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Exercise Frequency and Subjective Well-Being among Chinese Adolescents: Competing Indirect Associations through Depressive Symptoms and Sleep Duration

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Article

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Abstract

Adolescent well-being is multidimensional, and a favorable behavioral indicator need not align with psychological and recovery-related indicators. Using the 2022 China Family Panel Studies, we identified 2,985 respondents aged 10–18 years; 2,864 had valid happiness and exercise measures, and the fully adjusted complete-case model included 2,849. Ordinary least squares models used HC1 standard errors, survey analyses applied the 2022 cross-sectional person weight with strata and PSU clustering, and coefficient products used 5,000 bootstrap resamples. Exercise frequency was positively associated with subjective well-being in the adjusted model (b = 0.045, SE = 0.016, p = .006) and in the design-adjusted model (b = 0.052, SE = 0.022, p = .016). The largest positive indirect association involved fewer depressive symptoms (ab = 0.0182, 95% CI [0.0087, 0.0281]); smaller negative associations involved sleep duration (ab = − 0.0024, 95% CI [− 0.0053, − 0.0003]) and the sequential sleep–depressive-symptoms path. Loneliness and self-rated-health products included zero. Tutoring-time moderation (p = .084), formal gender interactions (p = .395 and .050), and the matched PSM estimate (p = .138) did not meet p < .05. The cross-sectional findings describe differentiated indicator patterns rather than causal mechanisms.

1 Introduction

Subjective well-being is a core indicator of how children evaluate their lives, not merely the absence of mental disorder. It captures young people's own assessments and therefore adds information that cannot be recovered from adult reports, school attainment, or clinical symptoms alone. Child well-being research has accordingly moved toward frameworks that combine subjective and objective evidence and include positive as well as negative indicators across health, education, relationships, behavior, and socio-emotional life (Hall et al., 2025; Moore, 2020). Within such frameworks, a global happiness item is informative but narrow. Its interpretation becomes stronger when it is examined alongside domain-specific measures that describe the circumstances under which favorable and unfavorable evaluations coexist.

Adolescence is especially relevant to this multidimensional perspective. Daily routines are reorganized as school demands intensify, peer relationships become more salient, and young people gain greater control over some activities while remaining constrained by family and institutional schedules. Longitudinal evidence shows that adolescent well-being does not follow a single developmental course, and Chinese adolescents can occupy distinct well-being trajectories or profiles (Gao et al., 2025). Behavioral participation, emotional distress, sleep, perceived health, and social connection may therefore change at different rates and even in different directions. Treating these domains as interchangeable would obscure precisely the heterogeneity that child-indicator research seeks to describe.

Physical activity is one behavioral domain repeatedly associated with adolescent mental well-being. Reviews link greater activity with fewer depressive symptoms and higher positive well-being, although estimates vary by design, measurement, and population (Biddle et al., 2019; Rodriguez-Ayllon et al.,

2019). Research in Child Indicators Research likewise reports positive associations between physical activity and adolescent mental well-being while emphasizing the limits of self-report and the possibility of reciprocal relationships (Davison et al., 2022). These findings make exercise relevant to child well-being monitoring, but they do not establish that frequency is a complete indicator of the quality, timing, or developmental meaning of activity.

Exercise occurs within a finite day. For school-aged adolescents, time allocated to exercise, homework, private tutoring, commuting, screen use, family interaction, and sleep is jointly constrained. Cross-national research in Asia demonstrates that children's time-use configurations are associated with subjective well-being and differ across social contexts (Cha & Yoo, 2024). This observation complicates simple accounts of exercise as an isolated health behavior. More frequent participation may coincide with experiences that support mood and competence, yet it may also be scheduled by reducing another well-being-relevant activity. Sleep is an especially plausible margin of adjustment when school and homework schedules remain fixed.

The present study distinguishes two principal indirect pathways. The first is psychological: exercise frequency may be associated with fewer depressive symptoms, and lower depressive symptoms with greater subjective well-being. The second concerns daily time and health: more frequent exercise may coexist with shorter sleep, while shorter sleep is associated with lower well-being and greater depressive symptoms. These paths should not be treated as components of a causal decomposition. They are cross-sectional coefficient products used to ask whether favorable and unfavorable domain-specific associations appear in the same fitted model.

China provides a useful setting for this question. National child well-being research based on the China Family Panel Studies (CFPS) has shown the value of integrating children's subjective evaluations with capabilities and contextual conditions (Kong et al., 2021; Lin et al., 2023). At the same time, Chinese adolescents' routines are shaped by school timetables, family expectations, and unequal access to supplementary education. These features do not make Chinese adolescents homogeneous, nor do they predetermine the meaning of exercise. They do, however, make it important to examine whether behavioral participation and recovery-related indicators move together.

The indicator perspective changes the question asked of exercise research. Child indicators were originally developed to move beyond survival and deficit counts toward accounts of how children are actually living (Ben-Arieh, 2008). Contemporary systems retain objective conditions, but they also recognize that young people's evaluations cannot be inferred from household resources or adult observations alone (Casas, 2011; Hall et al., 2025). Subjective well-being is therefore neither a decorative outcome nor a shorthand for the absence of distress. It is one component of a broader evidence architecture in which positive evaluations, negative symptoms, relationships, health, and daily activities may converge only partially.

That partial convergence is developmentally meaningful. Positive and negative indicators share correlates, yet they are not opposite endpoints of one scale (Diener et al., 2017). Reviews of youth life

satisfaction similarly show that family, peer, school, health, and personal domains make distinguishable contributions (Proctor et al., 2009). A behavior can accompany a favorable global appraisal while coinciding with strain in another domain. The resulting pattern should not be treated as a measurement failure. It may instead reveal which part of adolescent life a broad participation indicator captures and which parts it leaves unresolved.

Developmental evidence also cautions against treating adolescence as a stable interval. Life satisfaction often declines from late childhood into adolescence, but average trends mask substantial differences between young people and settings (Aymerich et al., 2021; Daly, 2022; Marquez & Long, 2021). A meta-analytic review of longitudinal studies identified age-related changes in several components of subjective well-being rather than one uniform trajectory (Buecker et al., 2023; Steinmayr et al., 2019). Recent CIR research likewise models adolescent life satisfaction through differentiated affective and regulatory paths (Chamizo-Nieto et al., 2026). These studies make the interpretation of cross-domain associations more important, not less: the same activity may sit within quite different emotional and temporal arrangements.

Population evidence further shows that adolescent activity is unequally distributed. Globally, most school-aged adolescents do not meet recommended activity levels, with marked variation by gender and country (Guthold et al., 2020). Such prevalence estimates are useful for surveillance, but frequency categories do not identify intensity, duration, context, or meaning. Systematic reviews associate physical activity with multiple health indicators, yet they also report heterogeneous measures and predominantly observational designs (Janssen & LeBlanc, 2010; Poitras et al., 2016). The present study therefore treats exercise frequency as a bounded behavioral indicator whose association with well-being requires interpretation alongside other domains.

Using the 2022 CFPS, this study examines respondents aged 10–18 years. It asks whether exercise frequency is conditionally associated with subjective well-being; whether depressive symptoms and sleep duration form opposing statistical indirect pathways; whether loneliness and self-rated health provide additional pathways; and whether an exercise–sleep–depressive symptoms–well-being sequence is compatible with the fitted coefficients. Tutoring-time and gender patterns are treated as exploratory, and alternative measures, propensity-score matching, and instrumental-variable estimates are reported as sensitivity analyses. The contribution lies in showing why a positive behavioral indicator should be interpreted together with psychological and recovery-related indicators, not in claiming that exercise causes happiness.

2 Theoretical Background

2.1 Adolescent Subjective Well-Being as a Multidimensional Child Indicator

Child well-being is multidimensional in both concept and measurement. Indicator systems commonly distinguish material circumstances, health, education, relationships, participation, safety, and subjective evaluations. A young person's global happiness rating belongs to the subjective domain and has the advantage of directly representing the respondent's appraisal. It does not, however, specify which life domain is favorable or unfavorable. Depressive symptoms, sleep duration, loneliness, and self-rated health are not substitutes for subjective well-being; they provide distinct information about emotional distress, recovery, social experience, and perceived health.

This distinction matters analytically. Positive and negative indicators are related but not mirror images. A child can report high overall happiness while also experiencing restricted sleep, and another can report few depressive symptoms without judging life very positively. Similarly, participation in an activity can be developmentally valuable without improving every measured domain. The relevant question is therefore not whether all indicators confirm one another, but what pattern emerges when they are considered together. Such cross-domain analysis is consistent with an applied child-indicator perspective because it identifies where a broad behavioral recommendation may require qualification.

The outcome available in CFPS is a single global happiness item rather than a multi-item scale of hedonic and eudaimonic well-being. It should consequently be interpreted as a bounded global evaluation, not as a complete latent construct. The study does not build a composite child well-being index and does not claim that the pathway variables exhaust the relevant domains. Its narrower purpose is to use multiple observed measures to clarify the correlates of one subjective indicator.

Multidimensionality has two implications for empirical work. First, a child-well-being framework should not assign conceptual priority solely because one measure is more readily available. Composite systems often include material, educational, health, relational, safety, behavioral, and subjective domains (Bradshaw et al., 2007; Moore, 2020). Second, the domains need not be collapsed into a single index when the research question concerns their relations. Keeping measures separate preserves information about direction, scale, and domain specificity that an overall score would hide.

A global happiness item also differs from a diagnostic or symptom measure in its frame of reference. Respondents can draw on recent affect, stable aspirations, social comparisons, and culturally informed standards when judging life as a whole (Pavot & Diener, 2008; Suh et al., 1998). Depressive symptoms, by contrast, ask about the presence or frequency of particular experiences. The measures are expected to correlate, but their non-equivalence is precisely why both are retained. A small exercise coefficient on global happiness should not be interpreted as a summary effect across all aspects of adolescent functioning.

2.2 Exercise Frequency and Subjective Well-Being

Exercise may be positively associated with subjective well-being through several experiences. Movement can provide immediate affective change, a break from academic routines, opportunities for mastery, and social participation. Self-determination theory suggests that activities are more likely to support well-

being when they allow meaningful choice, experiences of competence, and connection with others (Deci & Ryan, 2000). These qualities are not directly measured in CFPS, but they explain why the same frequency category may have different meanings across adolescents.

Frequency is a practical but limited behavioral indicator. It records how often activity occurred, not its intensity, duration, type, location, voluntariness, or social climate. A one-category increase may represent an additional enjoyable session, compulsory school activity, solitary exercise, or a demanding training routine. Accordingly, the expected association is modest and conditional on observed covariates. A positive coefficient would show that more frequent exercise and higher happiness occur together after adjustment; it would not establish that prescribing an additional session would produce the same change.

Evidence on physical activity and youth mental health is encouraging but uneven. Umbrella and meta-analytic reviews generally report associations with fewer depressive symptoms, less anxiety, and more favorable self-evaluations, while also emphasizing variation in study quality and the limited number of strong causal designs (Biddle et al., 2019; Dale et al., 2019; Rodriguez-Ayllon et al., 2019). The magnitude and even the meaning of a frequency difference can depend on whether activity is voluntary, socially supportive, developmentally appropriate, or embedded in a high-pressure schedule.

Self-determination theory helps specify this qualification. Participation is more likely to align with well-being when it supports autonomy, competence, and relatedness rather than merely adding another demand (Deci & Ryan, 2000). CFPS does not measure these experiential qualities, so the theory is used to interpret heterogeneity rather than to claim a tested psychological process. The analysis asks whether frequency retains a conditional association after adjustment and whether the accompanying psychological, social, and recovery indicators point in the same direction.

2.3 Depressive Symptoms as a Psychological Indirect Pathway

Depressive symptoms represent a negative psychological indicator rather than the opposite pole of subjective well-being. They include affective and somatic experiences that may interfere with motivation, social engagement, and positive evaluation. Exercise frequency may be associated with fewer symptoms because activity interrupts sedentary routines, offers attainable goals, or creates opportunities for supportive interaction. Reviews identify psychosocial, behavioral, and neurobiological processes as possible explanations, but no single process is established across designs (Lubans et al., 2016).

The present data cannot identify symptom change or clinical response. Adolescents with fewer depressive symptoms may be more willing to exercise, while family organization, school climate, or socioeconomic resources may shape both variables. The hypothesized path is therefore a statistical indirect association: exercise frequency is expected to be negatively associated with depressive

symptoms, which are expected to be negatively associated with subjective well-being. The product of two negative coefficients is positive, but the temporal mechanism remains untested.

Adolescent life satisfaction and depressive symptoms are empirically related, but each contributes distinct information. Life satisfaction represents a cognitive appraisal of life circumstances, whereas depressive symptom scales combine affective, motivational, interpersonal, and somatic experiences (Azpiazu Izaguirre et al., 2021; Diener et al., 1985). An adolescent can report limited positive evaluation without meeting a high symptom threshold, or can experience symptoms while retaining satisfaction in valued domains. Treating one as the reverse-coded version of the other would therefore narrow the construct space.

The exercise–symptom association is also open to selection. Activity may coincide with mastery, routine, and social engagement, but low motivation and fatigue may reduce participation. Shared family, school, and health conditions can influence both. Reviews of proposed mechanisms identify plausible psychosocial and behavioral routes without resolving their temporal ordering (Lubans et al., 2016). For that reason, the coefficient product is interpreted as a descriptive arrangement of associations rather than evidence that symptom reduction transmitted an exercise effect.

2.4 Sleep Duration as a Competing Daily-Life Pathway

Sleep duration supplies information about recovery and time allocation that is not contained in an exercise-frequency measure. Adolescent sleep is shaped by developmental shifts toward later sleep timing and by fixed morning obligations, producing what Carskadon (2011) described as a convergence of biological and social pressures. Exercise can be compatible with healthy sleep, and experimental evidence does not justify treating exercise as inherently sleep-reducing. Nevertheless, when activity is added to a crowded day without reductions in homework, tutoring, commuting, or screen use, bedtime can be delayed.

Short sleep is related to emotional reactivity and weaker regulatory control. Laboratory work identifies altered prefrontal–amygdala functioning following sleep deprivation (Yoo et al., 2007), while adolescent research consistently links inadequate sleep with psychological difficulties. A negative indirect association is therefore plausible if higher exercise frequency is associated with shorter reported sleep and longer sleep is associated with higher well-being. A further sequence can occur if shorter sleep is associated with more depressive symptoms, which in turn are associated with lower well-being.

Calling this path 'competing' refers only to its direction relative to the depressive-symptom product. It does not imply a biological trade-off or prove time displacement. The survey did not measure exercise timing, bedtime, sleep quality, or weekday–weekend differences. The interpretation is that behavior and recovery indicators may provide nonredundant signals and should be monitored together.

Duration is only one dimension of sleep, but it remains an important population indicator. Consensus recommendations recognize age-specific sleep needs (Paruthi et al., 2016), and international evidence documents later bedtimes and shorter sleep across adolescence (Gradisar et al., 2011). Reviews

associate insufficient sleep with multiple health and well-being outcomes, although thresholds, measures, and study designs vary (Chaput et al., 2016). A linear hours variable cannot determine whether an individual is below an optimal range, nor can it distinguish curtailed sleep from long sleep linked to poor health. Fixed early school start times can further restrict the opportunity to obtain adequate sleep (Owens, Adolescent Sleep Working Group, & Committee on Adolescence, 2014).

Sleep and depressive symptoms may also influence one another. A meta-analysis found a consistent relation between sleep disturbance and adolescent depression while emphasizing the need for longitudinal and mechanism-sensitive designs (Lovato & Gradisar, 2014). School start times, homework, family routines, and evening media use can constrain sleep independently of exercise (Carskadon, 2011). The present sequential product is therefore an empirically specified chain, not proof that exercise shortened sleep and thereby increased symptoms in that order.

2.5 Loneliness and Self-Rated Health as Distinct Well-Being Dimensions

Loneliness and self-rated health extend the analysis beyond mood and sleep. Exercise may create social contact, but frequency does not reveal whether activity is solitary, cooperative, competitive, or socially safe. A null exercise–loneliness coefficient would therefore be compatible with strong associations between loneliness and well-being. It would mean that exercise frequency alone does not capture the relational conditions required for a social-emotional pathway.

Self-rated health is a broad evaluative indicator that can reflect symptoms, functioning, and comparative judgments. Although regular activity is relevant to physical health, perceived health may respond slowly or may be weakly differentiated in a generally young sample. The study treats loneliness and self-rated health as additional questions rather than confirmatory mechanisms because their measures are brief and theoretical direction is less tightly linked to the available exposure.

Loneliness is a perceived discrepancy between desired and experienced connection, not a count of social contacts. It can arise in the presence of peers and may be reduced only when interactions feel accepting and meaningful. Developmental reviews describe adolescence as a period in which belonging and peer evaluation become especially salient (Qualter et al., 2015). Intervention evidence also suggests that loneliness is not readily changed by generic participation alone (Eccles & Qualter, 2021). Evidence following periods of social restriction also links loneliness with later depressive and anxiety symptoms, while underscoring variation in measures and causal direction (Loades et al., 2020). Exercise frequency cannot reveal whether the activity context supplies the quality of connection relevant to loneliness.

Self-rated health is broader still. It summarizes symptoms, functioning, comparison standards, and health expectations in a single appraisal, and adolescent ratings can reflect psychological and social conditions as well as diagnosed illness (Breidablik et al., 2008). A generally healthy age group may show limited variation, while perceived improvement may depend more on intensity, fitness change, chronic conditions, or body image than on frequency alone. Loneliness and self-rated health are consequently

modeled as separate candidate paths rather than as interchangeable components of a generic health mechanism.

2.6 Competing and Sequential Indirect Associations

The four intermediate indicators therefore occupy different places in a child-well-being framework. Depressive symptoms index psychological distress; sleep duration describes a recovery-related behavior; loneliness records a relational experience; and self-rated health is an evaluative health summary. Their associations with global happiness can be strong even when exercise frequency is weakly related to them. Evidence for the second link in a coefficient product does not imply that the first link exists.

The term competing is used descriptively. It denotes coefficient products that differ in direction or evidential support, not a formal contest between mediators and not a claim that benefits in one domain must be purchased through losses in another. Likewise, a sequential product represents multiplication of fitted cross-sectional coefficients. It cannot establish that one variable changed before the next. Cross-sectional mediation estimates can be biased representations of longitudinal processes even when model fit appears satisfactory (Cole & Maxwell, 2003; Maxwell & Cole, 2007).

This framing yields a deliberately asymmetric expectation. A positive exercise–happiness coefficient can coexist with a supported psychological indirect association, a small opposing sleep-related product, and unsupported relational or health products. The value of the model lies in preserving those differences. It does not depend on every path reaching a significance threshold, and it does not convert observed covariation into a developmental mechanism.

3 The Present Study

The analysis tests one confirmatory conditional association and one theoretically specified statistical indirect association, followed by five research questions. Each proposition concerns an observable cross-sectional pattern and does not imply that exercise preceded or changed an intermediate variable.

H1. Exercise frequency is positively associated with subjective well-being among Chinese adolescents after adjustment for observed covariates.

H2. Depressive symptoms form a positive statistical indirect association between exercise frequency and subjective well-being.

RQ1. Does sleep duration form a statistical indirect association between exercise frequency and subjective well-being?

RQ2. Do loneliness and self-rated health form distinct statistical indirect associations between exercise frequency and subjective well-being?

RQ3. Is the exercise–sleep–depressive symptoms–subjective well-being sequence supported by the observed coefficient-product estimates?

RQ4. Does the exercise–depressive symptoms association vary with reported tutoring time?

RQ5. Do the exercise–depressive symptoms or exercise–well-being associations differ by gender?

Figure 1 summarizes the associational framework and distinguishes the primary coefficient-product paths from exploratory or unsupported paths.

4 Methods

4.1 Data and Analytic Sample

Data came from the 2022 wave of the China Family Panel Studies (CFPS), administered by the Institute of Social Science Survey at Peking University. The person file contained 27,001 records. All variables used in the reported models were available in that file; a one-to-one merge with the family-roster file was used only to verify identifiers and did not overwrite person-level residence. The CFPS uses a multistage probability design and covers 25 provinces, municipalities, and autonomous regions (Xie & Hu, 2014).

The age restriction identified 2,985 respondents aged 10–18 years. Of these, 2,867 had a valid 0–10 happiness rating and 2,864 also had a valid exercise-frequency response. Eleven additional cases lacked valid person-level urban classification and four lacked valid education years, leaving 2,849 complete observations in the fully adjusted model, or 95.4% of the age-eligible sample. Complete cases were used for each specification without imputation; pathway-specific Ns were 2,846–2,849. The detailed flow appears in Table S1 and Fig. S1.

The data release identifies rswt_natcs22n as the standardized 2022 individual cross-sectional weight. Following CFPS documentation, subpopulation defines six sampling strata and psu identifies the baseline primary sampling unit (Institute of Social Science Survey, 2024). The principal model is reported unweighted with HC1 standard errors. Sensitivity models apply the cross-sectional weight alone and then combine that weight with stratification and PSU-clustered Taylor-linearized standard errors. Valid weights were available for 2,765 complete cases; no stratum contained a single PSU.

4.2 Measures

Subjective well-being was measured with the CFPS item asking respondents how happy they felt, scored from 0 (lowest) to 10 (highest). The measure is treated as a global subjective indicator. It offers a direct adolescent report but does not separate life domains, positive affect, negative affect, or eudaimonic functioning. Exercise frequency referred to sport, fitness, or recreational exercise during the previous 12 months, excluding cycling or walking undertaken solely for commuting. Responses were coded from 0 (never) to 7 (twice daily or more).

Depressive symptoms were calculated from qn406, qn407, qn411, qn412, qn414, qn416, qn418, and qn420, the eight-item Center for Epidemiologic Studies Depression Scale short form. Each item ranges from 1 (almost never) to 4 (most of the time). The two positively worded items—feeling happy and enjoying life—were scored as 5 minus the response. Scores were calculated only when all eight items were valid, producing a verified 8–32 range (observed range 8–32) and internal consistency of α = .766. The earlier minimum of 7 was therefore a scoring error and has been removed.

Sleep duration used qq4010, usual hours slept per day excluding naps (0.1–24 hours). Loneliness used qn414 separately from its role in CESD-8 and was scored as 5 minus the response, so higher values indicated less loneliness. Self-rated health used qp201 and was scored as 6 minus the original 1 (very healthy) to 5 (unhealthy) response. Life satisfaction used qn12012 (1–5). Exercise-session duration used qp702n (1–300 minutes) among respondents who reported exercising.

Covariates were mean-centered age, centered age squared, gender (female = 1), person-level urban residence (urban = 1), and completed education years. Weekly tutoring used pt201, the reported hours of school-course tutoring during the most recent non-vacation month. It was available for 641 members of the 2,864-case base sample (0.3–70 hours). Ten reports were below 1 hour and three were between 4 and 5 hours, showing that the earlier three categories did not exhaust the continuous measure. The verified interaction therefore retains all valid hours and has N = 639 after outcome missingness.

4.3 Analytical Strategy

Ordinary least squares (OLS) models estimated conditional mean differences in the 0–10 happiness rating. Models added centered age terms, gender and residence, and education sequentially. HC1 standard errors address heteroskedasticity. Ordered logit and ordered probit models evaluated the bounded outcome assumption; average marginal effects express their exercise estimates on the expected 0–10 score. Variance-inflation diagnostics were also calculated.

Statistical indirect associations were estimated as products of coefficients. Each single path multiplied the exercise-to-indicator coefficient (path a) by the indicator-to-well-being coefficient conditional on exercise and covariates (path b). The sequential product combined exercise-to-sleep, sleep-to-depressive-symptoms, and depressive-symptoms-to-well-being coefficients. Percentile 95% confidence intervals used 5,000 nonparametric bootstrap resamples with a fixed reproducibility seed.

These products are labeled statistical indirect associations rather than mediation effects. Cross-sectional mediation models can be biased when the assumed temporal process is longitudinal, and coefficient order does not identify causal order (Maxwell & Cole, 2007). Bootstrap intervals quantify sampling uncertainty under the fitted model; they do not solve confounding, measurement error, reverse association, or temporal ambiguity (Preacher & Hayes, 2008).

Exploratory analyses estimated the continuous exercise-by-tutoring interaction and formal exercise-by-gender interactions for happiness and depressive symptoms. A 2,000-resample bootstrap compared the depressive-symptom coefficient product by gender. Sensitivity analyses substituted logged exercise-

session duration and life satisfaction. Propensity-score matching compared exercise scores of at least 3 (at least 1–2 times per week) with lower frequency using age terms, gender, residence, and education.

The propensity score was estimated by logistic regression (Rosenbaum & Rubin, 1983). One-to-one nearest-neighbor matching without replacement used a caliper of 0.20 SD of the logit propensity score and restricted matches to common support. Balance was evaluated with standardized mean differences and variance ratios. The matched contrast remains associational because matching cannot address unmeasured confounding. A two-stage least-squares sensitivity analysis used the leave-one-out provincial exercise mean; its exclusion restriction is not verifiable and the estimate is not treated as causal. Table 1 summarizes the measures and verified coding.

Table 1
Measures and coding

Role	Measure	Verified coding
Outcome	Subjective well-being	qm2016; 0–10, higher = happier
Exposure	Exercise frequency	qp701n; 8 recoded to 0 (never), 1–7 retained
Indirect indicator	Depressive symptoms	Eight valid CESD-8 items; two positive items reversed; 8–32
Indirect indicator	Sleep duration	qq4010; usual hours/day excluding naps
Additional indicators	Loneliness; self-rated health	qn414 and qp201 reversed; higher = less lonely/better health
Covariates	Age; gender; residence; education	Centered age and age²; female = 1; urban = 1; education years
Exploratory condition	School-course tutoring	pt201; continuous weekly hours, 0.1–70

Note. CESD-8 = eight-item Center for Epidemiologic Studies Depression Scale. All negative CFPS special codes were treated as missing. CESD-8 requires all eight valid items and ranges from 8 to 32.

The analytical sequence estimated the exercise–well-being association first, followed by separate coefficient products, formal conditional tests, and sensitivity analyses. Bootstrap intervals quantify sampling uncertainty but do not correct temporal ambiguity, omitted variables, or reciprocal association (Cole & Maxwell, 2003; Maxwell & Cole, 2007; Preacher & Hayes, 2008).

5 Results

5.1 Descriptive Statistics

Within the 2,864-case base sample, mean age was 13.78 years (SD = 2.62), 46.8% were female, and 44.7% of respondents with valid residence data lived in urban areas. Mean subjective well-being was 8.11 (SD = 1.89), mean exercise frequency was 3.16 (SD = 2.26), mean CESD-8 score was 12.14 (SD =

3.53; verified range 8–32), and mean sleep duration was 8.28 hours (SD = 1.35). Table 2 reports variable-specific Ns and observed ranges.

Table 2
Descriptive statistics

Variable	N	Mean	SD	Observed range
Subjective well-being	2,864	8.11	1.89	0.0–10.0
Exercise frequency	2,864	3.16	2.26	0.0–7.0
Depressive symptoms (CESD-8)	2,861	12.14	3.53	8.0–32.0
Sleep duration (hours/day)	2,863	8.28	1.35	0.5–15.0
Loneliness (reversed)	2,862	3.61	0.69	1.0–4.0
Self-rated health (reversed)	2,864	4.12	0.88	1.0–5.0
School-course tutoring (hours/week)	641	12.17	14.66	0.3–70.0
Age (years)	2,864	13.78	2.62	10.0–18.0
Female	2,864	0.47	0.50	0.0–1.0
Urban residence	2,853	0.45	0.50	0.0–1.0
Education (years)	2,860	7.48	2.70	1.0–15.0

Note. Statistics are calculated within the N = 2,864 base sample with valid happiness and exercise frequency. Variable-specific Ns reflect item nonresponse. CESD-8 is calculated only with all eight valid items.

5.2 Exercise Frequency and Subjective Well-Being

Exercise frequency was positively associated with subjective well-being across the four OLS specifications (Table 3). The unadjusted coefficient was 0.052 (SE = 0.016, p = .001). After valid negative CFPS codes were treated as missing and age, gender, residence, and education were adjusted, the coefficient was 0.045 (SE = 0.016, p = .006, 95% CI [0.013, 0.078]; N = 2,849). A one-category frequency difference corresponded to a small 0.045-point conditional mean difference on the 0–10 scale. Model 4 explained 2.60% of observed variance, supporting H1 as an associational hypothesis.

Table 3
OLS associations with subjective well-being

Predictor	Model 1	Model 2	Model 3	Model 4
Exercise frequency	0.052**	0.048**	0.047**	0.045**
	(0.016)	(0.016)	(0.016)	(0.016)
Age (centered)	—	−0.105***	−0.106***	−0.139**
		(0.014)	(0.014)	(0.051)
Age²	—	0.001	0.001	0.002
		(0.006)	(0.006)	(0.006)
Female	—	—	0.050	0.052
			(0.070)	(0.070)
Urban residence	—	—	0.087	0.083
			(0.070)	(0.071)
Education (years)	—	—	—	0.035
				(0.049)
Constant	7.940***	7.943***	7.887***	7.631***
	(0.064)	(0.079)	(0.092)	(0.370)
N	2,864	2,864	2,853	2,849
R^2	0.0039	0.0249	0.0259	0.0260

Note. Entries are unstandardized coefficients with HC1 standard errors in parentheses. Age is mean-centered before squaring. * p < .05. ** p < .01. *** p < .001. Exact p = .006 for exercise frequency in Model 4.

5.3 Statistical Indirect Associations

Exercise frequency was negatively associated with depressive symptoms (a = − 0.118, p < .001), and depressive symptoms were negatively associated with subjective well-being (b = − 0.155, p < .001). Their product was positive (ab = 0.0182, 95% percentile bootstrap CI [0.0087, 0.0281]; N = 2,847), supporting H2. Exercise frequency was also associated with shorter sleep (a = − 0.028, p = .011), while sleep duration was positively associated with well-being (b = 0.083, p = .007). That product was negative (ab = − 0.0024, 95% CI [− 0.0053, − 0.0003]; N = 2,848), answering RQ1 at the statistical-association level.

For RQ3, the sequential product was − 0.0013 (95% CI [− 0.0026, − 0.0003]; N = 2,846). For RQ2, the loneliness product was 0.0044 (95% CI [− 0.0021, 0.0110]) and the self-rated-health product was 0.0042 (95% CI [− 0.0026, 0.0114]); both intervals included zero. Table 4 and Fig. 2 summarize the data-verified estimates.

Table 4
Statistical indirect associations

Pathway	Path a	Path b	Indirect	95% CI	N
Depressive symptoms	−0.118	−0.155	0.0182	[0.0087, 0.0281]	2,847
Sleep duration	−0.028	0.083	−0.0024	[− 0.0053, − 0.0003]	2,848
Loneliness (reversed)	0.008	0.558	0.0044	[− 0.0021, 0.0110]	2,848
Self-rated health (reversed)	0.009	0.468	0.0042	[− 0.0026, 0.0114]	2,849
Sequential: sleep → depression	−0.028; −0.298	−0.153	−0.0013	[− 0.0026, − 0.0003]	2,846

Note. Path a links exercise frequency to the intermediate indicator. Path b links that indicator to subjective well-being; the sequential row reports exercise-to-sleep, sleep-to-depressive-symptoms, and depressive-symptoms-to-well-being coefficients. Intervals use 5,000 percentile bootstrap resamples.

5.4 Exploratory Conditional Patterns

The continuous exercise-by-tutoring-time interaction predicting depressive symptoms was 0.0071 (SE = 0.0041, p = .084, 95% CI [− 0.0010, 0.0151]; N = 639). The coefficient did not meet the conventional .05 threshold. Conditional exercise slopes became less negative as tutoring hours increased, but this pattern is descriptive and RQ4 did not receive conventional statistical support.

Formal gender interactions did not support a difference in the exercise–well-being association (interaction b = − 0.027, SE = 0.032, p = .395) or the exercise–depressive-symptoms association (interaction b = 0.118, SE = 0.060, p = .0503). The bootstrap difference between female and male depressive-symptom coefficient products was − 0.0180 (95% CI [− 0.0380, 0.0015]). RQ5 therefore received no evidence at p < .05; group-specific significance decisions are not used as a difference test. Table 5 summarizes these exploratory conditional patterns.

Table 5
Exploratory conditional patterns

Analysis	Term	Estimate	SE	p/95% CI	N
Tutoring	Exercise × tutoring	0.0071	0.0041	= .084	639
Gender: well-being	Male exercise slope	0.058	0.023	= .010	2,849
Gender: well-being	Female exercise slope	0.031	0.023	= .190	2,849
Gender: well-being	Exercise × female	-0.027	0.032	= .395	2,849
Gender: depression	Male exercise slope	-0.172	0.039	< .001	2,847
Gender: depression	Female exercise slope	-0.055	0.046	= .234	2,847
Gender: depression	Exercise × female	0.118	0.060	= .050	2,847
Gender: depression indirect	Female − male	-0.0180	Bootstrap	[-0.0380, 0.0015]	2,847

Note. Tutoring is analyzed continuously among respondents with pt201 data. Gender differences are evaluated with formal interaction terms. CI = confidence interval.

5.5 Sensitivity Analyses

The positive association remained in the cross-sectional weighted model (b = 0.052, SE = 0.023, p = .022; N = 2,765) and after weighting, six-stratum adjustment, and PSU clustering (b = 0.052, SE = 0.022, p = .016). Ordered logit and probit models converged and produced expected-score average marginal effects of 0.042 and 0.045, respectively, with exercise coefficients p = .006 and .003. These results support the direction of the OLS association.

The unmatched higher- versus lower-frequency difference was 0.268 (p < .001). The verified PSM analysis used common support, a 0.093 logit-propensity caliper, and 898 matched pairs (matched N = 1,796). Maximum absolute standardized mean difference fell from 0.181 to 0.025. The matched ATT was 0.139 (SE = 0.094, 95% CI [− 0.045, 0.323], p = .138), so the earlier significant matched claim was not reproduced.

The leave-one-out provincial mean predicted exercise in the first stages (F = 23.03 for well-being and 22.73 for depressive symptoms). The 2SLS exercise estimates were imprecise and not different from zero for well-being (b = − 0.037, SE = 0.173, p = .831) or depressive symptoms (b = − 0.121, SE = 0.339, p = .721). Logged exercise-session duration was weakly associated with well-being (b = 0.113, SE = 0.060,

p = .059), whereas exercise frequency was unrelated to the 1–5 life-satisfaction item (b = 0.002, SE = 0.007, p = .818). Table 6 summarizes the sensitivity analyses.

Table 6
Sensitivity analyses

Analysis	Outcome	Estimate	SE/β	p	N
OLS, unweighted HC1	Well-being	0.045	0.016	= .006	2,849
Weighted HC1	Well-being	0.052	0.023	= .022	2,765
Weight + strata + PSU	Well-being	0.052	0.022	= .016	2,765
Ordered logit	Well-being	AME 0.042	β 0.042	= .006	2,849
Ordered probit	Well-being	AME 0.045	β 0.026	= .003	2,849
Logged session duration	Well-being	0.113	0.060	= .059	2,154
Exercise frequency	Life satisfaction	0.002	0.007	= .818	2,849
PSM, 898 matched pairs	Well-being	ATT 0.139	0.094	= .138	1,796
2SLS	Well-being	-0.037	0.173	= .831	2,847
2SLS	Depressive symptoms	-0.121	0.339	= .721	2,845

Note. HC1 = heteroskedasticity-consistent standard errors; PSU = primary sampling unit; AME = average marginal effect on the expected 0–10 score; PSM = propensity-score matching; ATT = average treatment contrast among matched treated cases; 2SLS = two-stage least squares. None of these analyses establishes causality.

6 Discussion

6.1 Principal Findings

Exercise frequency was positively but modestly associated with subjective well-being after valid CFPS missing codes were removed. A one-category difference corresponded to 0.045 points on the 0–10 scale in the unweighted complete-case model. The coefficient remained positive under individual cross-sectional weighting and design-adjusted inference, and ordered-response models yielded similar expected-score marginal effects. The association is detectable but small.

The indirect results were not uniform. The largest product linked more frequent exercise with fewer depressive symptoms and fewer symptoms with higher subjective well-being. A smaller product ran in the opposite direction through shorter sleep duration. The sleep–depressive symptoms sequence was also negative. Exercise was not associated with the reverse-coded loneliness or self-rated health

measures, although both intermediate variables were related to well-being. The data thus distinguish association with a downstream well-being indicator from evidence that exercise frequency generates the relevant domain resource.

Conditional findings remained limited. Tutoring moderation had $p = .084$. Formal gender interactions had $p = .395$ for well-being and $p = .0503$ for depressive symptoms, and the gender difference in the depressive-symptom product included zero. The balanced PSM contrast also included zero, while the 2SLS estimates were null and imprecise. These results support a differentiated descriptive account rather than a claim of universal or causal benefits.

6.2 Implications for Child Well-Being Research

The main contribution is to show why behavioral, psychological, and recovery-related indicators should not be expected to move as a single index. Exercise frequency is commonly treated as a favorable behavior, depressive symptoms as a negative psychological indicator, sleep duration as a health and time-use indicator, and happiness as a positive subjective outcome. Their associations can nonetheless diverge. A favorable pattern in one domain does not guarantee improvement in another, and a global well-being score can coexist with a less favorable recovery-related pattern.

This interpretation aligns with multidimensional approaches that use a mix of positive, negative, subjective, and objective indicators (Hall et al., 2025). It also clarifies what the present study does not offer. The analysis neither constructs a composite index nor estimates the relative normative weight of each domain. Rather, it demonstrates the analytical value of retaining domain specificity. Collapsing depressive symptoms and sleep into one broad 'health mechanism' would conceal their different empirical directions.

The findings also qualify the use of frequency as a stand-alone participation indicator. Frequency is easy to collect and compare, but it omits intensity, duration, timing, social context, voluntariness, and perceived quality. Child monitoring systems that include physical activity should therefore pair it with recovery and psychological measures when the policy question concerns well-being rather than participation alone. This recommendation follows from measurement logic, not from an assumption that exercise is intrinsically harmful or beneficial.

6.3 Interpreting the Opposing Indirect Associations

The depressive-symptom product is compatible with several explanations. Exercise can provide a structured break, perceived accomplishment, and social contact, while adolescents experiencing fewer symptoms may be more likely to initiate and sustain activity. Unmeasured family support, school resources, and prior health can produce both patterns. The present evidence therefore supports the coexistence of lower depressive symptoms and more frequent exercise, conditional on measured covariates; it does not establish symptom relief as the process by which exercise changes happiness.

The sleep coefficient requires equal restraint. It should not be read as evidence that exercise biologically shortens sleep. Exercise timing was unavailable, and healthy activity can support sleep in other designs. Within the CFPS cross-section, however, adolescents reporting more frequent exercise also reported slightly less sleep. In a constrained school day, one possible explanation is substitution: activity may be added without equivalent reductions in homework, tutoring, commuting, or screen use. Another is selection, such as highly scheduled adolescents reporting both more activities and shorter sleep.

The sequential product was numerically small even though its interval excluded zero. Sequential cross-sectional models impose more temporal structure than the data contain. Short sleep may precede depressive symptoms, depressive symptoms may disrupt sleep, and both may reflect stable family or school conditions. Repeated measures capturing exercise sessions, bedtimes, sleep quality, next-day mood, and happiness would be needed to distinguish within-person sequences from between-person differences.

The unsupported loneliness and self-rated health pathways are also informative without constituting proof of absence. The strong b paths show that relational and perceived-health indicators remain relevant to well-being. What was missing was an exercise-frequency association with those indicators. Social benefits may depend on whether activity is cooperative and inclusive; health perceptions may depend on chronic conditions, body image, or functioning not captured by exercise frequency. Better domain measurement is a more plausible next step than relabeling the null products as unexpected mechanisms.

6.4 Implications for Policy and Practice

The results favor integrated monitoring over a frequency-only target. Schools and families can support opportunities for activity while also tracking whether schedules preserve adequate sleep and whether young people experience emotional distress. This does not require treating every statistical pathway as an intervention mechanism. It requires recognizing that participation targets are incomplete when the policy goal is children's overall well-being.

Scheduling is a practical point of coordination. Activity placed within the school day or early after school may be less likely to compete with bedtime than late-evening additions, although the present study did not test specific times. Schools can examine the combined load created by homework, tutoring, commuting, screen-based assignments, and extracurricular activities. Families can likewise consider whether an apparently healthy behavior is being accommodated by reducing recovery rather than by reorganizing less essential demands.

Psychological quality also matters. Providing choice, achievable progression, and a socially safe climate may make activity more compatible with autonomy, competence, and relatedness. The gender-stratified results do not support different prescriptions for boys and girls, but they reinforce the need to examine whether equal frequency reflects equal access, comfort, and perceived competence. Policy evaluation

should collect formal interaction evidence before directing resources on the basis of subgroup significance patterns.

The pattern also illustrates why child indicators should be read relationally rather than ranked as isolated signals. Exercise frequency is favorable neither because it is behaviorally active nor unfavorable because one sleep-related product was negative. Its interpretation depends on the constellation in which it appears. This logic is consistent with indicator systems that retain children's own evaluations alongside health, behavior, and relational measures (Ben-Arieh, 2008; Casas, 2011). The present results add a concrete example: a modestly positive global association can coexist with different signs and levels of support across domain-specific paths.

The null exercise paths to loneliness and self-rated health sharpen that point. Neither result makes those indicators unimportant. Both remained related to subjective well-being, but exercise frequency did not identify the social quality or health change required to connect the two parts of the product. Future surveys would gain more from measuring activity context, perceived inclusion, sleep quality, and functional health than from adding more frequency categories. That recommendation follows from the mismatch between constructs and available measures, not from a search for statistically significant pathways.

6.5 Limitations and Future Research

Several limitations constrain the conclusions. First, the cross-sectional design cannot establish temporal order, developmental change, or causality. Reverse association is plausible for exercise, depressive symptoms, sleep, and happiness. The coefficient products should therefore be read as model-based indirect associations, not mediation mechanisms.

Second, all principal variables were self-reported. Exercise frequency covered the previous 12 months and did not measure intensity, duration in the principal model, type, location, motivation, or social setting. Sleep covered average daily duration but not quality, regularity, bedtime, weekday–weekend differences, or naps. Subjective well-being was a single global item. Future work should combine accelerometry, sleep diaries or actigraphy, repeated affect reports, and multidimensional well-being scales.

Third, complete-case analysis retained 2,849 of 2,985 age-eligible respondents (95.4%), but missing weights reduced design-adjusted models to 2,765. The tutoring interaction was limited to 639 cases because pt201 was asked conditionally. Missingness may still be informative, and the analysis did not use multiple imputation. The verified CESD-8 score requires all eight items and ranges from 8 to 32.

Fourth, the cross-sectional weight, six sampling strata, and PSU clustering were incorporated and did not reverse the principal association. Design-based inference nonetheless depends on the released weight and baseline cluster identifiers, and the 84 complete cases without a valid weight are not represented in the weighted models. Results should not be generalized beyond the CFPS target population.

Fifth, robustness evidence was mixed. Ordered and design-adjusted models supported the main direction, but the life-satisfaction substitution, PSM contrast, and 2SLS estimates did not. PSM achieved strong observed balance yet left 1,028 higher-frequency cases unmatched and cannot address unobserved confounding. The provincial instrument's exclusion restriction remains questionable. Longitudinal CFPS, fixed-effects, daily-diary, and school-based designs would provide stronger temporal evidence. Taken together, the PSM and 2SLS results do not provide consistent causal evidence.

Finally, the Chinese institutional setting limits direct generalization. School schedules, supplementary education, family expectations, and access to exercise opportunities vary within China and across countries. Comparative research should test whether the same cross-domain pattern appears under different educational and social-policy regimes rather than assuming a universal trade-off.

7 Conclusion

Among Chinese adolescents in CFPS 2022, exercise frequency was positively but modestly associated with subjective well-being in unweighted, weighted, design-adjusted, and ordered-response models. The principal positive statistical indirect association involved fewer depressive symptoms, while smaller negative associations involved shorter sleep. Loneliness and self-rated-health products included zero. Tutoring and gender interactions did not meet $p < .05$; the balanced PSM contrast and both 2SLS estimates were not statistically distinguishable from zero. The results support keeping behavioral participation, psychological distress, social experience, perceived health, and recovery as distinct child indicators. They do not show that exercise causes happiness or inherently reduces sleep.

Declarations

Data Availability

The data used in this study are from the 2022 wave of the China Family Panel Studies (CFPS), administered by the Institute of Social Science Survey, Peking University. CFPS data are available to registered users through the official CFPS data-access platform, subject to the CFPS Data User Agreement. Under that agreement, users are not permitted to redistribute the CFPS microdata, either in their original or modified form, through journal websites or third-party platforms. Accordingly, the authors cannot upload or redistribute the respondent-level CFPS data as supplementary material.

To facilitate verification and replication of the analyses, the supplementary materials accompanying this revision provide the variable definitions and coding scheme, sample-construction procedures, data-processing and analysis documentation, and information required to reproduce the reported analyses from the authorized CFPS 2022 data. Researchers with authorized access to CFPS 2022 can use these materials to reconstruct the analytical sample and reproduce the analyses reported in this article.

Ethical Approval

This article does not contain any studies with human participants performed by any of the authors.

Informed Consent

This article does not contain any studies with human participants performed by any of the authors

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Figures

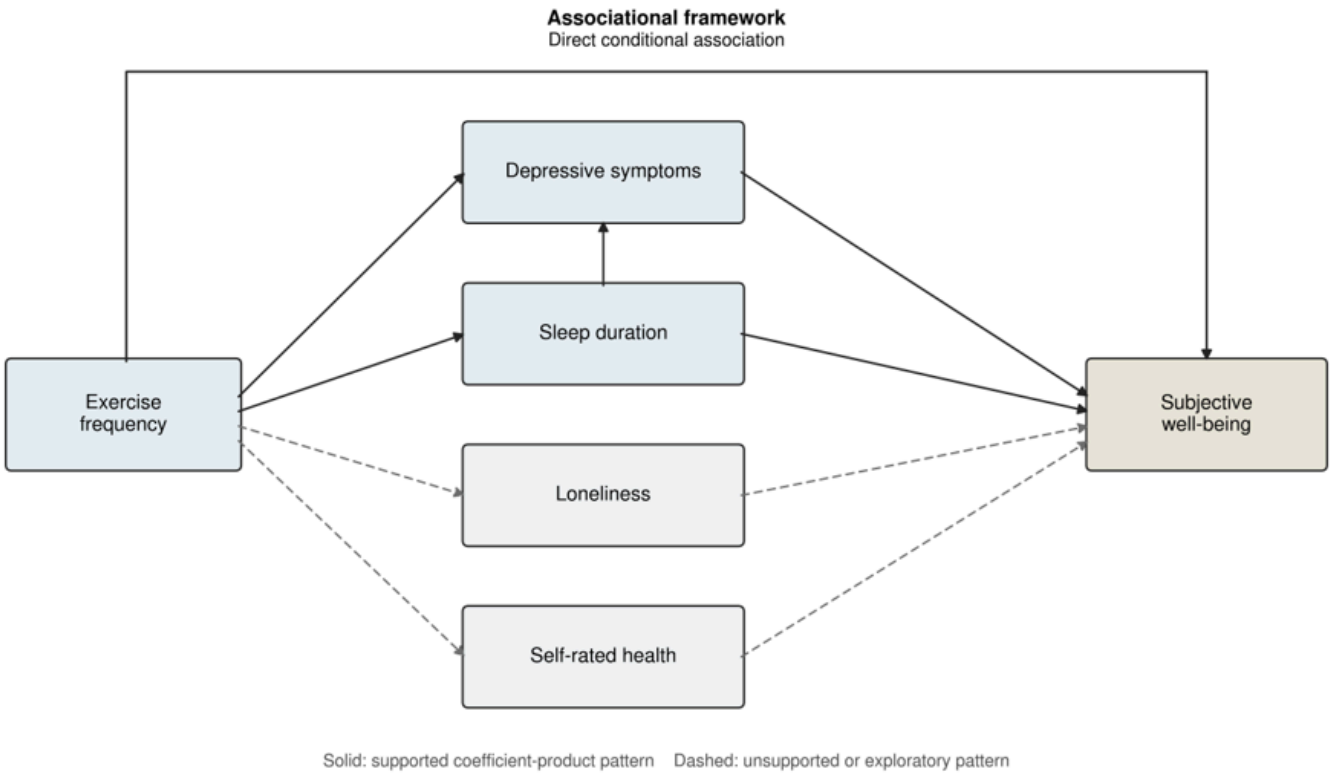

Figure 1

Associational framework linking exercise frequency with multidimensional adolescent well-being indicators

Note. Solid lines denote the primary supported coefficient-product paths. Dashed lines denote exploratory or unsupported paths. The framework does not identify temporal or causal order.

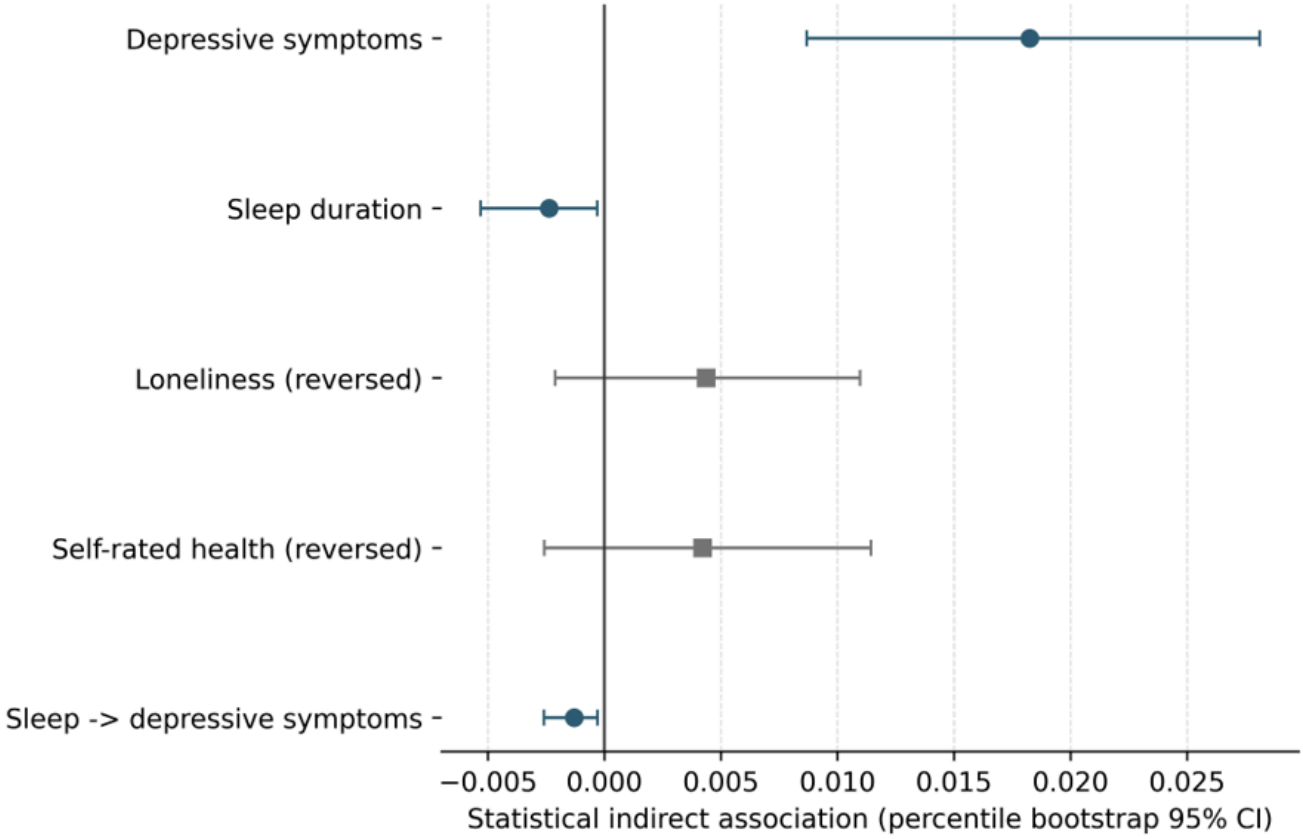

Figure 2

Data-verified statistical indirect associations with percentile bootstrap 95% confidence intervals

Note. All estimates derive from the 2022 CFPS adolescent analysis. Squares indicate intervals that include zero.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- CFPSReplicationREADMEandVariableCoding.docx