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Review

Trends in physical fitness among children and adolescents in Europe: A systematic review and meta-analyses during and after the COVID-19 pandemic

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Abstract

Background: Physical fitness is a key indicator of current and future health in children and adolescents. Evidence suggests that fitness levels have declined then stagnated in recent decades, but it remains unclear how the coronavirus disease 2019 (COVID-19) pandemic has impacted this trend.
Methods: We conducted a systematic review and meta-analyses to assess pandemic-related changes in physical fitness among children and adolescents (0−19 years) in the World Health Organization European Region. Seven databases were searched up to February 28, 2025 for studies reporting validated pre- and during/post-pandemic fitness measurements. Two reviewers independently performed screening, data extraction, risk-of-bias assessment (Risk Of Bias In Non-randomized Studies − of Exposure) (ROBINS-E), and certainty grading (Grading of Recommendations, Assessment, Development and Evaluation) (GRADE). Random-effects meta-analyses yielded standardized mean differences (SMDs) with 95% confidence intervals (95%CIs). Subgroup analyses examined sex, age, year, and national restriction severity (Oxford Stringency Index).
Results: Thirty-two studies comprising 270,179 participants and 1,519,386 fitness measurements from 17 European countries were included. Cardiorespiratory fitness declined significantly during the pandemic, especially in 2021, with reductions in endurance (SMD = −0.43; 95%CI: −0.61 to −0.25) and speed (SMD = −0.29; 95%CI: −0.61 to 0.03). While speed returned to baseline by 2023, endurance remained below pre-pandemic levels (SMD = −0.10; 95%CI: −0.12 to −0.08). Girls and adolescents were disproportionately affected. In contrast to cardiorespiratory fitness, muscular fitness remained largely unchanged. Stricter national regulations were associated with greater declines in cardiorespiratory fitness.
Conclusion: COVID-19 pandemic restrictions were associated with a marked decline in cardiorespiratory fitness in European children and adolescents, with levels not recovered by 2023. These findings call for urgent, targeted public health interventions to improve physical fitness and prevent long-term health consequences.

Keywords: Cardiorespiratory fitness; Muscular fitness; Endurance; Pandemic; Public health

1. Introduction

Physical fitness, including cardiorespiratory and muscular fitness, is a vital determinant of health, offering both immediate and long-term physical and mental health benefits for children and adolescents. It is associated with reduced risk of

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cardiovascular diseases, metabolic disorders, orthopedic conditions, as well as improvements in cognitive performance and mental health.[1–7] Importantly, high physical fitness levels early in life tend to track into adulthood, contributing to lower risks of non-communicable diseases, including cardiovascular disease, obesity, and mental health disorders.[8–11] Although specific recommendations for physical fitness are lacking, health organizations underscore its importance,[12,13] and the World Health Organization (WHO) recognizes physical fitness as a critical health outcome of being physically active.[12]

Despite these well-documented benefits, physical fitness levels in children and adolescents have declined over recent decades, particularly with regard to cardiorespiratory fitness, and have stagnated at low levels since the 2010s.[14–16] This previous downward trend has been attributed to multiple interacting social, behavioral, and environmental factors, such as rises in screen time, increasing safety concerns, urban planning deficiencies, and limited access to physical activity opportunities.[14–17]

Structured settings like schools and sports clubs provide important opportunities to increase physical fitness in children and adolescents.[18,19] However, measures taken in response to the coronavirus disease 2019 (COVID-19) pandemic in many European countries, including school closures, the suspension of organized sports, and restrictions on outdoor play, severely disrupted these opportunities. Evidence from several reviews already indicates pandemic-related declines in physical activity levels among children and adolescents, both globally[20,21] and within the WHO European Region,[22] with more pronounced reductions during periods of strict regulations.[22] However, comprehensive evidence on the extent to which these pandemic-related restrictions affected physical fitness and its various components is lacking. Existing primary studies differ in design, outcome measures, periods analyzed, and populations studied. Consequently, reported findings are heterogeneous, most notably in muscular fitness and, to some extent, in cardiovascular fitness. Given the stagnation of physical fitness at a low level,[14–16] systematically analyzing this evidence will shed light on the impact of the COVID-19 pandemic and its related restrictions on child and adolescent fitness trends, and will enable further investigation into the recovery of reduced physical fitness and its components.

We conducted a systematic review with meta-analyses to examine physical fitness among children and adolescents before, during, and after COVID-19–related restrictions in the WHO European Region. By comparing pre-pandemic with during- and post-pandemic data, we aimed to quantify changes across different fitness dimensions and subgroups, and to identify vulnerable populations in order to inform targeted public health interventions.

2. Methods

This systematic review with meta-analyses followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[23] and adhered to the Cochrane Handbook for Systematic Reviews.[24] We registered the review in the International Prospective Register of Systematic Reviews (PROSPERO; CRD42023395871)[25] and published an *a priori* protocol.[26] Protocol deviations are detailed in Supplementary Table 1.

2.1. Search strategy

We systematically searched 7 electronic databases (PubMed, Embase, Sports Medicine & Education Index, PsycINFO, Web of Science, Cochrane Central Register, and WHO COVID-19 Research Database) for articles published up until February 28, 2025. To identify additional potentially eligible publications, we manually screened the reference lists of all included studies and relevant systematic reviews. We also searched for registered observational studies on Clinicaltrials.gov. Furthermore, data sources referenced in the Global Matrix 4.0 Physical Activity Report[27] and websites of key organizations were reviewed (Supplementary Table 2). The search strategy included terms related to “children”, “adolescents” (using a validated search string[28]), “physical fitness”, and “COVID-19 pandemic” and was peer-reviewed using the Peer Review of Electronic Search Strategies (PRESS) checklist[29] (see protocol[26] for further details). Full search strategies for each database are provided in Supplementary Table 3.

2.2. Eligibility criteria

In accordance with the participants, exposure, comparison, outcome (PECO) framework,[30] studies were included if they met the following criteria: (a) involved children and adolescents under 19 years, (b) employed validated physical fitness measures, (c) reported measurements taken before and during or after the COVID-19 pandemic, and (d) were conducted in the WHO European Region. Eligible sources included primary studies, preprints, congress abstracts, and gray literature. No restrictions were applied regarding language or type of effect measure. Further details are provided in the study protocol.[26]

2.3. Outcomes

Physical fitness was classified into 2 dimensions based on the WHO definition[12]: cardiorespiratory fitness and muscular fitness, each further divided into specific components (cardiorespiratory: endurance, speed; muscular: coordination, flexibility, strength) using internationally recognized physical fitness constructs.[5,31] Different validated test protocols assessing the same component (e.g., 20-m shuttle run and 6-min run for cardiorespiratory endurance) were grouped together, as they are widely accepted proxies of the same underlying construct.[32] This grouping allowed us to synthesize evidence at the component level. Additionally, combined fitness tests (e.g., 4-Skills Scan) were also included. A detailed overview of validated physical fitness tests is provided in Supplementary Table 4.

2.4. Screening and data extraction

Initial screening of titles and abstracts was conducted independently by 2 authors (HLW with either ID or SH). Duplicate records were identified and removed using automated deduplication in EPPI Reviewer software (Version 6.16.2.0; University College London Institute of Education, London, UK).[33] Any disagreements at this stage resulted in the study being forwarded to full-text review. In the 2nd stage, full texts were independently assessed by the same reviewer pairs, with discrepancies resolved through discussion seeking consensus. Subsequently, 2 authors (HLW, ID, or SH) independently extracted data on study and participant characteristics. Extracted information included: first author, publication year, study design, sample size (total and by sex), age of the study population, timing within the COVID-19 pandemic, timing of the pre-pandemic baseline, validated fitness measures, standardization methods, study setting, subgroups analyzed, and the individual responsible for conducting the fitness measurements. Discrepancies were resolved through joint review. Additional data were requested from study authors as needed, and 7 responded with supplementary information.

2.5. Quality assessment

Study quality was assessed using the Risk of Bias in Non-randomized Studies – of Exposure (ROBINS-E) tool[34] (Supplementary Table 5), with HLW and SH independently evaluating all studies. This tool includes 7 assessment criteria, with risk of bias (RoB) ratings categorized as "low RoB", "some concerns RoB", "high RoB", or "very high RoB".[34] The studies were subsequently grouped into "some concerns RoB" and "high RoB" (including the categories "high RoB" and "very high RoB"); no study received the rating "low RoB". To ensure transparency, no studies were excluded based on quality scores. We used the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach[35] to evaluate the overall certainty of evidence for each physical fitness component (endurance, speed, coordination, flexibility, strength, combined fitness tests). Further details are available in the study protocol.[26] Two review authors (HLW and WS) independently assessed the certainty of evidence (CoE), with any disagreements resolved through discussion. A summary of the certainty ratings is presented in Table 1. The criteria used for grading are outlined in Supplementary Table 6, while more detailed explanations are provided in the evidence profiles in Supplementary Table 7. To enhance classification of studies included, we incorporated the validated Oxford Stringency Index (OSI) and the School Closure Index (SCI)[36] to capture the policy context during each study's measurement period. The OSI comprises 9 indicators, including one specifically reflecting school closure policies in each country. Following the COVID-Surg Collaborative framework,[37] we applied 3 thresholds to categorize the index: light restrictions (index < 20), moderate lockdowns (index: 20–60), and full lockdowns (index > 60). For the SCI, we used 2 thresholds: minimal or no change from pre-pandemic schooling (index < 2), and partial or complete school closures (index ≥ 2).[38] Additional information on these indices is available in the protocol.[26]

2.6. Statistical analysis

First, validated fitness measurements were grouped within their respective fitness dimensions (cardiorespiratory fitness, muscular fitness, or combined fitness tests) and further assigned to the specific fitness components (endurance, speed, coordination, flexibility, or strength). Effect estimates were documented at both the pre-pandemic and during/post-pandemic time points, where available.

Second, meta-analyses were conducted when data from at least 2 studies with distinct populations could be pooled. Effect changes for each fitness component and dimension were calculated using standardized mean differences (SMDs) and their corresponding 95% confidence intervals (95%CIs). Random-effects models were applied, with between-study variance estimated via the restricted maximum likelihood (REML) method.[39] Confidence intervals were computed using the DerSimonian-Laird method.[39] Some datasets required transformation before inclusion (Supplementary Table 8). For studies lacking

Table 1
Summary of findings.

Outcome	Number of measurements, comparisons	Results (SMD; 95%CI)	Certainty of evidence (GRADE)[a]	Importance of outcome (WHO)[b]
Cardiorespiratory fitness				Critical importance
Endurance	173,071 measurements, 19 comparisons	SMD = −0.43; 95%CI: −0.61 to −0.25	⊕⊖⊖⊖ Very low[c,d,e]	
Speed	139,499 measurements, 7 comparisons	SMD = −0.29; 95%CI: −0.61 to 0.03	⊕⊖⊖⊖ Very low[c,d,f]	
Muscular fitness				Critical importance
Coordination	178,008 measurements, 11 comparisons	SMD = −0.02; 95%CI: −0.18 to 0.14	⊕⊕⊖⊖ Low[c,d]	
Flexibility	172,844 measurements, 9 comparisons	SMD = 0.00; 95%CI: −0.14 to 0.14	⊕⊕⊖⊖ Low[c,d]	
Strength	689,856 measurements, 46 comparisons	SMD = −0.07; 95%CI: −0.15 to 0.01	⊕⊕⊖⊖ Low[c,d]	
Combined fitness tests				No information
	166,108 measurements, 4 comparisons	SMD = −0.30; 95%CI: −0.61 to 0.01	⊕⊖⊖⊖ Very low[c,d,f]	

[a] According to the handbook for grading the quality of evidence and strength of recommendations.[35]
[b] According to the WHO guidelines on physical activity and sedentary behavior.[12]
[c] Downgraded by −1 point due to high or very high risk of bias.
[d] Downgraded by −1 point due to serious inconsistency (marked variations in effect estimates, large I^2 values, and wide prediction intervals).
[e] Downgraded by −1 point due to visual inspection of the funnel plot suggesting asymmetry and being supported by an almost statistically significant test.
[f] Downgraded by −1 point due to serious imprecision (confidence interval includes moderate effects and no effects).
Abbreviations: 95%CI = 95% confidence interval; GRADE = Grading of Recommendations Assessment, Development and Evaluation; SMD = standardized mean difference; WHO = World Health Organization.

sufficient data for meta-analyses and where no response was received from authors, findings were summarized narratively.

Third, subgroup analyses were conducted when adequate data were available. These included comparisons by fitness component, sex (female *vs.* male), age group (children (approximately <12 years) *vs.* adolescents (approximately ≥ 13 years)), pandemic year (2020 *vs.* 2021 *vs.* 2022 *vs.* 2023), pandemic-related restrictions (OSI >60 *vs.* ≤ 60; SCI ≥ 2 *vs.* <2), and socioeconomic status (high *vs.* low). Additional subgroup analyses focused on studies involving soccer players (due to targeted interventions during the pandemic) and comparisons between children and adolescents with normal weight *vs.* those classified as overweight.

Heterogeneity was assessed using forest plots and quantified with the I^2 statistic, values $>50\%$ were considered substantial, and $>75\%$ indicated considerable heterogeneity. Where possible (≥ 10 studies per variable), sources of heterogeneity were further explored through sensitivity analyses and meta-regressions. Sensitivity analyses, defined *a priori*,[26] examined the impact of test type (e.g., 20-m shuttle run *vs.* 6-min run), risk of bias (low *vs.* high), and study design (cohort *vs.* cross-sectional). Meta-analyses were repeated using both the DerSimonian-Laird and Hartung-Knapp methods to test the stability of confidence intervals. Meta-regression analyses explored both categorical moderators (RoB, age group, country, OSI, SCI, and study design) and continuous moderators (year of publication, pandemic-period sample size, and percentage of female participants). Publication bias was evaluated by visual inspection of funnel plots and through Egger's test, applied when at least 10 studies were included in a meta-analysis.[40]

All statistical analyses were conducted using RStudio Web (Version 4.1.2; Posit Software, Boston, MA, USA) with the *meta* and *metafor* packages.[41] A *p*-value <0.05 was considered statistically significant.

3. Results

We included 32 studies[42–70] (3 studies are shown in the Supplementary Table 4) representing 30 unique populations, comprising 1,519,386 fitness measurements (552,622 pre-pandemic; 966,764 during or after the pandemic) from 270,179 children and adolescents, across 19 cohort and 13 cross-sectional studies. For cross-sectional data, baseline comparisons were based on earlier assessments conducted in comparable settings. A total of 28 studies[42–51,53,54,56–60,62–65,67–70] (3 studies are shown in the Supplementary Table 4) were eligible for inclusion in the meta-analyses. Full details of the study selection process are provided in the PRISMA flow diagram (Fig. 1). A list of studies excluded at the title/abstract screening stage is available in Supplementary Table 9, and Supplementary Tables 10–12 provide an overview of participants and measurements across studies.

Study characteristics are summarized in Table 2. Cardiorespiratory fitness was assessed in 21 studies,[42–62] comprising a total of 312,570 measurements. Of these, 20 studies[42–61] (173,071 measurements) assessed endurance, and 5 studies[48,56,57,59,62] (139,499 measurements) speed. Muscular fitness was examined

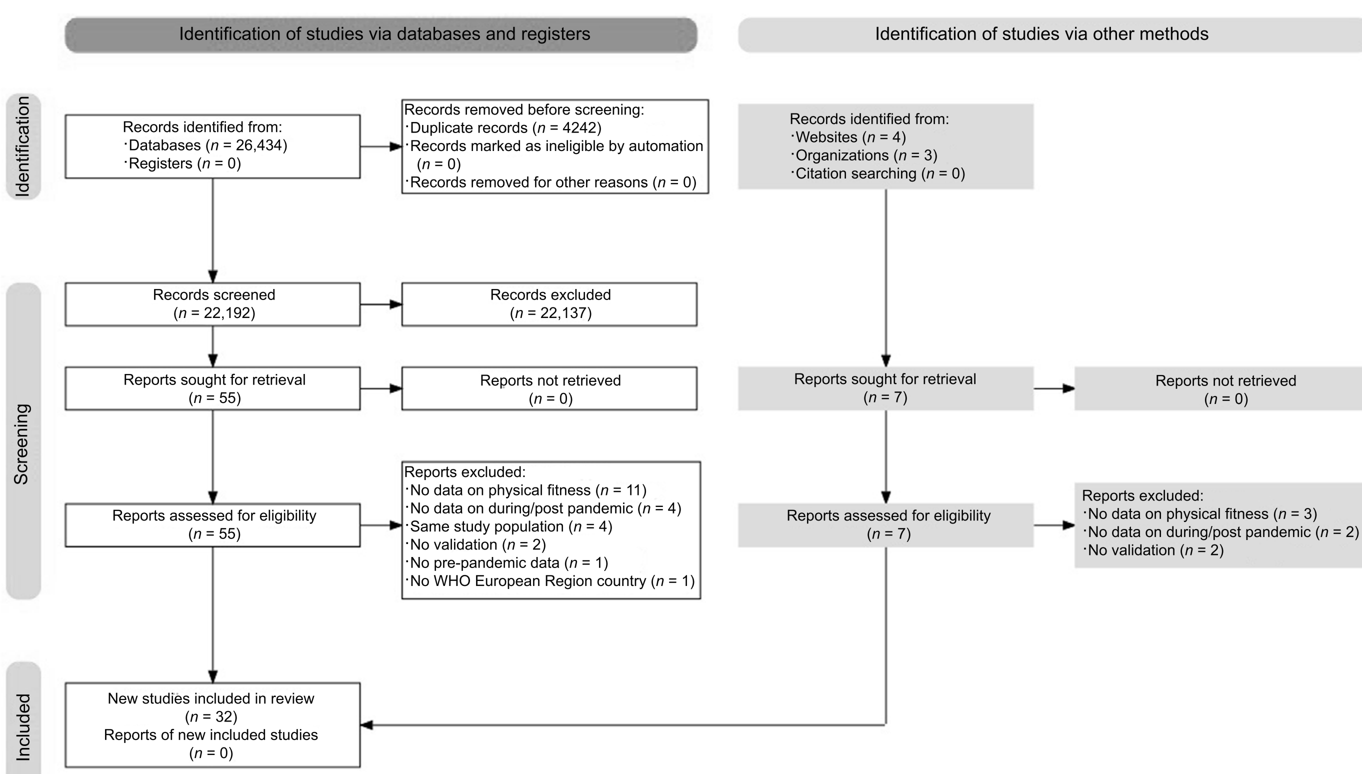

Fig. 1. Preferred reporting items for systematic reviews and meta-analyses 2020 flow diagram. WHO = World Health Organization.

Table 2
Characteristics of included studies.

Study characteristics	Studies	Number of measurements	Number of participants
All physical fitness tests	32	1,519,386	270,179
Pre-pandemic	32	552,622	142,150
During/post-pandemic	32	966,764	128,029
Cardiorespiratory fitness	21	312,570	258,119[a]
Endurance	18	173,071	144,571[a]
Speed	5	139,499	113,548[a]
Muscular fitness	25	1,040,708	633,726[a]
Coordination	7	178,008	107,533[a]
Flexibility	10	172,844	28,887[a]
Strength	23	689,856	497,306[a]
Combined fitness tests	4	166,108	83,448[a]
Cohort studies	19	893,617	87,483
Cross-sectional studies	13	625,770	182,696
Full lockdown	16	286,593	105,760
Full/partial school closures	13	599,458	85,741
Children (6−12 years)	17	652,723	158,960
Adolescents (∼13−19 years)	10	20,862	8936
Age mix (5−19 years)	5	845,801	102,283
Study location (studies)	Germany (6), Austria (3), Portugal (3), Spain (3), UK (2), Turkey (2), France (2), Slovenia (2), Croatia (1), Czech Republic (1), Estonia (1), Greece (1), Hungary (1), Netherlands (1), Poland (1), Serbia (1), and Switzerland (1).		

Notes: Full lockdown = Oxford Stringency Index > 60; full/partial school closures = School Closure Index ≥ 2.
[a] Some participants took part in more than one fitness test, potentially increasing the subset participant size.

in 25 studies[42−44,46−54,56−63,65−68,70] (1,040,708 measurements), including coordination in 8 studies[48,53,54,56,57,63,65,66] (178,008 measurements), flexibility in 10 studies[42,47,52,54,56−58,62,63,67] (172,844 measurements), and strength in 23 studies[42−44,46,47,49−54,56−63,65,67,68,70] (689,856 measurements). Additionally, combined fitness tests were analyzed in 4 studies,[63−65,69] contributing 166,108 measurements. Measurements were conducted during periods of full lockdown (OSI > 60) in 16 studies[42−45,47,49,52−54,57,62,63,69,70] (2 studies are shown in Supplementary Table 4) (44%) and during partial or full school closures (SCI ≥ 2) in 13 studies[43,44,54,55,57,58,62,63,69,70] (3 studies are shown in Supplementary Table 4) (34%). The majority of studies focused on children aged 6−12 years (*n* = 17, 53%), followed by adolescents aged approximately 13−19 years (*n* = 10, 31%) and studies covering broader age ranges (5−19 years; *n* = 5, 16%). RoB was rated as "some concerns" in 11 studies, "high" in 18, and "very high" in 3, with "bias due to missing data" being the most frequently identified domain contributing to high RoB (Supplementary Figs. 1 and 2). The included studies covered 17 countries within the WHO European Region and can be grouped according to the United Nations (UN) Geoscheme[71] as follows: Western Europe (Austria, France, Germany, Netherlands, and Switzerland), Southern Europe (Croatia, Greece, Portugal, Serbia, Slovenia, and Spain), Eastern Europe (Czech, Hungary, and Poland), and Northern Europe (Estonia and UK). Turkey, although not classified under Europe in the UN Geoscheme, was included due to its affiliation with the WHO European Region. Further details are provided in Table 1 and Supplementary Table 13.

3.1. *Cardiorespiratory fitness*

3.1.1. *Endurance*

Endurance was assessed using the 20-m shuttle run[42−52,61] and the 6-min run,[53−60] comprising 19 comparisons and 173,071 measurements collected before and during/post-pandemic. All but 3 studies[52,55,61] were included in the meta-analyses. The overall analysis showed a significant decline, with an SMD of −0.43 (95%CI: −0.61 to −0.25; CoE very low; Fig. 2, Table 1, and Supplementary Fig. 3). When considered separately, the 20-m shuttle run declined with an SMD of −0.56 (95%CI: −0.85 to −0.26), and the 6-min run with an SMD of −0.30 (95%CI: −0.52 to −0.09) (Supplementary Fig. 3). Significant reductions were observed in both girls (SMD = −0.35; 95%CI: −0.58 to −0.12; Fig. 2 and Supplementary Fig. 4) and boys (SMD = −0.28; 95%CI: −0.43 to −0.13; Fig. 2 and Supplementary Fig. 5). Adolescents showed a strong decline (SMD = −0.72; 95%CI: −1.14 to −0.30; Supplementary Fig. 6), primarily driven by reductions in the 20-m shuttle run (Supplementary Figs. 7 and 8). Children showed a moderate decline (SMD = −0.38; 95%CI: −0.59 to −0.16; Supplementary Fig. 6), also with larger reductions observed when considering the 20-m shuttle run specifically (SMD = −0.51; 95%CI: −0.96 to −0.06; Supplementary Figs. 7 and 8). When analyzed by year, the decline in endurance was most pronounced in 2021 (SMD = −0.54; 95%CI: −0.79 to −0.28), compared to 2020 (SMD = −0.33; 95%CI: −0.56 to −0.10), with signs of improvement in 2022 (SMD = −0.31; 95%CI: −0.61 to −0.02). Endurance performance showed further improvement in 2023, although values remained significantly below pre-pandemic levels (SMD = −0.10; 95%CI: −0.12 to −0.08; Fig. 3 and Supplementary Fig. 9); this was consistent in both girls (SMD = −0.13; 95%CI: −0.18 to −0.08) and boys (SMD = −0.08; 95%CI: −0.11 to −0.05), as detailed in the Supplementary Results (Subgroup Analyses). When analyzed by individual test, the timeline reductions were more pronounced in the 20-m shuttle run (Supplementary Figs. 10 and 11), whereas the 2023 data are based on the 6-min run (Supplementary Fig. 11). Stronger declines in endurance were observed in studies conducted during periods of full lockdown (OSI > 60: SMD = −0.69; 95%CI: −1.12 to −0.26) and during partial or full school closures (SCI ≥ 2: SMD = −0.70; 95%CI: −1.11 to −0.29; Fig. 4A and 4B, Supplementary Figs. 12 and 13), predominantly influenced by reductions in the 20-m shuttle run (Supplementary Figs. 14−17). This trend was particularly evident in girls (OSI > 60: SMD = −0.62, 95%CI: −1.29 to 0.05; SCI ≥ 2: SMD = −0.42, 95%CI: −0.83 to −0.01), whereas boys appeared to be less affected (OSI > 60: SMD = −0.23, 95%CI: −0.57 to 0.11; SCI ≥ 2: SMD = −0.35, 95%CI: −0.65 to −0.06), as reported in the Supplementary Results (Subgroup Analyses).

3.1.2. *Speed*

Speed was measured with the 20-m sprint,[48,56,57,59] 30-m sprint,[62] and 505 agility test,[62] totaling 7 comparisons and 139,499 measurements recorded pre- and during/post-pandemic, all included in the meta-analyses. The overall analysis showed a non-significant decline with an SMD of −0.29 (95%CI: −0.61 to 0.03; CoE: very low; Fig. 2, Table 1, and

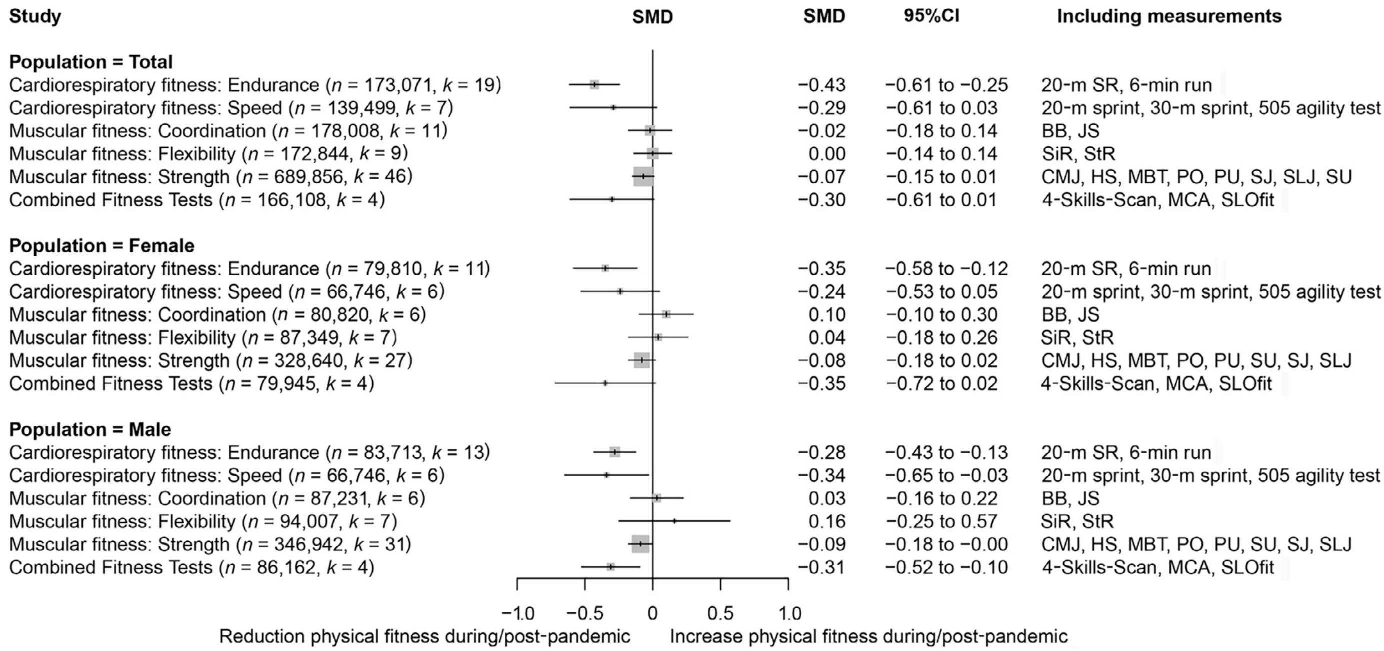

Fig. 2. Forest plot of changes in physical fitness components before *vs.* during/after the COVID-19 pandemic, by total population (n = 1,519,386; k = 96), female (n = 723,310; k = 61), and male (n = 764,801; k = 67). Box size reflects the precision of the pooled estimate, with larger boxes representing greater weight in the meta-analysis. 95%CI = 95% confidence interval; BB = balancing-backwards; CMJ = countermovement jump; HS = handgrip strength; JS = jumping-sideways; k = number of comparisons; MBT = medicine ball throw; MCA = motor competence assessment; n = number of measurements; PO = power output per kg; PU = push-ups; SMD = standardized mean difference; SiR = sit-and-reach; SJ = standing jump; SLJ = standing long jump; SR = shuttle run; StR = stand-and-reach; SU = sit-ups.

Supplementary Fig. 18). When examined by individual measurement, the 20-m sprint showed an SMD of −0.07 (95%CI: −0.26 to 0.12), the 30-m sprint an SMD of −0.93 (95%CI: −1.26 to −0.61), and the 505 agility test an SMD of −0.88 (95%CI: −1.21 to −0.56) (Supplementary Fig. 18). Sex-stratified analyses indicated declines for both girls (SMD = −0.24; 95%CI: −0.53 to 0.05; Fig. 2 and Supplementary Fig. 19) and boys (SMD = −0.34; 95%CI: −0.65 to −0.03; Fig. 2 and Supplementary Fig. 20). Age-stratified analyses were not possible, as only 1 study[62] with data on adolescents could be included. Considering the pandemic years, the decline was minimal in 2020 (SMD = −0.05; 95%CI: −0.32 to 0.21), more pronounced in 2021 (SMD = −0.39; 95%CI: −0.73 to −0.04), and stabilized in 2022 (SMD = −0.06; 95%CI: −0.09 to −0.03) and 2023 (SMD = −0.03; 95%CI: −0.07 to 0.00; Fig. 3 and Supplementary Fig. 21). In the sex-stratified analyses, the decline was also pronounced in both girls (SMD = −0.31; 95%CI: −0.62 to −0.01) and boys (SMD = −0.42; 95%CI: −0.77 to −0.07) in 2021 and stabilized in both groups in 2022 and 2023, according to the subgroup analyses in the Supplementary Results. The speed-decline in 2021 was largely attributable to reductions in the 30-m sprint and the 505 agility test (Supplementary Fig. 22). Stricter restrictions and school closures might be associated with greater reductions (OSI > 60 or SCI ≥ 2: SMD = −0.78; 95%CI: −1.01 to −0.54; Fig. 4A and 4B, Supplementary Figs. 23 and 24), which was confirmed in the analysis by individual measurement test (Supplementary Figs. 25 and 26). A similar trend was observed in both girls (OSI > 60 or SCI ≥ 2: SMD = −0.57; 95%CI: −0.88 to −0.27) and boys (OSI > 60 or SCI ≥ 2: SMD = −0.69; 95%CI: −0.92 to −0.46), as described in the Supplementary Results (Subgroup Analyses).

3.2. Muscular fitness

3.2.1. Coordination

Coordination was assessed using the balancing-backwards test[48,56,57,63] and the jumping-sideways test[48,53,54,56,57,65,66] across 11 comparisons and 178,008 measurements taken pre- and during/post-pandemic, with all but 1 study[66] included in the meta-analyses. The overall analysis showed no change during the pandemic (SMD = −0.02; 95%CI: −0.18 to 0.14; CoE: low; Fig. 2, Table 1, and Supplementary Fig. 27), with similar results for girls (SMD = 0.10; 95%CI: −0.10 to 0.30; Fig. 2 and Supplementary Fig. 28) and boys (SMD = 0.03; 95%CI: −0.16 to 0.22; Fig. 2 and Supplementary Fig. 29). Similar results emerged when individual measurements were examined (balancing-backwards: SMD = −0.04, 95%CI: −0.19 to 0.10; jumping-sideways: SMD = −0.01, 95%CI: −0.26 to 0.23; Supplementary Fig. 27). Age-stratified analyses were not possible. No changes in overall coordination were observed when data were analyzed by pandemic year (2020: SMD = 0.07, 95%CI: −0.10 to 0.24; 2021: SMD = −0.04, 95%CI: −0.24 to 0.15; 2022: SMD = −0.02, 95%CI: −0.26 to 0.21; Fig. 3 and Supplementary Fig. 30), with similar results in the analyses of individual tests (Supplementary Figs. 31 and 32); no data were available for 2023. In the sex-stratified analyses, no relevant changes occurred in 2020 and 2021; however, the results did show a reduction in 2022 for girls (SMD = −0.12; 95%CI: −0.15 to −0.09) and boys

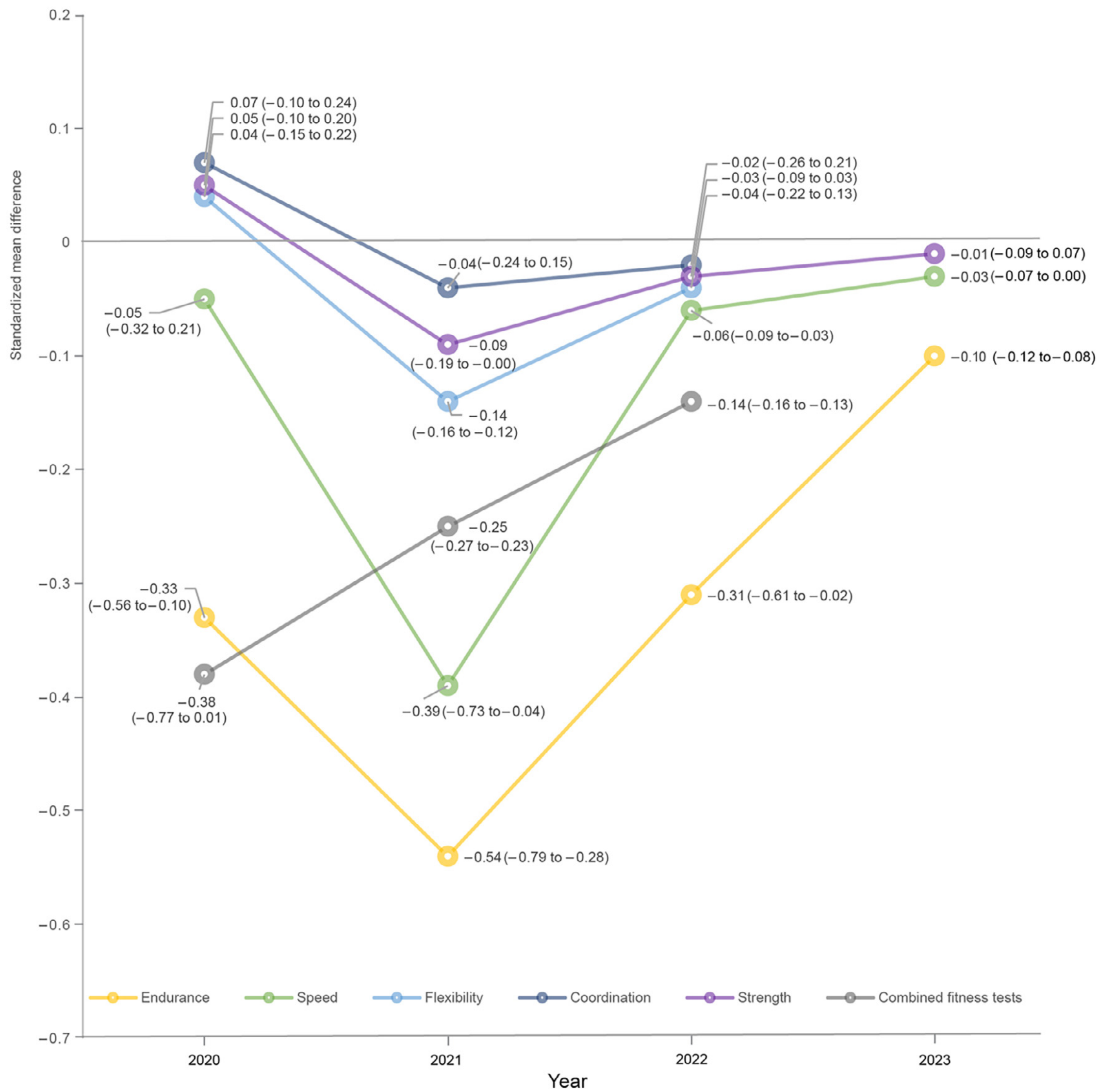

Fig. 3. Timeline of changes in physical fitness components during and after the coronavirus disease 2019 (COVID-19) pandemic (n = 1,519,386).

(SMD = −0.10; 95%CI: −0.13 to −0.07; detailed analyses are presented in the Supplementary Results (Subgroup Analyses). Stricter restrictions showed no association with coordination (OSI > 60: SMD = 0.15, 95%CI: −0.26 to 0.56; SCI ≥ 2: SMD = 0.04, 95%CI: −0.26 to 0.34; Fig. 4A and 4B, Supplementary Figs. 33 and 34). When analyzed separately by individual test, balancing-backwards showed a small but significant association with stricter pandemic measures (SMD = −0.16; 95%CI: −0.29 to −0.02; Supplementary Figs. 35−38) and with school closures (SMD = −0.21; 95%CI: −0.32 to −0.11; Supplementary Figs. 35−38), whereas jumping-sideways showed no association. Additionally, stratification by sex revealed no relevant differences regarding restriction severity, as reported in the Supplementary Results (Subgroup Analyses).

3.2.2. *Flexibility*

Flexibility was assessed using the sit-and-reach[42,47,52,54,62] and stand-and-reach tests[56−58,63,67] across 9 comparisons and 172,844 measurements recorded pre- and during/post-pandemic, with all but 1 study[53] included in the meta-analysis. The overall analysis showed no change (SMD = 0.00; 95%CI: −0.14 to 0.14; CoE: low; Fig. 2, Table 1, and Supplementary Fig. 39), and similar results were observed when individual measurements were analyzed (sit-and-reach: SMD = −0.05, 95%CI: −0.33 to 0.22; stand-and-reach: SMD = 0.03, 95%CI: −0.13 to 0.18; Supplementary Fig. 39). No meaningful differences were observed by sex (girls: SMD = 0.04, 95%CI: −0.18 to 0.26; boys: SMD = 0.16, 95%CI: −0.25 to 0.57; Fig. 2, Supplementary Figs. 40 and 41), nor by age group (children: SMD = −0.04, 95%CI: −0.23 to 0.16; adolescents: SMD = 0.07, 95%CI: −0.18 to 0.31; Supplementary Fig. 42), nor by individual test (Supplementary Figs. 43 and 44). Flexibility remained stable in 2020 (SMD = 0.04; 95%CI: −0.15 to 0.22), declined in 2021 (SMD = −0.14; 95%CI: −0.16 to −0.12; Fig. 3 and Supplementary Fig. 45), particularly in the sit-and-reach test (SMD = −0.19; 95%CI: −0.36 to −0.02; Supplementary Figs. 46 and 47), and recovered by 2022 (SMD = −0.04; 95%CI: −0.22 to 0.13; Fig. 3 and Supplementary Fig. 45). No data were available for 2023.

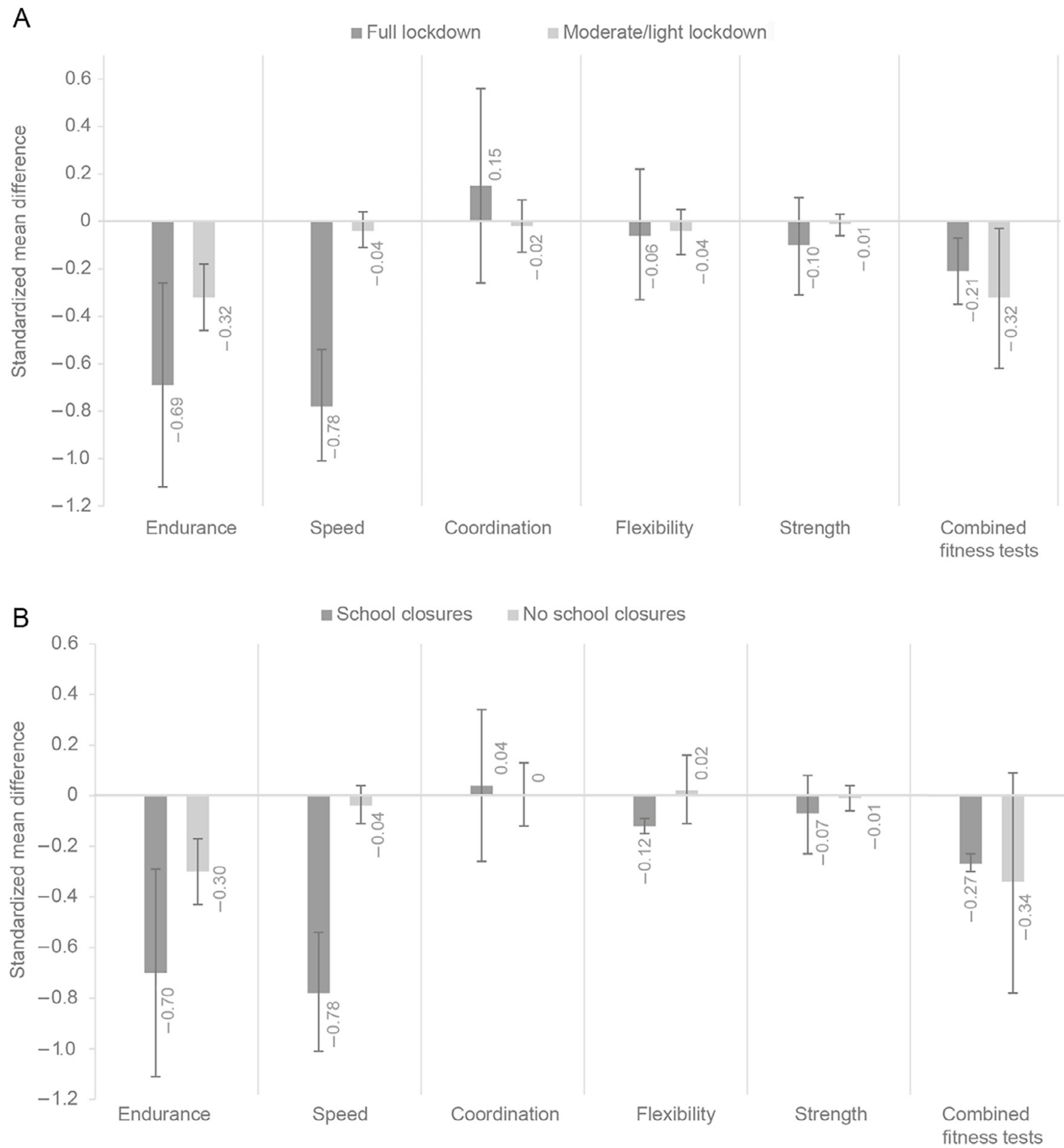

Fig. 4. Changes in physical fitness during the coronavirus disease 2019 (COVID-19) pandemic by severity of national restrictions (n = 1,519,386). (A) Full lockdown *vs*. moderate/light lockdown. (B) Partial/full school closure *vs*. no school closures. Bars show the magnitude and direction of standardized mean differences, with whiskers indicating 95% confidence intervals. Bar width does not represent weight or precision. Full lockdown = Oxford Stringency Index > 60; moderate/light lockdown = Oxford Stringency Index ≤ 60; full/partial school closures = School Closure Index ≥ 2; no school closures = School Closure Index < 2.

Stricter restrictions had no impact (OSI > 60: SMD = −0.06, 95%CI: −0.33 to 0.22; SCI ≥ 2: SMD = −0.12, 95%CI: −0.15 to −0.09; Fig. 4A and 4B, Supplementary Figs. 48 and 49). Findings on restrictions were consistent across sexes (Supplementary Results, Subgroup Analyses) and across individual tests (Supplementary Figs. 50−53).

3.2.3. *Strength*

Strength was assessed using the standing long jump,[42−44,49−57,59,60,63,65,67] countermovement jump,[43,46,58,61,62] handgrip strength,[42,43,44,49,51,52,62,67] sit-ups,[47,56,57,60,63,67,70] medicine ball throw,[43,54,58−61,67] push-ups,[47,57] squat jump,[46,61] and power output per kg[68] across 46 comparisons and 689,856 measurements taken pre and during/post pandemic, with all but 2 studies[52,61] included in the meta-analysis. The overall analysis showed no change (SMD = −0.07; 95%CI: −0.15 to 0.01; CoE: low; Fig. 2, Table 1, and Supplementary Fig. 54). With the exception of a moderate decline in countermovement jump performance (SMD = −0.38; 95%CI: −0.72 to −0.04, Supplementary Fig. 54), no further significant changes were found in the individual measurements (Supplementary Fig. 54). No overall sex-specific differences were found (girls: SMD = −0.08, 95%CI: −0.18 to 0.02; boys: SMD = −0.09, 95%CI: −0.18 to −0.00; Fig. 2, Supplementary Figs. 55 and 56). Adolescents exhibited a reduction (SMD = −0.23; 95%CI: −0.43 to −0.02, Supplementary Fig. 57), largely attributable to declines in countermovement jumps (SMD = −0.81; 95%CI: −1.13 to −0.49, Supplementary Fig. 58), sit-ups (SMD = −0.60; 95%CI: −1.18 to −0.02, Supplementary Fig. 59), and standing long jumps (SMD = −0.11; 95%CI: −0.21 to −0.01, Supplementary Fig. 60). In contrast, children showed no overall effect (SMD = −0.03; 95%CI: −0.12 to 0.07, Supplementary Fig. 57). Yet, stratified analyses of individual tests revealed improvements in children's push-ups (SMD = 0.52; 95%CI: 0.04–1.01, Supplementary Fig. 61) and sit-ups (SMD = 0.23; 95%CI: 0.07–0.39, Supplementary Fig. 59), while the medicine ball throw showed a small decline (SMD = −0.08; 95%CI: −0.14 to −0.02, Supplementary Fig. 62). No further significant changes were yielded (Supplementary Figs. 58−65). No changes were observed when analyzed overall by year (2020: SMD = 0.05, 95%CI: −0.10 to 0.20; 2021: SMD = −0.09, 95%CI: −0.19 to 0.00; 2022: SMD = −0.03, 95%CI: −0.09 to 0.03; 2023: SMD = −0.01, 95%CI: −0.09 to 0.07; Fig. 3, Supplementary Fig. 66, individual measurements are presented in Supplementary Figs. 67−74). Stricter restrictions also showed no effect (OSI > 60: SMD = −0.10, 95%CI: −0.31 to 0.10; SCI ≥ 2: SMD = −0.07, 95%CI: −0.23 to 0.08; Fig. 4A and 4B and Supplementary Figs. 75 and 76), nor were any effects observed in the individual tests (Supplementary Figs. 77−92). Further stratification by sex did not reveal substantial variation, as detailed in the Supplementary Results (Subgroup Analyses).

3.3. *Combined fitness tests*

Combined fitness tests included 2 studies on motor competence,[64,65] 1 on the 4-Skills Scan,[69] and 1 on SLOfit,[63] totaling 4 comparisons and 166,108 measurements recorded pre and during/post pandemic. The overall analysis showed a non-significant decline (SMD = −0.30; 95%CI: −0.61 to 0.01; CoE: very low; Fig. 2, Table 1, and Supplementary Fig. 93), with similar declines for girls (SMD = −0.35; 95%CI: −0.72 to 0.02; Fig. 2 and Supplementary Fig. 94) and boys (SMD = −0.31; 95%CI: −0.52 to −0.10; Fig. 2 and Supplementary Fig. 95). Age-stratified analyses were not possible, as only one study with data on adolescents could be included. After a non-significant decline in 2020 (SMD = −0.38; 95%CI: −0.77 to 0.01), the decline weakened till 2022 (SMD = −0.14; 95%CI: −0.16 to −0.13; Fig. 3 and Supplementary Fig. 96). A small association with stricter restrictions and school closures was found (OSI > 60: SMD = −0.21, 95%CI: −0.35 to −0.07; SCI ≥ 2: SMD = −0.27, 95%CI: −0.30 to −0.23), though declines might be more pronounced during periods of lighter restrictions (OSI ≤ 60: SMD = −0.32, 95%CI: −0.62 to −0.03; SCI < 2: SMD = −0.34, 95%CI: −0.78 to 0.09) (Fig. 4A and 4B, Supplementary Figs. 97 and 98). A similar trend was observed in stratified analyses for girls and boys, as detailed in the Supplementary Results (Subgroup Analyses).

Further results from subgroup analyses by age, sex, social status, weight status, and soccer players are provided in the Supplementary Results (Subgroup Analyses). Sensitivity analyses (Supplementary Tables 14−20), meta-regressions (Supplementary Tables 21−26), and publication bias assessments (Supplementary Table 27 and Supplementary Figs. 99−105) were also conducted.

4. Discussion

Our analyses provide a comprehensive synthesis of physical fitness trends among children and adolescents during and after the COVID-19 pandemic. Drawing on more than 1.5 million measurements from more than 270,000 participants across 17 European countries, our findings confirm that the pandemic-related restrictions had a significant negative impact on cardiorespiratory fitness (including endurance and speed), with endurance levels not recovered by 2023. Girls experienced greater declines in endurance, while boys were more affected by reductions in speed. Adolescents were more impacted than children, showing pronounced declines in endurance and moderate declines in strength. In contrast, most other components of muscular fitness remained largely stable.

Although physical fitness is recognized by the WHO as a critical health outcome,[12] to date, no systematic review with meta-analysis has addressed physical fitness in children and adolescents during and after the COVID-19 pandemic. A scoping review including eight studies with data up to 2022 reported consistent declines in cardiorespiratory fitness, particularly during lockdowns, whereas muscular fitness appeared largely unaffected.[72] Our study expands this evidence base by including 32 studies, extending the period analyzed to 2025 and providing multiple meta-analyses at the component level, the individual test level, and across several subgroups. Both reviews highlight that endurance was most affected during the pandemic; however, our findings further suggest that these short-term disruptions accelerated pre-existing secular declines in endurance,[14−16] as levels in 2023 remained below pre-pandemic values. Our findings are also in line with the broader literature on pandemic-related declines in physical activity across Europe[22] and worldwide[20,21]: Physical activity reductions are a plausible pathway for the observed declines in cardiorespiratory fitness, caused by disrupted routines and limited access to structured activities. Endurance decline was likely due to reduced participation in activities such as swimming and team sports, which depend on structured environments disrupted by lockdowns and school closures.[18] Speed levels also declined but recovered more quickly from 2022. In contrast, muscular fitness was less affected, likely due to its adaptability to home environments and lesser dependence on specialized settings.[73] Pandemic-related weight gain[74,75] may have also contributed, as higher body weight impairs endurance performance through increased energy costs, while potentially enhancing muscular strength through greater loading and anabolic effects.[76,77] The decline in cardiorespiratory fitness is concerning, since even modest fitness reductions across large populations increase the risks of non-communicable diseases such as cardiovascular disease, type-2-diabetes, and cancer[78]—conditions projected to rise in the coming years.[79] Endurance, a key indicator of cardiorespiratory fitness, is particularly important in this context. Beyond reducing the risk of obesity and cardiometabolic diseases later in life,[1,80] it has also been associated with better mental health and academic performance in children and adolescents.[3,6,81,82]

4.1. Sex differences

Within the dimension of cardiorespiratory fitness, girls exhibited greater declines in endurance, whereas boys showed more pronounced reductions in speed. Consistent with our findings, a U.S. longitudinal study reported that girls had lower odds of reaching healthy cardiorespiratory fitness norms during the pandemic compared with boys,[83] thereby amplifying an existing sex gap.[84] Prior research has shown that between ages 6 and 17, median maximal oxygen consumption (VO_{2max}) declines by about 14% in boys and 27% in girls,[85] indicating widening sex differences in aerobic reserve and cardiopulmonary adaptation.[14,32] This physiological vulnerability may be compounded by girls' stronger reliance on structured activities such as swimming, dance, or school athletics,[86−88] many of which were suspended during the pandemic.[36,89] The sharper endurance losses observed in girls, largely captured by the 20-m shuttle run, therefore likely reflect the disruption of organized sport. Psychosocial factors may have compounded these effects, as girls report lower self-efficacy, stronger body image concerns, and more depressive symptoms than boys,[88,90] factors that appear to have intensified during the pandemic.[38,91] At the same time, boys in the aforementioned U.S. study experienced greater absolute losses in cardiorespiratory fitness,[83] a pattern that may be mirrored in our meta-analysis by the sharper declines observed in boys' speed. Although boys were equally affected by the closure of organized sport, they were more likely to maintain some level of informal play outdoors,[86] which may have partially buffered endurance losses. However, such informal activity was probably not sufficient to sustain performance in speed, a dimension that depends more strongly on structured high-intensity training. Together, these findings underscore that the mechanisms underlying cardiorespiratory fitness declines during the pandemic differ by sex and carry important implications for future prevention and intervention.

4.2. Age differences

Adolescents aged 13−19 years were particularly affected in our study, showing strong declines in endurance and moderate declines in strength, whereas younger children displayed only moderate endurance losses and largely stable strength. Endurance declines were mainly driven by reductions in the 20-m shuttle run, a test that depends strongly on structured training[32] and is therefore sensitive to disruptions in organized activity. Our findings align with a recent scoping review reporting greater fitness declines with age, which reflects adolescents' stronger reliance on organized opportunities.[72] Adolescence is marked by rapid growth, neuromuscular adaptation, and hormonal maturation.[92] Since VO_{2max} plateaus after puberty,[93] adolescents are especially vulnerable to interruptions of physical fitness. These physiological processes are typically supported by structured physical exercise,[94] meaning that the suspension of such activities disproportionately affected this age group.[36,89] Younger children may have been less affected, as spontaneous activity is more characteristic of this age group,[95] which may have helped preserve fitness even during restrictions.[36,89] Strength declined moderately in adolescents, with losses in countermovement jumps, sit-ups, and standing long jumps likely reflecting their reliance on structured settings,[36,89] while stability in other tests may relate to greater adaptability to home-based exercises.[73] Additional lifestyle changes may further contribute to these effects, as adolescents reported the greatest increases in screen time,[96,97] reduced sleep,[97] and worsening mental health[22,38] during the pandemic, all of which likely reinforced declines in endurance and strength. Flexibility remained unchanged across age groups, while limited data on speed and coordination preclude firm conclusions. Taken together, these findings highlight adolescence as a critical developmental window in which interruptions to structured activity may have lasting effects on physical fitness trajectories.

4.3. Differences in individual tests

In addition to the component-level syntheses, our study also considered individual tests, which offered further insights. For example, declines in endurance were consistently more pronounced in the 20-m shuttle run than in the 6-min run, likely because the former depends on structured training and requires repeated accelerations and external pacing,[32] conditions that were particularly restricted during the pandemic.[36,89] In contrast, the 6-min run primarily tests continuous aerobic endurance and can be performed outdoors with minimal equipment, which may have mitigated declines. Changes in muscular strength were mainly age-driven (see above), suggesting that different individual tests vary by age in their outcomes and capture distinct physiological or motivational aspects of performance.[98] Components such as coordination and flexibility, however, showed broadly consistent results across tests.

4.4. Future research

Future research should employ standardized physical fitness assessments across studies, systematically include data on biological maturation to better interpret adolescents' trends, and develop longitudinal monitoring systems to capture fitness changes over time in a harmonized way.[99−101] In addition, evaluating the effectiveness of interventions and identifying at-risk subgroups, particularly by social status, remain essential priorities.

4.5. Strengths and limitations

A key strength of this study lies in its large and diverse dataset, which, to our knowledge, provides the first systematically recorded and comprehensive evidence base across multiple fitness dimensions. The use of validated fitness tests and stratification by sex, age, year, and restriction severity further enhanced the relevance and interpretability of our findings. By analyzing fitness at both the individual test and component level, a more complete picture of pandemic-related changes was captured. However, the overall certainty of evidence was low to very low, with 66% of studies assessed as high or very high RoB. Studies with higher RoB also showed stronger negative effects, suggesting that methodological limitations may have inflated estimates of decline. This highlights the importance of cautious interpretation, as true declines may be somewhat smaller than indicated by lower-quality studies. In addition, limited data on variables such as social status constrained deeper analyses. Due to the limited data from Eastern and Northern Europe, regional generalizability remains restricted and should be addressed in future studies. In the absence of correlation coefficients for pre−post data of cohort studies, we used time point-specific standard deviation as reported by the study authors, resulting in a conservative approach. Notably, no studies included maturation data, despite its potential influence on fitness trends; this is a known challenge in observational research due to ethical and practical concerns.[102]

4.6. Implications for policy and practice

To translate our findings into policy and practice, we applied the GRADE Evidence to Decision (EtD) framework,[103] which provides a structured set of criteria to support transparent and systematic decision-making in public health. Building on this framework, we drew on the EtD criteria to contextualize our findings and discuss the relevance of interventions: In the context of available evidence, our study confirms worrying trends of physical fitness levels among children and adolescents in Europe, with stagnations at low levels in some fitness components (particularly cardiorespiratory fitness) and additional declines due to COVID-19 pandemic restrictions, followed by incomplete recovery. Since childhood and adolescence are critical windows for establishing lifelong health behaviors,[8−11] the pandemic-related setbacks described in this review threaten to widen existing health disparities and increase future burdens on healthcare systems. This puts the physical and mental health of this population at risk, unnecessarily, now and in their future adult lives. Yet, effective interventions to promote physical activity and increase fitness levels exist. Especially in school settings, interventions have been rated as feasible, acceptable, and likely cost-effective.[104−106] Examples include daily physical activity sessions, integration of movement breaks into classroom routines, and reactivation programs for community-based sports.[12] Given the persistently low levels of endurance, combined with concurrent trends such as rising mental health disorders,[38,107] increasing obesity rates,[108] and growing screen time,[96] the opportunity costs for more than 156 million children and adolescents in Europe are likely to be substantial.[13,105] Successful strategies need collaboration across sectors and stakeholders, including young people themselves, and ensure action at all levels: individual, societal, environmental, and systemic. The WHO Global Action Plan on Physical Activity[13,101] offers a range of interventions that can be adapted to different settings and cultures, including across Europe. In this context, restoring and improving physical fitness among children and adolescents must be considered as an urgent public health priority. The time to act is now to mitigate negative effects resulting from the COVID-19 pandemic and to prevent unnecessary disease burden and related costs.

5. Conclusion

Cardiorespiratory fitness in children and adolescents declined markedly during the COVID-19 pandemic, in contrast to relatively stable levels of muscular fitness. The most pronounced reductions were observed in endurance, particularly among girls and adolescents, with endurance levels remaining below pre-pandemic baselines. This concerning trend highlights the urgent need for effective interventions to enhance physical fitness and foster lifelong healthy behaviors in younger populations. Future efforts should go beyond short-term recovery and focus on implementing sustainable, inclusive strategies that promote physical fitness for all children and adolescents.

Authors' contributions

HLW conceptualized and coordinated the study, contributed to the literature search, data extraction, risk of bias assessment, and certainty of evidence evaluation, performed the statistical analysis, and drafted the manuscript; MB and RG co-led the study and provided overall supervision; SH participated in the literature search, data extraction, and risk of bias assessment; WS supported the statistical analysis and contributed to the certainty of evidence evaluation; CN and TE contributed to study conceptualization, methodological development, and interpretation of results; ID contributed to the literature search and data extraction. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Declaration of competing interest

RG is a staff member of the WHO. The authors alone are responsible for the views expressed in this publication and they do not necessarily represent the views, decisions, or policies of the WHO. All authors declare that they have not competing interests.

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Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:10.1016/j.jshs.2025.101101.

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