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Lifestyle Habits, Problem Behaviors and Non-Suicidal Self-Injury in Adolescents: A Systematic Review with Meta-Analysis of Longitudinal Studies

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Abstract
Some lifestyle habits and problematic behaviors have been associated to non-suicidal self-injury (NSSI) in adolescents in cross-sectional studies but their role as individual risk factors needs to be analyzed through proper longitudinal designs. The objective is to analyze and summarize the evidence on the association of lifestyle habits and problem behaviors with NSSI in adolescents. Longitudinal studies were searched in Medline, Embase and APA PsycInfo without date or language restrictions. Adolescents with and without exposure factors were compared. Out of 5295 identified records, 13 longitudinal studies were included (39,575 participants). Studies included different age ranges (10–20 years, mean 14.3, SD 2.4), and 78% were female. Results showed a statistically significant increased risk of NSSI with regular smoking, alcohol use, early cannabis use, and poor physical activity. Inconsistent results were found for use of technology and sleep habits, and no studies analyzed dietary habits or gambling. Most studies were of moderate or high quality but certainty of the evidence was very low according to GRADE criteria. Longitudinal evidence suggests that some lifestyle habits and problem behaviors are risk factors for NSSI in adolescents. These findings highlight the importance of developing strategies to promote healthy lifestyles in adolescents.

Keywords Non-suicidal self-injury · NSSI · Adolescent · Problem behavior · Lifestyle

Introduction

Non-suicidal self-injury (NSSI) in adolescents is a growing problem and understanding the factors that may contribute to these behaviors is essential for a preventive approach. Lifestyle habits such as physical activity, sleeping and eating habits, different problematic behaviors such as tobacco, alcohol or substance use, problematic use of the Internet and mobile devices, or gambling, could play a role and have shown possible associations with NSSI in cross-sectional

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studies (Lai et al., 2024). However, their possible contribution to increased risk needs to be analyzed through proper longitudinal studies. This review focuses on analyzing the available longitudinal studies that evaluate the impact of different lifestyle habits and problematic behaviors on NSSI in adolescents.

Deliberate Self-Harm (DSH) in adolescence, including suicidal and non-suicidal behavior, has increased worldwide in recent years and constitutes a public health problem (Gillies et al., 2018). Adolescence is a sensitive stage for the development of non-suicidal self-injuries (NSSI) due to the psychological, social and physical changes that contribute to their onset and maintenance (Dahl et al., 2018). A recent systematic review obtained a pooled worldwide NSSI prevalence of 17.7% (21.4% among female adolescents and 13.7% among male adolescents) for adolescents aged 10–19 years (Moloney et al., 2024).

However, the definition and conceptualization of NSSI continues to be a challenge. Nock et al. defined NSSI as a direct and deliberate destruction of one's own body tissue in the absence of intent to die (Nock, 2010). According to the International Society for the Study of Self-Injury, NSSI is a deliberate, self-inflicted damage of body tissue without suicidal intent and for purposes not socially or culturally sanctioned (Lengel et al., 2021). In line with this, the Fifth Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) defines NSSI as an intentional self-inflicted damage to the surface of [one's] body of a sort likely to induce bleeding, bruising, or pain (e.g., cutting, burning, stabbing, hitting, excessive rubbing), with the expectation that the injury will lead to only minor or moderate physical harm (i.e., there is no suicidal intent) (American Psychiatric Association, 2013). A study found an acceptable-to-good agreement that NSSI behavior needs to be injurious (i.e., damage or pain), although a wound (i.e., breaking of body tissue; causing bruising/bleeding) is not required (Lengel et al., 2021). This diversity of definitions is reflected in the assessment tools, which are based on different conceptualizations and methodologies (Hooley et al., 2020), making consistent assessment across studies difficult.

The causes of self-injury in adolescents are complex and involve many factors ranging from neurobiological, psychological to social and cultural determinants (Hawton et al., 2012). NSSI may be a strategy to alleviate overwhelming negative emotions (Klonsky, 2007). Some systematic reviews and meta-analyses analyzing risk factors for NSSI in adolescence have been published. An umbrella review highlights that many reviews analyze self-harm by conflating NSSI, suicides and suicide attempts (McEvoy et al., 2023). It can also be seen that other reviews that analyze NSSI as an outcome focus on other populations beyond adolescence. A meta-analysis explored the risk factors for NSSI in longitudinal studies and found that prior history of NSSI, cluster b personality, and hopelessness were the risk factors with strongest effects, but it was not focused on adolescents (Fox et al., 2015). Another review aimed at assessing the stability of prevalence rates of NSSI and DSH over time, and at comparing incidence rates of NSSI and DSH in adolescents and adults (Plener et al., 2015). They also explored predictors for NSSI and DSH that have been reported constantly in longitudinal research. A review looked for any prospective predictors, mediators and moderators of NSSI in community adolescents (Valencia-Agudo et al., 2018). They classified variables investigated in the studies under three themes: sociodemographic, environmental and psychological factors; so, lifestyle habits and problematic behaviors were not specifically analyzed as risk factors in this review. Moreover, it included studies with publication year limited to January 2017, so it is expected that more studies not included in the review have been conducted. Another review studied factors associated with NSSI in Chinese adolescents and included cross-sectional and longitudinal studies (Fan et al., 2021). Finally, a recent systematic review analyzes all types of risk factors for NSSI in adolescents, and include a category of problem behaviors, where they calculate an effect estimator that encompasses 21 different factors, without being able to delineate how or whether each of them contributes. Other factors such as sleep problems are included in a category of physical symptoms, which also includes, for example, disabilities (Wang et al., 2022).

The influence on NSSI of different lifestyle and behavioral factors remains unclear, as previous reviews have not analyzed them individually or have included different populations, have used cross-sectional designs or have included suicidal and non-suicidal self-harm as outcome. Identifying modifiable factors associated with NSSI is fundamental to their prevention.

No meta-analysis has been published on the longitudinal development of NSSI associated with exposure to individual lifestyle variables and behavioral problems in adolescence. Identifying and understanding the factors associated with NSSI in adolescents over time may help guide future research for the development of NSSI prevention and intervention strategies. Therefore, the objective of this review is to analyze and summarize the evidence on the longitudinal association between lifestyle habits and problem behaviors with NSSI in adolescents.

Current Study

In adolescents, some lifestyles (physical activity, sleeping and eating habits) and problem behaviors (tobacco, alcohol or substance use, problematic use of the Internet and mobile devices, or gambling) have shown associations with NSSI in cross-sectional studies, but their role as causal factors

is unknown. The aim of this review and meta-analysis is to analyze and summarize the longitudinal evidence of the association of these individual risk factors. The PECO (Population, Exposure, Comparator, Outcomes) framework was used and the research question was as follows: P: adolescent population (10–19 years, both included); E: lifestyle habits and problem behaviors that could constitute risk factors for NSSI; C: no presence of lifestyle habits and problem behaviors that could constitute risk factors for NSSI; O: NSSI.

Method

The protocol of the present systematic review has been prepared following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) (Moher et al., 2015). The review protocol was registered at PROSPERO (CRD42024501154), including the review question, type of review, searches, study conditions, population of interest, exposures, comparators, types of studies included, outcomes, data extraction, risk of bias, data synthesis strategy, subgroups analysis and the language of the study.

The Population, Exposure, Comparator, and Outcomes (PECO) framework to guide the research question, study eligibility criteria, and search was used (Morgan et al., 2018). The research question is as follows: P: adolescent population (10–19 years, both included); E: lifestyle habits and problem behaviors that could constitute risk factors for NSSI; C: no presence of lifestyle habits and problem behaviors that could constitute risk factors for NSSI; O: NSSI.

Search Strategy

A comprehensive literature search was conducted in MEDLINE (access via PubMed), EMBASE, APA PsycInfo in January 2024 without publication date or language restrictions. The reference list of included studies were also revised. The search strategy included terms related with NSSI, adolescent, problem behavior, lifestyle, illegal drugs, internet, mobile phone, video games, and gambling. A detailed search strategy for each database can be found in Supplementary Materials.

Study Eligibility Criteria

The included articles met the following criteria: (1) the study design was either a case–control or longitudinal study; (2) the age of the population ranged between 10 and 19 years old, both included (World Health Organization, 2024); (3) the studies had to analyze one or more of the following exposure factors: sleeping habits and pattern; physical activity; eating habits and dietary pattern; toxic habits (tobacco, alcohol, illegal drugs); problematic use or abuse of mobile devices, screens or internet, social networks, videogames, betting, gambling; (4) the definition of NSSI met the DSM-5 criteria (American Psychiatric Association, 2013), other related terms used were accepted provided that there was no suicidal intent behind the conduct; (5) studies considering other outcomes were included if they provided specific data for NSSI or these data could be obtained from study authors.

The proportion of patients with NSSI as primary outcome, and frequency and severity of NSSI as secondary outcomes were analyzed. NSSI was considered severe when indicated by a validated scale or labelled by the study authors.

Selection of Studies and Data Extraction

Two independent reviewers carried out the study selection. In the first stage, titles and abstracts of the identified references were screened following eligibility criteria. Secondly, we reviewed the full-texts of every article considered for inclusion in the first stage, and each reviewer independently decided on their final inclusion. All potential discrepancies were resolved through discussion. The screening process was carried out using Rayyan software (Ouzzani et al., 2016). Studies' authors were contacted when necessary.

A specific data extraction form was designed. One reviewer extracted the information from the included studies, which was then cross-checked by another reviewer. Again, any inconsistency was discussed until a consensus was reached.

Quality Assessment

The Newcastle–Ottawa Scale (NOS) (Wells et al., 2021) was used to evaluate the quality of the articles. A study could be awarded a maximum of one star for each numbered item within the Selection and Outcome categories and a maximum of two stars could be given for Comparability. The total score for each study ranged from 0 to 9 points. Studies with a score of 0–4 points were considered to be of low quality, 5–6 of moderate quality and 7–9 points of high quality.

Statistical Analysis

Data synthesis and meta-analysis were carried out following the Cochrane methodology (Higgins et al., 2023). Review Manager 5.4 Software (RevMan version 5.4) was used to analyze the data.

Odds Ratios (OR) and adjusted Odds Ratios (aOR) as well as their 95% confidence intervals (CI) were calculated in case of dichotomous outcomes. Adjusted OR were used when possible. Mean differences (MD) or standardized mean

differences (SMD) with 95% CI were calculated in case of continuous outcomes.

Imputation methods were not used in the case of missing data, but a possible impact of missing information on the outcome was considered, and addressed it in the discussion.

Results from the included studies were meta-analyzed using the Mantel–Haenszel method and following a random-effects model or generic inverse variance. Each of the exposure factors were meta-analyzed separately. When data for a specific analysis came from a single study or if data from various studies cannot be combined due to heterogeneity or other reasons, meta-analysis was not performed and findings were described in a narrative form. The heterogeneity across the studies was examined with I-squared (I^2). Possible causes of heterogeneity through subgroup analyses were explored where applicable. Subgroup analyses of the primary outcome according to the population type (general population, population attended by a mental healthcare professional, etc.), age range and sex were planned. Sensitivity analysis of the primary outcome excluding low-quality studies (0–4 points in NOS scale) was performed.

Certainty of the Evidence

The certainty of the evidence of the primary outcome was assessed according to GRADE methodology (Guyatt et al., 2008), rating it as "high", "moderate", "low", or "very low". As evidence from observational studies was included, the certainty of the evidence was initially rated as "low", and then was considered to be upgraded when corresponds according to (i) the magnitude of the effect, (ii) the dose–response gradient, and (iii) the effect of plausible residual confounding. It was also considered to be downgraded when corresponds according to (i) the study limitations, (ii) inconsistency of the results, (iii) directness of the evidence, (iv) imprecision in estimates, and (v) probability of publication bias.

Results

Search Results

A total of 5295 records were identified through database searches (2785 from Pubmed, 1286 from Embase and 1224 from APA PsycInfo). After removal of duplicates, 4301 records remained and were screened according to pre-established inclusion and exclusion criteria. Finally, 17 records were included (Asarnow et al., 2020; Fang et al., 2022; Few et al., 2016; Garisch & Wilson, 2015; Korhonen et al., 2018; Lai et al., 2021; Larsson & Sund, 2008; Liu et al., 2018, 2019, 2021; Lundh et al., 2013; Ma et al., 2023; Marin et al., 2020; Nguyen et al., 2023; Tuisku et al., 2012, 2014; Wang et al., 2020), corresponding to 13 different studies. The PRISMA flowchart is shown in Fig. 1.

Characteristics of the Included Studies

Main characteristics of included studies are summarized in Table 1. The 13 included studies, all with a longitudinal study design, were published between 2008 and 2023. No case–control studies were found. Of these studies, 10 (77%) were multicenter and three (23%) were conducted at a single center. Furthermore, 10 (77%) of the studies were conducted in community settings and three (23%) in outpatient clinics.

The sample size of the studies ranged from 101 to 9583, with a total of 39,575 participants. The follow-up period ranged from 5 months to 6 years, with six (46%) studies lasting 1 year. The study population was adolescents, with a mean age of 14.3 years (SD 2.36) (from data available in 11 studies) and a range from 10 to 20 years old. The average percentage of females was 78%.

Regarding the exposure factors, tobacco use was analyzed in four studies (30.8%), sleep in five studies (38.5%), alcohol use in three studies (23.1%), internet use in two studies (15.4%), mobile phone use in one study (7.7%), physical exercise in one study (7.7%), cannabis use in one study (7.7%), and cannabis and illicit drug use in another study (7.7%).

The instruments used for the measurement of NSSIs were different in all studies. Interviews were used in 5 studies (38.5%) and self-reports in 8 studies (61.5%).

Quality Assessment of the Included Studies

The results of the quality assessment are shown in the Table 2. From the total number of studies, 30.8% (n = 4) were of low quality (0–4 points), 46.2% (n = 6) studies were of moderate quality (5–6 points), and 23.1% (n = 3) were of high quality (7–9 points).

Results for Each Exposure Factor

The summary of findings of the primary outcome for each exposure factor analyzed, including the assessment of the certainty of the evidence is shown in Table 3. For all the exposure factors, certainty of the evidence was rated as very low according to GRADE. Reasons for downgrading the level of evidence in each case are outlined in Table 3.

None of the included studies provided results for the established secondary outcomes. The main results are presented below.

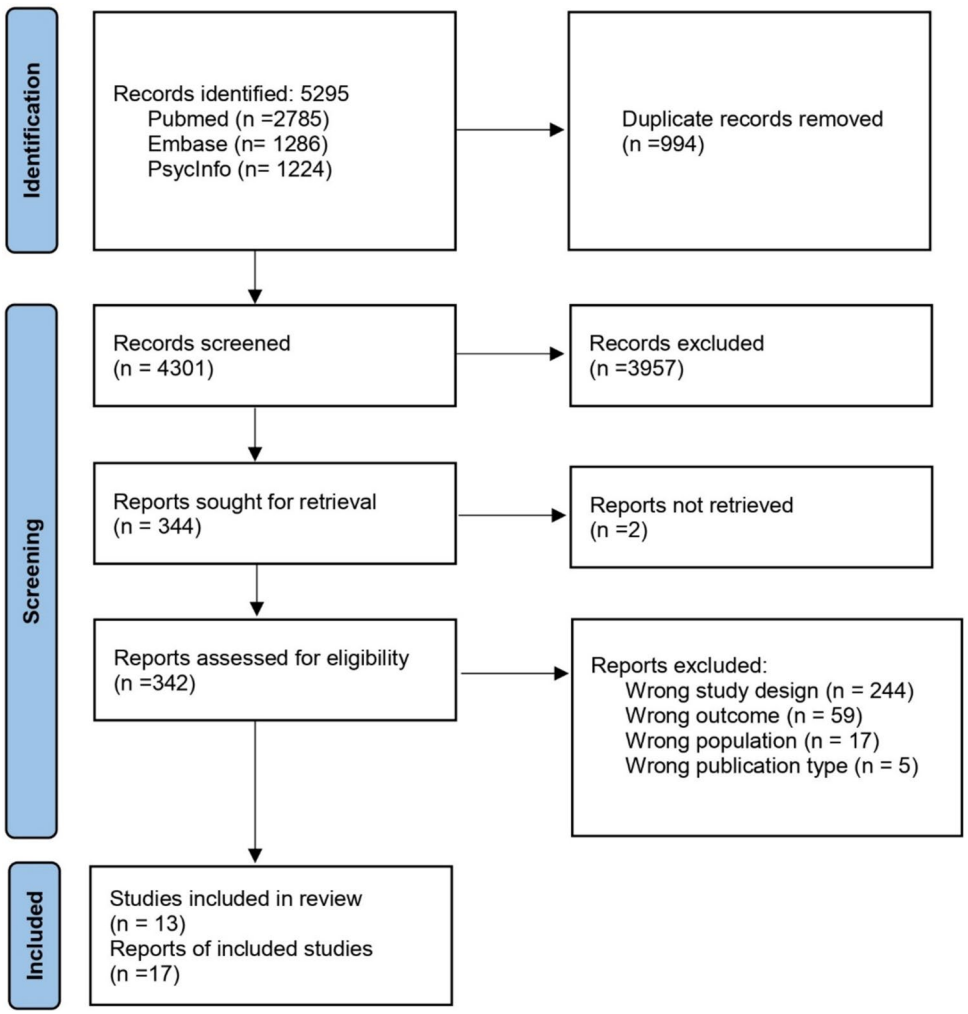

Fig. 1 PRISMA Flowchart of the screening process

Lifestyle

Sleep. Five studies analyzed the association between sleep and its characteristics with NSSI. The results of two studies could be pooled in a meta-analysis (Fig. 2). The study by Lundh et al. (2013) provided results from subgroups according to sex. The association between poor sleep quality and NSSI was analyzed at 1-year follow-up and no statistically significant association was found between the two variables. The age ranges in these studies were found to be relatively similar.

Three studies that could not be pooled in the meta-analysis also examined associations between sleep and NSSIs (Asarnow et al., 2020; Fang et al., 2022; Nguyen et al., 2023). In the study by Asarnow et al. (2020), with adolescents between 12 and 20 years, a one SD increase in Pittsburgh Sleep Quality Index (PSQI) score was associated with a twofold increase in the odds of a youth engaging in NSSI within the next 30 days (aOR 2.0 [95% CI 1.06–3.81]), but the p-value was not statistically significant when correcting for multiple testing. In Nguyen et al.'s study (2023), sleep disturbance did not predict a higher rate of NSSI within a 6-month follow-up period in a cross-lagged regression modeling in adolescents of 11–17 years old (Estimate – 0.001, SE: 0.085, Z-value 0.016, p-value 0.987).

Fang et al. (2022) found a significantly increased risk of NSSI in the groups with decreasing sleep duration trajectory (moderately or rapidly) when compared to a persistent sleep group (more than 8 h of sleep) at a 6-year follow-up (participants from 8 to 14 years old) (aOR 2.58 [95% CI 1.92–3.45] and aOR 4.16 [2.86–6.04] respectively). The Shandong Adolescent Behavior and Health Cohort (SABHC) study reported that sleep duration and insomnia in adolescents between 12 and 16 years old were not significantly associated with future NSSI after adjustment for adolescent and family covariates (aOR for < 6 h nocturnal sleep time 1.32 [95% CI 0.89–1.97]) (Liu et al., 2019).

Physical activity. One study in adolescents between 10 and 19 years old compared NSSI after 1 year of follow-up in a physically active group with a physically inactive group (Lai et al., 2021). The results showed that physical

Table 1 Characteristics of included studies

Author, year	Location	Unicenter / Multicenter	Sample size, n (% female)	Age (years), Mean (SD), Range	Setting	Exposure factor	NSSI assessment	Follow-up period
Asarnow et al. (2020)	USA	Multicenter	101 (95)	16.2 (1.9) 12–20	Mental health care, CARES (Collaborative Adolescent Research on Suicide and Emotions) youth selected with very high suicide and self-harm risk	Sleep	Interview with Suicide Attempt and Self-Injury Interview (SASII) brief	12 months
Fang et al. (2022)	China	Multicenter	2288 (41.1)	8.1 (0.9) 7–9	Community, 3 elementary schools grades 1-3	Sleep	Self-report screening questionnaire with Non-suicidal self-harm (NSSH)	6 years
Few et al. (2016)	USA, Australia	Multicenter	9583 (NR) 3788 (100)	Sample1: 24–40 Sample 2: 18–29 Early use < 17 years	Community, sample 1 from the Australian Twin Registry; sample 2 from The Missouri Adolescent Female Twin Study	Cannabis	Self-report Telephone interview with the Australian version of SSAGA-OZ	NR
Garisch and Wilson (2015)	New Zealand	Multicenter	495 (48)	16.23 (0.56) > 16	Community, secondary schools	Substance use (cigarettes, alcohol, illegal drugs)	Self-report questionnaire: Deliberate Self-Harm Inventory -Short form (DSHI-s)	Approximately 5 months
Korhonen et al. (2018)	Finland	Unicenter	1852 (49)	14.2 Early onset < 14 years	Community, Finland´s Population Register Centre, twins	Tobacco	Interview with the adolescent version of SSAGA at age 14 and adult version at age 22	11 years
Lai et al. (2021)	China	Multicenter	2744 (52.3)	14.7 (1.4) 10–19	Community, 2 rural schools, junior high schools grades 7–9 and senior high schools grades 10–12	Physical activity	Self-report questionnaire standardized	2 years
Larsson and Sund (2008)	Norway	Multicenter	2464 (50.8)	13.7 (0.6) 12–15	Community, schools aged 12–15 years old in two counties	Tobacco	Self-report: non-standardized questions	1 year

Table 1 (continued)

Author, year	Location	Unicenter / Multicenter	Sample size, n (% female)	Age (years), Mean (SD), Range	Setting	Exposure factor	NSSI assessment	Follow-up period
Lundh et al. (2013)	Sweeden	Multicenter	1052 (51.1)	50.6% grade 7 (13–14 years) and 49.4% grade 8 (14–15 years)	Community, 7th and 8th grade school students	Poor sleep	Self report with Deliberate Self-Harm Inventory, 9-item version (DSHI-9r)	1 year
Ma et al. (2023)	China	Multicenter	1530 (44.2)	12.9 (0.6) 11–14	Community, students at grade 7 from middle schools	Internet addiction	Self reported questionnaire: Chinese version of the Functional Assessment of Self-mutilation	14 months
Marin et al. (2020)	Iran	Multicenter	6229 (53.1)	15.8 (0.7) 14–18	Community, 82 high schools	Tobacco	Self-report questionnaire: non-standardized questions	1 year
Nguyen et al. (2023)	Germany	Unicenter	238 (89.5)	14.7 (1.4) 11–17	Outpatient clinic, adolescents in risk-taking and self-harming behaviors	Sleep	Interview with Self-Injurious Thoughts and Behaviors Interview (SITBI-G)	6 months
SABHC study (Liu et al., 2018, 2019, 2021; Wang et al., 2020)	China	Multicenter	7072 (50)	14.6 (1.5) 12–16	Community, 5 middle and 3 high schools (7–10th graders)	Sleep, tobacco, alcohol, Internet use, mobile phone use	Self-report questionnaire: structured questions on adolescent health	1 year
Tuisku et al., (2012, 2014)	Finland	Unicenter	139 (81.3)	16.5 (1.6) 13–19	Outpatient clinics, youth with depressive disorders	Alcohol	Interview: K-SADS-PL questions	1 year

NR Not Reported; *SD* Standard Deviation; *SSAGA* Semi-Structured Assessment of the Genetics of Alcoholism; *SABHC* Shandong Adolescent Behavior and Health Cohort; *USA* United States of America

Table 2 Newcastle–Ottawa quality assessment scale for included studies

	Selection				Comparability	Outcomes			Score
	1	2	3	4	1	1	2	3	Total
Asarnow et al. (2020)		*	*		*	*	*		5/9
Fang et al. (2022)	*	*			**		*	*	6/9
Few et al. (2016)	*	*	*	*	**		*	*	8/9
Garisch and Wilson (2015)	*	*	*				*		4/9
Korhonen et al. (2018)	*	*	*		**		*	*	7/9
Lai et al. (2021)	*	*					*	*	4/9
Larsson and Sund (2008)	*	*		*	**		*	*	7/9
Lundh et al. (2013)	*	*		*	*		*	*	6/9
Ma et al. (2023)	*	*			**		*	*	6/9
Marin et al. (2020)	*	*		*			*		4/9
Nguyen et al.(2023)		*			**		*	*	5/9
SABHC study (Liu et al., 2018, 2019, 2021; Wang et al., 2020)	*	*			**		*	*	6/9
Tuisku et al., (2012, 2014)		*				*	*	*	4/9

A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability (* Study controls for the most important factor. ** Study also controls for any additional factor). *Selection*: 1.Representativeness of the exposed cohort; 2. Selection of the non exposed cohort; 3. Ascertainment of exposure; 4. Demonstration that outcome of interest was not present at start of study. *Comparability*: 1. Comparability of cohorts on the basis of the design or analysis. *Outcomes*: 1. Assessment of outcome; 2. Was follow-up long enough for outcomes to occur; 3. Adequacy of follow up of cohorts

activity was associated with a lower risk of NSSI (OR 0.49 [95% CI 0.41–0.58]).

Dietary patterns. No studies were found that studied this exposure factor.

Problem Behaviors

Use of technological devices and internet. One study examined the association between duration of exposure to mobile phones and NSSI. The SABHC study, with participants between 12 and 16 years old and a 1-year follow-up, found no significant differences in the risk of NSSI with prolonged mobile phone use in those without previous NSSI: mobile phone use ≥ 2 h/day on weekdays aOR 0.81 (95% CI 0.46–1.44); mobile phone use ≥ 4 h/day on weekends aOR 0.76 (95% CI 0.47–1.20) (Wang et al., 2020). When analyzing in the same study the risk of repeated NSSI among those with self-harm at baseline they found a higher risk in the ≥ 5 h/day on weekends group (Liu et al., 2021).

Two studies examined the risk of NSSI according to internet exposure (Ma et al., 2023; Wang et al., 2020). Ma et al., (2023), by establishing three categories: no internet addiction, moderate addiction and severe addiction. They found in this adolescent population (11–14 years old) a statistically significant increased risk of NSSI, at 14 months follow-up, in the moderate (aRR 2.25; 95% CI 1.59–3.19) and severe (aRR 2.39; 95% CI 1.17–3.18) internet addiction groups compared to the non-internet addiction group.

The SABHC study (Wang et al., 2020) found no statistically significant differences in the risk of NSSI after 1 year of follow-up between the group using the internet more than 2 h per day on weekdays and the group using the internet less than half an hour (aOR 1.02; 95% CI 0.58–1.79). This association was also not confirmed when comparing internet use 3 or more hours per day at weekends with the group with the lowest internet use (aOR 1.16; 95% CI 0.76–1.77), although in this case they did find an increased risk of recurrent NSSI.

Tobacco. Four studies (Korhonen et al., 2018; Larsson & Sund, 2008; Liu et al., 2021; Marin et al., 2020) examined the potential association between tobacco use and the occurrence of NSSI. The findings of two of the studies (Korhonen et al., 2018; Marin et al., 2020) could be synthesized in a meta-analysis. The follow-up period for the study by Korhonen et al. (2018) was 11 years and focus on early onset (< 14 years), while follow-up for the study by Marin et al. (2020) was 1 year and included participants between 14 and 18 years. No statistically significant differences were identified in the risk of NSSI between the group who had experimented with smoking and those who did not smoke. Nevertheless, a notable correlation was observed between regular smoking and an elevated risk of NSSI, when compared to non-smokers (OR 2.89; 95% CI 1.42–5.90; $I^2 = 58\%$; 2 studies; 7374 participants). These findings are illustrated in Fig. 3.

Table 3 Summary of findings

Exposure	No. of studies (no. participants)	Relative effect (RR, OR, or aOR, 95%CI; I^2)	Certainty of the evidence (GRADE)
Sleep	5 (10751)	Poor sleep quality: OR 1.28 (0.88–1.86); I^2 36%; 2 studies Asarnow et al. (2020): one SD increase in PSQI (sleep quality) aOR 2,0 (1.06–3.81). p-value correcting for multiple testing 0.076 Nguyen et al. (2023): sleep disturbance did not predict NSSI at 6-month follow-up (p-value 0,987) Fang et al. (2022): vs persistent sleeping ≥ 8 h/day: aOR 2.58 (1.92–3.45) for moderately decreasing sleep duration; aOR 4.16 (2.86–6.04) for rapidly decreasing group Liu et al. (2019): aOR for < 6h nocturnal sleep time 1.32 (0.89–1.97)	Very low (⨁◯◯◯)[a]
Tobacco	4 (16910)	Experimenting smoking: OR 1.71 (0.85–3.42); I^2 80%, 2 studies Regular smoking: OR 2.89 (1.42–5.90); I^2 58%; 2 studies Liu et al. (2021): ever cigarette smoking OR 1.52 (1.12–1.80) for repeated NSSI Larsson and Sund (2008): significant sex by smoking interaction (girls who smoked "sometimes or daily" self-harmed more often than boys) (OR 2.2 [1.3–3.5])	Very low (⨁◯◯◯)[a]
Alcohol	2 (7211)	Liu et al. (2021): aOR 1.85 (1.41–2.44) for repeated NSSI Tuisku et al. (2014): alcohol use according to AUDIT score aOR 1.07 (1.00–1.14)	Very low (⨁◯◯◯)[b]
Cannabis	1 (6009)	Few et al. (2016): early vs later cannabis use (before/after 17 years) aOR 1.42 (1.13–1.75)	Very low (⨁◯◯◯)[c]
Substance use	1 (495)	Garisch and Wilson (2015): non-significant association in a cross-lag correlation (standardized coefficient 0.11)	Very low (⨁◯◯◯)[b]
Mobile phones	1 (7072)	Wang et al. (2020): Mobile phone use ≥ 2 h/day on weekdays: aOR 0.81 (0.46–1.44). Mobile phone use ≥ 4 h/day on weekends: aOR 0.76 (0.47–1.20). It was associated with recurrent NSSI	Very low (⨁◯◯◯)[d]
Internet	2 (8602)	Ma et al. (2023): Internet addiction. Moderate aRR 2.25 (1.59–3.19). Severe aRR 2.39 (1.17–3.08) Wang et al. (2020): Internet use Weekdays ≥ 2 h aOR 1.02 (0.58–1.79); Internet use Weekends ≥ 3 h aOR 1.16 (0.76–1.77). They were associated with recurrent NSSI	Very low (⨁◯◯◯)[a]
Physical activity	1 (2744)	Lai et al. (2021): OR 0.49 (0.41–0.58)	Very low (⨁◯◯◯)[b]

RR Relative Risk; *aRR* adjusted Relative Risk; *OR* Odds Ratio; *aOR* adjusted Odds Ratio; *SD* standard deviation; *PSQI* Pittsburgh Sleep Quality Index; *AUDIT score* score Alcohol Use Disorders Identification Test. Certainty of evidence is defined as the extent to which our confidence in an estimate of the effect is correct. Certainty of the evidence according to GRADE can be rated as "high", "moderate", "low", or "very low". Using the GRADE framework, body of evidence from observational studies is initially classified as "low" certainty of evidence. Reasons for downgrading from "low" in each case are as follows: (a) Downgraded one level for inconsistency; (b) Downgraded one level due to risk of bias (low quality); (c) Downgraded one level due to indirectness; d) Downgraded one level for imprecision

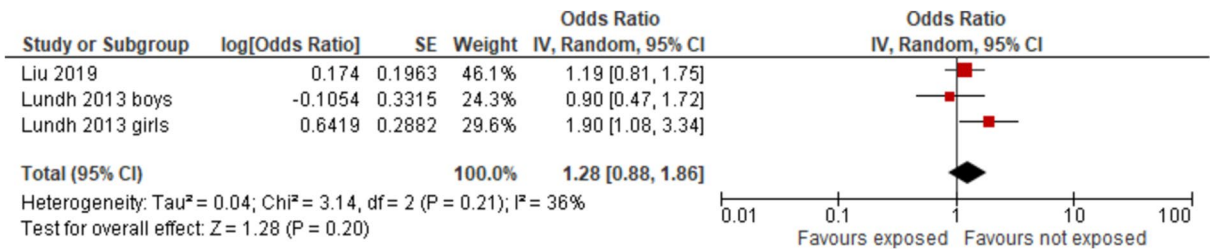

Fig. 2 Sleep quality. Forest plot showing individual studies and combined effect estimate for the exposure poor sleep quality

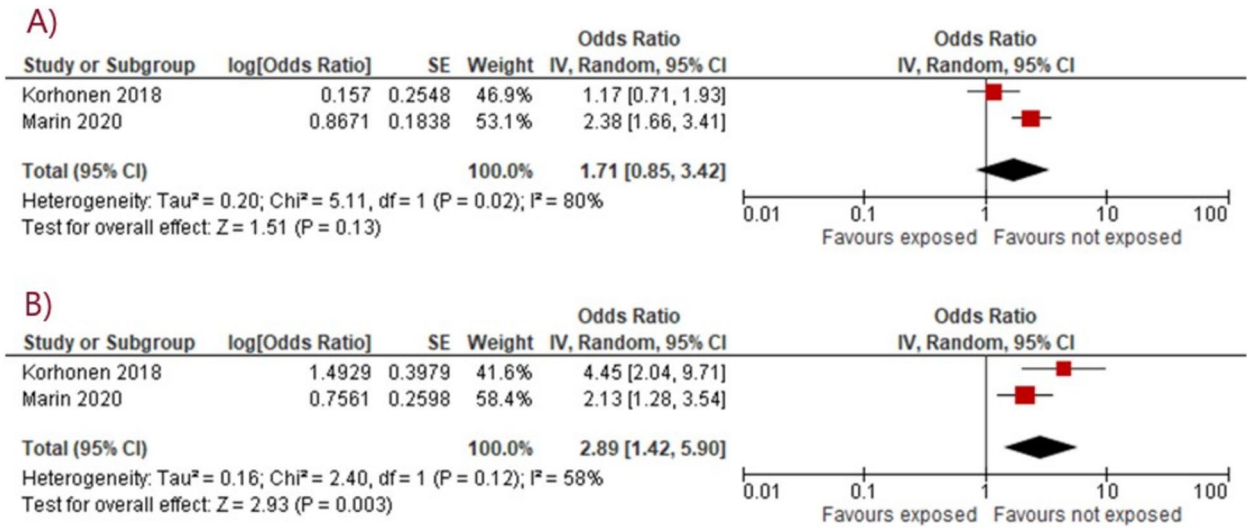

Fig. 3 Smoking. Forest plot showing individual studies and combined effect estimate for the exposure **a** Experimenting smoking and **b** Regular smoking

According to the sensitivity analysis excluding the low-quality studies (Marin et al., 2020), the results remain unchanged for the experimenting smoking group, and with a higher risk of NSSI in the case of regular smoking.

Of the two studies that could not be pooled in the meta-analysis, one of them (Liu et al., 2021) associated ever smoking with recurrence of NSSI in patients who had already had NSSI at the beginning of the study (OR 1.52; 95% CI 1.12–1.80). On the other hand, the other study (Larsson & Sund, 2008), also found a significant sex by smoking interaction (girls who smoked "sometimes or daily" self-harmed more often than boys after 1 year of follow-up (aOR 2.2; 95% CI 1.3–3.5).

Alcohol. Two studies found statistically significant associations between alcohol consumption and NSSIs (Liu et al., 2021; Tuisku et al., 2014). In the SABHC study (Liu et al., 2021) it was found that alcohol consumption was associated with recurrence of NSSIs after 1 year of follow-up (aOR 1.85; 95% CI 1.41–2.94) in adolescents between 12 and 16 years old.

Tuisku et al. (2014) found statistically significant association between alcohol consumption according to AUDIT score and NSSIs (aOR 1.07; 95% CI 1.00–1.14) with 1 year follow-up and adolescents aged 13–19 years old.

As both studies showed the same trend, sensitivity analysis excluding low-quality studies (Tuisku et al., 2014) showed the same conclusions.

Cannabis A study with twins examined the association between early cannabis use (before the age of 17) and NSSIs (Few et al., 2016). Among those who had ever used cannabis in their lifetime, early versus late cannabis use was associated with an increased risk of NSSIs, both in the overall sample (aOR 1.42 [95%CI 1.13–1.75]) and in an analysis of twins with discordant behavior (aOR 3.51 [95%CI 1.19–10.33]). The results were replicated in an independent sample of female twins with similar results.

Substance use. Substance use, assessed by asking adolescents older than 16 years if they had used cigarettes, alcohol "to excess", "(legal) party pills", and/or "illegal drugs (e.g., cannabis, etc.)", was analyzed by one study (Garisch & Wilson, 2015), with no significant association with NSSI over a period of 3–8 months in a cross-lag correlation (standardized coefficient 0.11; $p > 0.05$).

Gambling. No studies were found that studied this exposure factor.

Discussion

The phenomenon of NSSI among adolescents is a growing concern, underscoring the need for a comprehensive understanding of the contributing factors to these behaviors in order to develop effective preventive strategies. Lifestyle habits, including physical activity, sleeping and eating habits, as well as problematic behaviors such as tobacco, alcohol or substance use, problematic use of the Internet and mobile devices, or gambling, have been identified as potential contributing factors in cross-sectional studies. However, further longitudinal studies are required to ascertain their possible contribution to increased risk. While other reviews have touched upon this topic, they have not focused on longitudinal studies or analyzed the potential risk factors individually. Consequently, the contribution of lifestyle habits and problematic behaviors to engagement with NSSI in adolescents has so far not been elucidated. For all this reasons, this study proposed to systematically analyze the available longitudinal

studies that evaluate the impact of different lifestyle habits and problematic behaviors on NSSI in adolescents.

This systematic review is based on 17 articles from 13 longitudinal studies involving adolescents, analyzing the development of NSSI according to the exposure to selected exposure factors. Results showed a statistically significant increased risk of NSSI with regular smoking, alcohol use, early cannabis use, and poor physical activity. No significant association was found between NSSI and substance use, when considered in broad terms, or with experimenting smoking. Inconsistent results were found for use of technology devices and sleep quality. Most studies are of moderate quality but certainty of the evidence was very low for all studied exposures considering all GRADE criteria for rating certainty of evidence and starting from a "low certainty", as they are observational studies. Meta-analyses could only be performed for two exposure factors due to the paucity of studies and the variability in the measures recorded, which prevented more precise data. Limited information on frequency and no data on severity of NSSIs were identified. No studies were found that analyzed the impact of dietary habits or gambling on NSSIs.

Healthy behaviors such as regular physical activity, a balanced diet, adequate sleep, avoidance of tobacco and alcohol have been shown to be protective against the onset of some mental disorders in adolescence (Firth et al., 2020). However, there is a paucity of longitudinal studies examining exposure to specific lifestyle and behavioral problems as independent risk factors for NSSI. NSSIs are considered a public health problem given their prevalence and impact on adolescents and their immediate environment (Moloney et al., 2024). Analyzing their relationship to the shift away from healthy lifestyles and the current transformation of communication and digitalization is particularly relevant today.

The results of the five studies that looked at sleep and NSSIs are not consistent. The studies combined in meta-analysis (Liu et al., 2019; Lundh et al., 2013) and two of the non-aggregated studies (Asarnow et al., 2020; Nguyen et al., 2023) showed that overall sleep quality and sleep disturbance were not statistically significantly associated with NSSI during follow-up. In contrast, another study showed that a decrease in sleep hours over a 6-year follow-up period was associated with an increased risk of NSSI (Fang et al., 2022). It is known that sleep disturbance is a risk factor for emotional dysregulation and that one function of NSSIs is the regulation of intense emotions so, in theory, emotional dysregulation could mediate the relationship between sleep disturbance and NSSIs (Ennis et al., 2017). Similarly, sleep deprivation in adolescents has negative effects on attention and impulse control, as well as lower frustration tolerance and poorer coping with stress, which could contribute to the development of NSSIs (Lai et al., 2024). However, this systematic review cannot confirm the hypothesis of the association between sleep and NSSIs.

Regarding the use of technological devices, one study found no overall statistically significant association between NSSI and the number of hours of mobile phone use in those without previous NSSI, but found an association between at least 4 h of weekend mobile use and recurrent NSSI among those who had NSSI at baseline (Wang et al., 2020). The same study also found no association with the hours of internet use in people without previous NSSI, but again it does with recurrent NSSI. On the other hand, another study concluded that addictive internet use is associated with NSSIs in both moderate and severe addictions (Ma et al., 2023), understood as an inability to stop using the internet despite negative consequences (Young, 1998). Today, the use of the internet by young people has led to a significant change in their lifestyles and in the way they communicate and learn (Kostyrka-Allchorne et al., 2023). It also coincides with an increase in mental health problems and self-harm, but the association has so far not been proven causal (Keyes & Platt, 2024; Schmidt-Persson et al., 2024; Valkenburg et al., 2022). Although harmful effects predominate in the studies, more vulnerable adolescents, either because of their context or because they have mental health problems, are more exposed to harmful effects, making it more difficult for them to self-regulate (Kostyrka-Allchorne et al., 2023; Susi et al., 2023; Valkenburg et al., 2022). U.S. teenagers spend an average of 4.8 h a day using social media (American Psychological Association, 2024). Other authors also suggest that it is not so much the number of hours spent online that is relevant to the risk of NSSI, but rather the specific stressors they experience and the behaviors they engage in online (Nesi et al., 2021). On the other hand, for some young people, internet connectivity may have benefits, such as reducing social isolation by providing a sense of belonging and peer support (Marchant et al., 2017).

In relation to addictive internet use, a recent review demonstrates the effects of such use on the adolescent brain, including alterations in brain area connectivity, effects on neural networks, executive control and the reward system (Chang & Lee, 2024). A comparable effect to that observed in substance abuse addiction is postulated. The adolescent brain is undergoing extensive maturational development, encompassing anatomical and functional changes. Additionally, it is also the stage of greatest social sensitivity and connection with peers (Blakemore et al., 2010), which could partially account for the heightened vulnerability of the adolescent brain to internet addiction.

With regard to substance use, it was identified an elevated risk of NSSI with regular use of tobacco, alcohol and early cannabis use in all studies, with the exception of one study in which these substances and other illicit drugs were analyzed together (Garisch & Wilson, 2015). The heterogeneity

of the sample may have resulted in an increased influence of uncontrolled contextual and/or individual factors. The association between tobacco, alcohol and cannabis use and NSSIs has been previously suggested in cross-sectional studies (Brausch & Boone, 2015; Lai et al., 2024). The longitudinal studies identified in this review indicate that these substances may act as a risk factor in adolescents. Furthermore, cannabis use has been identified as a risk factor for self-injurious behaviors, including NSSI and suicidality (Escelsior et al., 2021). The potential cognitive effects of cannabis use, such as its impact on reasoning and decision-making (Morin et al., 2019), may contribute to the observed increase in risky behaviors. Furthermore, it has been proposed that the observed association may be attributed to the fact that the two behaviors share similar psychological processes. It has been suggested that substance use may contribute to the development of a tolerance to self-harm (Klonsky, 2007). It is notable that regular smoking is a risk factor for NSSI, particularly in females and when use commences at an early age (Korhonen et al., 2018). One potential explanation is that girls may be more dependent on nicotine due to their metabolic differences, and that the anxiolytic effect of nicotine is more pronounced in girls, increasing their vulnerability to the development of NSSIs (Keyes & Platt, 2024; Korhonen et al., 2018). In relation to alcohol, problematic alcohol use has also been linked to NSSIs in previous studies. This association has been attributed to the use of both behaviors as a means of avoiding negative emotions when emotional regulation difficulties exist (Kim et al., 2024). On the other hand, early cannabis use has been linked to mental health issues, including anxiety and depression (Scholes-Balog et al., 2013) and psychosis (Kiburi et al., 2021). Additionally, NSSIs may serve as either negative or positive reinforcement behaviors in the context of potential emotional challenges (Brausch & Boone, 2015).

A single longitudinal study has been found that examined the relationship between physical activity and NSSI. The findings of this study indicated that physical activity was associated with a significantly lower risk of NSSI (Lai et al., 2021). Additionally, a recent cross-sectional study of a representative sample of Chinese adolescents yielded comparable results (Lai et al., 2024). One potential explanatory mechanism may be that physical activity contributes to stress and emotion regulation through both psychological and physiological mechanisms by acting as a protective factor for NSSIs. At the physiological level, it modulates levels of stress hormones such as cortisol and DHEA-S, which are associated in adolescents with motivation to engage in self-injurious behavior (Piarulli et al., 2023). In addition, the elevation in endorphin levels resulting from physical activity has been linked to mood enhancement and pain reduction, which may contribute to a reduction in self-injurious behavior (Li et al., 2023). From a psychological perspective, individuals who engage in sports and other participatory tend to exhibit enhanced self-esteem and self-control (McMahon et al., 2017).

It is noteworthy that no studies were identified that assess the association between eating habits and NSSI. The extant literature indicates that unhealthy eating habits, including frequent snacking, consumption of fast food and sweets, and lower intake of fruits and vegetables, are associated with the presence of depressive symptoms and stress (Jao et al., 2019). Adolescents with a healthy weight exhibit superior mental health outcomes compared to their overweight or underweight counterparts (Chen et al., 2024). However, the potential association with NSSI has yet to be elucidated.

With regard to subgroup analysis, no information could be identified in the studies regarding the population type or age range. In general, no discernible patterns emerge with regard to the results according to the age of the adolescents. The associations identified with smoking and alcohol consumption were observed in both younger and older adolescents across the studies. One exception is the association between sleep quantity and NSSIs. The study that identified an association between decreased sleep duration and NSSIs examined trajectories from early ages (8 years) to 14 years. However, the study that found no association between < 6 h nocturnal sleep time and NSSI included older participants, with an average age of over 14 years (Fang et al., 2022). This suggests that decreasing sleep quantity may have a particular impact when it occurs at younger ages. According to participants' sex, one study has provided results regarding the association between sleep quality and NSSI, disaggregated by sex (Lundh et al., 2013). The subgroup of girls exhibited a tendency towards a higher risk of association between sleep quality and NSSI, which could be related to a higher prevalence in adolescent girls of internalizing disorders, anxiety and depression, as well as greater emotional vulnerability (Keyes & Platt, 2024; Khazaie et al., 2021).

The principal strength of this review is that, despite the limited number of included studies, it provides a comprehensive description of the available evidence on the lifestyle and behavioral factors that are independently and longitudinally associated with NSSIs. This highlights the continued importance of analyzing behaviors such as substance use, sleep and internet use. A comprehensive search strategy was employed across multiple data repositories, and a systematic methodology was followed for the selection of studies, synthesis of results, and assessment of study quality. A meta-analysis was conducted for each individual factor where information was available, and the certainty of the evidence was also analyzed. The absence of studies examining the relationship between healthy lifestyle habits, such as physical activity and dietary patterns, and NSSIs in adolescents highlights a significant gap in the literature on this public health issue (Gillies et al., 2018). This is particularly

relevant given that the risk of NSSI occurrence is higher at this developmental stage (Dahl et al., 2018).

The present study has limitations that need to be taken into account for a proper interpretation of the results. The most significant limitation is the scarce number of longitudinal studies examining the risk of NSSI due to exposure to unhealthy lifestyles and behavioral problems. In addition, the certainty of the evidence analyzed is very low for all exposures. This has limited the power of the analyses and influenced the accuracy of the results. Most of the scientific publications in this field are cross-sectional, so future research needs to analyze the effects of different exposure factors on self-harm over time. In some of the longitudinal studies found, there is a significant difference in the length of follow-up, which may affect the interpretation and comparability of the results. The lack of standardization of NSSI terms and the different measurement procedures and instruments used in the included studies may be another limitation. However, it is worth noting that this review has specifically analyzed NSSIs in a differentiated manner, with a special emphasis on identifying practices without lethal intent. This has made quantitative analysis and pooling for meta-analysis and generalization of results challenging, as noted by other authors (Hooley et al., 2020). Therefore, future studies must define and measure NSSIs in a consistent manner to ensure the reliability and comparability of the results.

Conclusion

In order to ascertain whether preventable factors such as lifestyles and problem behaviors exert an influence on the engagement with NSSI among adolescents, it is essential to focus attention towards longitudinal studies and analyze each factor individually. In this systematic review and meta-analysis, which focused specifically on longitudinal evidence on the effects of various lifestyle and problem behaviors on NSSI among adolescents, a statistically significant increased risk of NSSI was found with regular smoking, alcohol use, early cannabis use, and poor physical activity. However, inconsistent results were found for use of technology devices and sleep amount and quality, and no studies analyzed dietary habits or gambling. Certainty of the existent evidence is still very limited. These findings highlight the importance of further investigating their potential as risk markers in longitudinal studies, as well as developing strategies to promote healthy lifestyles in adolescents, especially at early ages.

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Data Availability All data in this systematic review were obtained from the original published studies.

Declarations

Conflict of interest The authors report no conflict of interests.

Preregistration The review and meta-analysis was registered in the International Prospective Register of Systematic Reviews (PROSPERO; registration number: CRD42024501154).

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*An asterisk indicates publications that were included in this systematic review and/or meta-analysis

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