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Dog companionship and cortisol levels in youth. A systematic review and meta-analysis

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ABSTRACT

Objective: Traditional and non-traditional strategies have been employed to improve youth health. Dog-assisted interventions have been proposed as a novel strategy to regulate stress and its consequences across all age groups. This systematic review and multilevel meta-analysis assessed the influence of dog-assisted interventions on cortisol levels in youth and explored potential moderators.

Sources: We conducted a comprehensive systematic search across multiple databases, including PubMed, Scopus, Web of Science, Cochrane Library, and ScienceDirect, up to June 17, 2024, to evaluate the impact of dog-assisted interventions on youth cortisol levels. Two reviewers independently extracted and verified data from eligible randomized clinical trials, with a third reviewer ensuring accuracy. Cochrane's RoB 2.0 tool was used to assess the risk of bias. Heterogeneity was analyzed using Q and I^2 statistics. A random-effects model was employed to calculate effect sizes (ES) using R software.

Summary of the findings: Significant cortisol reductions were found for interventions lasting >15 min (ES: 0.65; $p = .038$), with a non-significant trend towards reduced cortisol in non-medical settings (ES: 0.46; $p = .070$). No

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significant effects were observed for shorter interventions, different control groups, or age-specific analyses. Meta-regression analysis revealed significant differences, showing better outcomes with longer intervention times and fewer female participants.
Conclusion: Dog-assisted interventions lasting >15 min seem to be a promising and non-traditional strategy for regulating cortisol levels in children and adolescents in stressful situations. This study outlines gaps in the research and future directions.

1. Introduction

Cortisol, a widely recognized catabolic steroid hormone, is released from the adrenal cortex upon activation of the hypothalamic-pituitary-adrenal axis and serves as a standard physiological reaction to diverse stressors (Vicković et al., 2023). As such, events such as hospitalization, surgery, a complex school environment, and personal circumstances can lead to significant short- and long-term stress and mental health consequences in children, adolescents, and their families, resulting in higher cortisol levels (Vicković et al., 2023; Aguilar Cordero et al., 2014; Calcaterra et al., 2015; Zajkowska et al., 2022; Carlsson et al., 2014). Consequently, various non-pharmacological alternatives have been explored to mitigate cortisol levels during childhood and adolescence, a critical stage of development where pets play a pivotal role in promoting overall well-being, which can extend into adulthood (Grigoropoulou et al., 2023; Cañadas et al., 2021; Koyasu et al., 2023).

The psychological and biological effects of human-animal interactions have been extensively studied, with research highlighting their influence on physiological parameters such as blood pressure, heart rate, and electrodermal activity. Among these, short-term cortisol level measurements have been the most frequently analyzed biomarker, particularly in studies involving children with ASD who cohabit with dogs (Gee et al., 2021). Human-animal interactions have shown promising results in reducing stress and anxiety across various populations, particularly in children and adolescents (Kerns et al., 2018; Ng et al., 2014; Crossman et al., 2020). These interactions encompass a range of activities, including animal-assisted interventions, therapy, education, and activities (López Cepero, 2020). In this context, dogs are recognized as valuable sources of emotional support, especially in stressful situations where parental presence is lacking, helping to alleviate anxiety and loneliness in children (Vagnoli et al., 2015). Notably, dog-assisted interventions have consistently demonstrated positive effects on human well-being, including stress reduction, improvements in mental health (Ng et al., 2014; Crossman et al., 2020; Parbery Clark et al., 2021) beyond medical settings (Barbayannis et al., 2022), and decreased activation of the sympathetic autonomic nervous system (Machová et al., 2019).

Dogs are a common part of health-related interventions with increased popularity, especially for children and adolescents (Santaniello et al., 2020), as the human-dog bond is acknowledged to significantly influence their development (Giraudet et al., 2022). This relationship can be partly explained by neurobiological mechanisms similar to those between parents and children, which activate the oxytocinergic system. This activation highlights the importance of social attachment over the mere presence of a dog in achieving benefits, particularly in youth, where developmental processes are highly sensitive to emotional bonds (Reilly et al., 2024). Furthermore, studies have shown that variations in specific hormones, such as cortisol and oxytocin, in both owners and dogs can influence how owners interact with their dogs (Petersson et al., 2017).

Previous studies have primarily focused on animal-assisted interventions for hospitalized children undergoing cancer treatment (Feng et al., 2021), as well as in those with behavioral disorders (Hüsgen et al., 2022) and autism spectrum disorder (Rehn et al., 2023). Despite the existing literature, significant gaps remain regarding the effects of dog-assisted interventions, highlighting the need for further investigation. While some randomized controlled trials have reported reductions in cortisol levels (Vagnoli et al., 2015; Beetz et al., 2011; Meints et al., 2022; Gussgard et al., 2023; Krause-et al., 2018; Beetz et al., 2012; Jennings et al., 2021), others have found no significant differences (Calcaterra et al., 2015; Crossman et al., 2020; Kertes et al., 2017; Krause-et al., 2015; Branson et al., 2017). This heterogeneity limits the reliability of the findings and may arise from methodological variations, such as interaction duration and intervention settings (Faucher et al., 2023).

Therefore, this study could contribute significantly to a clearer understanding of the benefits and potential limitations of dog-assisted interventions for children and adolescents. The translational evidence derived from our findings could inform policy and practice in key areas such as education, health care, mental health, and appropriate protocols, facilitating the effective integration of animal-assisted interventions for this demographic (Meixner and Kotrschal, 2022). Thus, this systematic review and meta-analysis aimed to evaluate the influence of dog-assisted interventions on cortisol levels in children and adolescents while exploring the session duration, control group conditions, age group, and intervention context as potential moderators. The analysis encompassed both short- and long-term changes in cortisol levels following the intervention.

2. Materials and methods

This study was registered in the International Prospective Register of Systematic Reviews (PROSPERO registration number: CRD42024534982). We followed the protocol in accordance with the PRISMA guidelines for systematic reviews and meta-analyses (Page et al., 2021). Studies were considered eligible for inclusion if they met the following "PICOS" criteria (P: participants; I: interventions; C: comparisons; O: outcomes; S: study design) (Liberati et al., 2009). (a) Participants: Children and adolescents (<18 years old); (b) Intervention: Interventional studies including dogs as part of the experimental protocol; (c) Comparator: Comparative group without dog intervention (control group); (d) Outcome: Cortisol levels (blood, serum, or salivary); and (e) Study design: Randomized controlled trials.

2.1. Search strategy

A comprehensive literature search was conducted across PubMed, ScienceDirect, Cochrane Library, Scopus, and Web of Science databases to gather reliable evidence from human clinical trials. The search had no initial date restriction and included studies published up to June 17, 2024. Search terms encompassed cortisol, dog, relative concepts, and their combinations. The search strategy was tailored to each database's specific features. Further details on the search methodology are provided in the Supplementary Materials (Table S1). Fig. 1 outlines the stepwise article selection process following PRISMA guidelines.

2.2. Inclusion criteria

The following inclusion criteria were applied: (1) studies conducted in humans (children and/or adolescents); (2) studies written in English; (3) studies involving dogs in the interventional protocol (trained or not trained); (4) studies with pre- and post-cortisol measurements, or mean change and standard deviation (SD) difference; and (5) randomized controlled trials.

2.3. Exclusion criteria

The following exclusion criteria were applied: (1) studies where the control group involved any form of contact or interaction with animals; (2) studies including robot dogs as part of the intervention; (3) studies including children or adolescents, but the cortisol levels cannot be separated from the adult's outcome; and (4) studies that did not appropriately report data for computing effect sizes (after reaching the corresponding author for information) or when they were not feasibly calculated.

2.4. Study selection

The selection of studies adhered to the PICOS criteria outlined in the Methods section and was conducted by two evaluators (H.P.-J and J.E.-P). First, both evaluators independently searched the literature and compiled the findings into separate folders using the same searching strategy and terms. Second, duplicates extracted from all databases were removed using reference management software (Zotero). Third, titles and abstracts of the remaining studies were screened independently by each evaluator, and those misaligned with the research objectives were excluded. When necessary, the authors were consulted to obtain additional information or specific data for inclusion in the analysis. Fourth, full-text versions of potentially eligible studies underwent a detailed evaluation. Fifth, studies that met the inclusion criteria and passed the prior steps were selected for final analysis. Additionally, Excel and Jamovi were used to calculate interrater reliability through Cohen's Kappa and the percentage of agreement between evaluators. Of the 44 eligible articles, discrepancies were identified in three cases. In such instances, a third author (C.C.-M) resolved the disagreements. As a result, twelve articles were included in the systematic review, and ten were incorporated into the meta-analysis.

2.5. Data extraction

Two evaluators (HP-J and JPE-P) independently collected the data. The extracted information was presented chronologically in ascending order and included: (1) the characteristics of the article (e.g., first author, year of publication, and location); (2) the objective of the study; (3) participant characteristics (e.g., n, age, health status, and sex); (4) duration of the intervention and/or sessions per week and/or a brief protocol summary; (5) time employed with dog interaction; and (6) blood, serum, or salivary cortisol levels as outcomes. In cases where pertinent information (e.g., sample details, means, or SD) was not provided in the primary studies or supplementary materials, we contacted the corresponding authors to request the missing data. Of the two authors contacted, only one responded; however, neither provided sufficient data for the meta-analysis, though their findings were included in

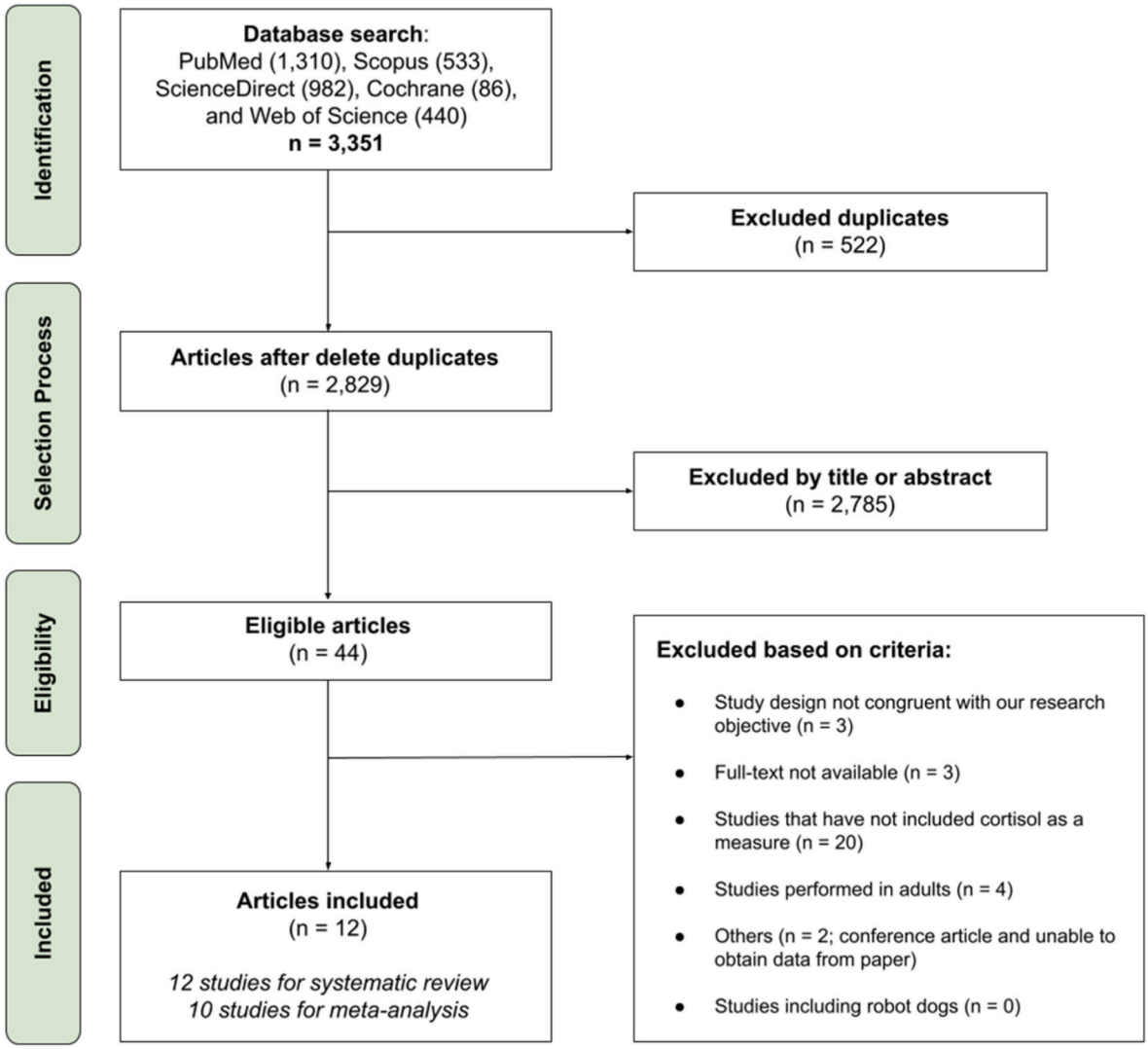

Fig. 1. The flowchart shows the process used to select studies.

the systematic review.

2.6. Assessment of risk of bias for individual studies

The Cochrane Risk of Bias tool, developed by the Cochrane Collaboration (Higgins et al., 2011), was used to evaluate the methodological risk of bias for all studies included in this systematic review and meta-analysis. Further, specific versions designed for crossover and parallel randomized controlled trials were used. Each criterion was evaluated and categorized as "low risk," "some concerns," or "high risk" of bias according to five pre-established domains: randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of the reported result (Higgins et al., 2011). Quality assessment was conducted independently by two researchers, HP-J and JPE-P, to ensure a rigorous evaluation process for the included studies. Conflicts in assessments were thoroughly discussed to ensure consensus. A third author resolved any disagreements (CC-M).

2.7. Statistical analysis

We conducted this three-level meta-analysis using the "metafor" package in R (version 4.2–0 R Project for Statistical Computing) utilizing the rma.mv function (R:The R Project for Statistical Computing; Viechtbauer, 2010). A random-effects model was applied using Hedges' g effect size (Hedges, 1981), allowing us to compute and interpret each possible effect size as follows: trivial (0.0–0.19), small (0.20–0.49), medium (0.50–0.79), and large (≥0.80) (Cohen, 1992). Furthermore, effect sizes and 95% confidence intervals were calculated based on a random-effects model owing to the high heterogeneity. Building on this notion, we conducted a multilevel analysis that carefully considered the unique characteristics of the sample and the study's diverse methodologies, addressing within-study dependence related to effect size. Negative effect size values indicated a favorable outcome for the intervention group, reflecting a reduction in cortisol levels.

Egger's test and funnel plot analysis were used to assess publication bias (Egger et al., 1997). Statistics regarding Q ($p < .10$ suggests significant heterogeneity) and I^2 were used to assess heterogeneity among the studies. According to Higgins (Higgins et al., 2003), I^2 values were categorized as follows: values less than 25% were considered to represent small amounts of heterogeneity, values between 25% and 50% were categorized as medium amounts, and values exceeding 50% were classified as large amounts of heterogeneity.

Additionally, a subgroup analysis was conducted to explore the potential influence of session duration (≤15 min or >15 min), interventional context (medical and non-medical), age group (≤10 years = children and >10 years = adolescents), and the condition of the control groups (relaxing, no dog, or human support) as moderator factors. For better understanding, a medical intervention was defined as any activity involving the application of traditional medical protocols, such as the use of anesthesia, blood tests, or dental procedures, among others. In contrast, non-medical interventions refer to activities conducted outside a formal medical setting, such as those implemented in schools, foster homes, and similar contexts. A meta-regression analysis was also performed to assess the association between session duration in minutes, the proportion of female participants, and age effects on cortisol levels.

When the SD of the mean difference was unavailable, it was calculated as follows: SD_{change} = square root $[(SD^2_{baseline} + SD^2_{final}) - (2 \times Corr \times SD_{baseline} \times SD_{final})]$. If a pre-post correlation coefficient (Corr) was not available, we imputed using a weighted Corr derived from studies with available data by applying a conservative value of 0.5 (Follmann et al., 1992). A sensitivity analysis was performed using a Corr of 0.7 to complement our statistical and robustness analysis. Additionally, a sensitivity analysis was performed incorporating a random-effects model for multilevel analysis, focusing exclusively on acute protocols and their respective meta-regressions. To further substantiate our findings, we present these results in Supplementary Materials (Figs. S1–S5). Furthermore, the inter-rater reliability was evaluated through Cohen's Kappa, with values interpreted as follows: scores ≤0 indicating no agreement, 0.01–0.20 as none to slight agreement, 0.21–0.40 as fair agreement, 0.41–0.60 as moderate agreement, 0.61–0.80 as substantial agreement, and 0.81–1.00 as almost perfect agreement between reviewers (McHugh, 2012).

3. Results

Fig. 1 shows a flowchart of the search strategy for the selected articles. The Kappa score for selection between H.P.-J and J.E.-P was 0.83, with an overall agreement rate of 93.2% (3 out of 44 articles) before arbitration by a third independent researcher. A total of 3351 references were preliminarily identified from the database search, of which 2785 were excluded based on the title and/or abstract information, leaving 44 studies for review. After a full-text review of potentially eligible articles (excluded studies are available in the Supplementary Materials, Table S2), 12 references were included in this review after meeting all eligibility criteria. Of the 12 studies reviewed, only 10 were included in the meta-analysis because of insufficient pre- or post-intervention data reporting and/or inability to obtain a response from the corresponding authors (Vagnoli et al., 2015; Branson et al., 2017).

Regarding the two partially excluded articles, Branson et al. (2017) assessed the effectiveness of animal-assisted activities on biobehavioral stress responses in hospitalized children. While the authors observed certain tendencies, no significant differences were found between groups. In contrast, Vagnoli et al. (2015) investigated the effectiveness of animal-assisted interventions in reducing children's pain and distress during a standard blood collection procedure. Their results indicated lower cortisol levels in the intervention group compared to the control group.

3.1. Study characteristics

This review covered data from 715 participants (309 in the experimental group and 406 in the control group; 44.76% female) with sample sizes ranging from 16 to 101. In some studies, control group participants received only standard care or traditional protocols (Calcaterra et al., 2015; Krause-et al., 2018; Jennings et al., 2021; Krause-et al., 2015), while in others, they were provided with relaxing materials or social support from family or friends (Crossman et al., 2020; Vagnoli et al., 2015; Beetz et al., 2011, 2012; Meints et al., 2022; Gussgard et al., 2023; Kertes et al., 2017; Branson et al., 2017).

All studies reported the participants' sex, with 41.7% (5/12) including a higher proportion of girls than boys, while two studies included only boys (Beetz et al., 2011, 2012). Participants ages, reported in all studies, ranged from 3 to 17 years (mean = 9.98). The samples were drawn from six countries: six studies were conducted in the United States of America (Crossman et al., 2020; Krause-et al., 2018; Jennings et al., 2021; Kertes et al., 2017; Krause-et al., 2015; Branson et al., 2017), two in Italy (Calcaterra et al., 2015; Vagnoli et al., 2015), two combining Germany and Austria (Beetz et al., 2011, 2012), one in the United Kingdom (Meints et al., 2022), and one in Norway (Gussgard et al., 2023). Almost all studies corresponded to acute interventions, with only one study (Meints et al., 2022) performed using a chronic protocol (four weeks). According to the publication data, the studies were published between 2011 and 2023. Table 1 provides a comprehensive summary of the studies included in this review.

3.2. Characteristics of the sample and protocols

The sample characteristics varied significantly across studies. Three studies focused on hospitalized children: one measured cortisol levels before and after surgery and following interactions with dogs (Calcaterra et al., 2015); another study examined children in intensive care units (Jennings et al., 2021), and a third study assessed children in a

Table 1
Characteristics of included studies.

Author, Year, Location	Objective	Sample Characteristics n, age, health status, sex	Protocol, Time Dog Interaction, and Context	Cortisol Outcomes
Beetz et al. (2011) Germany/Austria (Beetz et al., 2011)	Investigated whether boys with insecure/disorganized attachment would profit more from the presence of a dog compared to others' support conditions during a socially stressful situation	n: 31 participants (11 EG - 20 CG) Age: 7–12 years old (mean: 9.6 ± 1.14) HS: attachment disorders children Sex: boys (31)	Acute intervention AAI: a total of 25 min divided into one session of 5 min and two sessions of 10 min each Context: Non-medical Time-IC: 2 min	↓: Salivary cortisol was significantly lower in the real dog condition, suggesting that physical contact with dogs performs a critical role in stress reduction.
Beetz et al. (2012) Germany/Austria (Beetz et al., 2012)	Examine whether children with attachment will experience a greater stress-alleviating effect from the presence of a friendly dog than of a friendly person when exposed to a social stressor	n: 47 participants (24 EG - 23 CG) Age: 7–11 years old (mean: 9.25 ± 1.12) HS: insecure/avoidant disorganized attachment children Sex: boys (47)	Acute intervention AAE: a total of 25 min divided into one session of 5 min and two sessions of 10 min each Context: Non-medical Time-IC: 2 min	↓: Cortisol levels dropped significantly faster and to lower levels after a stressor when supported by a real dog in comparison with other support conditions (experimental group vs. control group, respectively)
Calcaterra et al. (2015) Italy (Calcaterra et al., 2015)	Understand the impact of an animal-assisted therapy program on children's response to stress and pain in the immediate post-surgical period	n: 40 participants (20 in each group) Age: 3–17 years old (mean: 7.97 ± 3.17) HS: immunocompetent children Sex: boys (32) and girls (8)	Acute intervention AAT: 20 min session Context: Medical Time-IC: immediately	↔: Salivary cortisol levels did not show different behaviors over time between groups
Vagnoli et al. (2015) Italy (Vagnoli et al., 2015)	Investigate the effectiveness of animal-assisted intervention for reducing children's pain and distress before, during, and after standard blood collection procedure	n: 50 participants (25 in each group) Age: 4–11 years old (mean: 7.24 ± 2.2) HS: healthy children Sex: boys (24) and girls (26)	Acute intervention AAI: 15 min session Context: Medical Time-IC: not detailed	↓: Cortisol levels were lower in the interventional group compared with the control condition
Krause-Parello and Gulick (2015) United States of America (Krause- et al., 2015)	Investigate changes in salivary cortisol, IgA, BP, and HR as a result of the forensic interview phenomenon (e.g., disclosure of sexual abuse by the child) in children interviewed for alleged child sexual abuse allegation	n: 42 participants (19 EG - 23 CG) Age: 5–14 years old (mean: 8.92 ± 2.34) HS: sexual abuse allegations in children Sex: boys (2) and girls (40)	Acute intervention AAI: No time described Context: Medical *Duration related to the forensic interview Time-IC: immediately	↔: There were no significant differences in cortisol levels for the intervention group
Branson et al. (2017) United States of America (Branson et al., 2017)	Assessed the effectiveness of animal-assisted activities (AAA) on biobehavioral stress responses (anxiety, positive and negative affect, and salivary cortisol and C-reactive protein (CRP) levels) in hospitalized children	n: 48 participants (24 in each group) Age: 7–17 years old (mean: 13.2 ± 2.8) HS: hospitalized children Sex: boys (24) and girls (24)	Acute intervention AAA: 10 min session Context: Medical Time-IC: immediately	↔: Although increases in positive affect and decreases in negative affect were larger in the AAA condition, pre- and post-intervention differences between the AAA and control conditions were not significant
Kertes et al. (2017) United States of America (Kertes et al., 2017)	Tested whether pet dogs have stress-buffering effects for children during a validated laboratory-based protocol, the Trier Social Stress Test for Children	n: 101 participants (34 EG - 67 CG) Age: 7–12 years old (mean: 10.2 ± 1.31) HS: healthy children Sex: boys (51) and girls (50)	Acute intervention FD: 10 min Context: Non-medical Time-IC: 25 min	↔: Dog presence significantly buffered the perceived stress response in comparison to children in the alone condition, however, no main condition effect was observed for cortisol levels
Krause-Parello et al. (2018) United States of America (Krause- et al., 2018)	Investigate the effects of service-trained facility dogs on stress levels using biomarkers	n: 51 participants (29 EG - 22 CG) Age: 4–16 years old (mean: 9.10 ± 3.46) HS: sexual abuse allegations in children Sex: boys (22) and girls (29)	Acute intervention AAI: No time described Context: Medical *Duration related to the forensic interview Time-IC: immediately	↓: Significantly non-monotone changes in cortisol levels were found for the AAI condition, and this was based on the frequency of abuse
Crossman et a. (2020) United States of America (Crossman et al., 2020)	Explored the role of children's ownership of, experience with, and feelings and behavior toward pets in their responses to the interactions	n: 78 participants (26 EG - 52 CG) Age: 10–13 years old (mean: 12.01 ± 1.13) HS: healthy children Sex: boys (35) and girls (43)	Acute intervention AAA: 15 min Context: Non-medical Time-IC: immediately	↔: No effect of the interactions on salivary cortisol was detected
Jennings et al. (2021) United States of America (Jennings et al., 2021)	Determine the effects of animal-assisted interactions on activity and stress response in pediatric acute care settings	n: 80 participants (44 EG - 33 CG) Age: 2–19 years old (mean: 11.78 ± 4.50) HS: children in acute care settings	Acute intervention AAI: 5–10 min Context: Medical Time-IC: 60 min	↓: In the context of pediatric inpatient acute care hospital settings, the effects of AAI decreased salivary cortisol

(*continued on next page*)

Table 1 (*continued*)

Author, Year, Location	Objective	Sample Characteristics n, age, health status, sex	Protocol, Time Dog Interaction, and Context	Cortisol Outcomes
		Sex: boys (39) and girls (41)		
Meints et al. (2022) United Kingdom (Meints et al., 2022)	Investigate dog-assisted interventions as a mediator of stress in school children with and without special educational needs over the school term	Study 1 = Mainstream school n: 90 participants (30 EG - 60 CG) Age: 8.2–10.1 years old (mean: 8.9 ± 0.39) HS: healthy children Sex: boys (43) and girls (47) Study 2 = SEN school n: 44 participants (15 EG - 29 CG) Age: 8.3–11.4 years old (mean: 9.8 ± 0.71) HS: ASD, ADHD, DS, OT, UD children Sex: boys (38) and girls (6)	Chronic intervention AAI: 4/week x 20 min each Context: Non-medical Time-IC: 25 min	↓: Dog interventions lead to significantly lower stress in children compared to their peers in relaxation or no treatment control condition ↓: Children with SEN showed significantly decreased cortisol levels after dog group interventions. No changes in the control condition
Gussgard et al. (2023) Norway (Gussgard et al., 2023)	Evaluate whether the presence of a certified therapy dog specially trained for working in a dental setting may facilitate dental care of anxious pediatric patients	n: 16 participants (8 in each group) Age: 6–12 years old (mean: 8.5 ± NR) HS: healthy children Sex: boys (10) and girls (6)	Acute intervention AAT: No time described Context: Medical *Duration depending on dental procedure/ examination Time-IC: not detailed	↓: The salivary cortisol level reduction during the clinical examination on the first visit decreased by 30% (AAT) and 29% during the second visit

Abbreviations: AAA: animal-assisted activities; AAE: animal-assisted education; AAI: animal-assisted interventions; AAT: animal-assisted therapy dog; ADHD: Attention Deficit Hyperactivity Disorder; ASD: Autism Spectrum Disorder; CG: control group; DS: Down Syndrome; EG: experimental group; FD: family dog; HS: health status; NR: non-reported; OSBD: Amended Observation Scale of Behavioral Distress; OT: other learning difficulties (e.g., profound and/or multiple learning difficulties, global developmental delay); SEN: special education needs; Time-IC, time between last intervention and cortisol measurement; UD: unknown diagnosis. * Parentheses correspond to samples used in each study.

hospital with an existing animal-assisted intervention program (Branson et al., 2017).

Among the remaining studies, one involved a blood collection procedure (Vagnoli et al., 2015), another included children with a history of avoiding dental treatment due to dental fear (Gussgard et al., 2023), and two included sexually abused children and adolescents (Krause-et al., 2018; Krause-et al., 2015). Two studies were conducted using well-established stress tests/tasks (Crossman et al., 2020; Kertes et al., 2017). One study included children with insecure attachment (Beetz et al., 2012), and the last two studies included school contexts comparing results between mainstream and special education needs schoolchildren (Meints et al., 2022) or children with learning/behavioral problems (Beetz et al., 2011).

Almost all studies incorporated trained animal-assisted therapy into their experimental protocol. The exception was a study by Kertes et al. (2017), which involved a dog belonging to the child's family. Despite this, in all conditions, the interaction strategy with dogs was defined according to the children's comfort, choosing between direct contact and closeness to the dog.

According to the protocol duration, two studies implemented a total intervention period of 25 min, distributed across three distinct intervals. Interaction with the social supporter occurred with the initial segment lasting 5 min, followed by two subsequent intervals, each spanning 10 min between tests (Beetz et al., 2011, 2012). Two studies performed a 20-min intervention (Calcaterra et al., 2015; Meints et al., 2022), two studies performed a 15-min intervention (Crossman et al., 2020; Vagnoli et al., 2015), three studies used a 10-min or less interaction duration (Jennings et al., 2021; Kertes et al., 2017; Branson et al., 2017), and the remaining three studies did not provide the specific duration of the intervention (Gussgard et al., 2023; Krause-et al., 2018; Krause-et al., 2015). In these three studies, the duration of the interaction depended on the dental procedure or forensic interview process. The average duration of the intervention across the evidence included was approximately 16.6 min.

Regarding cortisol measurement, all studies used salivary cortisol evaluation, except one that employed blood cortisol analysis (Vagnoli et al., 2015). Overall, seven studies (58.3% of those included) reported significant reductions in cortisol levels following dog interaction, mostly acute intervention (Vagnoli et al., 2015; Beetz et al., 2011; Meints et al., 2022; Gussgard et al., 2023; Krause-et al., 2018; Beetz et al., 2012; Jennings et al., 2021), while the remaining five studies did not observe significant effects (Calcaterra et al., 2015; Crossman et al., 2020; Kertes et al., 2017; Krause-et al., 2015; Branson et al., 2017).

3.3. Dog-assisted interventions effects on cortisol levels

Our primary outcome was to assess the influence of dog-assisted interventions on cortisol levels among children and adolescents. Eighteen effect sizes were analyzed, revealing no significant overall effect on cortisol levels between the groups (ES = −0.20; 95%CI: 0.58 to 0.17; $p < .286$). Moreover, two sensitivity analyses were conducted. The first analysis included only studies that employed acute protocols, whereas the second incorporated a correlation coefficient of 0.7. In both instances, the results were consistent with the initial global analysis of cortisol levels. Fig. 2 shows the overall forest plot analysis, detailing the effect size of each study along with the mean change and SD difference.

3.4. Subgroups and meta-regression analysis

According to the secondary results obtained from the moderators, four categorical analyses were examined: protocol duration, intervention context, control group condition, and age group, while three continuous moderators were analyzed, corresponding to the time intervention, female proportion, and age. Concerning the former, only protocols lasting more than 15 min displayed a significant reduction in cortisol levels (ES: 0.65; 95%CI; $p = .038$), although no significant difference was observed between the time protocols employed. Further, a sensitivity analysis was performed by excluding the only chronic

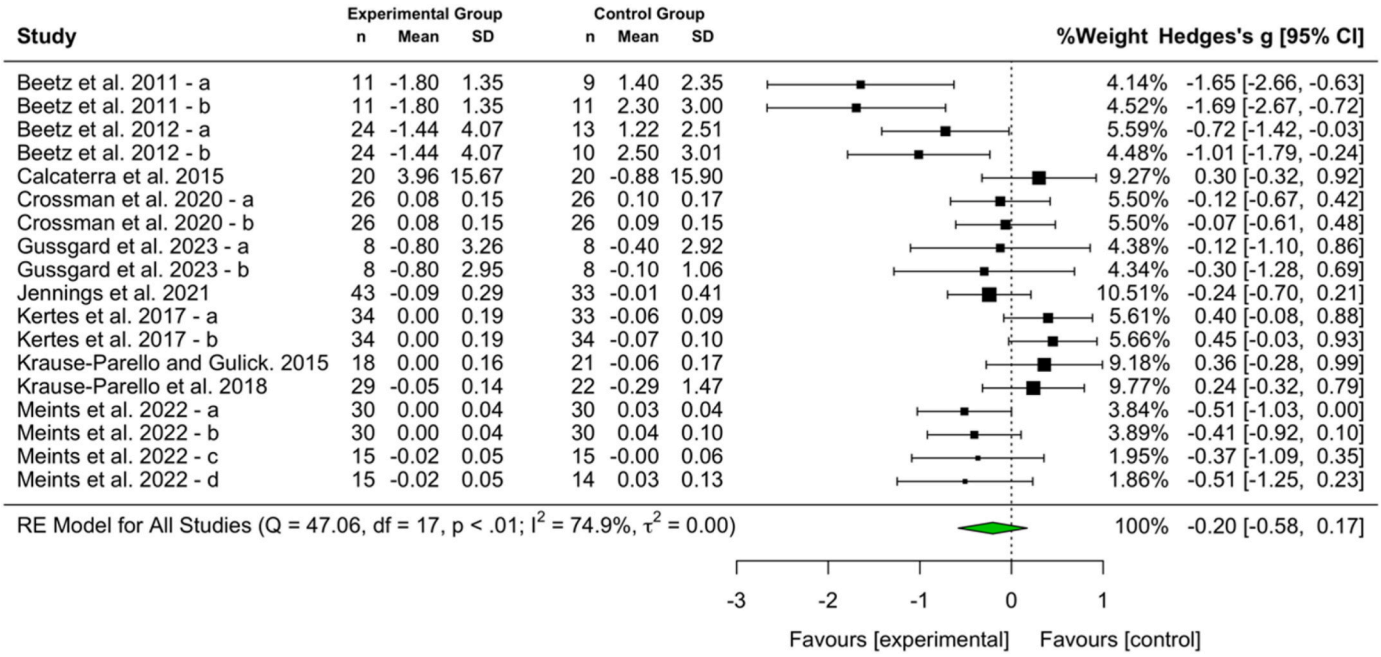

Fig. 2. The forest plot illustrates the influence of the human-dog interaction among children and adolescents on cortisol levels compared to the control group.
Abbreviation. n, sample; mean, mean difference; SD, standard deviation difference; $p < .05$ was used as a significant. When the same study reported more than one effect size, a letter was included in the study column for differentiation.

intervention study, reflecting no variation in the significance of the results (Fig. S6). Concerning the other categorical moderators, no significant effect was observed for the interventional, control, and age groups.

On the other hand, considering the continuous moderators, the lower the proportion of girls, the greater the effect size (lower cortisol levels). Table 2 summarizes the results of these moderator analyses.

Additionally, our meta-regression analysis examined the relationship between session duration, proportion of female participants (Fig. 3), and age (Supplementary Materials Fig. S7). According to the former, session duration described a negative association, indicating that longer interventions were associated with more favorable effect sizes in reducing cortisol levels (left panel). Regarding the latter, a significant positive relationship was found between the proportion of female participants and the effect size, suggesting that a higher proportion of female participants was associated with larger, less favorable effect sizes (right panel). Concerning age, the meta-regression revealed no significant association with cortisol levels.

3.5. Risk of bias in the included articles

All the studies included in this analysis were randomized controlled trials, with only one utilizing a crossover design (Gussgard et al., 2023). Regarding risk of bias assessment, 83.3% of the studies (10 out of 12) were rated as having some concerns; one study was classified as high risk, and one was rated as low risk.

The higher risk of bias corresponds to the "selection of the reported result" domain, in which 10 of the 12 studies showed some concerns. In all these studies, the risk corresponded to the difficulty in accessing the previous protocol and analyzing its agreement with the final process of the intervention. In the case of the "randomization process" domain, only one study reported a high risk due to classification as an open-label controlled study condition. In contrast, two studies reported some concerns because they did not explicitly declare a randomization process in their protocol. No bias was observed in the remaining three domains. More details can be found in Supplementary Material Fig. S8.

3.6. Publication bias and heterogeneity

We conducted a multilevel meta-analysis owing to the dependency of effect sizes among some studies using a random-effects model. The heterogeneity analysis suggested a large amount of variability among studies according to Q (47.06, $p < .01$) and I^2 statistics (74.86%). To further enrich our study, the restricted variance components were evaluated, yielding AIC = 25.76 and BIC = 28.26 values, facilitating a thorough examination of the data. Egger's test analysis was performed to complement our analysis. Based on the results (k = 18, −8.119, CI -17.299 to 1.061, $p = .083$), funnel plot asymmetry was observed, indicating potential publication bias among the studies. More details can be found in the Supplementary Materials (Figs. S9 and S10).

4. Discussion

This systematic review and three-level meta-analysis evaluated the impact of dog-assisted interventions on managing cortisol levels in children and adolescents with exploring potential moderators. Although no significant differences were found between groups, the analysis of session duration and female proportion as continuous moderator factors revealed a favorable effect of dog-assisted interventions on cortisol levels, particularly in protocols lasting more than 15 min and in studies involving a lower proportion of girls. Additionally, trend suggests that non-medical settings might be more effective in reducing cortisol levels compared to medical settings. These findings highlight the promising benefits of interactions with dogs for human health under certain conditions, highlighting the potential of dog-assisted interventions as a valuable intervention strategy for mitigating stress and promoting well-being in youth in protocols lasting more than 15 min and predominantly in groups considering a greater proportion of boys.

Cortisol plays a crucial role in biological processes, and maintaining normal levels is essential for health. McCarthy et al. (2009) and Branson et al. (2017) delineated salivary cortisol ranges in children as 0.301 to 0.119 μg/dL for ages 4–10 years and 0.021–0.883 μg/dL for ages 12–18 years, aligning with biological circadian rhythms. Consequently, when comparing baseline data with these normal ranges, it is possible that

Table 2
Results of moderator analysis.

Intervention moderators	No. of effect sizes	Estimate mean (95% CI)	P-value	Q statistic	Test of moderators
Time intervention				Q_{12} = 25.78; ***p* =.012**	$F_{1,12}$ = 2.18; p = .166
≤ 15 min	5	0.04 (−0.63 to 0.71)	0.914		
> 15 min	9	−0.65 (−1.25 to −0.04)	**.038**		
Context				Q_{16} = 42.95; ***p* < .001**	$F_{1,16}$ = 2.18; p = .159
Medical	6	0.08 (−0.44 to 0.61)	0.754		
Non-medical	12	−0.46 (−0.96 to 0.04)	0.070		
Control group				Q_{15} = 39.73; ***p* < .001**	$F_{2,15}$ = 0.28, p = .762
Relaxing	5	−0.24 (−0.71 to 0.24)	0.333		
No dog	8	−0.14 (−0.54 to 0.25)	0.479		
Human	5	−0.32 (−0.83 to 0.20)	0.225		
Age				Q_{16} = 38.24; ***p* =.001**	$F_{1,16}$ = 0.75; p = .400
Children (≤10 y)	13	−0.32 (−0.79 to 0.14)	0.175		
Adolescents (>10 y)	5	0.04 (−0.63 to 0.71)	0.914		

Abbreviation. y, years. The age categorization was based on the WHO classification.

some studies did not observe significant differences between the experimental and control groups because the baseline values were already within or near the normal range.

Consistent with the above, previous systematic reviews (Faucher et al., 2023; Teo et al., 2022) have explored the effectiveness of dog-assisted interventions in reducing cortisol levels, highlighting their potential impact on the human stress response. However, conclusive evidence regarding their superiority over other therapies or differences in effectiveness across contexts remains uncertain (Faucher et al., 2023).

From a medical context, our findings align with a previous meta-analysis (Feng et al., 2021), which also reported no significant difference between children in dog-assisted interventions and those in control groups. However, in the Feng et al. meta-analysis, only two studies directly measured cortisol levels in children, and their protocols lasted for 20 and 10 min (Calcaterra et al., 2015; Branson et al., 2017). Notably, our subgroup analysis suggested that interventions lasting more than 15 min are necessary to observe significant differences in cortisol levels.

In contrast, evidence in non-medical contexts remains limited (Meixner and Kotrschal, 2022); however, our findings indicate a trend in adolescents (ES: 0.46; p = .070) that could hold clinical significance, particularly given the small number of studies in this area. Supporting this, Meints et al. (2022) and Beetz et al., 2011, 2012 reported a favorable reduction in cortisol levels in educational settings. The discrepancy between medical and non-medical contexts may be attributed to differences in intervention protocols. The first study employed a 20-min protocol with sessions four times per week for four weeks, potentially creating a synergistic chronic effect. The latter two studies implemented a 25-min intervention protocol across three intervals during the stress tests, which may have further alleviated stress and improved outcomes (Gee et al., 2009).

Regarding the above, Clark et al. (2019) described neurochemical changes in catecholamines and cortisol during stressful situations. In particular, serum cortisol levels can increase within 15 min of acute stress (Vicković et al., 2023). Previous studies have shown that 20 min of petting a dog increases oxytocin levels (Teo et al., 2022; Clark et al., 2019), a hormone that strengthens the emotional bond between children and dogs while inhibiting cortisol synthesis (Beetz et al., 2012; Marshall Pescini, 2019). Therefore, variations in the intervention duration and frequency may help explain the neutral outcomes observed in some studies.

Notably, two studies with interventions lasting less than 20 min reported significant cortisol reduction (Vagnoli et al., 2015; Jennings et al., 2021). However, factors such as race, age, and sex can influence cortisol levels beyond the intervention itself (Calcaterra et al., 2015; Gandenberger et al., 2022). In this regard, our analysis revealed that a lower proportion of girls in the sample had more favorable effects on cortisol levels. The underlying reasons remain unclear but may be related to differences in sex hormones or attachment to dogs.

Importantly, the large heterogeneity of contexts complicates the accumulation of studies in the same category. Some studies have involved children and adolescents in special and sensitive contexts (Meints et al., 2022; Krause Parello et al., 2018; Krause Parello and

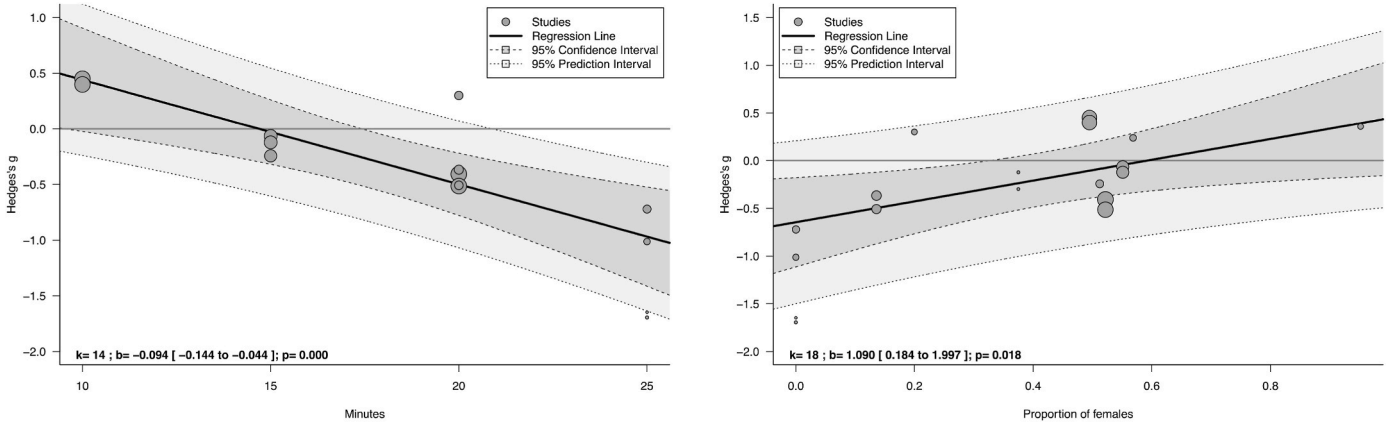

Fig. 3. Meta-regression results for session duration and proportion of females as a continuous moderator analysis.

Gulick, 2015), potentially affecting the experimental results. Nonetheless, more consistent outcomes may arise from more frequent sessions rather than relying solely on acute interventions (Clark et al., 2019). Equally important, some studies did not calculate or specify the appropriate power analysis required in their protocols, which could have led to non-significant results (6 out of 12). Another important topic is the quality of the evidence included. According to the ROB 2.0 assessment, most studies present issues in the quality evaluation. Future research should emphasize the importance of random allocation, account for how different contexts may influence outcomes, and carefully consider baseline values and the timing of measurements. This is particularly crucial given cortisol's chronobiological curve, which can significantly affect findings.

Finally, cortisol elevation under stress is a normal physiological response. While our analysis found a statistical difference only in interventions lasting more than 15 min, this suggests that dog-assisted interventions help regulate cortisol levels and prevent excessive increases in stressful situations. Given that family interactions provide similar benefits, dogs can be regarded as viable emotional support alternatives when family presence is not possible. Thus, our findings support the role of dog-assisted interventions in promoting well-being and managing cortisol levels in stressful situations for children and adolescents.

4.1. Strengths and limitations

Our study has several strengths that are important to mention. First, a three-level analysis better manages study heterogeneity and addresses within-study effect dependence, leading to more accurate outcome estimation. Second, by including effect modifiers, we were able to specify the potential influence of moderator factors despite the small number of studies in each category. Third, our review covered both medical and non-medical data interventions and provided a comprehensive comparison. Fourth, targeting cortisol to compare group differences, instead of subjective self-perceived stress evaluations, improved methodological quality and the robustness of our findings. Fifth, we performed a sensitivity analysis using a correlation coefficient of 0.7 and the acute intervention model to compare the significance of acute interventions against the overall analysis.

However, it is essential to acknowledge the limitations of the present study. Despite using a multilevel analytic approach, the limited number of randomized controlled trials in each context constrained a deeper analysis. The limitations of our findings were exacerbated by the small total sample size and the high methodological quality of only one study. We recommend exercising prudence in the interpretation of our results because there is considerable variability in the contexts and procedures for collecting cortisol samples across various studies.

4.2. Further considerations

To the best of our knowledge, this is the first study to compare the effectiveness of dog-assisted interventions in managing cortisol levels in youth across medical and non-medical contexts. Our findings may potentially improve this strategy under different conditions, warranting further investigation that distinguishes between types of dogs. While most studies focus on therapy or facility dogs (trained dogs used in specific contexts), less is known about the effects of companion or family dogs.

We recommend that future studies (a) establish a minimum acute interaction protocol lasting >15 min; (b) future research should explore chronic interventions to address the lack of evidence in the literature on this topic; (c) based on Kertes et al. (2017), it needs to be declared if the intervention was direct (e.g., petting the dog) or just in proximity to them; (d) explore contexts beyond medical conditions for a comprehensive understanding; and (e) explore if these changes in cortisol levels translate into an improvement in overall well-being. These adjustments are vital for improving the quality of the dog-assisted intervention research and ensuring robust data collection.

5. Conclusions

In summary, our meta-analysis highlights the potential health benefits of dog-assisted interventions as a non-traditional approach for mitigating cortisol elevation in children and adolescents in stressful contexts. Interventions lasting more than 15 min offer a promising strategy for stress management without reported adverse effects. Importantly, we must not overlook the mutual well-being aspect of dog assistance for the benefit of children and adolescents, recognizing the reciprocity of this well-being, as dogs are equal sentient beings. Moving forward, tailored dog-assisted intervention programs should consider various factors influencing effectiveness to optimize their impact on youth health outcomes, warranting further translational research and integration into healthcare and educational settings.

CRediT authorship contribution statement

Humberto Peña-Jorquera: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Sam Hernández-Jaña:** Software, Formal analysis, Data curation, Conceptualization. **Javier Sanchez-Martinez:** Supervision, Software, Investigation, Formal analysis, Conceptualization. **Juan Pablo Espinoza-Puelles:** Validation, Methodology, Formal analysis, Data curation. **Ricardo Martínez-Flores:** Visualization, Validation, Resources, Data curation. **Felipe Barreto-Schuch:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Rodrigo Yáñez-Sepúlveda:** Visualization, Validation. **Pedro Delgado-Floody:** Visualization, Validation, Supervision. **Gerson Ferrari:** Writing – review & editing, Supervision, Conceptualization. **Kabir P. Sadarangani:** Writing – review & editing, Supervision, Conceptualization. **Jorge Cancino-López:** Writing – review & editing, Supervision, Conceptualization. **Joao Bento-Torres:** Validation, Supervision, Methodology. **Alexis Espinoza-Salinas:** Writing – review & editing, Supervision. **Emmanuel Stamatakis:** Supervision, Methodology, Conceptualization. **Carlos Cristi-Montero:** Writing – review & editing, Supervision, Software, Formal analysis, Conceptualization.

Institution or service with which the work is associated for indexing

Pontificia Universidad Católica de Valparaíso.

Data availability statement

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Registration and protocol

This systematic review and meta-analysis protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024534982), and registration number CRD4202453498.

Ethics approval

This study was a systematic review and meta-analysis; therefore, no ethics approval was necessary.

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Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2025.117815.

Data availability

Data will be made available on request.

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