diseases (NCDs), and their associated risk factors [35, 40]. Thanks to our large sample, we were able to explore how major NCD risk factors vary across relevant socio-demographic characteristics and report differences by sex. Although sex differences were not observed across all variables, where they did occur, they were substantial. Males were more likely to engage in substance use, while females were found to be twice as likely to experience insufficient physical activity. This pattern is in line with global evidence regarding gender disparities in physical inactivity and substance use [41–43]. Adiposity was notably higher in Jakarta's more urbanised environment and among participants who identified as having above-average socio-economic status. While this reflects common global narratives about urbanisation and exposure to obesogenic environments, both international and Indonesian research point to a more complex picture. In fact, body mass index (BMI) in rural areas is rising faster—despite being lower overall—compared to urban areas in low- and middle-income settings, and individuals in urban Indonesian areas show mixed dietary patterns that may simultaneously elevate and reduce NCD risk, such as greater intake of sugary beverages and processed foods along with increased consumption of vegetables and fish [44, 45].

Certain limitations should be acknowledged. The study was conducted in just two provinces, limiting broader generalisability. However, the provinces were intentionally selected for their contrasting contexts—urban, rural, and peri-urban settings, varying levels of population density, differing adolescent demographics, and Human Development Index scores. Additionally, the cross-sectional design restricts our ability to determine causality. Nonetheless, the study contributes to the expanding research documenting the rise of NCD risks in Indonesian adolescents and enhances understanding of how these risks intersect with current mental wellbeing. The observed relationship between co-existing NCD risks and both wellbeing and quality of life is likely reciprocal in nature, and future studies are needed to better explore these complex pathways. Still, the current findings underline the importance of addressing NCD risks early to support adolescents' immediate health and wellbeing—not solely to prevent adult disease later in life.

We observed a high proportion of adolescents in Jakarta and South Sulawesi experiencing multiple NCD risk factors concurrently. This supports previous findings indicating a growing trend of co-occurring risks over time [46]. The proportion of adolescents not meeting the WHO recommendation of 60 minutes of moderate-to-vigorous physical activity daily was strikingly high in our study (96.1%). However, this aligns with other studies applying the same standard. A 2019 report found that 86.4% of Indonesian adolescents aged 11–17 were insufficiently active, while the 2015 Indonesian Global School Health Survey showed 87.8% among 13–16-year-olds [41, 46]. Our slightly higher prevalence may be explained by our older age group (16–18 years), which is associated with reduced activity, and the fact that our sample was limited to two provinces. We also found a very high prevalence of inadequate fruit and vegetable intake (91.1%). Data from Indonesia's 2018 RISKESDAS survey similarly show that over 95% of 15–19 and 18–24-year-olds fall short in this area [47, 48]. These findings, along with their alignment with prior studies, suggest these risk behaviours are nearly universal. Although the definitions used for these risks are widely accepted, their widespread presence raises questions about their effectiveness in distinguishing individuals with especially high risk from the general adolescent population.

One major strength of this study lies in its mixed-methods approach, using a large, representative sample. We incorporated self-report surveys alongside objective measurements—such as anthropometric data and biomarkers—which is a step beyond many comparable studies that rely solely on self-reports. Measurements of height, weight, waist circumference, blood pressure, and lipid profiles strengthen our findings. Furthermore, our tools for assessing mental wellbeing and quality of life were based on robust, validated scales. Our previous work on culturally validating the K10 scale through diagnostic interviews (MINI-KID) in a subsample supports the reliability of our estimates [18, 49]. Another notable strength is the integration of qualitative research. Early qualitative input played a central role in shaping the survey to ensure cultural relevance. The analysis also drew upon more recent qualitative interviews with national stakeholders in adolescent health and NCD prevention, enriching our understanding of local data needs and priorities [17, 50, 51].

Conclusion

This study underscores the widespread presence of non-communicable disease (NCD) risk factors—confirmed through both biological markers and anthropometric assessments—among adolescents in Indonesia. Moreover, we identified a significant connection between the clustering of multiple NCD risks and current levels of adolescent wellbeing. Compared to earlier research, our findings point to a concerning rise in both individual and combined risk factors, reinforcing the urgency of implementing preventive strategies targeted at adolescents and even younger age groups. The link between NCD risks and present-day wellbeing and quality of life highlights additional, immediate benefits of early intervention—beyond future health gains—offering compelling justification for early action. Initiatives that promote healthier diets, increased physical activity, and reduced substance use can simultaneously support adolescent wellbeing and curb future NCD burden. Public health policies aimed at adult populations should consider shifting their focus earlier in the life-course to improve young people's health now while lowering long-term disease risk. There remains a critical need for more in-depth research to better understand how NCDs develop during adolescence, how they relate to social determinants, and how they can be prevented effectively—both in Indonesia and in similar settings globally.

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