Journal of Affective Disorders 339 (2023) 648–659

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Review Article

The development of Non-Suicidal Self-Injury (NSSI) during adolescence: A systematic review and Bayesian meta-analysis

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ARTICLE INFO

Keywords:
Non-Suicidal Self-Injury
Systematic review
Bayesian meta-analysis
Longitudinal development
Adolescence

ABSTRACT

Background: Despite a surge in research on self-injury in the last decade, a summary of research findings about the development of Non-Suicidal Self-Injury (NSSI) over time in community youth samples is not yet present in the scientific literature. This study aims to summarize the empirical literature on this topic, examining both the occurrence (Study 1) and frequency (Study 2) of NSSI over time, and for this reason, a Systematic Review and Bayesian Meta-Analysis were conducted.

Methods: Following the PRISMA guidelines, the longitudinal studies included in the systematic review consisted of 41 papers (Study 1 = 16; Study 2 = 25). Only studies with available data were included in the meta-analysis (Study 1 = 12; Study 2 = 11).

Results: First, the findings highlight limits related to methodological aspects, the design of the studies, and the availability of data. Meta-analytic results shows that across development, the frequency (i.e., not the occurrence) of NSSI increases for the group of younger adolescents, remains stable in the group of middle adolescents, and it decreases for older adolescents.

Limitations: This study highlights some limitations that can be summarized in three different macro categories: the first refers to methodological aspects (e.g., the lifetime prevalence of NSSI), the second to the design of the studies (e.g., not homogeneous cohort; short-term covered), and the third to the availability of data.

Conclusions: The current meta-analysis tries to shed light on the longitudinal research on NSSI behavior and how this behavior develops in terms of both occurrence and frequency, providing practical and methodological indications for future research.

1. Introduction

Non-Suicidal Self-Injury (NSSI) is defined as a subcategory of self-injurious behavior that refers to the direct and deliberate destruction of one's body tissue without suicidal intent (e.g., Kiekens et al., 2018). NSSI has been identified as a serious public health concern worldwide, particularly alarming among adolescents (Klonsky, 2011; Rodham and Hawton, 2009), for both the high incidence and the consequences for emotional and cognitive development (e.g., suicide attempts and psychological symptoms; Castellvi et al., 2017; Baetens et al., 2014; Buelens et al., 2019). Prior research suggests that adolescents who engage in self-injurious behaviors show a later maladaptive coping cycle in which emotions, cognition, and self-injurious behavior reinforce each other (Buelens et al., 2019). Moreover, Daukantaitė et al. (2020) showed that adolescents who have engaged in NSSI for reasons of stress relief, albeit not regularly, may still experience negative outcomes in young adulthood. Therefore, it may be important to examine the development of NSSI over adolescence, from early adolescence to young adulthood, to better understand *when* (i.e., which period) and for *who* (i.e., which youth) the occurrence and frequency of NSSI behavior is a danger.

Generally, NSSI is widespread in adolescence, which is a critically vulnerable period for the onset and development of mental health problems and risky behaviors (Lloyd-Richardson, 2008). In fact, this sensitive developmental period is characterized by profound biological,

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https://doi.org/10.1016/j.jad.2023.07.091
Received 21 December 2022; Received in revised form 7 June 2023; Accepted 16 July 2023
Available online 20 July 2023

psychological, and social changes, as well as important developmental tasks in defining one's identity and autonomy (e.g., Brown and Plener, 2017; Dahl et al., 2018). Specifically, biological models may provide an explanation for why adolescence is a crucial period for engagement in this behavior (e.g., Kaess et al., 2021). Early adolescence is a significant period for brain development and neuroplasticity constitutes a possible risk and vulnerability for the onset of mental health. Concurrent changes in brain development might lead to a developmental imbalance in emotional control that resolves with the maturation of the prefrontal cortex (e.g., Giedd et al., 2009; Moran et al., 2012). Any increase in NSSI over adolescence may reflect not only the increase in hormonal changes, but also the increase in psychological distress over this age range (e.g., Patton et al., 2007).

According to the theoretical model of NSSI defined by Nock and Prinstein (2004), this behavior can be used as a maladaptive coping strategy to avoid distressed emotional states (Chapman et al., 2006) and to down-regulate the arising of negative feelings (e.g., anxiety and depression) or communicate their emotions with others (Liu et al., 2016). Both intrapersonal (e.g., elevated psychological arousal, internalizing symptoms, emotion dysregulation) and interpersonal (e.g., perceived social support by parents and peers) factors are recognized as crucial factors for the initiation and maintenance of NSSI behavior over time (e.g., Tatnell et al., 2014; Fox et al., 2015). Therefore, these factors represent vulnerabilities that could lead adolescents to difficulties in managing and coping with struggles or stressful events, putting them at risk of engaging in risky behaviors, such as NSSI, to modulate their experience (Nock et al., 2009).

The prevalence of NSSI in community samples of adolescents is remarkably high. Previous studies found that approximately 23 % of adolescents reported deliberately injuring themselves at least once in their life, and almost 19 % in the previous year (Gillies et al., 2018). However, rates of NSSI during adolescence vary greatly (Muehlenkamp et al., 2012). As for the onset of the phenomenon, previous studies reported that self-injury occurs between the ages of 11 and 15 (Rodav et al., 2014), whereas a recent study (Plener et al., 2015) found that NSSI peaks in adolescence at around 15 to 17 years old, and wanes/remits in late adolescence/early adulthood. Although there is some evidence of NSSI beginning before puberty (Hanania et al., 2015), other studies found a later increase during adolescence (Marshall et al., 2013), and puberty can be considered a key point in the initiation of self-injury (Gillies et al., 2018). Despite the increasing number of studies on the prevalence of NSSI in the last decade, it is difficult to understand the actual extent of the phenomenon across development because of the different terms used to define the construct and the differences in methodological aspects to detect the phenomenon (Giletta et al., 2012; Gillies et al., 2018). Despite a surge in research on NSSI in the last decade (Glenn and Klonsky, 2011; Guerry and Prinstein, 2010), there is still a paucity of longitudinal studies focused on the development of NSSI from adolescence to young adulthood. Most studies addressed NSSI behavior at a cross-sectional level, and thus little is known about its longitudinal growth (Glenn and Klonsky, 2011; Guerry and Prinstein, 2010).

To date, there are no studies that have summarized quantitatively what we know about the development of this behavior concerning community samples (i.e., meta-analysis). In fact, most systematic reviews and meta-analyses focus on the global prevalence of NSSI (Gillies et al., 2018; Swannell et al., 2014) and the risk factors for its development (Tatnell et al., 2014), principally using one-wave studies. To our knowledge, only one systematic review on the longitudinal development of NSSI has been published (Plener et al., 2015). It lacks a specific focus on community samples, taking into consideration clinical samples, and without making a quantitative synthesis that can explain the development of NSSI behavior from early adolescence to young adulthood. Moreover, it has not taken into consideration possible variables that could influence the development of NSSI such as the developmental period or the age of participants.

Previous systematic reviews and meta-analyses (Gillies et al., 2018; Swannell et al., 2014) showed how NSSI prevalence estimates are influenced by different theoretical and methodological factors. However, existing studies have examined the role of these factors at the cross-sectional level, while it is important to investigate how these factors can influence and affect the longitudinal development of the behavior over adolescence. Among the main factors, we can identify the participants' age, and other methodological aspects related to the measurement tool.

Sample age is a crucial variable in the development of NSSI behavior. Previous meta-analyses found a significant increase in the prevalence of self-injury as age increased (e.g., Gillies et al., 2018). In contrast, Swannell et al. (2014) did not find significant differences across the ages in their data collection. Additionally, an earlier age of onset was found to be related to a higher frequency and more severe methods (Ammerman et al., 2018). Finally, Plener et al. (2015) found that NSSI is higher in adolescence, between ages 15 and 17, with a decrease in young adulthood. Considering these contrasting results and the important developmental changes which occur between adolescence and young adulthood, the specific age seems to be an important variable to be considered.

Besides, prior studies found that methodological factors contributed to the heterogeneity in prevalence estimates (Swannell et al., 2014). In fact, not only have the definitions for self-injurious behavior varied over time but the related tools are also characterized by different methodologies. Whereas some studies include single items on the presence or absence of self-injury (i.e., yes vs no), others include the assessment of frequency, functions, body parts injured, along with the likelihood of keeping up these behaviors (i.e., checklist and scales; Gillies et al., 2018; Swannell et al., 2014). Thus, this specific aspect related to the measure could influence the different prevalence rates across studies (Brown and Plener, 2017). Notably, scales may yield more accurate results because the list of items requires participants to take more time to process each item while the binary question (i.e., yes or no) is a free recall task and more cognitively labor-intensive (Schaeffer and Presser, 2003), which may lower estimates, as participants may not immediately recall episodes of NSSI without examples (Swannell et al., 2014).

Overall, given the considerable increase in attention these past years for NSSI behavior and the negative consequences it has on mental health, it is important to understand the longitudinal development of NSSI behavior, identifying possible periods most at risk for the engagement in the behavior. A systematic review and meta-analysis could provide researchers and clinicians with relevant information about critical periods for prevention and interventions and about subgroups of individuals who may engage in different patterns of self-injury at various developmental phases.

To synthesize the available evidence, the current study has two aims. First, to synthesize the existing literature on this issue through a systematic review. Second, it aims to investigate the occurrence and the frequency of NSSI across development, from early adolescence to young adulthood, using a meta-analytic Bayesian approach.

2. Methods

The PRISMA guidelines for systematic reviews and meta-analyses (Moher et al., 2014) were followed to conduct a structured review. The stages are summarized in the flowchart in Fig. 1.

2.1. Search strategy

The studies were identified following an Internet-based search of the literature using four electronic databases: SCOPUS, PsycINFO, PubMed, and Web of Science. The search includes papers published until the 24th of September 2022. The keywords belonged to three different clusters: the first cluster regards *Non-Suicidal Self-Injury* (keywords: ‘self-harm’, ‘self-injur*’, ‘self-cutting’, ‘self-punishment’, ‘self-mutilation’); the second cluster regards the *longitudinal design* (keywords: ‘trajector*’,

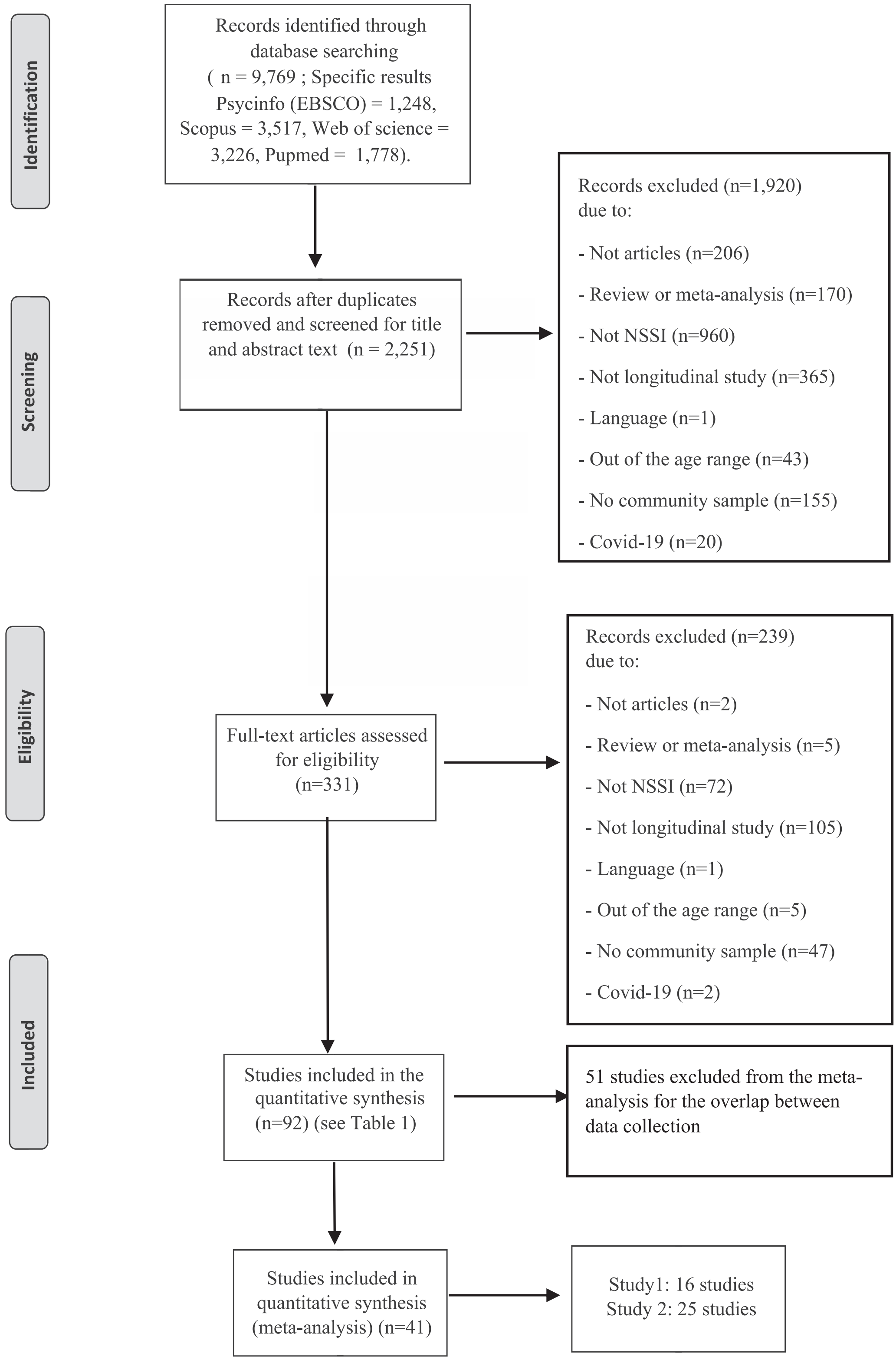

Fig. 1. Flowchart of study identification, screening, eligibility, and inclusion.

'continuity', 'discontinuity', 'stage*', 'grow*', 'progress*', 'longitudinal'); the third regards the *developmental period* (keywords: 'youth', 'teen*', 'adolescen*', 'young*', 'student*'). The search was conducted by combining Abstract, Title, and Keywords in Scopus and Web of Science databases. For the PubMed database, the title and abstract were searched and, for the PsycINFO database, only the abstract was analyzed, as there was no other option. At this stage, 3517 articles in Scopus, 1248 articles in PsycINFO, 1778 articles in PubMed, and 3226 articles in Web of Science were identified.

2.2. Screening

According to PRISMA, the selection phase based on reading the title, keywords, and abstract was done under the following criteria: (1) only journal papers (e.g., no books chapters, dissertation); (2) only quantitative empirical research (e.g., no qualitative studies, systematic review, and meta-analysis); (3) the topic on NSSI, articles not referring to this topic were excluded; (4) longitudinal studies, cross-sectional articles were excluded; (5) languages, paper not in English and Italian were excluded; (6) age ranged between 10 and 25 years old, articles not referring to this range were excluded; (7) community sample, papers that included clinical or a selected sample were excluded; (8) articles conducted during COVID-19 pandemic were excluded. Specifically, as concerns the criteria related to the topic, given the complexity and the differences in the definition of the construct used by the studies, we included only and exclusively those that explicitly defined the NSSI construct, while we excluded those that did not make a precise difference between NSSI and other forms that could also include the suicidal component. The screening was done in parallel by four coders independently: a professor and a group of young scholars (i.e., doctoral level and master's degree student). The inter-rater agreement between the coders, computed on the acceptance/rejection criterion, was excellent (Cohen's $K = 0.84$).

2.3. Selection procedure

Overall, the search in all four databases included 9769 articles. The duplicates were removed automatically and manually (i.e., 7518), leading to 2251 articles (see Fig. 1). We reviewed the titles and abstracts of all articles found and we excluded 1920 articles under the exclusion criteria reported above (see Fig. 1). The full-text articles assessed for eligibility were 331. A total of 239 articles were further excluded according to exclusion criteria. Finally, of the 92 that remained, 51 studies were excluded because based on overlapping databases (i.e., studies that used the data from the same data collection). Given that some studies were (partially) based on the same longitudinal dataset, we chose the study that provided more detailed information for estimating mean effect size and moderation effects in our meta-analysis (see Supplementary Tables S1, S2, these articles are marked with an asterisk). Finally, 41 studies were included in the systematic review (for references see Supplementary). Specifically, 16 for study 1, and 25 for study 2. Authors have been contacted to ask for missing information if the paper did not report the values necessary for estimating developmental changes. Papers that did not have sufficient data were excluded from the analysis conducted for the meta-analysis. Consequently, only 23 studies were included in the meta-analysis: 12 for Study 1 and 11 for Study 2.

2.4. Data extraction and coding

All eligible studies were coded including the following information: (1) study identification items (e.g., first author, year of publication), (2) sample characteristics (e.g., number of participants, mean age), (3) measure characteristics (e.g., type of measure used, number of items); (4) data for the computing the effect size. Specifically, for the latter point, we extracted data from the proportions of adolescents that engaged in NSSI (i.e., Study 1); the mean of self-injury behavior, standard deviation (SD), and the correlations of self-injury behavior between each wave and the next (i.e., Study 2). To operationalize the variable of time into the model, we extracted data about the months that passed since the first wave of data collection and the mean age of the sample at the baseline. Specifically, months passed since the first wave of data collection were calculated as months between one wave and the next, identifying as 0 the months at the first wave.

2.5. Quality assessment

To measure the quality of the studies that met the inclusion criteria, we decided to use the *Standard Quality Assessment Criteria* proposed by Kmet et al. (2004). Due to the diversity of approaches applied in the retrieved articles, this tool allows us to examine the quality of papers, using a checklist for quantitative studies that evaluate relevant aspects. Each article was evaluated independently by two of the authors. For each criterion/aspect of the checklist, it was attributed 2 points if the study respected it (YES), 1 point if it partially respected it (PARTIALLY), or 0 if it did not respect it (NO). The total quality score was calculated by summing the total score and dividing it by the total possible score for each study. Among the included articles, all of them were assessed by the criteria for quantitative studies. To assess the interrater reliability of the summary scores, a random selection of 25 % of the papers was double-coded. Interrater reliability was excellent, with an interclass correlation coefficient of 0.93. For differently rated studies, a mean score was calculated as an average of the two scores. None of the studies had a quality score below 0.55 (liberal cut-off point). Therefore, all studies were used for data analysis. All quality scores are displayed in Supplementary Table S1 (Study 1) and Table S2 (Study 2).

2.6. Strategy of analysis

Data were analyzed using the statistical software R (Team, 2013). For data analysis frameworks we used the metafor R package (Viechtbauer, 2010), and the Bayesian approach, using the *brms* R package (Bürkner, 2017). The Bayesian framework is widely used in meta-analyses on the topic of health care (Egger et al., 2008), and it is enjoying increasingly frequent use in recent years in the field of developmental psychology (van de Schoot and Depaoli, 2014). The Bayesian framework allows to use of (1) prior distribution that is related to information from previous studies proposed by the researcher; (2) the observed evidence that refers to knowledge from the current studies, expressed in terms of the likelihood function; and (3) the posterior distribution that reflect the updated knowledge, derived from comparing data (i.e., the likelihood function) with the prior distribution. The posterior distribution is what is usually referred to as the result of the analysis. Besides, we considered two different levels in the data organization. The first level refers to the different waves of each study (e.g., each line of the dataset represents a wave of the included studies). The second level concerns the studies included in the analysis.

The current meta-analysis is composed of three different steps. Firstly, we analyzed a null model (M000) which estimates the overall effect size considering studies as a random effect. Specifically, given that the considered effects were nested in different studies we adopted a multilevel approach. As a second step, we compared the null model (M000) and two models (M001, M002) with the longitudinal effect expressed by the variable *months*. Specifically, a random intercept model (M001) includes the temporal effect by adding the variable *months*, in which the related parameter value represents the expected differences between effects observed at one month of distance, and a model (M002) which introduces the random slopes in the different studies, which translates into a further parameter that measures the variability between the different lines estimated in the various studies. Finally, in the third step, we introduced two variables (i.e., time passed from the first data collection, and the mean age of participants at the first wave) to operationalize respectively the development of NSSI, and the developmental period, identifying the best possible model among a set of proposals[1] (i.e., meta-regression). Specifically, given the high heterogeneity of the

[1] M000: null model, M001: months; M002: months; M003: months + 1st mean age (33, 43); M004: months × 1st mean age (33, 43). The numbers in brackets indicate the number of observations. Specifically, the first refers to study 1, and the second to study 2.

studies caused by the strong difference in tools used to measure NSSI, and the difficulty of using one measure of effect size for all studies, we decided to conduct two different studies. Specifically, Study 1 examines the occurrence of NSSI across development (i.e., presence), using the proportion of youth that engaged in NSSI (i.e., yes or no questions). Study 2 analyzes the frequency of the behavior, obtained through the average frequency of behavior reported in the included articles, which refers more to the systematic nature of the behavior.

For the estimation of the parameters, we adopted a *full Bayesian* approach with the *brms* package (Bürkner, 2017) using a *Markov Chain Monte Carlo* (MCMC) procedure via Stan (Stan Development Team, 2019). The posterior distributions were obtained from 4 MCMC chains of 10,000 iterations each for a total of effective 20,000 replicas. For the comparison between the models, we used the following statistics: *Bayesian* R^2 (Gelman et al., 2019), *leave-one-out cross-validation information criterion* (LOO; Vehtari et al., 2017), and *model weight* (W; Yao et al., 2018). The latter indicator, normalized in the range 0–1, represented the probability of the model being the best at predicting new data conditional on the set of models examined (McElreath, 2018). To find the best model, we have to consider the LOO value and the weight (W), the first should be lower, while the second higher than the other models. Two different methodologies, respectively for Study 1 and Study 2, have been used to synthetize the effect size.

For Study 1, the effect size measure was the *logit transformed proportion* (PLO) of individuals that engaged in NSSI on the total. The type of transformation allows us to map the real numbers of the values between 0 and 1 (e.g., the values between 0 and 0.5 are negative, while those between 0.5 and 1 are positive).

We defined prior knowledge from the most relevant studies and systematic reviews (e.g., Gillies et al., 2018). Given that the prevalence of the phenomenon varies greatly based on many factors (i.e., methodological factors), we have assumed a skeptic prior. Based on the literature, given that the percentages of NSSI vary between 15 % and 20 %, we expected a value for the proportion of individuals that engage in NSSI around 0.18; transforming this proportion into logit we obtain a value of approximately −1.52. Consequently, the prior for the proportion was a Student's t (3, −1.5, 0.15). Based on the assigned standard deviation, 0.15, we expected, with a probability of 90 %, that the logit of the proportion is between −1.87 and −1.17 and consequently that the proportions fall between 0.13 and 0.24 approximately. For the variability parameter (τ) we choose a truncated Student's t (3, 0, 0.2), constraining it to assume only positive values. This prior assumes a variability between included studies between 0 and about 0.47, with a probability of 90 %. Translated in proportions means to expect values between 0.12 and 0.26 in studies. These same priors were also used in the second model (M001) in which it was added third prior serves to model the regression coefficient associated with the months. This parameter expressed the expected average change in effect size between two subsequent months. The prior for this parameter was a Student's t (3, 0, 0.5). This prior, rather wide, admits that the differences in logit between two consecutive months fall, with the usual probability of 90 %, between −1.18 and 1.18, that is, translated into proportions, between 0.24 and 0.76. In the third model, we used the same priors, assuming an identical a priori variability for intercepts and slopes. For the parameters related to other moderators – time passed from the first data collection and mean age of participants – we used skeptical priors centered around zero.

For Study 2, the effect size measure was the *standardized mean change* using the *raw score standardization* (SMCR; Roberts et al., 2006; Viechtbauer, 2010), always considering the differences compared at the first time point. Specifically, each effect size was calculated as the difference between two consecutive waves, using the means with relative standard deviations, the correlations of NSSI between each wave, and sample sizes. For the first parameter of the null model (M00) we adopted a skeptical prior, centered on zero and with little variability, assuming that 90 % of the expected changes were between −0.94 and 0.94; formally a Student's t (3, 0, 0.4). For the variability parameter (τ), we choose a truncated Student's t (3, 0, 0.2), constraining it to assume only positive values. This prior assumed a variability between included studies, with a probability of 90 %, between 0 and about 0.47. The same priors were also used in the second model (M001) in which it was added third prior serves to model the regression coefficient associated with the months. This parameter expressed the expected average change in effect size between two subsequent months, that is Student's t (3, 0, 0.5). This prior admitted that the differences between two consecutive months fall, with the usual probability of 90 %, between −1.18 and 1.18. In the third model, we used the same priors, thus the assumption was identical a priori variability for intercepts and slopes. The same priors were used for parameters associated with models with the variables time passed from the first data collection and mean age of participants.

3. Results

The main characteristics of all the articles included in the meta-analysis are summarized in the Supplementary material (see Tables S1 and S2).

Additionally, the distribution (N; %) of the studies according to the reference time of the measurement, the time covered by the data collection, the months covered by the data collection, the age range of the participants at the first wave of the data collection are reported as well in the Supplementary material (see Tables S3–S6). Specifically, for Study 1 ($N = 16$), we find heterogeneity related to the reference time of measurement (i.e., lifetime prevalence of NSSI, last 3 months, last 12 months). Most of the studies assess the lifetime prevalence of NSSI (i.e., 56 %). The number of assessment waves ranges from 2 to 5. Most studies include 3 waves (i.e., 57 %). The number of months of data collection ranges from 6 to 120 months, with most studies covering 24 months (i.e., 44 %). Finally, the age of participants at the first wave of data collection ranges from 8 to 25 years, with high heterogeneity across studies. For Study 2 ($N = 25$; one paper includes two different studies), we find a high heterogeneity regarding the reference time of the assessment, with a consistent number of studies assessing NSSI behavior in the past 6 months (36 %) and in the past 12 months (24 %). The number of assessment waves ranges from 2 to 12. Most of the studies include 3 waves (i.e., 56 %). For the months of data collection, the range is from 2 to 132 months, with most of the studies covering 12 months (i.e., 32 %). Finally, the mean age at the first wave of data collection ranges from 10 to 25 years, with a high heterogeneity among the studies.

3.1. Study 1: overview of effects' distribution

This study includes 12 final papers with available data (see Table S1). Specifically, 4 study (ID = 7a, 8a, 26a, 30a) was excluded from the initial 16 articles, as they did not have sufficient available data to conduct the analyses (i.e., we have not received the data from the authors despite two e-mail). Table 1 summarizes the effect size computed for each study included. The number of waves that make up the studies ranges from a minimum of 2 to a maximum of 4.

Comparing the null model (M000) with model 1 (M001) and model 2 (M002), the model that provided the best fit was Model 2 (M002), which included the random intercepts and slopes. Table 2 reports the performance indices of the three compared models. Notably, model M002 had a weight (W) of about one, larger than the weights of the other models. This result, therefore, suggests that it is very plausible that the studies differ not only in the observed estimates (random intercepts) but also in the trajectories detected during the waves (random slopes). The parameter estimates of the model M002 with the related 90 % Credibility Intervals are $\mu = -2.080$ [−2.400, −1.710], $\beta = -0.014$ [−0.043, 0.022], $\tau = 0.610$ [0.420, 0.870] and $\sigma_\beta = 0.060$ [0.040, 0.090]. Notably, transforming the parameter μ into proportions gives a value equal to 0.110, 90 % CI [0.080, 0.150].

Fig. 2 displays the Forest Plot (panel [A]) and the Funnel Plot (panel

Table 1
Effect size of the included studies (Study 1).

ID	Reference	Wave	Months	ni	yi	vi	1st M_{age}
2a	Baetens et al. (2014)	1	0	1397	−2.90	0.0145	12
		2	12	827	−3.65	0.0489	–
		3	30	748	−2.25	0.0156	–
5a	Buelens et al. (2019)	1	0	528	−1.83	0.0159	15
		2	12	384	−2.50	0.0373	–
		3	24	326	−2.29	0.0367	–
10a	Gandhi et al. (2019)	1	12	384	−2.50	0.0373	15
		2	24	326	−2.29	0.0367	–
13a	Heilbron and Prinstein (2010)	1	0	493	−2.70	0.0344	12.6
		2	12	493	−3.46	0.0688	–
		3	24	493	−3.46	0.0688	–
17a	Li et al. (2021)	1	0	516	−2.62	0.0307	12
		2	6	516	−2.50	0.0277	–
18a	Liu et al. (2019)	1	0	7072	−1.08	0.0007	14.59
		2	12	7072	−2.34	0.0018	–
22a	Marin et al. (2020)	1	0	6229	−2.71	0.0027	15.78
		2	12	6629	−3.44	0.0050	–
24a	Polek et al. (2020)	1	0	2403	−2.28	0.0049	18.9
		2	12	1815	−2.09	0.0056	–
		3	24	1245	−1.67	0.0060	–
27a	Robinson et al. (2019)	1	0	489	−1.41	0.0130	13.56
		2	12	489	−1.53	0.0140	–
		3	24	489	−1.56	0.0142	–
32a	Voon et al. (2014)	1	0	1424	−2.42	0.0094	13.9
		2	12	1424	−1.95	0.0065	–
		3	24	1418	−1.66	0.0053	–
33a	Wan et al. (2015)	1	0	17,622	−1.58	0.0004	16.1
		2	3	16,170	−2.14	0.0007	–
		3	9	14,407	−2.47	0.0010	–
		4	18	13,923	−2.43	0.0010	–
35a	Whitlock et al. (2013)	1	0	1466	−1.84	0.0058	20.3
		2	12	1466	−2.89	0.0137	–
		3	24	1466	−4.88	0.0916	–

Note. ID = identification number; ni = sample size; yi = effect size; vi = effect size variance; 1st Mean Age = mean age at the first assessment.

Table 2
Model comparison results (Study 1).

	R^2	CI	LOO	se	W
M002	0.88	[0.84;0.91]	424.1	192.0	0.999
M001	0.53	[0.49;0.56]	1569.5	384.0	<0.001
M000	0.41	[0.36;0.45]	2221.0	798.2	<0.001

Note. R^2 = Bayesian R-square, CI = 90 % Credibility Interval, LOO = leave-one-out cross-validation information criterion, se = standard error, W = model weight.

[B]). The Forest Plot displays the posterior distributions of the intercepts (in gray), showing that the studies are not very close to the estimated average value ($\mu = -2.080$). The Funnel Plot shows no important asymmetries in the distribution of values; therefore, we can assume that there has not been a very marked publication bias.

3.2. Study 1: meta-regression

To evaluate the effects of potential moderators (i.e., time passed from the first data collection and mean age of participants – operationalization of developmental periods), we used the best model (*M002: months* + (*months* | *ID*)), which includes the temporal effect with random intercepts and slopes. The sample size of observations was respectively 33. The best model remains M002, which measures the variability between the different lines estimated in the various studies, with a weight significantly higher than that of the other models (W = 0.825), highlighting that the effect of the moderators is not very strong. Anyway, in the comparison between the two models that include the variables *months* and *1st Mean age*, the model without the interaction (M003) has a weight higher (W = 0.133) than model M004 with the interaction (W = 0.042). Specifically, as the months passed since the first data collection (i.e., time) there is a decrease in the expected proportions of NSSI (i.e., occurrence).

3.3. Study 2: overview of effects' distribution

This study includes 11 papers with available data (see Table S2). Specifically, 14 were excluded from the 25 selected articles, as they did not have sufficient and available data to conduct the analysis (i.e., we have not received the data from the authors despite two contacts by e-mail). The excluded studies are those with the following identification number: 4b, 10b, 13b, 21b, 22b, 26b, 27b, 36b, 38b, 41b, 42b, 46b, 52b, 53b. Table 3 summarizes the effect sizes computed for each study. The number of waves that make up the studies ranges from a minimum of 2 to a maximum of 8.

Comparing the null model (M000) with model 1 (M001) and model 2 (M002), the model that provided the best relative evidence is Model 2 (M002), which included the variables intercept and slope. Table 4 reports the performance indices of the three compared models. Notably, model M002 had a weight (W) of about one, greater than the weight of the other models. This model, therefore, suggests that it is very plausible that the studies differ not only in the observed estimates (random intercepts) but also in the trajectories detected during the waves (random slopes). The parameter estimates of the model M002 with the related 90 % Credibility Intervals are $\mu = -0.017$ [−0.129, 0.095], $\beta = 0.001$ [−0.006, 0.008], $\tau = 0.210$ [0.140, 0.310] and $\sigma_\beta = 0.010$ [0.010, 0.020].

Fig. 3 displays the Forest Plot (panel [A]) and the Funnel Plot (panel [B]). The Forest Plot displays the posterior distributions of the intercepts, compared to the estimated average value ($\mu = -0.017$). The Funnel Plot shows no important asymmetries in the distribution of values; therefore, we can assume that there has not been a very marked publication bias.

3.4. Study 2: meta-regression

To evaluate the effects of the two moderators (i.e., time passed from the first data collection and mean age of participants), we used the best model (*M002: months* + (*months* | *ID*)), which includes variables intercepts and slopes. The sample size of observations was respectively 43, and thus we compared the models included. The best and most informative model is M004, which includes the interaction between months of assessment and the mean age of participants at the first wave (i.e., *months* × *1st Mean age*). Table 5 displays the estimated parameters for the model with the main effect of months and mean age (M004).

Fig. 4 displays the interaction between the variables months and 1st mean age of participants. In the abscissa the months after the first assessment (i.e., time) are reported, while the three lines refer to the average age that has been categorized on three levels (i.e., ±1 SD from the mean; M = 12.93; M = 14.23; M = 15.53). As the months passed since the first data collection (i.e., time), the expected mean change of NSSI behavior increased for the group of younger adolescents (i.e., mean age of 12.93 years), remained stable in the group of middle adolescents (mean age of 14.23 years), and decreased for the group of older adolescents (mean age of 15.53 years). However, we should note that the uncertainty increases across development as highlighted by the huge gray area on the right side of the figure. It is related to the fact that only one study covered a period higher than 36 months (i.e., 132 months).

4. Discussion

In the last ten years, the attention given to the development of Non-Suicidal Self-Injury has increased (e.g., Gillies et al., 2018). To date, most of the existing systematic reviews and meta-analyses on this topic have examined this behavior (e.g., prevalence, risk factors) by relying on cross-sectional studies. Therefore, this study aims first to conduct a

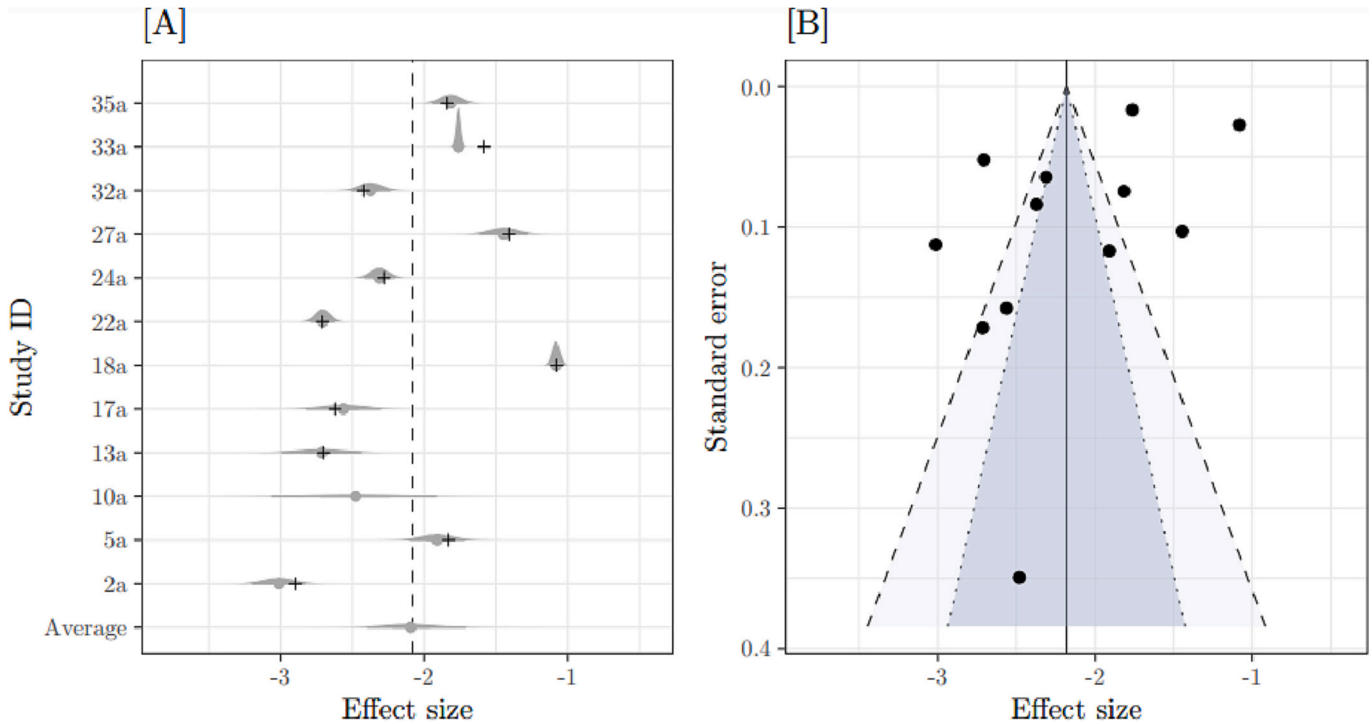

Fig. 2. Forest plot (Panel [A]) and funnel plot (Panel [B]) of model M002 (Study 1).
Note. The posterior distributions of the intercepts in the different studies are in gray. The black symbols represent the observed values at zero months.

Systematic Review and then to summarize the empirical literature on the occurrence (Study 1) and the frequency of the behavior (Study 2) of NSSI across development (Meta-analyses). Specifically, in the analysis, we included all longitudinal studies published up until the end of September 2022 on NSSI behavior in adolescence and young adulthood, in community samples. 41 studies (i.e., Study 1 = 16; Study 2 = 25) were judged as suitable on the bases of the criteria chosen and so were included in the systematic review.

According to previous works (Swannell et al., 2014; Gillies et al., 2018), the results of the Systematic Review showed a high heterogeneity of the methodology used by the different studies included. Notably, findings showed a paucity of longitudinal studies on multiple time points that cover a long period. Most of the studies were conducted in two or three waves (e.g., Liu et al., 2019; Buelens et al., 2019; Baetens et al., 2014), covering a very short period that did not allow for examining NSSI behavior trend over an extended period. Therefore, having detected the behavior in a short development period, makes it difficult to capture longitudinal trajectories of NSSI across development from early adolescence to young adulthood. Besides, this do not allow us to examine how different ages of NSSI onset and the duration may be associated with frequency and the later development of NSSI.

Instead, only a few studies assessed the behavior over a longer period (e.g., Giletta et al., 2015; De Luca et al., 2022). Moreover, the cohorts are not homogeneous between the different studies analyzed. Some studies considered very wide age ranges, others very limited ranges. For example, in some studies, the age is between 11 and 16 years old (e.g., You et al., 2012), one study considers an age range from 10 to 14 years old (Zhu et al., 2020), and another between 14 and 18 years old (Giletta et al., 2013). Besides, it is important to underline the heterogeneity in the measures used to assess the behavior and in terms of the reference time of the measurement. In fact, some studies measure the lifetime prevalence of the behavior (e.g., Voon et al., 2014; Whitlock et al., 2013), others the prevalence or the frequency in the previous 12 months (e.g., Wan et al., 2015; Glenn et al., 2016), others in the previous 6 (e.g., Wang et al., 2017; Daukantaitė et al., 2020) or 3 months (e.g., Giletta et al., 2015). Thus, as highlighted by these first findings, the differences in the age range of participants and in the reference period of the NSSI assessment (e.g., past six or three months, past year, lifetime) make it difficult to compare findings across studies, not allowing to fully grasp the changes and variability in NSSI behavior across development.

These data highlight how important it still is to extend research in this field using a more homogeneous methodology, to be able to compare the data and analyze the development of this behavior.

Study 1 was focused on the occurrence of NSSI (i.e., the presence of the behavior). Findings showed that the model that provided the best fit was the one with the variable intercepts and slopes, suggesting that it was very plausible that the studies differed not only in the estimates observed at the outset (i.e., random intercepts) but also in the trajectories detected during the waves (i.e., random slopes). Notably, the posterior distributions showed that the studies were not very close to the estimated average value, suggesting some variability between the studies, even if reduced.

The meta-regression showed that the best model was the one with variable intercepts and slopes (i.e., M002). It showed a decrease in the expected proportions of NSSI (i.e., occurrence of NSSI behavior) across development according to the passing of time from the first data collection. However, it's important to note the wide confidence interval that may be caused by the great heterogeneity in the time covered by the different studies and the small sample of studies included. These results may have been influenced using dichotomous data. Indeed, it uses the proportions of individuals engaged in NSSI on the total, thus not allowing to capture the change and variability across development. Further studies would consider other variables in the operationalization of development to better understand the occurrence of NSSI behavior over adolescence. Therefore, the use of dichotomous data, together with the high heterogeneity of the included studies, suggests that these results should be interpreted with caution, without drawing definitive conclusions on the trend of occurrence of NSSI behavior.

Study 2 examined the frequency of behavior of NSSI from early adolescence to young adulthood. Consistent with the results of Study 1, findings showed that the model that provided the best fit was the one with the variables intercepts and slopes, suggesting that it was very

Table 3
Effect size of the studies included (Study 2).

ID	Reference	Wave	Months	ni	ri	yi	vi	1st M_{age}
7b	Daukantaitė et al. (2020)	1	0	982	1	0	0	13.7
		2	12	979	0.48	−0.04	0.001	–
		3	132	556	0.26	0.26	0.003	–
8b	De Luca et al. (2022)	1	0	866	1	0	0	13.12
		2	12	790	0.46	−0.03	0.001	–
		3	24	772	0.58	0.35	0.001	–
		4	36	714	0.62	0.06	0.001	–
		5	48	649	0.48	0.02	0.002	–
		6	60	323	0.39	0.05	0.004	–
11b	Esposito et al. (2022)	1	0	430	1	0	0	14.18
		2	12	430	0.22	−0.17	0.004	–
		3	24	398	0.29	0.12	0.004	–
		4	36	406	0.41	0.10	0.003	–
14b	Giletta et al. (2015)	1	0	546	1	0	1	16.19
		2	3	519	0.59	0.21	0.002	–
		3	6	503	0.37	−0.03	0.003	–
		4	9	468	0.21	0.16	0.003	–
		5	12	559	0.41	−0.06	0.002	–
		6	15	397	0.43	0.03	0.003	–
		7	18	439	0.40	0	0.003	–
		8	21	441	0.58	0.03	0.002	–
15b	Giletta et al. (2013)	1	0	348	1	0	0	15.02
		2	6	348	0.55	−0.10	0.002	–
		3	12	348	0.55	0.18	0.003	–
		4	18	335	0.55	0.10	0.003	–
23b	Huang et al. (2021)	1	0	859	1	0	0	12.73
		2	12	859	0.48	−0.16	0.001	–
		3	24	859	0.26	0.17	0.003	–
33b	Marshall et al. (2013)[a]	1	0	161	1	0	0	13.82
		2	12	161	0.72	0.02	0.003	–
		1	0	513	1	0	0	–
		2	12	513	0.44	−0.10	0.002	–
		3	24	513	0.45	−0.017	0.002	–
40b	Wang et al. (2017)	1	0	3381	1	0	0	14.50
		2	6	3381	0.51	0.12	0.0003	–
		3	12	3381	0.51	0.04	0.0003	–
44b	Wu et al. (2019)	1	0	738	1	0	1	13.20
		2	12	515	0.42	0.05	0.002	–
51b	You et al. (2012)	1	0	2435	1	0	0	14.63
		2	6	2435	0.45	0.23	0.0005	–
55b	Zhu et al. (2020)	1	0	1987	1	0	0	12.32
		2	6	1846	0.45	0	0.0006	–
		3	12	1819	0.45	−0.04	0.0006	–

Note. ID = identification number; ni = sample size; ri = average correlation between measures; yi = difference between the averages of two successive survey; vi = variance of effect sizes.
[a] It contains two studies (i.e., Study 1 and Study 2).

Table 4
Model comparison results (Study 2).

	R^2	CI	LOO	se	W
M002	0.43	[0.36;0.50]	183.2	146.6	0.999
M001	0.26	[0.19;0.33]	250.4	136.2	<0.001
M000	0.12	[0.08;0.17]	295.1	143.0	<0.001

Note. R^2 = Bayesian R-square, CI = 90 % Credibility Interval, LOO = leave-one-out cross-validation information criterion, se = standard error, W = model weight. On the right, graphical representation of log-relative evidence.

plausible that the studies differed not only in the estimates observed (random intercepts) but also in the trajectories detected along the waves (random slopes). Specifically, the average change was rather low, probably because the various positive and negative changes observed in the different studies tend to cancel out. Notably, the posterior distributions showed that the studies were very close to the estimated average value. This could be explained by the high variability between the different studies, which leads, once again, to cancel each other out. In fact, the increase in NSSI in some studies and the decrease in others suggested a more complex association between the development of the behavior and the number of months since the first data collection. This could be due to the presence of other possible factors that may explain the association. Besides, there is also the possibility that there is no linear association between the variables considered, thus suggesting a curvilinear distribution that fluctuates across development.

The meta-regression analyses showed that the best fitting model include an interaction between the time that passed since the first data collection and the mean age of participants at the first data collection. Findings showed that as the months passed (i.e., time), the frequency of NSSI behavior increased for the group of younger adolescents in our sample (i.e., mean age of 12.93 years at baseline), remain stable in the group of middle adolescents (i.e., mean age of 14.23 years at baseline), and it decreases in the group of older adolescents (i.e., mean age of 15.53 years at baseline). This is in line with studies that found that NSSI seems to increase between 13 and 14 years old, and then decrease in late adolescence at about 17–19 years (e.g., Gillies et al., 2018; Plener et al., 2015). Adolescence represents a crucial and sensitive period for the development of NSSI characterized by profound psychological, social, and biological changes that contribute to initiation and maintenance of the behavior (e.g., Dahl et al., 2018). Notably, this period is characterized by stressors that are difficult to manage, thus leading to a higher frequency of maladaptive behavior (Garisch and Wilson, 2015). It is possible that this period is characterized by greater individual

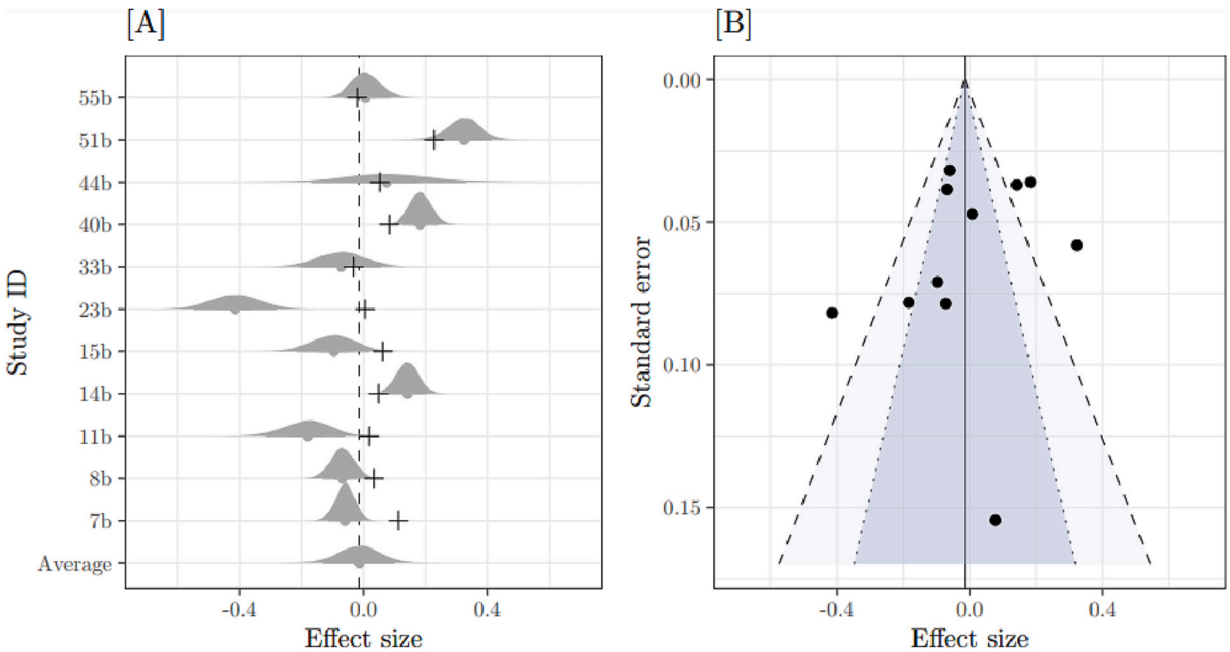

Fig. 3. Forest plot (Panel [A]) and funnel plot (Panel [B]) of model M002 (Study 2).
Note. The posterior distributions of the intercepts in the different studies are in gray. The black symbols represent the observed mean changes.

Table 5
Estimates of the parameters of the M004 model ($N = 11$).

Parameter	Estimate	SE	Q5	Q95
Intercept	−1.19	0.81	−2.51	0.13
Months	0.05	0.05	−0.04	0.14
Mean age	0.08	0.06	−0.01	0.18
Months × mean age	−0.00	0.00	−0.01	0.00

vulnerabilities (i.e., interpersonal, and intrapersonal vulnerabilities) that expose adolescents to a higher risk of engagement in NSSI (i.e., frequency). In fact, NSSI can be used as a maladaptive strategy to cope with stressful events and to regulate emotions (e.g., Nock and Prinstein, 2004). During the development, different factors may be involved in helping to interrupt the engagement in NSSI. First, the natural evolution of the critical and vulnerable period of adolescence and a maturation at the neurobiological level may contribute to a decrease in engagement in NSSI behavior (e.g., Kaess et al., 2021). Then, the development of intrapersonal skills such as learning to manage and regulate emotions more adaptively and the activation of interpersonal support (i.e., from family, peers, and psychologist) could be able to buffer the impact of different stressful life events on the NSSI engagement (e.g., Prinstein et al., 2009). However, we should not forget that some of them, the most vulnerable, may continue to engage in NSSI, with a consequent chronicity of the behavior (i.e., clinical sample). Specifically, some risk factors (i.e., depression history, rumination, anxiety, negative attributional style) can be salient for chronic NSSI engagement also in late adolescence (e.g., Barrocas et al., 2015).

Overall, the current meta-analysis tries to shed light on the longitudinal research on NSSI behavior and how this behavior develops from early adolescence to young adulthood over adolescence. Despite

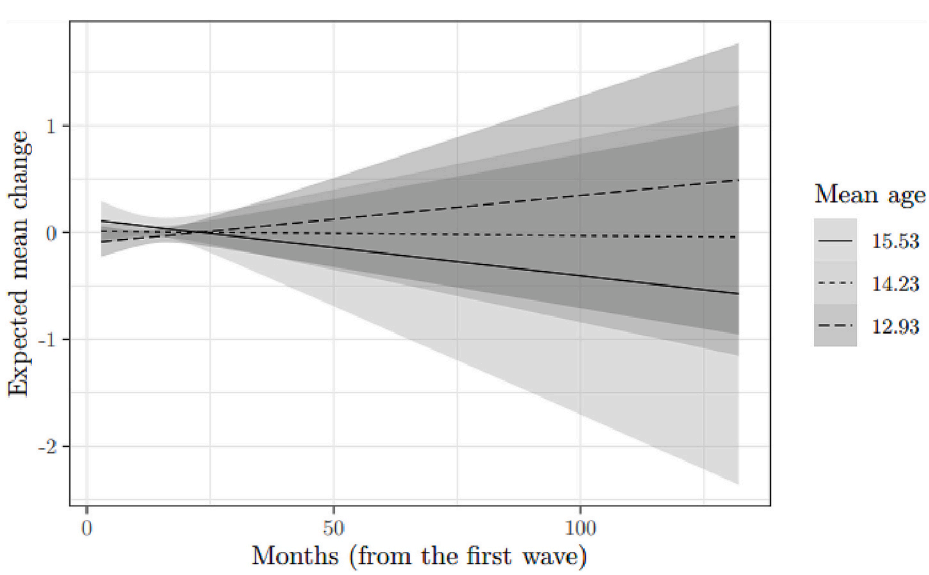

Fig. 4. Interaction between months passed from the first wave and mean age at the first wave of data collection (model M004, Study 2).

difficulties to make conclusive statements about the development of NSSI behavior over time, our results in community samples of adolescents seems to indicate a curve in the trend of NSSI frequency across development, with an initial increase, a peak and a decline, the further people get forward in adolescence.

Following the model of the Public Health Prevention Framework (Springer and Phillips, 2007) the results we found can be linked to different strategies of preventive interventions (i.e., universal, selective and indicated actions) in the community sample. Schools represent the reference context for prevention, and it is recommendable to shape the interventions according to the school level, especially for school most at risk. Specifically, universal prevention should begin in early adolescence (e.g., 12–14 years of age), during the years of middle school, to prevent the onset of this behavior. Universal prevention strategies should raise awareness of the consequences and risk factors of this behavior and should include individualized training programs that promote and reinforce skills that are key mechanisms in NSSI behavior (e.g., emotional problem-solving, emotion regulation, interpersonal and problem-solving skills). Moreover, universal prevention actions such as sensibilization to NSSI should be aimed not only at students, but also at teachers and families. Indicated interventions could be particularly suitable for high school students, as this is the most critical period for NSSI development. It would be crucial to support the most vulnerable adolescents who engage in NSSI in order to prevent the increase in frequency of the behavior over time. This could be done in two ways. First, through intervention programs to reduce NSSI and behaviors. Second, promoting an individualized support network between schools and community services could be helpful in improving the intake and preventing the behavior from becoming chronic, leading to further serious consequences. The school psychologist, along with the school personnel, could have a key role in these actions.

4.1. Limitations

Several limitations should be considered when interpreting the present findings. Specifically, we can summarize the limits in three different macro categories: the first refers to methodological aspects, the second to the design of the studies, and the third to the availability of data.

As for the methodological aspects, the studies included in our systematic review and meta-analysis used a high heterogeneity methodology to assess the prevalence of NSSI (e.g., different reference times of the measurement), making it difficult to capture longitudinal trends in behavior. Future studies should define and measure the construct consistently across different studies to produce reliable and comparable results across developmental period and across countries. Additionally, it would be preferable to use a scale (i.e., a checklist) that measures the different types of self-injury, clearly defining each type of construct to examine. A scale rather than a series of yes or no questions would allow one to detect the frequency of the behavior to examine the extension and the severity of the phenomenon. Among the measures that could be used to assess the frequency of the NSSI behavior, it is important to refer to scales with good psychometric properties that are already widely used (e.g., *Non-Suicidal Self-Injury Scale*, Prinstein, 2008; *Deliberate Self-Harm Inventory*, Gratz, 2001; *The Inventory of Statements About Self-Injury*, Klonsky and Glenn, 2009).

Regarding the design of the studies, the studies included not homogeneous cohorts, some studies considered very wide age ranges and others very limited ranges. Besides, few longitudinal studies covered a long period of assessment with multiple time points. Thus, future studies would define age ranges that are not too broad, to capture all the different stages of the development of self-injury behavior. Moreover, they should analyze the changes in self-injury behavior, using a longitudinal research design over several and constant time points of assessment to cover a large period and to capture the development of the behavior.

As concerns, the third category, many studies did not report data about the variables of interest (i.e., descriptives data). This lack of information was a major limitation of the meta-analytic analysis, which led to a large reduction in the number of studies included (i.e., Study 1: 12 included out of 16; Study 2: 11 included out of 25). Although the authors were repeatedly contacted, just few of them provided descriptive data. Thus, this affected the reliability and validity of the results. Besides, the lack of availability of data did not allow us to use more comprehensive models and fully trust the results of the meta-analyses, especially for the second study on the frequency of NSSI. Notably, we used the mean age of participants at baseline to operationalize the development period, as there was not enough data to estimate it at all time points and the rates of response to our request for additional data were very low. The limited number of studies included did not allow us to explore other moderating variables, such as the country of data collection. More attention should be devoted to the possible influence of cultural and/or contextual factors, because of the high variability of self-injury across countries and ethnicity. Last but not least, we have not considered gender as a possible moderator, because we have no data on the proportion and mean age of students that engaged in NSSI in the different waves considered separately for males and females (i.e., we have not received data from the majority of the authors and, to avoid further reduction of the sample size of studies in the meta-analysis, this variable was not included as a moderator).

5. Conclusion

The present study represents the first meta-analysis that tries to shed light on the longitudinal development of NSSI behavior from early adolescence to young adulthood, using a systematic review and a Bayesian meta-analysis. Specifically, it has the added value of having considered both the occurrence and the frequency of NSSI behavior across development. Although it needs further research, the current meta-analysis provides important methodological and practical implications. First, the present study contributes to future research, providing important suggestions to extend research in this field using a more homogeneous methodology. Second, this study highlights how the frequency of NSSI seems to increase for younger adolescents (i.e., 12.93 years at baseline), representing a crucial period for the development of NSSI behavior. Thus, findings suggest the importance to promote, at the school level, both universal preventive strategies as well as indicated actions according to the school level (i.e., middle, and high school).

Funding

We did not receive financial support to conduct this research.

CRediT authorship contribution statement

Conceptualization: LD, BEP, and EM; Methodology: LD, MP, and BEP; Data curation: LD, BR, and PW; Software: MP; Formal Analysis: LD and MP; Investigation: BR and PW; Writing - Original draft preparation: LD; Supervision: BEP and EM; Writing - Review & Editing: BEP, BR, and EM. All authors reviewed the results and approved the final version of the manuscript.

Declaration of competing interest

The authors declare that there are no conflicts of interest.

Data availability

The data that support the findings of this study are available on request from the corresponding author.

Acknowledgments

The authors thank T.S, E.I, and E.C for their support in data collection.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2023.07.091.

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