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REVIEW ARTICLE

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Prevalence of cardiovascular risk factors according to Life's Essential 8 in children and adolescents during the COVID-19 pandemic: A systematic review and meta-analysis including 1 526 173 participants from 42 countries

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Summary

Introduction: Cardiovascular health is a crucial aspect of overall health. The aim of this study was to estimate the prevalence of cardiovascular risk factors among children and adolescents during the COVID-19 pandemic based on the Life's Essential 8 domains.

Methods: PubMed, Scopus and Web of Science were systematically searched until 24 February 2023. Studies had to meet the following criteria: (1) observational studies, (2) studies reporting proportion of selected risk factors, (3) studies involving children or adolescents, (4) studies that collected data during the COVID-19 pandemic and (5) studies with representative samples. The outcomes included were diet, physical activity, nicotine exposure, sleep health, obesity, dyslipidaemia, diabetes and elevated blood pressure.

Results: Sixty-two studies with 1 526 173 participants from 42 countries were included. Of these, 41 studies were used in the meta-analyses. The overall pooled prevalence of risk factors in the behavioural domain was as follows: poor quality diet 26.69% (95% CI 0.00%–85.64%), inadequate physical activity 70.81% (95% CI 64.41%–76.83%), nicotine exposure 9.24% (95% CI 5.53%–13.77%) and sleep disorders 33.49% (95% CI 25.24%–42.28%). The overall pooled prevalence of risk factors in the health domain was as follows: obesity 16.21% (95% CI 12.71%–20.04%),

dyslipidaemia 1.87% (95% CI 1.73%–2.01%), diabetes 1.17% (95% CI 0.83%–1.58%) and elevated blood pressure 11.87% (95% CI 0.26%–36.50%).

Conclusions: These results highlight the need for prevention strategies to maintain better cardiovascular health from an early age, particularly by increasing physical activity levels, sleep time and promoting the consumption of more fruits and vegetables.

KEYWORDS
health promotion, healthy lifestyle, public health

1 | INTRODUCTION

Cardiovascular health is a crucial aspect of overall health and is essential for preventing a number of serious chronic diseases such as coronary heart disease, stroke and cancer.[1–3] Recently, the American Heart Association (AHA) published an updated recommendation for assessing cardiovascular health, which includes a series of behaviours and health conditions defined as Life's Essential 8 components (diet, physical activity, nicotine exposure, sleep health, body mass index, blood lipids, blood glucose and blood pressure).[4]

In this regard, the COVID-19 pandemic has had a significant impact on public health, changing many aspects of the daily lives of children and adolescents. A high prevalence of depressive/anxiety symptoms and sleep disturbances was observed in adolescents during the COVID-19 outbreak,[5] which may also contribute to an increase in tobacco and other substance use.[6] Social distancing and quarantine also resulted in children spending more time at home, which may contribute to decreased physical activity[7] and increased consumption of unhealthy foods and weight gain.[8]

Despite the distribution of COVID-19 vaccines, resistant virus variants such as Omicron sub-variant BA.2 continue to affect people's daily lives,[9] compounded by the recent resurgence of COVID-19 in densely populated countries such as China.[10] Thus, it is crucial to have up-to-date data on the prevalence of risk factors recognized as critical for cardiovascular health in children and adolescents. Furthermore, the early childhood and preschool years are critical for promoting healthy behaviours through interventions aimed at maintaining better cardiovascular health, which may contribute to a next generation of healthier children.[4] Therefore, this study aimed to estimate the prevalence of the eight cardiovascular health risk factors underscored by the Life's Essential 8 seminal paper[4] in children and adolescents during the COVID-19 pandemic.

2 | METHODS

This systematic review follows the PRISMA guidelines.[11] Additionally, the meta-analysis was reported according to the MOOSE checklist.[12] The protocol was pre-registered in PROSPERO (registration number: CRD42023402563).

2.1 | Search strategy

A systematic search of PubMed/MEDLINE, Web of Science and Scopus databases was conducted, supplemented by grey literature searches using Google Scholar and Open Grey until 24 February 2023 (Table S1). Additional studies were also selected from the reference lists of eligible articles and topic-related reviews. All records were analysed using the free web version of Rayyan (http://rayyan.qcri.org).[13] Duplicates were removed and two authors (RNC and RLP) independently reviewed titles/abstracts and full texts, and a third author resolved disagreements (BdPC).

2.2 | Eligibility criteria

Inclusion criteria were based on the PECOS methodology: (1) population: studies involving children or adolescents (up to 19 years of age) and studies with representative samples; (2) exposure: cardiovascular risk factors according to Life's Essential 8 domains collected during the COVID-19 pandemic; (3) comparison: no specific comparator was established; (4) outcomes: studies reporting the prevalence or proportion of at least one of the 8 selected risk factors and (5) study design: observational studies. To ensure population representativeness and comparability between estimates, studies with a sample size of less than 73 (calculated using the formula of Naing et al.[14]) were excluded. We also excluded studies with hospitalized or institutionalized participants, as well as studies focusing specifically on clinical populations, health conditions, single-sex participants or athletes.

2.3 | Data extraction

Using a standardized protocol and reporting forms, two independent authors extracted the first author's name, year of publication, nationality of the study population, number of participants, age, measurement tool and prevalence estimate. If relevant data were not included in the article, the corresponding authors of these publications were contacted by e-mail to obtain the information. For the quantitative synthesis, we selected studies that used a valid instrument to measure the risk factor. The prevalence for each of the 8 risk factors was considered as follows: (1) diet: not daily fruit nor vegetable consumption;

(2) physical activity: <60 minutes of moderate-intensity activity (or higher) per day; (3) nicotine exposure: current combusted tobacco use or inhaled consumption of nicotine; (4) sleep health: average number of hours of sleep per night above or below the age-optimal range according to the pediatric guidelines[15]; (5) obesity: body mass index in the 95th percentile according to their reference population; (6) dyslipidaemia: one or more abnormal levels of any lipid profile according to the pediatric guidelines[15]; (7) diabetes: fasting blood glucose 40 mg/dL and (8) elevated blood pressure (EBP): systolic blood pressure and/or diastolic blood pressure according to the 95th percentile of their reference population or medical records.

2.4 | Quality assessment

Quality assessment was performed independently by two reviewers (RNC and RTC), and disagreements were resolved by consensus with a third reviewer (RLB). The quality of included studies was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Tools for prevalence data.[16] In the case that the items of this tool may not be directly applicable to other observational designs, we adapted its application considering the following criteria: adequate sampling frame (Item 1): we assessed whether the sampling frame adequately includes the population of interest, considering representativeness or adequate selection. Selection of participants (Item 2): we assessed whether participants were adequately selected according to exposure or diagnosis, minimizing bias. Sample coverage (Item 5): we assessed the rate of follow-up in cohorts or that all selected cases and controls are included in the analysis, avoiding loss of data. Condition measurement (Item 7): we checked whether the condition was measured consistently in cohorts over time and whether equivalent diagnostic methods were used in cases and controls to avoid bias. Response rate (Item 9): we assessed how losses were handled in cohorts and the comparability of the response rate in cases and controls, minimizing the impact of dropout or non-response.

2.5 | Data synthesis

We used Stata 16.1 (StataCorp, TX, USA) and the metaprop user command to pool data from eligible studies using the DerSimonian and Laird random-effects procedure.[17] The Clopper-Pearson method (also known as exact method) was used to determine 95% CIs for prevalence from the selected individual studies.[18] A Freeman-Tukey double arcsine transformation was conducted to stabilize the variances before calculating the pooled prevalence.[19] These results were displayed as forest plots. We used Higgin's I^2 statistics to assess heterogeneity. Based on I^2, heterogeneity was classified as negligible (I^2 = 0%–40%), moderate (I^2 = 30%–60%), substantial (I^2 = 50%–90%) or considerable (I^2 = 75%–100%).[20] To assess the potential small-study effects due to publication bias, we used the Luis Furuya-Kanamori (LFK) index and the Doi plot.[21] Whenever possible, subgroup analyses were performed taking into account the geographical location (continent) of the studies. In addition, for variables with a sufficient number of studies, sensitivity analyses were performed by including only high-quality studies in the meta-analyses (i.e. 8 and 9 points in the JBI Critical Appraisal Tools).

3 | RESULTS

The study selection process is summarized in Figure S1. Sixty-two studies remained in the final selection for the systematic review.[22–83] Of these, 41 studies remained valid for quantitative synthesis.[23–28,30–33,37,39,43,44,46,47,49–53,55–62,64,66,69–71,74–79,81] The characteristics of the included studies are shown in Table 1. This systematic review included 1 526 173 participants from 42 countries. Figure 1 illustrates the countries with available prevalence data for the risk factors studied. The mean age of participants ranged from 4.0 (SD = 0.5) to 17.5 (SD = 1.2) years. Among the included studies, a median score of 7 of 9 (Interquartile Range: 6–8) was obtained using the JBI Critical Appraisal Tools. The criteria with the worst compliance were "appropriate sampling" (22.6%) and "response rate" (37.1%) (Table S2).

3.1 | Health behaviours

Eight studies had data on the prevalence of diet as a risk factor. Three studies (n = 1668) with data on daily fruit and vegetable consumption prevalence were included in the quantitative synthesis (Figure 2A).[30,31,49] The pooled estimate of risk factor prevalence in the dietary domain was 26.69% (95%CI 0.00% to 85.64%).

Twenty-five studies assessed physical activity. Overall, non-compliance with international guidelines ranged from 1.4% to 92.8%.[57,60] The qualitative synthesis included 19 studies (n = 23 622) that used a valid measurement tool and reported data on the proportion of participants with less than 60 minutes of physical activity per day (Figure 2B).[23,25,26,32,37,43,44,47,49–53,55,57,58,60,69,74] The pooled estimate of the prevalence of risk factors in the physical activity domain was 70.81% (95%CI 64.41% to 76.83%).

Nine studies have assessed current cigarette or inhaled nicotine use, which ranged from 2.5% to 30%.[39,78] Eight studies (n = 27 744) were included in the quantitative synthesis (Figure 2C).[30,31,33,39,61,66,76,78] The pooled estimate of the prevalence of risk factors in the nicotine exposure domain was 9.24% (95%CI 5.53%–13.77%).

Twenty-eight studies assessed sleep health. Sixteen studies assessed sleep duration. The prevalence of non-compliance with the recommended daily hours according to international guidelines ranged from 10.7% to 79.7%.[26,50] On the other hand, four studies assessed sleep quality, and the rating of poor sleep quality ranged from 15.2% to 74.3%,[29,82] whereas eight studies assessed sleep disturbances or sleep-related difficulties/problems, ranging from 11.8% to 90%.[35,83] The quantitative synthesis included 12 studies (n = 9370) that used a valid measurement tool to provide data on non-compliance with the recommended daily hours of sleep

TABLE 1 Description of included studies.

Author	Country	Participants (N)	Age (years)	Risk factor prevalence	Measurement tool
Androutsos 2021	Greece	397	7.8 (4.1)	Sleep (<8 h o < 10 h): 29%	Ad-hoc question
Al-Hourani 2021	Jordan	477	6–17	Obesity: 20.3%	Ad-hoc question
Alhowimel 2022	Saudi Arabia	2000	14–18	DM T2: 1.6% Smoking (not reliable)	Interview
Al-Rahamneh 2021	Jordan	1309	5–11	PA: 69.1% Sleep: 42.4%	Orgiles'questionnaire
Almugti 2021	Saudi Arabia	651	3–15	PA: 49% Sleep: 33%	Canadian 24-Hour Movement Guidelines for Children and Youth
Alonso-Martínez 2021	Spain	268	4.28 (0.80)	PA: 21% Sleep: 79.7%	Wrist-worn GENEActiv tri-axial accelerometer
Ban 2023	South Korea	1 111 300	12–18	Obesity: 13.5% (95% CI, 13.1–13.9%)	Ad-hoc question
Bani-Issa 2020	United Arab Emirates	1720	12–19	Sleep (poor sleep): 74.3%	PSQI
Basu 2022	India	103	13–17	Diet: 10% Smoking: 9.8%	GSHS
Berki 2021	Hungary	705	14–19	Smoking: 19.9% PA (none): 14% Diet: 78.3% (daily fruit) 78.6% (daily vegetables)	Smoking: Ad-hoc question PA: HBSC Diet: HBSC
Bronikowska 2021	Poland	127	15.4 (0.5)	PA:86.6%	Physical Activity Screening Measure for Use With Adolescents in Primary Care
Chaffee 2021	USA	1423	14–16	Smoking:8%	Ad-hoc question
Chi 2020	China	1794	15.26 (0.47)	PA (low): 40.9	PA: IPAQ (short form)
Curatola 2022	Italy	205	6–12	Sleep (sleep-related difficulties): 90%	CSHQ
El Refay 2021	Egypt	765	4–16	Sleep (sleep disturbance): 65.6%	SDSC
Francisco 2020	European countries	All ($n = 1480$) Italy ($n = 712$) Spain ($n = 431$) Portugal ($n = 335$)	3–18	PA: All = 85.2% Italy = 84.5% Spain = 85% Portugal = 88.6%	Ad-hoc question
Ghanamah 2021	Israel	329	1–10	Sleep (sleep problems): 41.7%	Ad-hoc question
Gilic 2021	Bosnia and Herzegovina	661	15–18	PA: 14.8% (individual) 15% (team) Smoking: 30%	PA: PAQ-A Smoking: Ad-hoc question
Giorgio 2020	Italy	245	2–5	Sleep (sleep disturbance): 44.7%	SDSC
Greier 2021	Austria	221	14–18	PA: Moderate (22.1%) Vigorous (57.1%)	IPAQ (short form)
He 2022	China	5963	10.7 (2.2)	Obesity: 10.6%	Scale and stadiometer
Hyunshik 2021	Japan	290	4.8 (0.3)	PA: 17.6% Sleep: 20.8%	PA: A triaxial accelerometer (Active Style Pro HJA-750C) Sleep: Ad-hoc question
Jáuregui 2021	Mexico	631	1–5	PA: 63.8% Sleep: 25.9%	PA: SUNRISE questionnaire Sleep: Ad-hoc question
Jia 2021	China	2824	17.5 (1.2)	Obesity: 19.3%	Ad-hoc question
Kang 2020	South Korea	226	10.5 (8.7–12.4)	Obesity: 18.6% DM T2: 1.3%	Medical records

TABLE 1 (Continued)

Author	Country	Participants (N)	Age (years)	Risk factor prevalence	Measurement tool
Kovacs 2022	European countries	All = 8395 Germany ($n = 241$), Hungary ($n = 2626$), Poland ($n = 523$), Russia ($n = 315$), Slovenia ($n = 1897$), Spain ($n = 894$), France ($n = 209$), Italy ($n = 240$), Portugal ($n = 1956$), Romania ($n = 294$)	6–18	PA: Germany (82.2%, IQR [76.7–86.8]), Hungary (80.1%, IQR [78.5–81.6]), Poland (82.8%, IQR [79.3–85.9]), Russia (79.0%, IQR [74.1–83.4]), Slovenia (73.3%, IQR [71.2–75.2]), Spain (81.9%, IQR [79.2–84.3]), France (84.7%, IQR [79.1–89.3]), Italy (92.5%, IQR [88.4–95.5]), Portugal (92.4%, IQR [90.7–93.8]), Romania (76.5%, IQR [71.3–81.3]), All (81.0%, IQR [80.1–81.8])	Ad-hoc question
Liu 2020	China	1619	4–6	Sleep disturbance: 55.6%	CSHQ
López-Bueno 2020	Spain	860	9.6 (3.9)	PA: 48% Diet: 5% Sleep: 30%	PA: Ad-hoc question Diet: Ad-hoc question Sleep: Ad-hoc question
López-Gil 2021	Spain Brazil	Spain ($n = 604$), Brazil ($n = 495$)	Spain: 12.1 (4.6), Brazil: 10.7 (4.3)	PA: Spain (73.5%), Brazil (78.2%) Sleep: Spain (15.2%), Brazil (12.3%)	PA: Physical Activity Screening Measure for Use With Adolescents in Primary Care Sleep: Ad-hoc question
Łuszczk 2021	Poland	640	10.79 (2.02)	Obesity: 6.4% PA: 90.8% Diet (consumption of raw vegetables never/less than once a week): 12.5%	Obesity: SECA 213 portable stadiometer (height), Tanita BC-420 (weight) PA: Ad-hoc question Diet: FFQ-6
Medrano 2020	Spain	112	8–16	Obesity: 0.9% PA: 45.5% Sleep time: 71.8% (weekdays), 77.3% (weekend) Diet: 79.1%	Obesity: SECA 217 (height), SECA 899 (weight) PA: YAP questionnaire Sleep: Ad-hoc question Diet: kidmed questionnaire
Mekkawy 2021	Egypt	672	6–18	PA (none): 52.7% Sleep (<7 h o > 10 h): 55.1%	PA: IPAQ-SF Sleep: BEARS sleep screening tool
Metwally 2020	Egypt	1600	6–12	Diet (lack of nutrient-rich foods): 53.36%	Diet: Ad-hoc question
Moore 2021	Canada	1568	11.6 (3.72)	PA: 85.7% Sleep: 42.63%	PA: Ad-hoc question Sleep: Ad-hoc question
Mulugeta 2021	USA	701	2–18	Obesity: 27.4%	Medical records
Nyström 2020	Sweden	100	4.0 ± 0.5	PA: 1.4% Sleep (<10 h o > 13 h): 37.5%	PA: Ad-hoc question Sleep: Ad-hoc question
Okely 2021	14 countries	948	5.2 (0.6)	PA: 51.3% Sleep: 20.7%	PA: Ad-hoc question Sleep: Ad-hoc question
Palermi 2022	Italy	307	10.1 (2.3)	Obesity: 20.5%	Obesity: TANITA weight scale (model MC-780MA) and GIMA altimeter (model "Astra")
Parker 2021	Australia	963	16.1 (1.2)	PA: 92.8%	Brief MVPA self-report questionnaire
Pelham 2021	U.S.	5284	12.4 (range: 10.5–14.6)	Smoking (nicotine): 3.6 [95%CI: 2.9, 4.4]	Nicotine: Ad-hoc question
Pierce 2022	U.S.	241 600	2–19	Obesity: 22.5%	Obesity: Medical record
Puteikis 2022	Lithuania	628	16.1 (1.2)	Sleep (poor sleep): 63.4%	Sleep: PSQI
Qiu 2021	China	445	7–12	Obesity: 49.4% BP (Elevated BP): 34.6%	Obesity: Scale and stadiometer BP: electronic sphygmomanometer (Omron HEM-7136)
Ranjbar 2021	Iran	20 697	13.76 (2.50)	Sleep (<6 h o > 12 h): 66.9%	Sleep: Ad-hoc question
Rogés 2021	Spain	303	14–18	Smoking: 8.9%	Smoking: Ad-hoc question

(Continues)

TABLE 1 (Continued)

Author	Country	Participants (N)	Age (years)	Risk factor prevalence	Measurement tool
Rojas 2022	Mexico	209	8.9	Sleep (sleep disturbance): 59.8%	Sleep: Pediatric Symptom Checklist and the Children Sleep Habits Questionnaire.
Ruíz-Roso 2020	European and Latin American Countries	All = 726 Brazil (115) Chile (170) Colombia (161) Spain (147) Italy (133)	10–19	PA (<300 min/week): Brazil (93%) Chile (90.6%) Colombia (70.8%) Spain (70.7%) Italy (73.7%)	PA: IPAQ
Schmidt 2020	Germany	1711	4–17	PA: 69.8%	PA: Ad-hoc question
Shalitin 2022	Israel	36 837	11.2 (6.6–16.1)	Obesity: 12.3% Type 2 DM/ IGT: 1.2% Hypertension: 0.5% Dyslipidaemia: 1.5%	Obesity: Medical files (undetermined) Type 2 DM/IGT: Medical files Hypertension: Medical files Dyslipidaemia: Medical files
Song 2023	South Korea	1428	10–18	Obesity: 13.8% Hypertension: 12.5% Dyslipidaemia: 25.1%	Obesity: Holtain portable stadiometer (height), HANA calibrated balance beam scale (weight) Hypertension: Baumanometer sphygmomanometer Dyslipidaemia: Labospect 008AS
Sugimoto 2022	Japan	6220	11 (1.9)	PA (inactive or low level): 62% Sleep (<8 h o ≥10 h): 38%	PA: Ad-hoc question Sleep: Ad-hoc question
Sugimoto 2023	Japan	4084	8–15	Diet (zero intake of cereal, pulses, fruit, vegetables, fish and shellfish meat): 6.8%	Diet: BDHQ15y
Tandon 2021	U.S.	1000	10.8 (3.5)	PA: 79.1%	PA: Youth Risk Behaviour Surveillance Survey (adapted for parent response for younger children)
Tanveer 2022	Pakistan	3551	9–17	Obesity: 5.4%	Obesity: Digital CERTEZA weight machine and A SECA scale (body height)
Thorisdottir 2021	Iceland	17 475	13–18	Smoking: 3.8%	Ad-hoc question
Top 2022	Turkey	1040	9.16 (2.05)	Sleep (sleep disturbances): 55.5%	CSHQ
Wang 2022	China	1790	14.92 (1.55)	Sleep (poor sleep): 26% Smoking: 2.5%	Sleep: PSQI Smoking: Ad-hoc question
Wen 2021	China	19 066	3 to 5.3	Obesity: 12.3%	Obesity: Mechanical column scale (weight), Stadiometer (height)
Yazew 2022	Ethiopia	500	6–59 months	Diet (poor dietary diets): 52.2%	Diet: Dietary diversity scores (DDS)
Zengin 2020	Turkey	309	10.3 (1.2)	Sleep (<8 h or > 10 h): 39.2%	Sleep: Ad-hoc question
Zhai 2021	China	3464	12–15	Sleep (poor sleep): 15.2%	Sleep: PSQI
Zhou 2021	China	1108	16.39 (0.80)	Sleep (sleep problems): 11.8%	Sleep: SRSS

Note: Table displaying prevalence levels for insufficient physical activity (less than 1 h a day), diet (not daily fruit nor vegetable consumption), smoking (current use of cigarettes or inhaled nicotine), sleep (not meeting recommended daily hours according to the American Academy of Pediatrics),[16] obesity (body mass index in the 95th percentile according to their reference population), dyslipidaemia (one or more abnormal levels of any lipid profile according to the pediatric guidelines), diabetes (fasting blood glucose 126 mg/dL), blood pressure (systolic blood pressure and/or diastolic blood pressure according to the 95th percentile of their reference population), unless other prevalence outcomes stated.

Abbreviations: BP, blood pressure; CSHQ, Children's Sleep Habits Questionnaire; DM, diabetes mellitus; FFQ-6, Food Frequency Questionnaire; GSHS, Global School Health Survey Questionnaire; HBSC, International Health Behavior in School-aged Children survey; IGT, impaired glucose tolerance; IPAQ, International Physical Activity Questionnaire; PA, physical activity; PAQ-A, Physical Activity Questionnaire for Adolescents; PSQI, Pittsburgh Sleep Quality Index; SDSC, Sleeping quality assessment using Sleep Disturbance Scale for Children; SRSS, Self-Rating Scale of Sleep; YAP, Youth Activity Profile.

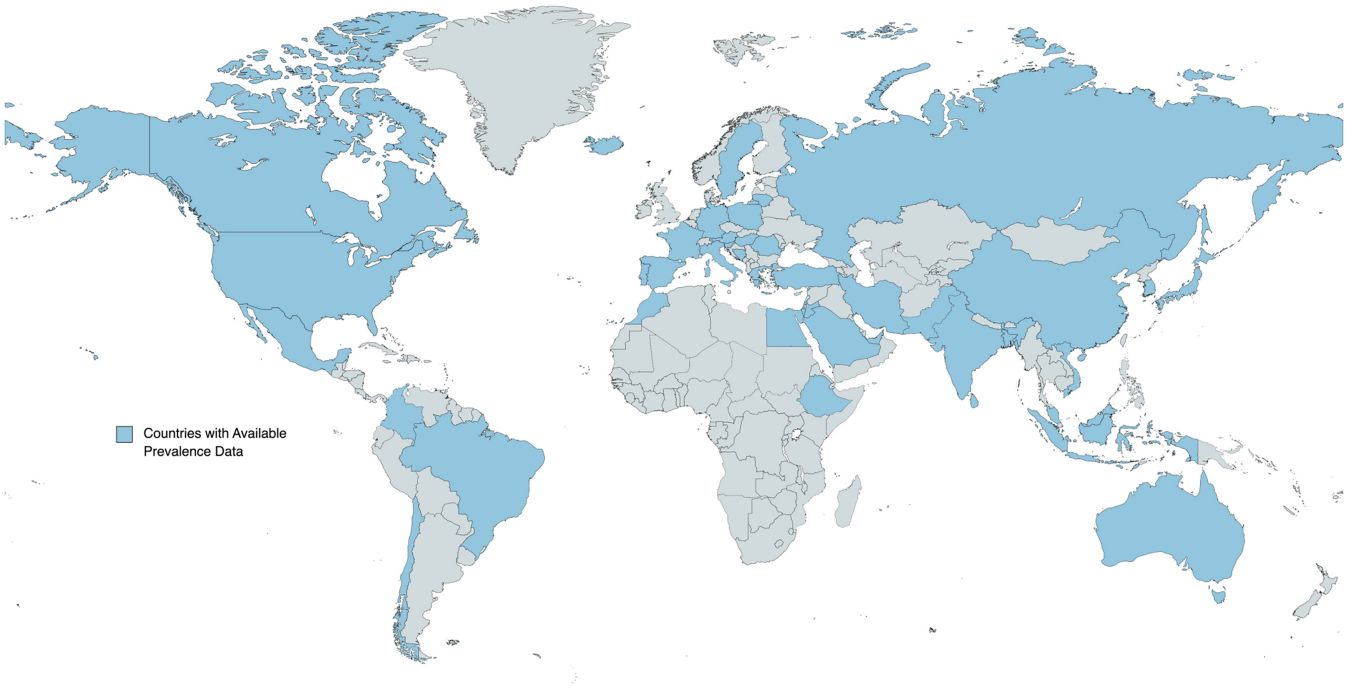

FIGURE 1 Countries with available data for prevalence estimates of cardiovascular risk factors.

(Figure 2D).[23,25–27,43,44,49,50,55,58,77,81] The pooled estimate of the prevalence of risk factors in the sleep health domain was 33.49% (95%CI 25.24%–42.28%).

3.2 | Health factors

Fifteen studies assessed the prevalence of obesity, which ranged from 0.9% to 49.4%.[52,64] Ten studies (n = 1 415 347) were included in the quantitative synthesis (Figure 3A).[28,52,56,59,62,64,70,71,75,79] The pooled estimate of the prevalence of risk factors in the body mass index domain was 16.21% (95%CI 12.71%–20.04%).

Two studies (n = 38 265) provided data on the prevalence of dyslipidaemia and were included in the quantitative synthesis (Figure 3B).[70,71] The pooled estimate of the prevalence of dyslipidaemia was 1.87% (95%CI 1.73% to 2.01%).

Three studies (n = 39 063) provided data on the prevalence of diabetes mellitus or glucose intolerance and were included in the quantitative synthesis (Figure 3C).[24,46,70] The pooled estimate of the prevalence of elevated blood glucose was 1.17% (95%CI 0.83%–1.58%).

Three studies (n = 38 710) assessed the presence of EBP and were included in the quantitative synthesis (Figure 3D).[64,70,71] The pooled estimate of the prevalence of EBP was 11.87% (95%CI 0.26%–36.50%).

3.3 | Publication bias

The LFK index for the Doi plots showed no asymmetry for diabetes (LFK = 1.00) and sleep (LFK = 0.80), minor asymmetry for obesity (LFK = 1.91), and major asymmetry for, physical activity (LFK = -2.29), diet (LFK = 2.99), smoking (LFK = 5.83), dyslipidaemia (LFK = 7.41) and EBP (LFK = 9.69) (Figures S2–S9).

3.4 | Subgroup analyses

A higher prevalence of obesity was observed in the Americas compared to the estimated global prevalence (22.49% vs. 16.1 respectively) (Figure S10). Non-compliance with physical activity recommendations was lowest in Asia (Figure S11), whereas non-compliance with sleep duration recommendations was fairly similar between continents (Figure S12). The prevalence of smoking was highest in Europe (Figure S13).

3.5 | Sensitivity analyses

Sensitivity analysis including only high-quality studies in meta-analyses was possible for the variables obesity, activity, physical activity, sleep health and smoking. The results show consistency with the main results except for obesity, where heterogeneity went from substantial to null (Figures S14–S17).

4 | DISCUSSION

Based on the data from 1 526 173 children and adolescents from 42 countries, we found a high prevalence of risk factors for cardiovascular health during the COVID-19 pandemic, especially with regard to health behaviours (e.g., diet, physical activity and sleep health). In

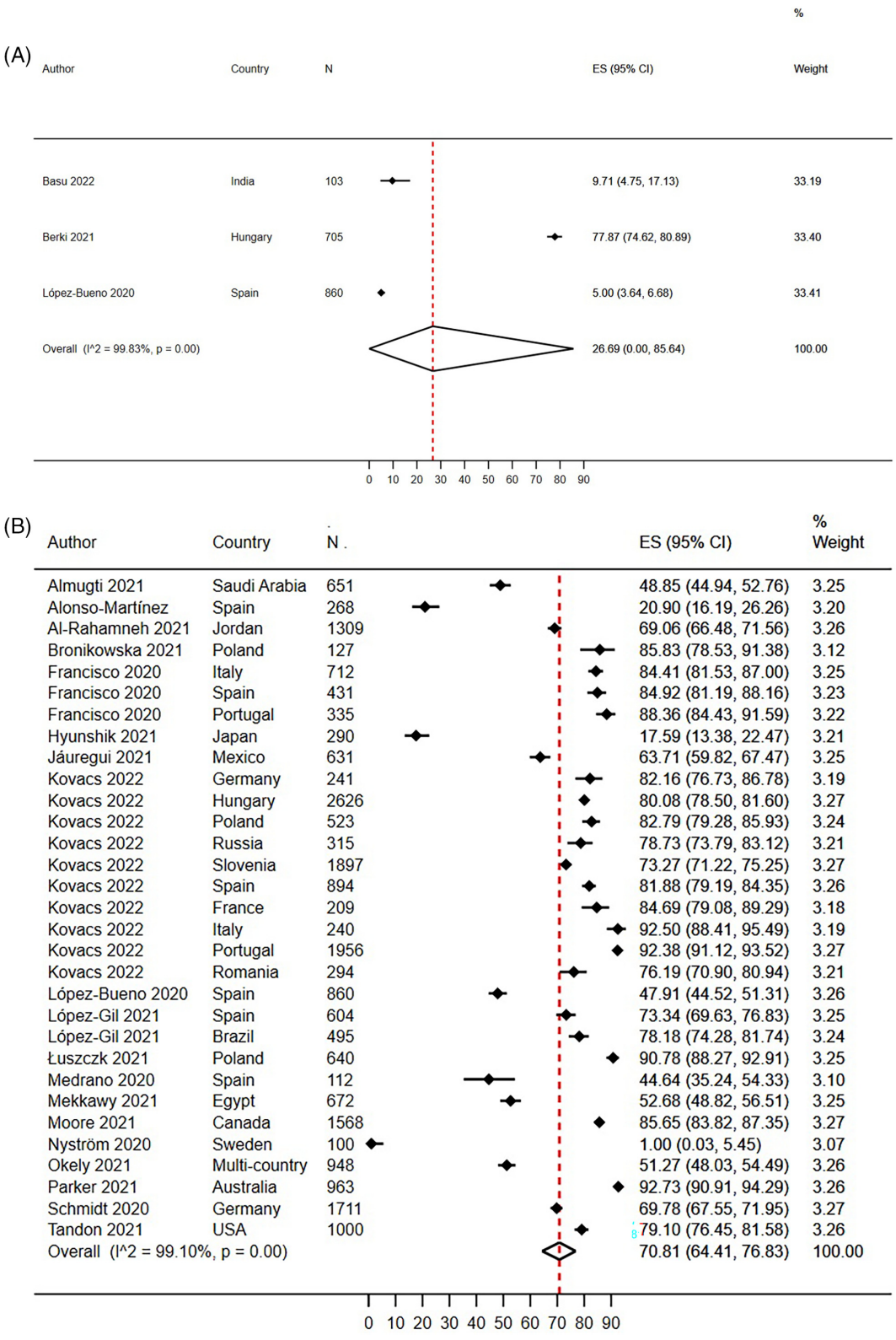

FIGURE 2 Estimated prevalence for health behaviours. (A) Diet; (B) Physical activity; (C) Smoking; (D) Sleep duration. Forest plot for prevalence (%) and 95% Confidence Interval of each risk factor among children and adolescents (up to 19 years old). Risk factors were the following: insufficient physical activity (less than 1 h a day), diet (not daily fruit nor vegetable consumption), smoking (current use of cigarettes or inhaled nicotine), sleep (not meeting recommended daily hours according to the American Academy of Pediatrics). The Clopper-Pearson method was used to determine 95% CIs for prevalence from the individual studies. A Freeman-Tukey double arcsine transformation was conducted to stabilize the variances before calculating the pooled prevalence. CI, confidence interval; ES, effect size (prevalence); I^2, Higgins' I^2.

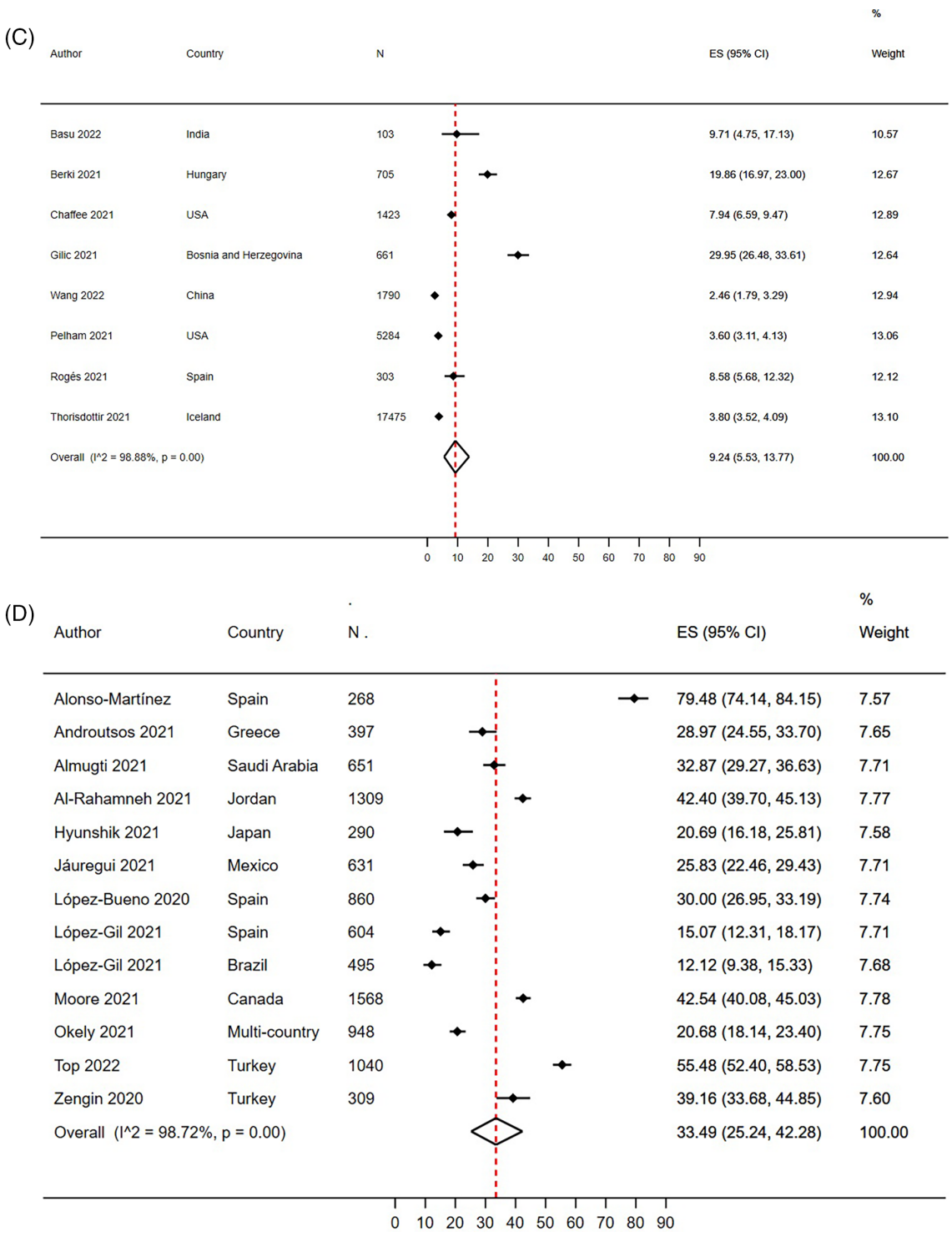

FIGURE 2 (Continued)

addition, we identified important data gaps related to the health factor domain, probably because the COVID-19 pandemic made it difficult to access more blood biomarkers for these variables. However, to our knowledge, this is the first meta-analysis that has comprehensively examined the overall prevalence of cardiovascular risk factors according to Life's Essential 8 in children and adolescents during the COVID-19 pandemic. Therefore, these results are important for priority setting (e.g., strategies aimed at maintaining better cardiovascular health from an early age), as well as for benchmarking progress and cross-country comparisons. It is of particular concern the scarcity of data from low-and-middle income countries, especially from the African region.

The initial assessment of pre-COVID-19 cardiovascular health in the US population, using the AHA's Life's Essential 8 score,

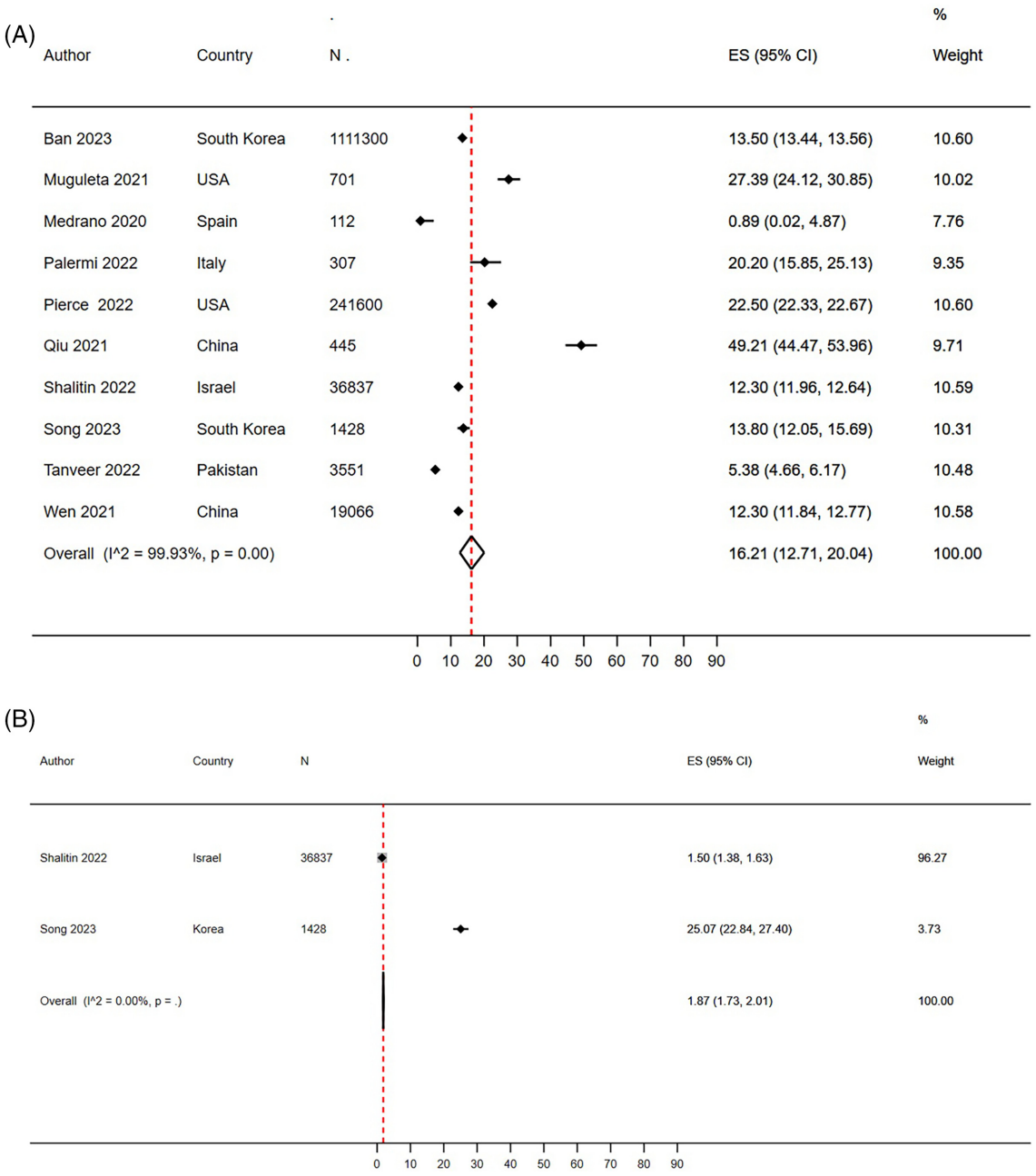

FIGURE 3 Estimated prevalence for health factors. (A) Obesity; (B) Dyslipidaemia; (C) Diabetes; (D) Elevated blood pressure. Forest plot for prevalence (%) and 95% Confidence Interval of each risk factor among children and adolescents (up to 19 years old). Risk factors were the following: obesity (body mass index in the 95th percentile according to their reference population), dyslipidaemia (one or more abnormal levels of any lipid profile according to the pediatric guidelines), diabetes (fasting blood glucose 126 mg/dL), blood pressure (systolic blood pressure and/or diastolic blood pressure according to the 95th percentile of their reference population). The Clopper-Pearson method was used to determine 95% CIs for prevalence from the individual studies. A Freeman-Tukey double arcsine transformation was conducted to stabilize the variances before calculating the pooled prevalence. CI, confidence interval; ES, effect size (prevalence); I^2, Higgins' I^2.

revealed suboptimal cardiovascular health in children, largely due to poor diet, insufficient physical activity and an unhealthy body mass index.[84] Our meta-analysis found that these risk factors, along with sleep health, were highly prevalent during COVID-19. Improving communication and advocacy efforts around these recommendations can lead to better cardiovascular health outcomes in children.[84]

4.1 | Health behaviours

Several systematic reviews have examined the impact of the COVID-19 pandemic on various health behaviours among children and adolescents. The available evidence indicates a detrimental effect on diet, physical activity, sleep and nicotine exposure in this population.[6,8,85–87] However, these reviews are limited by a lack of quantitative analysis.

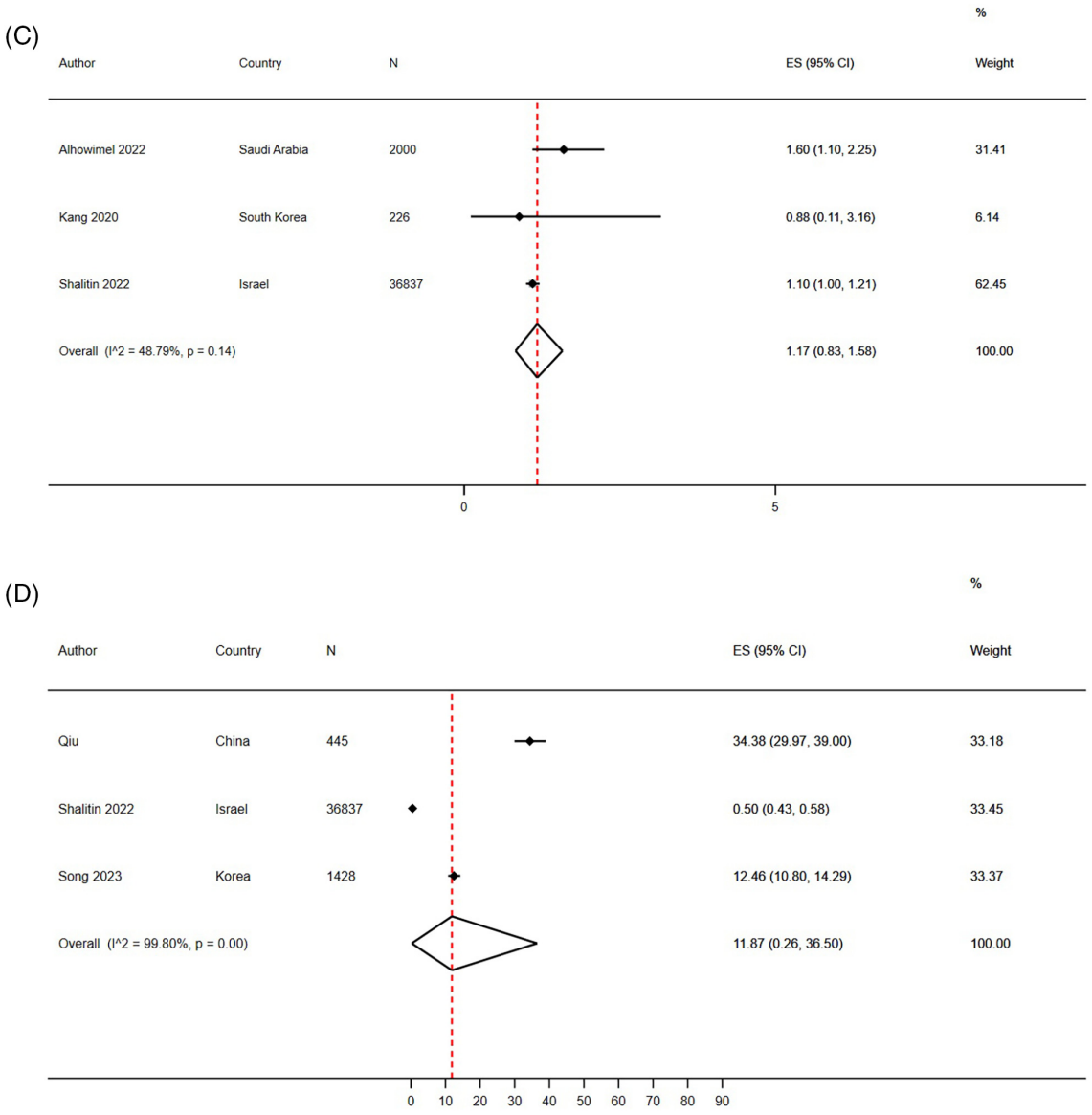

FIGURE 3 (Continued)

This study found that physical inactivity had the highest prevalence among the studied risk factors. The estimated prevalence of children and adolescents not meeting the recommended 60 min of daily physical activity (or 420 minutes per week) was 70.81%. In a recent meta-analysis by Neville et al.,[7] physical activity levels among children and adolescents decreased by 20% from before to during the COVID-19 pandemic. However, the analysis did not report the estimated overall prevalence at each time point, making comparisons difficult. In contrast, Chaabna et al.[88] estimated a 19.5% prevalence of physically active children during COVID-19 movement restrictions in their previous meta-analysis, using different criteria from those proposed by the AHA (Life's Essential 8).

Sleep health was found to be the second most prevalent risk factor in this study. Approximately one in three children and adolescents did not meet the daily hours of sleep recommended by international guidelines.[15] A previous meta-analysis by Ma et al.[5] identified the prevalence of sleep disorders to be 44%. Similarly, Sharma et al.[89] found that the combined prevalence of any sleep disorder in children during the pandemic was 54%, whereas worsening sleep quality was 27%. Although both studies did not assess the prevalence of compliance with recommended hours of sleep per night, they highlighted the impact of the COVID-19 pandemic on the sleep of children and adolescents.

The prevalence of daily intake of a dietary pattern including fruit and vegetables was 26.69%. Maintaining a healthy and balanced diet is essential, especially during the current COVID-19 pandemic, as it can strengthen the immune system.[90] Previous studies have also reported that fruit and vegetable consumption has an inverse relationship with depression, highlighting the need to promote good eating habits in both children and adolescents.[91] On the other hand, smoking prevalence was 9.24%, which is concerning given that tobacco initiation in children is associated with lower cognitive performance and

reduced brain structure with long-term effects.[92] Moreover, the dramatic increase in youth smoking initiation due to the marketing of flavoured tobacco products could even increase the potentially toxic effects of the product.[93] However, it has been reported that the prevalence of substance use among young people has largely declined during the pandemic, probably due to reduced availability and access to drugs and other substances during this period.[6] With the threat of increased prevalence post-pandemic, there is an urgent need for strict regulation of all tobacco products, as well as more comprehensive tobacco education and prevention programs.[94]

It is important to note that the results should be interpreted with caution due to the large variability in the prevalence ranges of health behaviours observed in this review, which could be explained by the different instruments used to assess the behaviours and by contextual differences between the countries included. Public health restrictions and policies during the COVID-19 pandemic varied significantly between countries, affecting access to recreational activities, healthy foods and health services. On the other hand, the sensitivity analysis showed that, by including only high-quality studies, the results were consistent with the main analysis, but with more precise confidence intervals. This indicates that the heterogeneity previously observed may be due, in part, to the inclusion of studies of lower methodological quality. Despite the heterogeneity, the results highlight the need for personalized and context-specific strategies to mitigate adverse effects on cardiovascular health in children and adolescents.

4.2 | Health factors

Although our review showed that research on health factors is scarce, we were able to retrieve data to quantify the prevalence of the four risk factors in this Life's Essential 8 domain. First, we identified an estimated overall prevalence of obesity of 16.21%. During the first year of the COVID-19 pandemic, small but clinically relevant increases in weight gain and BMI were observed.[95] This is likely to be related to virtual schooling policies, the closure of recreational facilities and gyms, which reduced opportunities for physical activity, as well as sedentary behaviour and dietary changes during the pandemic.[7,96,97] Importantly, children with obesity had a high prevalence of severe COVID-19.[98] Also, children with high BMI and influenza infection are more likely to be hospitalized and have a worse prognosis.[99] A pre-pandemic COVID-19 meta-analysis (period 2006–2016) using data from 27 European countries estimated a pooled prevalence of 5.3% obesity among European children.[100] This highlights that the prevalence estimated in our meta-analysis during the COVID-19 pandemic, which includes five WHO territories, is alarming. Therefore, the identification of most-at-risk populations is crucial for the prevention and recovery after COVID-19 pandemic.

EBP was the second most prevalent health factor among children and adolescents during the pandemic, with a prevalence of 11.87%. A meta-analysis conducted up to 2018 reported a pooled prevalence of 4.0% for pediatric hypertension and 9.67% for prehypertension in children aged 19 years or younger.[101] Although the increase in blood pressure prevalence during the COVID-19 pandemic may seem logical given the significant increase in obesity, a known risk factor for hypertension, caution should be taken in interpreting the results during this period.[95] Due to the limited availability of data, the prevalence of hypertension may have been overestimated in our meta-analysis and may not be representative.

The estimated prevalence of dyslipidaemia and diabetes was 1.87% and 1.17%, respectively. Although both conditions are rare in children and adolescents, these risk factors are known to begin in childhood and may accelerate the development of cardiovascular disease, such as atherosclerosis.[15] Moreover, risk reduction can delay progression to clinical disease.[15] Gregory et al.[102] estimated, based on pre-pandemic data, that there were about 1.5 million children and adolescents with type 1 diabetes worldwide in 2021, and it is expected to increase rapidly, especially in resource-limited countries. Thus, future studies measuring the prevalence of these health factors associated with cardiovascular risk using blood biomarkers may be potentially helpful in establishing preventive strategies to improve pediatric cardiovascular health.

4.3 | Limitations

The results of the present study should be interpreted in accordance with the following limitations: (1) Given that three variables from the health factor domain (i.e. dyslipidaemia, diabetes and EBP) are substantially under-represented, quantitative analyses from such variables should be treated with caution. In addition, it is possible that the COVID-19 pandemic made it difficult to access more blood biomarker data and to use valid measurement instruments in studies conducted during this period, leading to a certain degree of selection bias. However, our results are based on the studies with relatively large sample sizes. (2) It is important to note that a high degree of heterogeneity was observed when pooling data from the included studies for most of the risk factors studied. (3) The generalizability of the results is limited to the studies included in our study, in which high-income countries were overrepresented. (4) The studies based on self-report questionnaires to assess diet, physical activity, nicotine exposure and sleep were included; therefore, recall bias could influence the results. (5) Despite our exhaustive search, the outcomes of physical activity, diet, smoking and dyslipidaemia had a high risk of publication.

5 | CONCLUSIONS

The high prevalence of cardiovascular risk factors among children and adolescents during the COVID-19 pandemic, particularly in the behavioural health domain, is a significant public health concern. A higher prevalence of obesity was observed in the Americas compared to the estimated global prevalence. Non-compliance with physical activity recommendations was lower in Asia, whereas smoking prevalence was higher in Europe. The findings highlight the need for prevention strategies aimed at promoting and maintaining better cardiovascular

health from an early age. However, there is a dearth of data on critical health factors such as diabetes, blood pressure and dyslipidaemia, as well as a lack of comprehensive data on cardiovascular health in the low-and-middle income countries region. Addressing these gaps in knowledge is critical for developing effective interventions to mitigate cardiovascular risk in pediatric populations.

AUTHOR CONTRIBUTIONS

Concept and design: R. Núñez-Cortés, R. López-Bueno and B. del Pozo Cruz. Acquisition, analysis or interpretation of data: All authors. Drafting of the manuscript: R. López-Bueno and B. del Pozo Cruz. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: R. López-Bueno. Obtained funding: Not applicable. Administrative, technical or material support: R. López-Bueno and B. del Pozo Cruz. Supervision: B. del Pozo Cruz.

CONFLICT OF INTEREST STATEMENT

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DATA AVAILABILITY STATEMENT

Data are available from the corresponding author (rlopezbu@unizar.es).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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