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Does sedentary behaviour cause spinal pain in children and adolescents? A systematic review with meta-analysis

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ABSTRACT

Objective To evaluate whether sedentary behaviour is a risk or prognostic factor for spinal pain in children and adolescents. Specifically, to estimate the (1) direction and strength of the association; (2) risk of spinal pain onset and (3) effect on spinal pain prognosis.

Design Systematic review with meta-analysis.

Data sources Electronic searches of MEDLINE, Embase, CINAHL and Web of Science up to 23 March 2023.

Eligibility criteria for selecting studies Reports estimating the effect of sedentary behaviour on spinal pain in young people (≤ 19 years).

Results We included 129 reports, 14 were longitudinal ($n = 8\ 433$) and 115 were cross-sectional ($n > 697\ 590$). We incorporated 86 studies into meta-analyses. (1) From cross-sectional data, we found low certainty evidence of a small positive association between sedentary behaviour and spinal pain (adjusted odds ratio 1.25 (95% CI 1.17 to 1.33), $k = 44$, $n > 92\ 617$). (2) From longitudinal data, we found low certainty evidence of no increased risk for the onset of spinal pain due to sedentary behaviour (adjusted risk ratio 1.07 (95% CI 0.84 to 1.35), $k = 4$, $n = 1\ 292$). (3) No studies assessed prognosis.

Conclusion Cross-sectional data suggest minimally higher odds of spinal pain for children and adolescents who engage in greater sedentary behaviours. However, longitudinal data do not support a causal relationship, indicating that sedentary behaviour does not increase the risk for onset of spinal pain. Due to the low certainty of evidence, these findings must be interpreted with caution. We found no evidence of the effect sedentary behaviour has on spinal pain prognosis in children and adolescents, highlighting a considerable gap in the literature.

INTRODUCTION

Rationale

Spinal pain, encompassing discomfort in the neck, mid back or low back, exhibits an increasing prevalence from childhood through adolescence. Nearly 40% of individuals younger than 19 report experiencing spinal pain at least once in their lifetime, with 20% reporting a rise in frequency over time.^{1–4} A substantial portion—nearly one-quarter—of children and adolescents experience chronic or recurrent spinal pain that impacts various aspects of their lives, including healthcare and medication use, physical activity, daily functioning, school and work attendance, and overall quality of life.^{5–7} Chronic

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ The prevalence of spinal pain increases from childhood to adolescence, and previous episodes elevate the risk of adult spinal pain.
- ⇒ In young populations, psychosocial and familial factors are often negatively associated with spinal pain; however, motor performance factors and backpack weight are not linked to spinal pain.
- ⇒ The impact of sedentary behaviour on the risk for onset of spinal pain and its prognosis in children and adolescents remains unclear.

WHAT THIS STUDY ADDS

- ⇒ The relationship between sedentary behaviour and spinal pain in children and adolescents has been extensively estimated in cross-sectional studies (115 reports); however, few longitudinal studies assessed risk of onset (14 reports) and prognosis (0 reports).
- ⇒ Based on low-certainty evidence from meta-analyses of cross-sectional data involving more than 224 862 participants, there are minimally higher odds of spinal pain for children and adolescents who engage in greater sedentary behaviours.
- ⇒ However, from meta-analyses of longitudinal data involving more than 1 292 participants, sedentary behaviour is not a risk factor for the onset of meaningful spinal pain in children and adolescents.

spinal pain can also create financial burden on families and society.⁸ Musculoskeletal pain, including spinal pain, has an estimated annual healthcare cost ranging from US\$143 to US\$41 379 per child or adolescent in 2021. Associated annual costs include patient/family costs (US\$287–US\$27 972), lost productivity costs (US\$124–US\$4671) and societal costs (US\$1095–US\$69 351) per child or adolescent.⁸ Importantly, adolescent spinal pain strongly predicts its occurrence in adulthood, where low back pain emerges as the leading cause of years lived with disability.^{9 10} The onset of first episodes of spinal pain during childhood or adolescence, therefore, marks a critical stage for prevention and early intervention.

The majority of spinal pain diagnosed in adolescents is considered primary, lacking a discernible



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pathoanatomical cause and identified mechanism.¹¹ In young populations, psychosocial and familial factors are often negatively linked to spinal pain, while some biomechanical factors, including motor performance and backpack weight, are not consistently linked to spinal pain in young populations.^{3 12–16} Conversely, evidence for the role of other biomechanical and lifestyle factors, including sedentary behaviour, remains inconsistent.^{3 12 14} Strong evidence links sedentary behaviour, particularly screen time, to obesity and moderate evidence indicates adverse effects on blood pressure, cholesterol levels, physical fitness, self-rated health, life satisfaction, social behaviour, academic performance and psychological health in young populations.^{17–23} As a result, many countries endorse public health guidelines limiting additional (outside school) daily screen time to under two hours; recent updates target sedentary time in classrooms.^{24 25} However, children and adolescents frequently exceed the recommended limits, with adolescents surpassing children in time spent sedentary.²⁶ This trend of increased sedentary behaviour, along with decreased physical activity, persists from childhood through adolescence.^{27 28}

Popular culture links spinal pain, specifically neck pain, in children and adolescents to sedentary behaviours and screen use, often labelled as ‘text neck’ by clinicians, researchers and the public.^{29 30} Exploration of the mechanisms linking sedentary behaviour and spinal pain, such as direct mechanisms (eg, sustained forward head posture) and indirect mechanisms (eg, increased adiposity, sleep disturbance, poor mental health), have been inconsistent and inconclusive.^{28 31 32} No existing systematic review has comprehensively explored the link between sedentary behaviour and spinal pain exclusively in children and adolescents. While previous reviews over the last decade touch on this relationship, they vary in scope and quality. Some solely rely on cross-sectional evidence,^{33 34} lack quantitative analysis,^{15 33 35 36} encompass a wide range of risk factors,^{15 35} focus on adults^{37–39} or exhibit questionable methodological rigour.^{34 40} Understanding the potential association between sedentary behaviour and spinal pain in children and adolescents may help resolve the controversy, provide actionable insights for public health, clinicians and families, establish the quality of available evidence, identify trends and pinpoint targets for future research.

Objectives

We aimed to evaluate whether sedentary behaviour is a risk or prognostic factor for spinal pain in children and adolescents. Specific objectives were to (1) estimate the direction (ie, protective or not) and strength (ie, magnitude) of the association between sedentary behaviour and spinal pain; (2) determine if sedentary behaviour increases the risk for onset of the first or recurrent episode of spinal pain and (3) examine if sedentary behaviour worsens the prognosis of spinal pain in children and adolescents.

METHODS

Protocol registration and reporting

Our review protocol is registered with the International Prospective Register of Systematic Reviews (PROSPERO 2020 CRD42020148254). Our reporting adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020.⁴¹

Eligibility criteria

Types of studies and population

Peer-reviewed reports were eligible for inclusion where the participant’s mean age was ≤ 19 years at enrolment, aligning with the WHO defined upper limit of adolescence.⁴² We did not limit the minimum age, follow-up period, sample size, participant characteristics or study context/setting (eg, athletes, school children and data registry). Clinical trials with no-care control group data were eligible for inclusion (ie, wait list and no intervention). Trials with a usual-care or active control group were excluded, as were grey literature or unpublished studies, including conference proceedings.

Types of exposure factors

Reports were eligible for inclusion if they measured and reported sedentary behaviour exposure in accordance with the Sedentary Behaviour Research Network definition: sedentary behaviour includes any behaviour while (1) awake, (2) in a seated, lying or reclining posture and (3) with low energy expenditure.⁴³ Low energy expenditure is classified as less than three metabolic equivalents (METs), including activities such as watching television (TV) (1.0–1.3 METs), playing traditional video or computer games (1.0 METs), reading or studying (1.3 METs), riding in a car (1.3 METs) and sitting playing a musical instrument (2.0–2.5 METs).⁴⁴

Types of outcomes

To be included, reports must have measured spinal pain according to the following definition by the International Association for the Study of Pain: spinal pain is perceived as arising from the vertebral column or its adnexa (ie, muscles, tendons, nerves, bones and joints of the spine).⁴⁵ Reports measuring pain as single or multiregional (eg, neck pain, mid and low back pain) or in combination with an adjacent anatomical region (eg, neck and shoulder pain) were eligible for inclusion. We included all measures of spinal pain intensity, frequency and impact. Spinal pain impact may have included absence from school, taking pain medication or seeking healthcare. We excluded reports where the pain was disease or injury related, including but not limited to cancer, juvenile spondyloarthritis, postsurgical, Scheuermann’s disease, scoliosis, sporting injury, spondylolisthesis or trauma.

Information sources and search strategy

We searched MEDLINE (OvidSP), Embase (OvidSP), CINAHL (EBSCOhost) and Web of Science from inception to 23 March 2023. During April 2023, we conducted manual reference checks and citation tracking on Scopus for all included reports and relevant reviews. We collaborated with an academic librarian with medical systematic review search methodology expertise at the University of Sydney Library to formulate our search strategy, covering key concepts: sedentary behaviour (eg, TV and screen time), spinal pain (eg, backache, low back pain) and children and adolescents (eg, student and teen). We applied no language restrictions. Online supplemental table 1–4 supply detailed search strategies and results for each database.

Selection process

Records were exported from databases to EndNote for consolidation and deduplication, then remaining records were imported into Covidence and deduplicated again. Covidence software randomly paired two review authors (of LRCM, MS, ABD, MO’K and TPY) to independently screen English records

and subsequently evaluate full-text reports against eligibility criteria for inclusion. For non-English records, researchers in the field fluent in the necessary language were engaged to screen. Discrepancies were resolved via discussion between paired review authors, with the involvement of a third review author if necessary.

Data extraction

Two review authors (LRCM and ABD) independently tested data extraction using a Microsoft Excel pilot form. One review author (LRCM) then extracted data for all English reports; a second review author (of MS, ABD, MO'K and TPY) independently cross-checked all extracted data. Researchers who were fluent in the necessary language extracted data for non-English reports. We extracted details including study characteristics, sample details, sedentary behaviour exposure, spinal pain outcomes and statistical methods (see online supplemental table 5). Both adjusted and unadjusted estimates, such as risk (RR), odds (OR) or prevalence ratios (PR), along with variance measures (eg, 95% CI), were extracted as published in original reports. When multiple adjusted models were reported, we extracted the estimate with more potential confounders to reduce the overall risk of residual confounding. Potential confounders were categorised into individual characteristics (eg, age, sex and BMI) and environmental characteristics (eg, family history and socioeconomic status). Data were extracted for all follow-up periods.

Study risk of bias assessment

Two randomly selected review authors (of LRCM, MS, ABD, MO'K and TPY) independently assessed each included report using our modified Quality in Prognosis Studies (QUIPS) tool via Covidence.⁴⁶ Researchers fluent in the necessary language applied QUIPS to non-English reports. Risk of bias (RoB) was assessed across six domains: (1) study participation, (2) study attrition (longitudinal reports only, not applicable for cross-sectional reports), (3) exposure measure, (4) outcome measure/s, (5) study confounding and (6) statistical analysis and reporting. Domains (3), (4) and (5) were modified a priori (see online supplemental table 6). A report received an overall 'low' RoB classification if it scored low in four of the six domains, including (5) study confounding. Discrepancies were resolved via discussion between paired review authors, with the involvement of a third review author if necessary.

Synthesis methods and effect measures

We tabulated and synthesised the included reports in alignment with our three review objectives: (1) cross-sectional reports estimating the association between sedentary behaviour and spinal pain; (2) longitudinal reports with participants free of spinal pain, or adjusted for its presence, at baseline examining baseline sedentary behaviour and risk for onset or recurrence of spinal pain and (3) longitudinal reports with participants initially experiencing spinal pain, measuring the effect of baseline sedentary behaviour on the persistence of spinal pain or its impact at follow-up.

For objectives (2) and (3), we planned a priori to pool the most adjusted estimates, RRs and ORs separately, when ≥ 2 longitudinal reports demonstrated sufficient clinical and methodological homogeneity. Due to limited data availability, we made a post hoc decision to also pool the unadjusted longitudinal estimates for objectives (2) and (3), as well as the most adjusted and unadjusted cross-sectional estimates, PRs and ORs separately, for objective (1). Inclusion decisions for estimates in meta-analyses

adhered to specified criteria (see online supplemental material figure 1), such as selecting the estimate from the report with a lower RoB when two or more reports present estimates on the same sample. Where an estimate required for meta-analyses was not reported, we contacted study authors once to request missing information. If there was no response, the review authors calculated an unadjusted OR with a 95% CI from the information available if possible. Where we could not complete quantitative synthesis, we provided a narrative synthesis.

Statistical methods

We present primary meta-analysis results for each review objective using forest plots and tabulated results for subgroup and sensitivity analyses. Results are reported as the pooled estimate (OR, RR or PR) with 95% CIs. We employed the inverse variance weighted DerSimonian and Laird random effects model with the 'metan' command in STATA/IC V.15.1 for Mac (code available in online supplemental material). We assessed heterogeneity in pooled estimates via visual inspection and I^2 statistic, categorised as might not be important (<40%), moderate (30%–60%), substantial (50%–90%) or considerable heterogeneity (>75%).

Subgroup and sensitivity analyses

A priori planned subgroup analyses for longitudinal data aimed to explore the impact of screen-based (eg, TV and computer) and non-screen-based (eg, reading a book and passive travel) sedentary behaviours on spinal pain outcomes. We decided post hoc to also run this subgroup analysis in cross-sectional data. Additionally, post hoc, we performed subgroup analyses to investigate the effect of sex (ie, male and female), age (ie, child <13 years and adolescent ≥ 13 years), spinal pain region (ie, neck, mid-back and low back) and duration of sedentary behaviour exposure in increasing 2 hours/day increments. We performed post hoc sensitivity analyses to assess the effect of overall low RoB on pooled estimates and duration of follow-up (<12 months and >12 months) on longitudinal pooled estimates.

Certainty assessment and reporting bias assessment

Two review authors (LRCM and ABD) independently applied our a priori modified Grading of Recommendations, Assessment, Development and Evaluation framework to assess evidence certainty for each review objective (see online supplemental material table 7).^{47–49} We rated evidence certainty as 'high', 'moderate', 'low' or 'very low'. Starting with 'high' confidence, as outlined by Iorio *et al* 2015 for systematic reviews of prognosis.⁴⁸ We downgraded by one level of certainty for the following: (1) study limitations; if <30% of participants came from reports rated as overall low RoB, (2) inconsistency; if the pooled estimate showed substantial or considerable heterogeneity (I^2 statistic >50%), or there was wide variability across point estimates, (3) imprecision; if the pooled estimate had excessively wide 95% CIs, or the evidence comprised few studies with small populations and imprecise estimates, (4) indirectness; if heterogeneity substantially altered the pooled estimate, or limited its applicability and generalisability and (5) reporting bias; if there was statistical evidence of reporting bias (based on funnel plot and Egger's test results), or the relationship had not been repeatedly investigated. Where we could pool ≥ 10 samples, we inspected funnel plots and results of Egger's test for reporting bias and small study effects. We upgraded by one level of certainty for (1) a moderate-to-large pooled effect size (OR >2.5 or equivalent) and (2) evidence

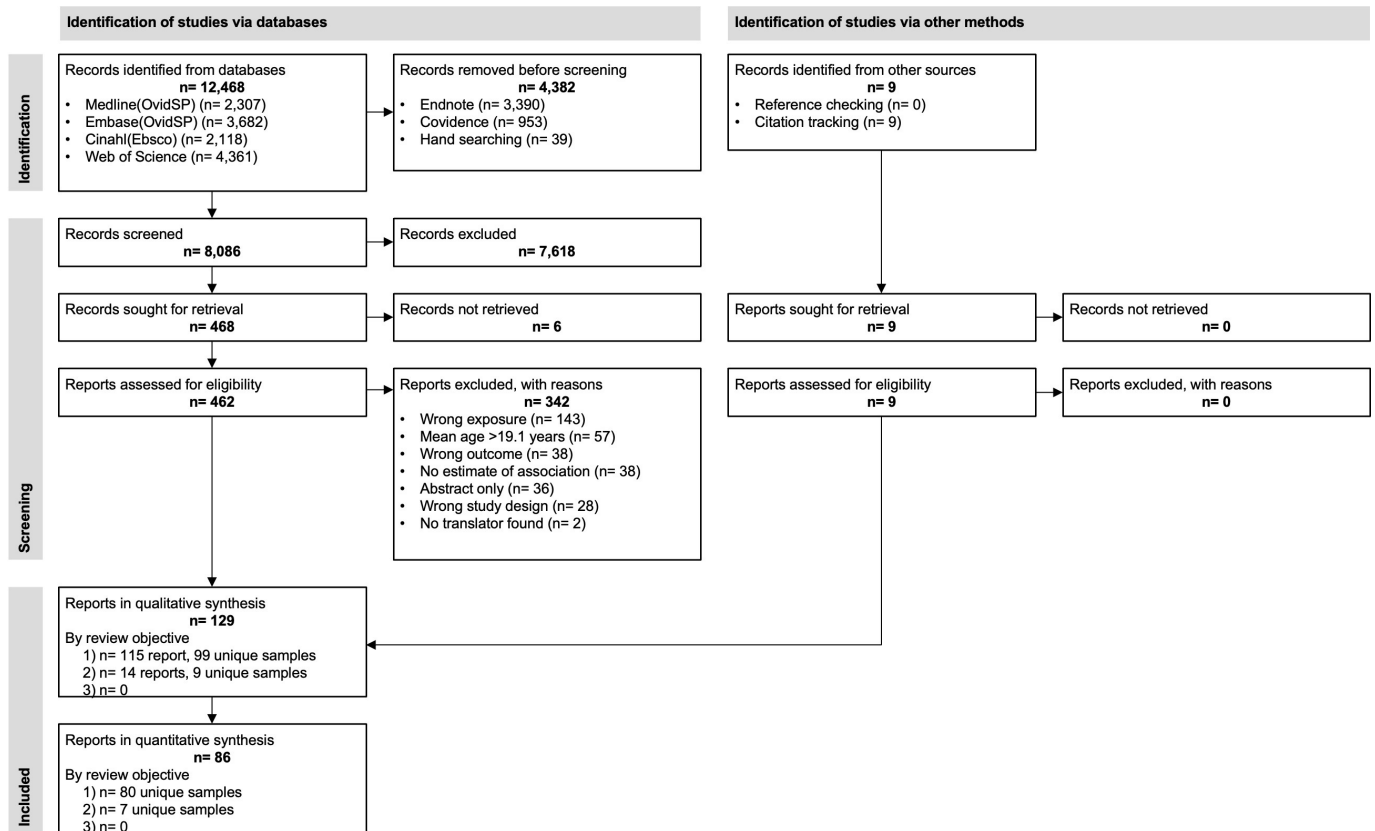


Figure 1 PRISMA 2020 Study selection flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

of an exposure-response gradient. Judgement was applied on overall assessment of the criteria, as there is overlap, so to not excessively downgrade. Discrepancies were resolved via discussion between paired review authors, with the involvement of a third review author if necessary.

Equity, diversity and inclusion statement

In our commitment to inclusivity and thoroughness, we imposed no restrictions on participant characteristics (eg, sex, race, culture and socioeconomic status), study context or setting (eg, regional, city, school and athlete) or publication language to encompass data on marginalised groups. We address limitations in evidence representative of marginalised groups and the generalisation of findings in our discussion. Our review team is committed to promoting equity, diversity and inclusion, and this reflects our gender-balanced composition from diverse cultural backgrounds and different career stages, including early (one), mid (three) and senior (five) researchers.

Patient and public involvement

There was no patient or public involvement in this systematic review.

RESULTS

Study selection

Our searches returned 12 468 records. After screening, we included 129 reports, of which we included 86 studies in meta-analyses (figure 1). We engaged translators proficient in Chinese, French, German, Korean, Portuguese, Spanish and Turkish to screen abstracts, extract data and assess RoB

when required. We excluded one Polish⁵⁰ and one Slovenian⁵¹ report due to the unavailability of translators.

Cross-sectional associations: assessing the direction and strength of the relationship between sedentary behaviour and spinal pain

Study selection, characteristics and results of individual studies
We included 115 cross-sectional reports^{28 52-165} covering 99 unique samples, ranging 7–20 years old, and published between 1988 and 2023 (23% in the past 5 years). These studies represent 37 countries, categorised by World Bank income level as 65% high income, 19% upper middle income, 14% lower middle income and 3% low income.¹⁶⁶ Each report, detailed in online supplemental appendix 1 table 1, estimated the direction (ie, protective or not) and strength (ie, magnitude) of the association between sedentary behaviour and spinal pain in children and adolescents.

Risk of bias

Five of the 115 cross-sectional reports had low RoB (overall) (online supplemental appendix 2 table 1).^{60 92 129 160 161} For individual RoB domains, approximately half of the reports received low RoB ratings for study participation (54/115), outcome measurement (60/115) and statistical analysis and reporting (59/115). Fewer reports received low RoB ratings in exposure measurement (3/115) and study confounding (21/115) domains.

Results of syntheses

Our pooled unadjusted OR of 1.27 (95% CI 1.19 to 1.34, I² 86.9%) included 75 estimates and >118 561 participants. After

Table 1 Primary, subgroup and sensitivity analyses by review objective

Meta-analysis					
(1) Association analysis: cross-sectional studies		Adjusted OR (95% CI), n, k, I ² (χ ²)	Adjusted PR (95% CI), n, k, I ² (χ ²)	Unadjusted OR (95% CI), n, k, I ² (χ ²)	Unadjusted PR (95% CI), n, k, I ² (χ ²)
Primary		1.25 (1.17 to 1.33), n=92 617, k=44, I ² 88.6% (p=0.000)	1.04 (0.97 to 1.11), n=5754, k=6, I ² 15.3% (p=0.316)	1.27 (1.19 to 1.34), n=118 561, k=75, I ² 86.9% (p=0.000)	1.10 (1.01 to 1.19), n=7930, k=7, I ² 60.6% (p=0.018)
Subgroups: sex	Female	1.48 (1.25 to 1.76), n=12 092, k=10, I ² 93.6% (p=0.000)	–	1.62 (1.35 to 1.96), n=11 638, k=13, I ² 0.0% (p=0.621)	1.20 (1.05 to 1.36), n=2070, k=2, I ² 35.2% (p=0.214)
	Male	1.08 (1.02 to 1.15), n=10 846, k=10, I ² 34.1% (p=0.135)	–	1.14 (0.95 to 1.36), n=10 275, k=13, I ² 8.2% (p=0.364)	–
Age	≤13 years	1.13 (0.93 to 1.38), n=9912, k=5, I ² 58.9% (p=0.045)	–	1.26 (1.00 to 1.57), n=22 981, k=26, I ² 86.8% (p=0.000)	–
	>13 years	1.28 (1.18 to 1.40), n=51 694, k=26, I ² 79.8% (p=0.000)	–	1.39 (1.22 to 1.58), n=37 165, k=24, I ² 71.8% (p=0.000)	–
SP region	NP	1.62 (1.40 to 1.87), n=22 401, k=12, I ² 48.6% (p=0.029)	–	1.28 (1.15 to 1.44), n=23 137, k=13, I ² 70.8% (p=0.000)	1.37 (1.14 to 1.66), n=2826, k=2, I ² 0.0% (p=0.470)
	MBP	1.11 (0.98 to 1.25), n=3814, k=3, I ² 18.3% (p=0.294)	–	1.03 (0.78 to 1.36), n=5010, k=13, I ² 54.8% (p=0.009)	–
	LBP	1.20 (1.08 to 1.34), n=27 732, k=17, I ² 77.6% (p=0.000)	–	1.20 (1.07 to 1.36), n=41 393, k=36, I ² 83.0% (p=0.000)	0.92 (0.60 to 1.40), n=2908, k=2, I ² 73.1% (p=0.054)
SB type	Screen	–	–	–	–
	Non-screen	–	–	–	–
SB duration	>2 hours/day	1.47 (1.27 to 1.70), n=44 561, k=14, I ² 78.8% (p=0.000)	1.09 (0.99 to 1.21), n=3 256, k=2, I ² 26.7% (p=0.243)	1.22 (1.00 to 1.47), n=43 105, k=30, I ² 83.7% (p=0.000)	1.07 (0.98 to 1.17), n=1732, k=2, I ² 0.0% (p=0.491)
	>4 hours/day	1.43 (1.17 to 1.74), n=7744, k=10, I ² 41.7% (p=0.079)	1.05 (0.88 to 1.26), n=406, k=2, I ² 0.0% (p=0.967)	1.47 (1.17 to 1.85), n=18 140, k=12, I ² 72.9% (p=0.000)	–
	>6 hours/day	1.70 (1.23 to 2.34), n=13 672, k=7, I ² 34.5% (p=0.165)	–	1.65 (1.18 to 2.30), n=7271, k=5, I ² 40.9% (p=0.149)	–
	>8 hours/day	–	–	1.32 (1.15 to 1.51), n=16 419, k=6, I ² 21.4% (p=0.272)	1.22 (0.96 to 1.57), n=4423, k=3, I ² 77.1% (p=0.013)
	>10 hours/day	–	–	1.49 (1.34 to 1.65), n=7437, k=4, I ² 0.0% (p=0.897)	–
Sensitivity: RoB	Low	1.62 (1.13 to 2.32), n=4399, k=4, I ² 84.9% (p=0.000)	–	–	–
(2) Risk assessment: longitudinal studies		Adjusted OR (95% CI), n, k, I ² (χ ²)	Adjusted RR (95% CI), n, k, I ² (χ ²)	Unadjusted OR (95% CI), n, k, I ² (χ ²)	Unadjusted RR (95% CI), n, k, I ² (χ ²)
Primary		–	1.07 (0.84 to 1.35), n=1292, k=4, I ² 48.7% (p=0.119)	1.13 (0.82 to 1.55), n=850, k=2, I ² 0% (p=0.335)	1.14 (0.76 to 1.70), n=323, k=3, I ² 56.4% (p=0.101)
Subgroups:		–	–	–	–
Sensitivity: RoB	Low	–	1.18 (0.57 to 2.45), n=284, k=2, I ² 80.1% (p=0.025)	–	–
Follow-up duration		–	–	–	–
(3) Prognosis assessment: longitudinal studies		–	–	–	–
Primary		–	–	–	–

Primary, subgroup and sensitivity analyses are presented for each review objective, separately for each type of effect estimate.

–, denotes where there were not enough data to pool an estimate; 95%CI, 95% confidence interval; I² (χ²), measures of heterogeneity in pooled estimate; k, number of estimates pooled; LBP, low back pain; MBP, mid-back pain; n, pooled sample size; NP, neck pain; OR, odds ratio; PR, prevalence ratio; RoB, risk of bias; RR, risk ratio; SP, spinal pain.

adjusting for confounders, a similar weak positive association was found in our pooled adjusted OR of 1.25 (95% CI 1.17 to 1.33, I² 88.6%) from 44 estimates and >92 617 participants. Our pooled unadjusted PR of 1.10 (95% CI 1.01 to 1.19, I² 60.6%) included 7 estimates and 7930 participants. After adjusting for confounders, our pooled adjusted PR of 1.04 (95% CI 0.97 to 1.11, I² 15.3%) included 6 estimates and 5754 participants. High heterogeneity in pooled estimates was explored in subgroup analyses. There were significant subgroup effects for female sex, age older than 13 years and neck pain. There was no apparent dose–response relationship based on the duration of sedentary behaviour. Sensitivity analysis of reports with overall low RoB remains consistent with our primary meta-analyses. See [table 1](#), forest plots in online supplemental appendix figure 1a and 2 and the details of the estimate selection process are provided in online supplemental table 8).

Certainty of evidence and reporting bias

We found low to very low certainty evidence in cross-sectional associations ([table 2](#)). We downgraded against study limitations, inconsistency and publication bias. Our pooled adjusted and

unadjusted ORs had statistical evidence of reporting bias and small study effects. Both funnel plots were asymmetrical, highlighting that studies with smaller effect sizes were missing, and both Egger's tests had p<0.005 (online supplemental appendix 1 figure 1b,c). We could not inspect for reporting bias in our pooled adjusted and unadjusted PRs.

Longitudinal risk assessment: determining if sedentary behaviour increases the risk for onset of spinal pain

Study selection, characteristics and results of individual studies
We included 14 longitudinal reports^{167–180} covering 9 unique samples, ranging 7–18 years, and published between 2002 and 2023 (36% in the past 5 years). These studies represent 8 countries (75% high-income, 25% upper-middle-income, 0% lower-middle or low-income level)¹⁶⁶ ([table 3](#)).

RoB in studies

Two of the 14 longitudinal reports had low RoB (overall) (online supplemental appendix 2 table 2).^{168 178} The domains with the highest number of low RoB ratings were outcome

Table 2 GRADE level of confidence in the certainty of the evidence by review objective

Primary meta-analyses				GRADE factors							
n	k	Pooled estimate (95%CI)	I ²	▼ Study limitations*	▼ Inconsistency†	▼ Imprecision‡	▼ Indirectness§	▼ Reporting bias¶	▲ Moderate to large pooled estimate	▲ Dose response	Level of confidence
Association analysis: cross-sectional studies											
>92 617	44	aOR 1.25 (1.17 to 1.33)	88.6%	▼	▼	✓	✓	▼	×	×	Very low
5754	6	aPR 1.04 (0.97 to 1.11)	15.3%	▼	✓	✓	✓	▼	×	×	Low
>118 561	75	cOR 1.27 (1.19 to 1.34)	86.9%	▼	▼	✓	✓	▼	×	×	Very low
7930	7	cPR 1.10 (1.01 to 1.19)	60.6%	▼	▼	✓	✓	▼	×	×	Very low
Risk assessment: longitudinal studies											
NA	4	aOR NA	NA	✓	▼	✓	✓	▼	×	×	Low
1292	4	aRR 1.07 (0.84 to 1.35)	48.7%	▼	✓	✓	✓	▼	×	×	Low
850	2	cOR 1.13 (0.82 to 1.55)	0%	▼	✓	✓	✓	▼	×	×	Low
323	3	cRR 1.14 (0.76 to 1.70)	56.4%	✓	▼	✓	✓	▼	×	×	Low
Prognosis assessment: longitudinal studies											
0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

n; number of participants included in pooled estimate, k; number of samples included in pooled estimate, I²; measure of heterogeneity in pooled estimate.
 ▼ Downgrade once.
 ▲ Upgrade once.
 ✓ No limitations to downgrade.
 × No evidence to upgrade.
 Levels of confidence: high (start point), moderate, low, very low.
 * <30% from low risk of bias.
 † I² >50% or wide variability in point estimates.
 ‡ Wide pooled 95% CIs or few studies with small samples and imprecise estimates.
 § Heterogeneity substantially alters pooled estimate.
 ¶ Evidence of reporting bias or <10 studies investigating relationship.
 aOR/aPR/aRR, adjusted odds/prevalence/risk ratio; cOR/cPR/cRR, unadjusted odds/prevalence/risk ratio; GRADE, Grading of Recommendations, Assessment, Development and Evaluation; NA, not applicable.

measurement (11/14) and statistical analysis and reporting (10/14). Approximately half of the reports received low RoB in the study participation and study confounding domains (6/14 each). Only two reports used an objective measure of sedentary behaviour via an accelerometer to achieve low RoB in the exposure measure domain.^{167 168} No report achieved a low RoB rating in the study attrition domain.

Results of quantitative syntheses

Our pooled unadjusted OR of 1.13 (95% CI 0.82 to 1.55, I² 0%) included 2 estimates with 850 participants.^{169 179} We did not pool an adjusted ORs. Our pooled unadjusted RR of 1.14 (95% CI 0.76 to 1.70, I² 56.4%) included 3 estimates and 323 participants.^{168 171 175} After adjusting for confounders, we found a similar pooled adjusted RR of 1.07 (95% CI 0.84 to 1.35, I² 48.7%) from 4 estimates and 1292 participants.^{168 175 177 178} Limited data hindered our ability to run subgroup analyses. Our sensitivity analysis of reports with overall low RoB remains consistent with our primary analyses (adjusted RR 1.18 (95% CI 0.57 to 2.45, I² 80.1%) from 2 estimates and 284 participants). See [table 1](#), forest plots in [figures 2 and 3](#) and the details of the estimate selection process are provided in online supplemental material [table 8](#).

Certainty of evidence and reporting bias

We found low certainty evidence that sedentary behaviour was not a risk factor for the onset of spinal pain in children and adolescents ([table 2](#)). We downgraded due to doubt in publication bias, study limitations and inconsistency. Sedentary behaviour has not been investigated as a risk factor for spinal pain in a large number of longitudinal studies. We could not inspect for statistical evidence of reporting bias.

Longitudinal prognosis assessment: evaluating if sedentary behaviour affects the prognosis of spinal pain

We found no longitudinal reports investigating the effect of sedentary behaviour on the prognosis of spinal pain in children and adolescents.

DISCUSSION Interpretation

Based on 115 reports, we found that cross-sectional estimates suggest children and adolescents with greater sedentary behaviour have minimally higher odds of spinal pain and no difference in spinal pain prevalence. These associations are unlikely to be causal, as it is equally plausible that children and adolescents with spinal pain tend towards sedentary behaviours. In fact, based on 14 longitudinal reports, our findings indicate sedentary behaviour does not increase the risk for the onset of the first or a recurrent episode of meaningful spinal pain in children and adolescents, regardless of adjustment for potential confounders. These results were consistent in sensitivity analyses, where weak and non-significant associations were found, supporting the robustness of our findings. These review findings should be interpreted cautiously as the evidence is of low certainty and only 11% of the data are longitudinal. We could not identify any evidence of the effect of sedentary behaviour on spinal pain prognosis, highlighting a notable gap in the current literature.

Our cross-sectional analyses aligned with the pooled cross-sectional estimates from Baradaran Mahdavi *et al*, which showed a weak positive association between sedentary behaviour and neck (unadjusted OR 1.13 (95% CI 0.98 to 1.30)) and low back (unadjusted OR 1.20 (95% CI 1.07 to 1.37)) pain in young individuals.^{34 40} Our longitudinal assessment of risk mirrors findings observed in the adult population. Damato *et al* pooled longitudinal estimates of sedentary behaviour and the risk of low back pain, revealing no association (unadjusted RR 1.01 (95%

Table 3 Summary of longitudinal reports estimating if sedentary behaviour increased the risk for onset of spinal pain

Report	Sample country, setting	Baseline sample size (n=), age range (mean±SD)	Follow-up period, n= (F%), response rate	Sedentary behaviour Exposure vs reference	Spinal pain outcome vs reference	Unadjusted estimate (95%CI)	Adjusted estimate (95%CI)	Potential confounders included in the analysis
Aartun 2016 ^{63xw}	Denmark, School students	n=181, 11–15 y (NR±NR)	2 y, n=144 (F46.8%), 87.3%	T5B: >50th centile vs <50th centile T5B: >75th centile vs <75th centile	SP vs No SP	RR 0.81 (0.65 to 1.02) RR 1.04 (0.70 to 1.55)	RR 0.83 (0.66 to 1.04) RR 1.02 (0.78 to 1.32)	Individual (sex, hand grip strength test) Individual (sex, weight squared, height, BMI, waist-to-height ratio, contact/collision sport, 10×5 m shuttle run, hand grip strength test, Andersen test)
Aartun 2016 ^{68xw}	Denmark, School students	n=906, 11–15 y (NR±NR)	2 y, n=625 (F50.2%), 95.8%	T5B: >90th centile vs <90th centile T5B: >75th centile vs <25th centile	SP, 1–3 sites vs No SP SP, 2–3 sites vs SP, 0–1 sites	RR 0.83 (0.54 to 1.29) RR 0.99 (0.94 to 1.05) RR 1.04 (0.92 to 1.18)	RR 0.82 (0.52 to 1.28)	Individual (sex, height, BMI, hand-grip strength test, Andersen test)
Brink 2009 ^{69xw}	South Africa, School students	n=104, 15–17 y (16.0±0.7)	6 m, n=93 (F43.3%), 89.4%	Computer: ≥105 m/d vs <105 m/d Computer: ≥6 h/w vs <6 h/w	UQMP, last m vs No UQMP F M UQMP, in last m vs No UQMP UQMP, last m	OR 1.70 (0.7 to 4.2) OR 0.50 (0.1 to 4.3) OR 1.00 (0.3 to 3.4) OR 1.60 (0.7 to 3.8) OR 1.80 (0.4 to 8.7) OR 0.90 (0.3 to 2.8)	– – – – – –	– – – – – –
Brink 2015 ^{70xw}	South Africa, School students	n=235, 15–17 y (16.3±0.5)	6 m, 12 m, n=153 (F73.0%), 89.8%	Computer: NR vs NA Computer: ≥30 m vs <30 m	No UQMP vs NA UQMP, <4.5/10 NRS vs NA UQMP, >4.5/10 NRS vs NA UQMP, last m, seated related vs No UQMP, last m	Mean8.9±5.0 (8.0 to 9.8) Mean9.1±5.7 (7.4 to 10.9) Mean8.6±4.1 (6.9 to 10.3) –	– – – OR 0.90 (0.5 to 1.9)	– – – Individual (change in postural angles from T1 to T2)
Brink 2020 ^{80xw}	South Africa, School students	n=211, 15–18 y (NR±NR)	12 m, n=153 (NR%), 72.5%	Computer: >30 m vs <30 m	UQMP, last m, seated related vs No UQMP, last m	–	–	–
de Vitta 2021 ^{179xw}	Brazil, School students	n=1628, 14–18 y (NR±NR)	12 m, n=757 (F43.8%), 85.6%	Computer: ≥3 h/d vs <3 h/d TV: ≥3 h/d vs <3 h/d Mobile: ≥3 h/d vs <3 h/d Tablet: ≥3 h/d vs <3 h/d	New LBP, 12 m vs No LBP New LBP, 12 m vs No LBP OR 0.90 (0.65 to 1.25) OR 1.44 (0.97 to 2.14) OR 0.66 (0.21 to 2.11)	OR 1.06 (0.75 to 1.49) OR 0.90 (0.65 to 1.25) OR 1.49 (1.11 to 2.00) OR 3.21 (1.41 to 7.30)	– – – –	Individual (sex, age, skin colour, marital status, clinical mental health, mobile and tablet use, physical activity) and environmental (SES)
de Vitta 2023 ^{78xw}	Brazil, School students	n=1628, 14–18 y (NR±NR)	12 m, n=140 (F50.3%), 85.6%	Mobile: ≥3 h/d vs <3 h/d	New TSP at T2 vs No TSP at T1 or T2	–	RR 1.72 (1.08 to 2.74)	Individual (sex, clinical mental health, mobile and tablet use) and environmental (SES, race)
Jones 2003 ¹⁷⁷	England, School students	n=1046, 11–14 y (NR±NR)	12 m, n=933 (NR%), 89.0%	TV+computer games: >275 m/d vs <120 m/d 183–270 m/d vs <120 m/d 125–183 m/d vs <120 m/d 70–180 m/d vs <120 m/d	LBP, new onset, lasting ≥1 d last m vs No LBP, last m, or lasting less than 1 d	– – – –	RR 1.00 (0.6 to 1.8) RR 1.20 (0.7 to 1.9) RR 1.00 (0.6 to 1.6) RR 0.90 (0.6 to 1.5)	Individual (age, gender)

Continued

Table 3 Continued

Report	Sample country, setting	Baseline sample size (n=), age range (mean±SD)	Follow-up Period, n= (F%), response rate	Sedentary behaviour Exposure vs reference	Spinal pain outcome vs reference	Unadjusted estimate (95%CI)	Adjusted estimate (95%CI)	Potential confounders included in the analysis
Noll 2021 ^{176,swi}	Brazil, School students	n=726, 11–16y (NR±NR)	3y, n=525 (F54.3%), 72.3%	Computer: ≥6h/d vs <1h/d Computer: 2–5h/d vs <1h/d TV: ≥6h/d vs <1h/d TV: 2–5h/d vs <1h/d	BP vs No BP	RR 1.06 (0.97 to 1.13) RR 0.98 (0.94 to 1.03) RR 1.08 (1.01 to 1.14) RR 0.95 (0.91 to 0.99)	RR 1.06 (0.99 to 1.14) RR 1.00 (0.96 to 1.05) RR 1.07 (1.01 to 1.13) RR 0.96 (0.92 to 1.01)	Individual (sex, age, way to carry backpack, sitting computer posture, sitting writing posture, sleeping posture, read/study in bed, sleep h/h, TV h/d, computer h/d) and environmental (parents with back pain)
Rosa 2022 ^{175,swi}	Brazil, School students	n=165, NRy (B11.6 G11.4±0.5)	6y, n=75 (F53.3%), 45.5%	Computer: ≥6h/d vs 0–1 h/d Computer: 2–5h/d vs 0–1 h/d TV: ≥6h/d vs 0–1 h/d TV: 2–5h/d vs 0–1 h/d	BP vs No BP	RR 1.38 (1.17 to 1.63) RR 1.31 (1.17 to 1.46) RR 1.54 (1.38 to 1.72) RR 1.39 (1.24 to 1.56)	RR 1.01 (0.99 to 1.02) RR 1.02 (0.99 to 1.01) RR 1.56 (1.15 to 2.13) RR 1.40 (0.9 to 1.99)	Individual (sex, age, competitive PA, TV h/d, computer h/d, read/study on bed, sleep posture, lifting posture, backpack carry posture, backpack type) and environmental (parents with back pain)
Sivola 2004 ¹⁷¹	Finland, School students	n=714, 15–18y (NR±NR)	7y, n=104 (F59.8%), 87.0%	Computer, playing musical instrument, crafts etc. NR vs NR	NSP, occasional or weekly in last 6m vs no NSP, in last 6m F M	RR 1.20 (0.3 to 4.7) RR 1.50 (0.2 to 11.3) RR 1.00 (0.1 to 7.4)	– – –	– – –
				Homework: Q2 vs Q1	NSP, occasional or weekly in last 6m vs no NSP, in last 6m F M	RR 1.40 (0.7 to 2.9) RR 1.20 (0.5 to 2.8) RR 1.60 (0.5 to 5.2)	– – –	– – –
				Homework: Q3 vs Q1	NSP, occasional or weekly in last 6m vs no NSP, in last 6m F M	RR 1.00 (0.5 to 2.0) RR 1.10 (0.5 to 3.2) RR 0.90 (0.2 to 3.3)	– – –	– – –
				Homework: Q4 vs Q1	NSP, occasional or weekly in last 6m vs no NSP, in last 6m F M	RR 1.10 (0.6 to 2.3) RR 1.60 (0.6 to 4.7) RR 1.40 (0.4 to 5.2)	– – –	– – –
				Reading, listening to music, etc. NR vs NR	NSP, occasional or weekly in last 6m vs no NSP, in last 6m F M	RR 1.00 (0.4 to 2.4) RR 0.60 (0.1 to 2.5) RR 1.60 (0.5 to 5.3)	– – –	– – –
Smith 2017 ¹²	Australia, Western Australian Pregnancy Cohort (Raine)	n=1608, 14 –17y (NR±NR)	3y, n=1088 (F35.3%), 67.7%	Computer: 0–7, 7–14, 14–21, >21 h/w TV: 0–7, 7–14, 14–21, >21 h/w	No LBP, LBP with minimal impact and LBP with impact	– –	P value, p=0.40 P value, p=0.57	Individual (Sex, back pain at 14 years)

Continued

Table 3 Continued

Report	Sample country, setting	Baseline sample size (n=), age range (mean±SD)	Follow-up Period, n= (F%), response rate	Sedentary behaviour Exposure vs reference	Spinal pain outcome vs reference	Unadjusted estimate (95%CI)	Adjusted estimate (95%CI)	Potential confounders included in the analysis
Szita 2018 ¹⁷³	Hungary, School students	n=NR, 7–16 y (11.8±1.8)	5y, n=NR (F52.0%), NR%	Computer &/or gaming, weekdays: >2 v. <2 h/d Computer &/or gaming, weekends: >2 v. <2 h/d Homework (Afternoon learning): >2 v. <2 h/d Transportation by car to school: NR vs NR TV, weekdays: >2 vs <2 h/d TV, weekends: >2 vs <2 h/d	SP, nonspecific for days vs NR	OR 1.36 (0.67 to 2.76) OR 0.91 (0.59 to 1.39) OR 1.91 (1.20 to 3.02) OR 0.97 (0.65 to 1.44) OR 1.87 (1.11 to 3.17) OR 1.99 (1.36 to 2.91)	ORNR (NR) ORNR (NR) OR 1.82 (1.05 to 3.22) ORNR (NR) ORNR (NR) OR 2.59 (1.65 to 4.05)	Individual (age >12 years, no sports activity, asymmetrical school bag, carrying school bag tiring, uncomfortable school desk, frequent sleeping problems, general discomfort, frequent missing from school) and environmental (afternoon learning >2 hrs/day, TV >2 hours weekdays, TV >2 hours weekend days, uncomfortable school desk, spinal disorder among relatives)
Szpalski 2002 ¹⁷⁴	Belgium, School students	n=392, 9–12 y (NR±NR)	2y, n=287 (F50.9%), 73.2%	Computer games: 0–1, 1–2, >2 h/d vs 0 h/d	New LBP, at T2 vs No LBP, at T1 or T2	ORNR (NR)	ORNR (NR)	Individual (NR) and environmental (NR)

Superscript Roman numerals indicate reports that analysed the same cohort.

Bold indicates significant association.

BMI, body mass index; BP, back pain; d, day; F, female; h, hours; h/d, hours per day; l/v/w, hours per week; LBP, low back pain; M, male; n, months or minutes; mid, minutes per day; n, sample size; NA, not applicable; NR, not reported; NRS, Numerical Rating Scale; NSP, neck shoulder pain; PA, physical activity; Q, quartile; RR, risk ratio; SES, socioeconomic status; SP, spinal pain; TSB, total sedentary behaviour; TSP, thoracic spine pain; TV, television; UQMP, upper quadrant musculoskeletal pain; W, weeks; y, years.

CI 0.98 to 1.04)).³⁹ Similarly, both Damato *et al* and Alzahrani *et al* investigated whether prolonged sedentary behaviour heightened the risk of low back pain in adults.^{38 39} Their results, consistent with our cross-sectional subgroup analysis, suggested that increased duration of sedentary behaviours did not correlate strongly with increased risk of back pain. No exposure–response relationship was observed between sedentary behaviour and spinal pain. Our results suggest that transient back discomfort felt following prolonged sedentary behaviour is unlikely to progress to meaningful spinal pain in children and adolescents. De Carvalho *et al* observed the same nuanced relationship in their analysis of objectively measured prolonged sitting in adults.³⁷ The current evidence does not support the demonising of sedentary behaviours, including screentime, as a cause of meaningful spinal pain in children and adolescents.

Strengths and limitations

The strength of our review includes protocol registration and a thorough search strategy to encompass all existing evidence of the relationship between spinal pain and sedentary behaviour in children and adolescents. Including longitudinal studies allowed us to explore potential causal relationships by examining temporality, specifically that sedentary behaviour preceded spinal pain. However, several limitations warrant consideration. The current evidence base suffers from a scarcity of longitudinal research investigating sedentary behaviour as a risk factor and a complete absence of longitudinal research investigating sedentary behaviour as a prognostic factor for spinal pain in children and adolescents. Additionally, there is an under-representation of lower middle-income or low-income populations, as no longitudinal studies and only 17% of cross-sectional studies represented these populations.

Our confidence in the evidence is low to very low, suggesting the true measure of association or risk may substantially differ from our pooled estimates. This uncertainty stems primarily from the high RoB in included studies, inconsistency in effect estimates across studies and reporting bias. The high RoB and inconsistency in effect estimates may exist due to the majority of studies using subjective measures of sedentary behaviour. Only 5 of 129 reports used objective measures,^{52 72 118 167 168} which are the preferred tool and have the highest validity for measuring physical activity and sedentary time in an adult population.^{181 182} Evidence of reporting bias in cross-sectional data suggests potential under-representation of studies with negative or more negligible positive associations in our pooled estimates. Scarcity of longitudinal data prevented thorough examination of reporting bias. However, had we pooled an adjusted OR, the study by Szpalski *et al* would have been excluded as the authors noted their estimate was ‘not significant’ and did not report the value.¹⁷⁴ Such reporting practices raise concern that our pooled estimates may be an overestimate of the true effect size.

While heterogeneity in meta-analysis is expected and common, our decision to pool spinal pain and sedentary behaviour data, meeting broad definitions and reporting time frames, may contribute to the high statistical heterogeneity. Nonetheless, we undertook this approach because it provides a more comprehensive synthesis of data and has minimal impact on understanding the impact of sedentary behaviour on spinal pain, clinical or otherwise. Our consistent findings across subgroup and sensitivity analyses suggest that the heterogeneity in our pooled estimates stems from unexamined study characteristics, that is, measures of sedentary behaviour and spinal pain, as discussed above, or potential residual confounding. If a robust association

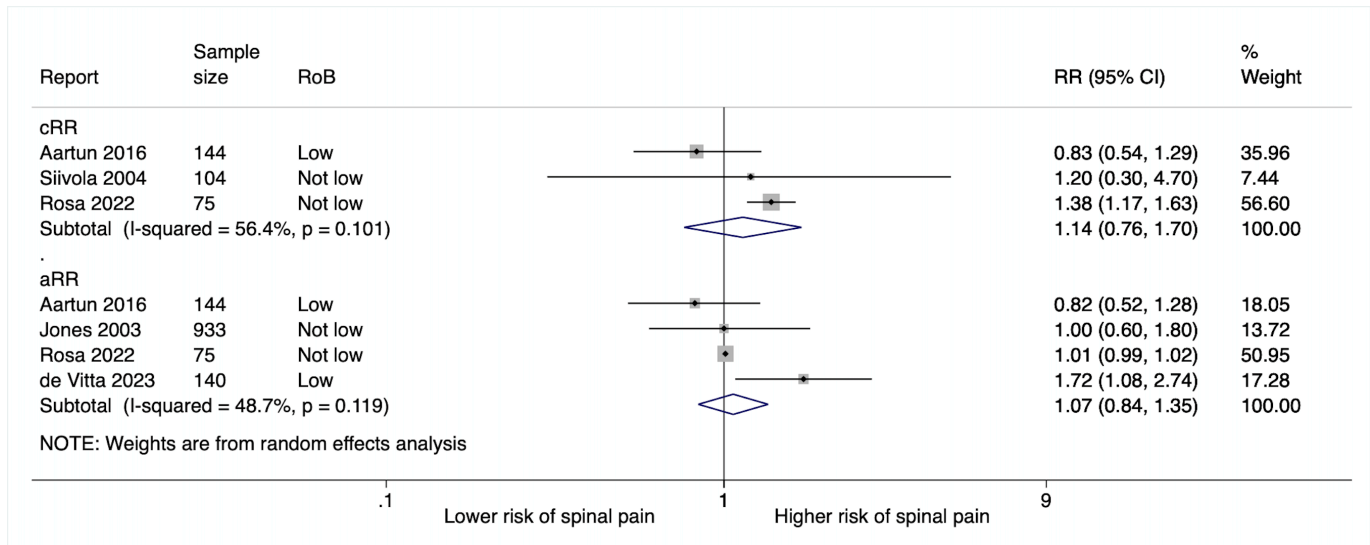


Figure 2 Pooled adjusted (aRR) and unadjusted risk ratios (cRR) estimating if sedentary behaviour increased the risk for onset of spinal pain (review objective 2). RoB; risk of bias.

existed, we believe it should withstand scrutiny across heterogeneous populations, exposures and outcomes.

Implications

While reducing sedentary behaviours is important for overall health, it is unlikely to significantly reduce the incidence or lessen the burden of spinal pain in children and adolescents. Clinicians are encouraged to take a balanced approach when discussing sedentary behaviour with children and adolescents experiencing spinal pain. While sedentary behaviour is not a risk factor for clinically meaningful spinal pain, beyond temporary discomfort, it may still be valuable to monitor as part of a comprehensive assessment of overall lifestyle. This may include promotion of healthy habits such as regular physical activity, adequate sleep and addressing psychosocial factors such as stress and mental well-being. There is no evidence yet to inform whether sedentary behaviour affects the persistence (prognosis) of spinal pain, thus when discussing this relationship caution around language use is warranted.

To effectively address spinal pain in young people, it is imperative to identify and address modifiable risk and

prognostic factors that have a stronger effect on meaningful or impactful spinal pain. Future research in this field must be more robust, and appropriately designed longitudinal studies are needed to elucidate causal pathways and mechanisms underlying spinal pain. Ideally, prospective cohort studies that objectively capture daily behaviours, measure daily or weekly spinal pain intensity, frequency and impact, and adequately account for relevant confounders. Alternatively, causal inference can be drawn from longitudinal observational research. Given its limitations in establishing causal relationships, further cross-sectional research in this field is unnecessary.

Conclusions

Cross-sectional data suggest a small positive association between sedentary behaviour and spinal pain in children and adolescents. Specifically, our meta-analyses, including over 98 371 participants combined, indicate slightly higher odds of spinal pain among those with greater sedentary behaviours. However, longitudinal data, including 2465 participants combined, do not support a causal relationship;

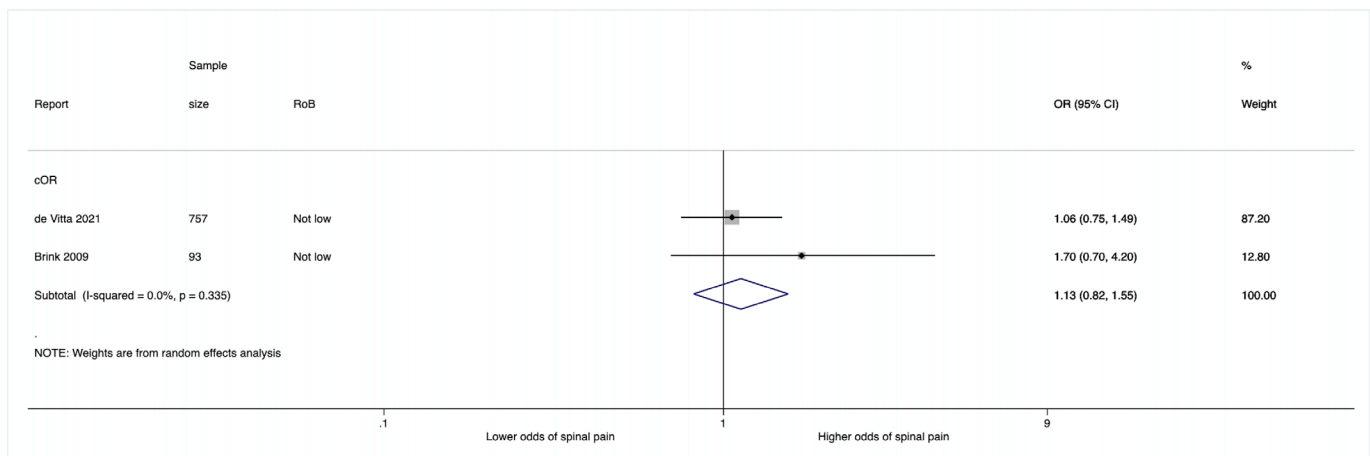


Figure 3 Pooled unadjusted OR (cOR) estimating if sedentary behaviour increased the risk for onset of spinal pain (review objective 2). RoB, risk of bias.

sedentary behaviour does not appear to increase the risk of developing spinal pain over time in children and adolescents. Given the low certainty of evidence, these findings need to be interpreted with caution. We found no evidence assessing the effect of sedentary behaviour on the prognosis of spinal pain in children and adolescents, highlighting a gap in the literature and area for future research.

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REFERENCES

- King S, Chambers CT, Huguet A, *et al*. The epidemiology of chronic pain in children and adolescents revisited: a systematic review. *Pain* 2011;152:2729–38.
- Calvo-Muñoz I, Gómez-Conesa A, Sánchez-Meca J. Prevalence of low back pain in children and adolescents: a meta-analysis. *BMC Pediatr* 2013;13:14.
- Kamper SJ, Yamato TP, Williams CM. The prevalence, risk factors, prognosis and treatment for back pain in children and adolescents: An overview of systematic reviews. *Best Pract Res Clin Rheumatol* 2016;30:1021–36.
- Hébert JJ, Beynon AM, Jones BL, *et al*. Spinal pain in childhood: prevalence, trajectories, and diagnoses in children 6 to 17 years of age. *Eur J Pediatr* 2022;181:1727–36.
- O'Sullivan PB, Beales DJ, Smith AJ, *et al*. Low back pain in 17 year olds has substantial impact and represents an important public health disorder: a cross-sectional study. *BMC Public Health* 2012;12:100.
- Santos E de S, Bernardes JM, Vianna LS, *et al*. The Impact of Low Back Pain on the Quality of Life of Children between 6 and 12 Years of Age. *Healthcare (Basel)* 2023;11:948.
- Santos VS, Leite MN, Camargo BIA, *et al*. Three in Every 10 School-aged Children in Brazil Report Back Pain in Any Given Year: 12-Month Prospective Cohort Study of Prevalence, Incidence, and Prognosis. *J Orthop Sports Phys Ther* 2022;52:554–62.
- CdME S, Santos VS, Kamper SJ, *et al*. Overview of the economic burden of musculoskeletal pain in children and adolescents: a systematic review with meta-analysis. *Pain* 2022.
- Hestbaek L, Leboeuf-Yde C, Kyvik KO, *et al*. The course of low back pain from adolescence to adulthood: eight-year follow-up of 9600 twins. *Spine (Phila Pa 1986)* 2006;31:468–72.
- Ferreira ML, de Luca K, Haile LM, *et al*. Global, regional, and national burden of low back pain, 1990–2020, its attributable risk factors, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. *Lancet Rheumatol* 2023;5:e316–29.
- Yang S, Werner BC, Singla A, *et al*. Low Back Pain in Adolescents: A 1-Year Analysis of Eventual Diagnoses. *J Pediatr Orthop* 2017;37:344–7.
- Beynon AM, Hébert JJ, Hodgetts CJ, *et al*. Chronic physical illnesses, mental health disorders, and psychological features as potential risk factors for back pain from childhood to young adulthood: a systematic review with meta-analysis. *Eur Spine J* 2020;29:480–96.
- Calvo-Muñoz I, Kovacs FM, Roqué M, *et al*. The association between the weight of schoolbags and low back pain among schoolchildren: A systematic review, meta-analysis and individual patient data meta-analysis. *Eur J Pain* 2020;24:91–109.
- Dario AB, Kamper SJ, O'Keeffe M, *et al*. Family history of pain and risk of musculoskeletal pain in children and adolescents: a systematic review and meta-analysis. *Pain* 2019;160:2430–9.
- Huguet A, Tougas ME, Hayden J, *et al*. Systematic review with meta-analysis of childhood and adolescent risk and prognostic factors for musculoskeletal pain. *Pain* 2016;157:2640–56.
- Yamato TP, Maher CG, Traeger AC, *et al*. Do schoolbags cause back pain in children and adolescents? A systematic review. *Br J Sports Med* 2018;52:1241–5.
- Chinapaw MJM, Proper KI, Brug J, *et al*. Relationship between young peoples' sedentary behaviour and biomedical health indicators: a systematic review of prospective studies. *Obes Rev* 2011;12:e621–32.
- LeBlanc AG, Gunnell KE, Prince SA, *et al*. The Ubiquity of the Screen: An Overview of the Risks and Benefits of Screen Time in Our Modern World. *Transl J ACSM* 2017;2:104–13.
- Salmon J, Tremblay MS, Marshall SJ, *et al*. Health risks, correlates, and interventions to reduce sedentary behavior in young people. *Am J Prev Med* 2011;41:197–206.
- Tremblay MS, LeBlanc AG, Kho ME, *et al*. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *Int J Behav Nutr Phys Act* 2011;8:98.
- Zhang T, Lu G, Wu XY. Associations between physical activity, sedentary behaviour and self-rated health among the general population of children and adolescents: a systematic review and meta-analysis. *BMC Public Health* 2020;20:1343.
- Rodriguez-Ayllon M, Cadenas-Sanchez C, Estevez-Lopez F, *et al*. Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Med* 2019;49:1383–410.
- Biddle SJ, O'Connell S, Braithwaite RE. Sedentary behaviour interventions in young people: a meta-analysis. *Br J Sports Med* 2011;45:937–42.
- Chaput J-P, Willumsen J, Bull F, *et al*. 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: summary of the evidence. *Int J Behav Nutr Phys Act* 2020;17:141.
- Tremblay MS, Carson V, Chaput J-P, *et al*. Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. *Appl Physiol Nutr Metab* 2016;41:S311–27.
- Bucksch J, Sigmundova D, Hamrik Z, *et al*. International Trends in Adolescent Screen-Time Behaviors From 2002 to 2010. *J Adolesc Health* 2016;58:417–25.
- Schwarzfischer P, Gruszfeld D, Stolarczyk A, *et al*. Physical Activity and Sedentary Behavior From 6 to 11 Years. *Pediatrics* 2019;143:e20180994.

- 28 Roman-Juan J, Roy R, Jensen MP, *et al.* The explanatory role of sedentary screen time and obesity in the increase of chronic back pain amongst European adolescents: The HBSC study 2002-2014. *Eur J Pain* 2022;26:1781-9.
- 29 David D, Giannini C, Chiarelli F, *et al.* Text Neck Syndrome in Children and Adolescents. *Int J Environ Res Public Health* 2021;18:1565.
- 30 Grasser T, Borges Dario A, Parreira PCS, *et al.* Defining text neck: a scoping review. *Eur Spine J* 2023;32:3463-84.
- 31 Hoare E, Milton K, Foster C, *et al.* The associations between sedentary behaviour and mental health among adolescents: a systematic review. *Int J Behav Nutr Phys Act* 2016;13:108.
- 32 Liu M, Wu L, Yao S. Dose-response association of screen time-based sedentary behaviour in children and adolescents and depression: a meta-analysis of observational studies. *Br J Sports Med* 2016;50:1252-8.
- 33 Wirth B, Potthoff T, Rosser S, *et al.* Physical risk factors for adolescent neck and mid back pain: a systematic review. *Chiropr Man Therap* 2018;26:36.
- 34 Baradaran Mahdavi S, Mazaheri-Tehrani S, Riahi R, *et al.* Sedentary behavior and neck pain in children and adolescents; a systematic review and meta-analysis. *Health Promot Perspect* 2022;12:240-8.
- 35 Calvo-Munoz I, Kovacs FM, Roque M, *et al.* Risk Factors for Low Back Pain in Childhood and Adolescence: A Systematic Review. *Clin J Pain* 2018;34:468-84.
- 36 Tholl C, Bickmann P, Wechsler K, *et al.* Musculoskeletal disorders in video gamers - a systematic review. *BMC Musculoskelet Disord* 2022;23:678.
- 37 De Carvalho DE, de Luca K, Funabashi M, *et al.* Association of Exposures to Seated Postures With Immediate Increases in Back Pain: A Systematic Review of Studies With Objectively Measured Sitting Time. *J Manipul Physiol Ther* 2020;43:1-12.
- 38 Alzahrani H, Alshehri MA, Alzhrani M, *et al.* The association between sedentary behavior and low back pain in adults: a systematic review and meta-analysis of longitudinal studies. *PeerJ* 2022;10:e13127.
- 39 Damato TM, Christofaro DGD, Pinheiro MB, *et al.* Does sedentary behaviour contribute to the development of a new episode of low back pain? A systematic review of prospective cohort studies. *Eur J Pain* 2022;26:1412-23.
- 40 Baradaran Mahdavi S, Riahi R, Vahdoutpour B, *et al.* Association between sedentary behavior and low back pain; A systematic review and meta-analysis. *Health Promot Perspect* 2021;11:393-410.
- 41 Page MJ, Moher D, Bossuyt PM, *et al.* PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ* 2021;372:160.
- 42 Lynch K. Adolescent health WHO: world health organisation. 2024. Available: https://www.who.int/health-topics/adolescent-health#tab=tab_1
- 43 Tremblay MS, Aubert S, Barnes JD, *et al.* Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act* 2017;14:75.
- 44 Butte NF, Watson KB, Ridley K, *et al.* A Youth Compendium of Physical Activities: Activity Codes and Metabolic Intensities. *Med Sci Sports Exerc* 2018;50:246-56.
- 45 Classification of chronic pain online: international association for the study of pain. 2017. Available: https://iaspfiles.s3.amazonaws.com/production/public/2021/PART_I-C.pdf
- 46 Hayden JA, van der Windt DA, Cartwright JL, *et al.* Assessing bias in studies of prognostic factors. *Ann Intern Med* 2013;158:280-6.
- 47 Hayden JA, Wilson MN, Riley RD, *et al.* Individual recovery expectations and prognosis of outcomes in non-specific low back pain: prognostic factor review. *Cochrane Database Syst Rev* 2019;.CD011284.
- 48 Iorio A, Spencer FA, Falavigna M, *et al.* Use of GRADE for assessment of evidence about prognosis: rating confidence in estimates of event rates in broad categories of patients. *BMJ* 2015;350:h870.
- 49 Huetet A, Hayden JA, Stinson J, *et al.* Judging the quality of evidence in reviews of prognostic factor research: adapting the GRADE framework. *Syst Rev* 2013;2:71.
- 50 The assessment of risk factors of low back pain in adolescents between 11-14 years old. *Post Rehabil* 2014;28:23-31.
- 51 Pirnat J, Skela Savic B. Effects of internet use on youth health and challenges for health education in primary health care. *Obz Zdr Nege* 2013;47:309-16.
- 52 Leininger B, Schulz C, Gao Z, *et al.* Accelerometer-Determined Physical Activity and Clinical Low Back Pain Measures in Adolescents With Chronic or Subacute Recurrent Low Back Pain. *J Orthop Sports Phys Ther* 2017;47:769-74.
- 53 Onofrio AC, da Silva MC, Domingues MR, *et al.* Acute low back pain in high school adolescents in Southern Brazil: prevalence and associated factors. *Eur Spine J* 2012;21:1234-40.
- 54 Myrvtveit SM, Sivertsen B, Skogen JC, *et al.* Adolescent neck and shoulder pain--the association with depression, physical activity, screen-based activities, and use of health care services. *J Adolesc Health* 2014;55:366-72.
- 55 Meziat Filho N, Coutinho ES, Azevedo E Silva G. Association between home posture habits and low back pain in high school adolescents. *Eur Spine J* 2015;24:425-33.
- 56 Meziat-Filho N, Azevedo E Silva G, Coutinho ES, *et al.* Association between home posture habits and neck pain in High School adolescents. *J Back Musculoskelet Rehabil* 2017;30:467-75.
- 57 Yang S-Y, Chen M-D, Huang Y-C, *et al.* Association Between Smartphone Use and Musculoskeletal Discomfort in Adolescent Students. *J Community Health* 2017;42:423-30.
- 58 O'Sullivan PB, Smith AJ, Beales DJ, *et al.* Association of biopsychosocial factors with degree of slump in sitting posture and self-report of back pain in adolescents: a cross-sectional study. *Phys Ther* 2011;91:470-83.
- 59 Faridzad R, Ahadi Z, Heshmat R, *et al.* Association of screen time with subjective health complaints in Iranian school-aged children and adolescents: the CASPIAN-V study. *J Public Health (Berl)* 2020;28:31-40.
- 60 Lemes IR, Oliveira CB, Silva GCR, *et al.* Association of sedentary behavior and early engagement in physical activity with low back pain in adolescents: a cross-sectional epidemiological study. *Eur Spine J* 2022;31:152-8.
- 61 Spjolie AN. Associations between activities and low back pain in adolescents. *Scandinavian Med Sci Sports* 2004;14:352-9.
- 62 Auvinen J, Tammelin T, Taimela S, *et al.* Associations of physical activity and inactivity with low back pain in adolescents. *Scand J Med Sci Sports* 2008;18:188-94.
- 63 Martínez-Crespo G, Rodríguez-Piñero Durán M, López-Salguero AI, *et al.* Back pain among adolescents: prevalence and associated factors. *Rehabilitacion (Madr)* 2009;43:72-80.
- 64 Wedderkopp N, Leboeuf-Yde C, Bo Andersen L, *et al.* Back pain in children: no association with objectively measured level of physical activity. *Spine (Phila Pa 1976)* 2003;28:2019-24; .
- 65 Fernandes França E, Monteiro Macedo M, Francisco Pazello Mafrá F, *et al.* . *AIMS public health* 2020;7:562-73. 10.3934/publichealth.2020045
- 66 Fraile Garcia PA. Back pain in primary school students and its causes. *Fisio* 2009;31:137-42.
- 67 Troussier B, Davoine P, de Gaudemaris R, *et al.* Back pain in school children. A study among 1178 pupils. *Scand J Rehabil Med* 1994;26:143-6.
- 68 Noll M, Candotti CT, Rosa B da. Back pain prevalence and associated factors in children and adolescents: an epidemiological population study. *Rev Saude Publica* 2016;50:31.
- 69 Noll M, de Avelar IS, Lehnen GC, *et al.* Back Pain Prevalence and Its Associated Factors in Brazilian Athletes from Public High Schools: A Cross-Sectional Study. *PLoS One* 2016;11:e0150542.
- 70 Lewandowski J, Lukaszewska K. Characteristics of back pain in Polish youth depending on place of residence. *Ann Agric Environ Med* 2014;21:644-8.
- 71 Silva AG, Couto PS, Queirós A, *et al.* Chronic pain in high school students is associated with physical activity and sleeping hours but not with screen time. *Int J Adolesc Med Health* 2019;31.
- 72 Geldhof E, De Clercq D, De Bourdeaudhuij I, *et al.* Classroom postures of 8-12 year old children. *Ergonomics* 2007;50:1571-81.
- 73 Skemiene L, Ustinaviciene R, Luksiene D, *et al.* Computer use and musculoskeletal complaints in the Lithuanian adolescent population. *Open Med* 2012;7:203-8.
- 74 Palm P, Risberg EH, Mortimer M, *et al.* Computer use, neck and upper-extremity symptoms, eyestrain and headache among female and male upper secondary school students. *Scand J Work Environ Health* 2007;33:33-41.
- 75 Hakala PT, Saarni LA, Ketola RL, *et al.* Computer-associated health complaints and sources of ergonomic instructions in computer-related issues among Finnish adolescents: A cross-sectional study. *BMC Public Health* 2010;10:11.
- 76 Shan Z, Deng G, Li J, *et al.* Correlational Analysis of neck/shoulder Pain and Low Back Pain with the Use of Digital Products, Physical Activity and Psychological Status among Adolescents in Shanghai. *PLoS ONE* 2013;8:e78109.
- 77 Burke A, Peper E. Cumulative trauma disorder risk for children using computer products: results of a pilot investigation with a student convenience sample. *Public Health Rep* 2002;117:350-7.
- 78 Buabbas AJ, Al-Mass MA, Al-Tawari BA, *et al.* The detrimental impacts of smart technology device overuse among school students in Kuwait: a cross-sectional survey. *BMC Pediatr* 2020;20:524.
- 79 Chiwaridzo M, Naidoo N. Differences in personal and lifestyle characteristics among Zimbabwean high school adolescents with and without recurrent non-specific low back pain: a two part cross-sectional study. *Arch Physiother* 2015;5:13.
- 80 Nazik F, Disli F, Yilmaz E, *et al.* The Effects of Physical Activity Digital Product Use and Psychological Health on Low Back Pain in Adolescents: School Based Study in Eastern Turkey. *Int J Caring Sci* 2022;15:158-66.
- 81 Deng G, Zhang Y, Cai H, *et al.* Effects of physical factors on neck or shoulder pain and low back pain of adolescents. *Zhonghua Yi Xue Za Zhi* 2014;94:3411-5.
- 82 Azabagic S, Spahic R, Pranjić N, *et al.* EPIDEMIOLOGY OF MUSCULOSKELETAL DISORDERS IN PRIMARY SCHOOL CHILDREN IN BOSNIA AND HERZEGOVINA. *Mater Sociomed* 2016;28:164-7.
- 83 Noll M, Silveira EA, Avelar IS de. Evaluation of factors associated with severe and frequent back pain in high school athletes. *PLoS One* 2017;12:e0171978.
- 84 Montgomery LRC, Kamper SJ, Hartvigsen J, *et al.* Exceeding 2-h sedentary time per day is not associated with moderate to severe spinal pain in 11- to 13-year-olds: a cross-sectional analysis. *Eur J Pediatr* 2022;181:653-9.
- 85 Namwongsa S, Puntumetakul R, Neubert MS, *et al.* Factors associated with neck disorders among university student smartphone users. *Work* 2018;61:367-78.
- 86 Noll M, Fraga RA, da Rosa BN, *et al.* Fatores de risco associados à intensidade de dor nas costas em escolares do município de Teutônia (RS). *Rev Bras Ciên Esporte* 2016;38:124-31.

- 87 Hakala PT, Rimpelä AH, Saarni LA, *et al.* Frequent computer-related activities increase the risk of neck-shoulder and low back pain in adolescents. *Eur J Public Health* 2006;16:536–41.
- 88 González-Gálvez N, Carrasco-Poyatos M, Vaquero-Cristóbal R, *et al.* Gender Mediation in Adolescents' Back Pain and Physical Fitness: A Cross-Sectional Study. *Healthcare (Basel)* 2022;10:696:08.
- 89 Grimmer K, Williams M. Gender-age environmental associates of adolescent low back pain. *Appl Ergon* 2000;31:343–60.
- 90 Chiang HY, Jacobs K, Orsmond G. Gender-age environmental associates of middle school students' low back pain. *Work* 2006;26:19–28.
- 91 Nawrocka A, Mynarski W, Powerska A, *et al.* Health-oriented physical activity in prevention of musculoskeletal disorders among young Polish musicians. *Int J Occup Med Environ Health* 2014;27:28–37.
- 92 Shan Z, Deng G, Li J, *et al.* How Schooling and Lifestyle Factors Effect Neck and Shoulder Pain? A Cross-sectional Survey of Adolescents in China. *Spine (Phila Pa 1986)* 2014;39:E276–83.
- 93 Cankurtaran F, Menevşe Ö, Namlı A, *et al.* The impact of digital game addiction on musculoskeletal system of secondary school children. *Niger J Clin Pract* 2022;25:153–9.
- 94 Brindova D, Veselska ZD, Klein D, *et al.* Is the association between screen-based behaviour and health complaints among adolescents moderated by physical activity? *Int J Public Health* 2015;60:139–45.
- 95 Yabe Y, Hagiwara Y, Sekiguchi T, *et al.* Late bedtimes, short sleeping time, and longtime video-game playing are associated with low back pain in school-aged athletes. *Eur Spine J* 2018;27:1112–8.
- 96 Masiero S, Sarto F, Cattelan M, *et al.* Lifetime Prevalence of Nonspecific Low Back Pain in Adolescents: A Cross-sectional Epidemiologic Survey. *Am J Phys Med Rehabil* 2021;100:1170–5.
- 97 Rossi M, Pasanen K, Kokko S, *et al.* Low back and neck and shoulder pain in members and non-members of adolescents' sports clubs: the Finnish Health Promoting Sports Club (FHPSC) study. *BMC Musculoskelet Disord* 2016;17:263.
- 98 Erne C, Elfering A. Low back pain at school: unique risk deriving from unsatisfactory grade in maths and school-type recommendation. *Eur Spine J* 2011;20:2126–33.
- 99 Gunzburg R, Balagué F, Nordin M, *et al.* Low back pain in a population of school children. *Eur Spine J* 1999;8:439–43.
- 100 Vanti C, Gasperini M, Morsillo F, *et al.* Low back pain in adolescent gymnasts. Prevalence and risk factors. *Sci Riab* 2010;12:45–50.
- 101 Bento TPF, Cornelio GP, Perrucini P de O, *et al.* Low back pain in adolescents and association with sociodemographic factors, electronic devices, physical activity and mental health. *J Pediatr (Rio J)* 2020;96:717–24.
- 102 Prista A, Balagué F, Nordin M, *et al.* Low back pain in Mozambican adolescents. *Eur Spine J* 2004;13:341–5.
- 103 Fernandes JAA, Genebra CVDS, Maciel NM, *et al.* LOW BACK PAIN IN SCHOOLCHILDREN: A CROSS-SECTIONAL STUDY IN A WESTERN CITY OF SÃO PAULO STATE, BRAZIL. *Acta Ortop Bras* 2015;23:235–8.
- 104 Watson KD, Papageorgiou AC, Jones GT, *et al.* Low back pain in schoolchildren: the role of mechanical and psychosocial factors. *Arch Dis Child* 2003;88:12–7.
- 105 Balague F, Dutoit G, Waldburger M. Low back pain in schoolchildren. An epidemiological study. *Scand J Rehabil Med* 1988;20:175–9.
- 106 Alghadir AH, Gabr SA, Al-Eisa ES. Mechanical factors and vitamin D deficiency in schoolchildren with low back pain: biochemical and cross-sectional survey analysis. *J Pain Res* 2017;10:855–65.
- 107 Straker L, Harris C, Joosten J, *et al.* Mobile technology dominates school children's IT use in an advantaged school community and is associated with musculoskeletal and visual symptoms. *Ergonomics* 2018;61:658–69.
- 108 Toh SH, Coenen P, Howie EK, *et al.* Mobile touch screen device use and associations with musculoskeletal symptoms and visual health in a nationally representative sample of Singaporean adolescents. *Ergonomics* 2019;62:778–93.
- 109 Alberola López S, Pérez García I, Casares Alonso I, *et al.* Mochilas escolares y dolor de espalda en la población infantil. *Rev Pediatr Aten Primaria* 2010;12:385–97.
- 110 Dolphens M, Vansteelandt S, Cagnie B, *et al.* Multivariable modeling of factors associated with spinal pain in young adolescence. *Eur Spine J* 2016;25:2809–21.
- 111 Hulsegge G, van Oostrom SH, Picavet HSJ, *et al.* Musculoskeletal complaints among 11-year-old children and associated factors: the PIAMA birth cohort study. *Am J Epidemiol* 2011;174:877–84.
- 112 Picavet HSJ, Berentzen N, Scheuer N, *et al.* Musculoskeletal complaints while growing up from age 11 to age 14: the PIAMA birth cohort study. *Pain* 2016;157:2826–33.
- 113 Minghelli B. Musculoskeletal spine pain in adolescents: Epidemiology of non-specific neck and low back pain and risk factors. *J Orthop Sci* 2020;25:776–80.
- 114 Hakala PT, Saarni LA, Punamäki R-L, *et al.* Musculoskeletal symptoms and computer use among Finnish adolescents--pain intensity and inconvenience to everyday life: a cross-sectional study. *BMC Musculoskelet Disord* 2012;13:41.
- 115 Gheysvandi E, Dianat I, Heidaramoghadam R, *et al.* Neck and shoulder pain among elementary school students: prevalence and its risk factors. *BMC Public Health* 2019;19:1299.
- 116 Auvinen J, Tammelin T, Taimela S, *et al.* Neck and Shoulder Pains in Relation to Physical Activity and Sedentary Activities in Adolescence. *Spine (Phila Pa 1986)* 2007;32:1038–44.
- 117 Vitta A, Bento TPF, Perrucini PO, *et al.* Neck pain and associated factors in a sample of high school students in the city of Bauru. *Sao Paulo Med J* 2021;139:38–45.
- 118 Briggs AM, Straker LM, Bear NL, *et al.* Neck/shoulder pain in adolescents is not related to the level or nature of self-reported physical activity or type of sedentary activity in an Australian pregnancy cohort. *BMC Musculoskelet Disord* 2009;10:87.
- 119 Straker LM, Smith AJ, Bear N, *et al.* Neck/shoulder pain, habitual spinal posture and computer use in adolescents: the importance of gender. *Ergonomics* 2011;54:539–46.
- 120 Diepenmaat ACM, van der Wal MF, de Vet HCW, *et al.* Neck/Shoulder, Low Back, and Arm Pain in Relation to Computer Use, Physical Activity, Stress, and Depression Among Dutch Adolescents. *Pediatrics* 2006;117:412–6.
- 121 De Vitta A, Trize D de M, Fiorelli A, *et al.* Neck/shoulders pain and its relation to the use of tv/computer/videogame and physical activity in school students from Bauru. *Fisioter mov* 2014;27:111–8.
- 122 Minghelli B, Oliveira R, Nunes C. Non-specific low back pain in adolescents from the south of Portugal: prevalence and associated factors. *J Orthop Sci* 2014;19:883–92.
- 123 Balague F, Nordin M, Skovron ML, *et al.* Non-specific low-back pain among schoolchildren: a field survey with analysis of some associated factors. *J Spinal Disord* 1994;7:374–9.
- 124 Mohseni-Bandpei MA, Bagheri-Nesami M, Shayesteh-Azar M. Nonspecific Low Back Pain in 5000 Iranian School-age Children. *J Pediatr Orthop* 2007;27:126–9.
- 125 Shehab DK, Al-Jarallah KF. Nonspecific low-back pain in Kuwaiti children and adolescents: Associated factors. *J Adolesc Health* 2005;36:32–5.
- 126 Zapata AL, Moraes AJP, Leone C, *et al.* Pain and musculoskeletal pain syndromes related to computer and video game use in adolescents. *Eur J Pediatr* 2006;165:408–14.
- 127 Wirth B, Humphreys BK. Pain characteristics of adolescent spinal pain. *BMC Pediatr* 2015;15:42.
- 128 Silva AG, Sa-Couto P, Queirós A, *et al.* Pain, pain intensity and pain disability in high school students are differently associated with physical activity, screening hours and sleep. *BMC Musculoskelet Disord* 2017;18:194.
- 129 Skoffer B, Foldsang A. Physical activity and low-back pain in schoolchildren. *Eur Spine J* 2008;17:373–9.
- 130 Keane E, Kelly C, Molcho M, *et al.* Physical activity, screen time and the risk of subjective health complaints in school-aged children. *Prev Med* 2017;96:21–7.
- 131 Cardon G, De Bourdeaudhuij I, De Clercq D, *et al.* Physical Fitness, Physical Activity, and Self-Reported Back and Neck Pain in Elementary Schoolchildren. *Pediatr Exerc Sci* 2004;16:147–57.
- 132 Minghelli B, Oliveira R, Nunes C. Postural habits and weight of backpacks of Portuguese adolescents: Are they associated with scoliosis and low back pain? *WOR* 2016;54:197–208.
- 133 Mafanya C, Rhoda A. Predictors of neck pain among South African youth. *Af J Phys, Health Edu Rec & Dance* 2011;17.
- 134 Song Y-M, *et al.* Prevalence and Associated Factors of Neck Shoulder Pain in High School Students. *Korean J Fam Med* 2008;29:595–603.
- 135 Dianat I, Alipour A, Asghari Jafarabadi M. Prevalence and risk factors of low back pain among school age children in Iran. *Health Promot Perspect* 2017;7:223–9.
- 136 Fonseca CD, Sandotti CT, Noll M, *et al.* Prevalence of back pain among high school students in a municipality in southern Brazil. *Fisioter mov* 2016;29:137–46.
- 137 Khalil NS, Alrubaey MGJ. Prevalence of Back Pain and its Socio-Demographic, Postural and Behavioral Associated Factors among Primary Schoolchildren in Baghdad City. *Ind Jour of Publ Health Rese & Develop* 2019;10:716.
- 138 Kędra A, Kolwicz-Gańko A, Sitariski D, *et al.* Prevalence of back pain and the knowledge of preventive measures in a cohort of 11619 Polish school-age children and youth--an epidemiological study. *Medicine (Baltimore)* 2019;98:e15729.
- 139 Paranjape S, Ingole V. Prevalence of Back Pain in Secondary School Students in an Urban Population: Cross-sectional Study. *Cureus* 2018;10:e2983.
- 140 Akbar F, AlBesharah M, Al-Baghli J, *et al.* Prevalence of low Back pain among adolescents in relation to the weight of school bags. *BMC Musculoskelet Disord* 2019;20:37.
- 141 Santos EDS, Bernardes JM, Noll M, *et al.* Prevalence of Low Back Pain and Associated Risks in School-Age Children. *Pain Manag Nurs* 2021;22:459–64.
- 142 Schwertner DS, Oliveira RANS, Koerich MHAL, *et al.* Prevalence of low back pain in young Brazilians and associated factors: Sex, physical activity, sedentary behavior, sleep and body mass index. *BMR* 2020;33:233–44.
- 143 De Vitta A, Martinez MG, Piza NT, *et al.* Prevalência e fatores associados à dor lombar em escolares. *Cad Saúde Pública* 2011;27:1520–8.
- 144 Silva GRR, Pitanguí ACR, Xavier MKA, *et al.* Prevalence of musculoskeletal pain in adolescents and association with computer and videogame use. *J Pediatr (Rio J)* 2016;92:188–96.
- 145 Saueressig IB, Oliveira VMA de, Xavier MKA, *et al.* Prevalence of musculoskeletal pain in adolescents and its association with the use of electronic devices. *Rev Dor* 2015;16:129–35.
- 146 Smith L, Louw Q, Crous L, *et al.* Prevalence of Neck Pain and Headaches: Impact of Computer Use and Other Associative Factors. *Cephalgia* 2009;29:250–7.

- 147 Turk Z, Vauhnik R, Micetic-Turk D. Prevalence of nonspecific low back pain in schoolchildren in north-eastern Slovenia. *Coll Antropol* 2011;35:1031–5.
- 148 Graup S, de Araújo Bergmann ML, Bergmann GG. Prevalence of nonspecific lumbar pain and associated factors among adolescents in Uruguaiana, state of Rio Grande do Sul. *Rev Bras Ortop (Eng Ed)* 2014;49:661–7.
- 149 Ben Ayed H, Yaich S, Trigui M, et al. Prevalence, Risk Factors and Outcomes of Neck, Shoulders and Low-Back Pain in Secondary-School Children. *J Res Health Sci* 2019;19:e00440.
- 150 Dutra ES, Rosa BN da, Candotti CT. Prevalência de dor nas costas e fatores associados de escolares de Viamão, RS. *Cons Saúde* 2017;16:417–23.
- 151 Noll M, Candotti CT, Tiggemann CL, et al. Prevalência de dor nas costas e fatores associados em escolares do Ensino Fundamental do município de Teutônia, Rio Grande do Sul. *Rev Bras Saude Mater Infant* 2012;12:395–402.
- 152 Munoz-Serrano J, Garcia-Duran S, Avila-Martin G, et al. Relationship between low back pain and screen time among schoolchildren. *Rev Esp Salud Publica* 2021;95:13.
- 153 Aktürk S, Büyükcavcı R, Aktürk Ü. Relationship between musculoskeletal disorders and physical inactivity in adolescents. *J Public Health (Berl)* 2019;27:49–56.
- 154 Rezapur-Shahkolai F, Gheysvandi E, Tapak L, et al. Risk factors for low back pain among the elementary school students, using penalized logistic regression, Iran. *Epidemiol Health* 2020;42:e2020039.
- 155 Harreby M, Nygaard B, Jessen T, et al. Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. *Eur Spine J* 1999;8:444–50.
- 156 Dianat I, Alipour A, Asgari Jafarabadi M. Risk factors for neck and shoulder pain among schoolchildren and adolescents. *J Paediatrics Child Health* 2018;54:20–7.
- 157 Yao W, Luo C, Ai F, et al. Risk Factors for Nonspecific Low-Back Pain in Chinese Adolescents: A Case-Control Study. *Pain Med* 2012;13:658–64.
- 158 Kristjansdóttir G, Rhee H. Risk factors of back pain frequency in schoolchildren: a search for explanations to a public health problem. *Acta Paediatr* 2002;91:849–54.
- 159 Torsheim T, Eriksson L, Schnohr CW, et al. Screen-based activities and physical complaints among adolescents from the Nordic countries. *BMC Public Health* 2010;10:324.
- 160 da Costa L, Lemes IR, Tebar WR, et al. Sedentary behavior is associated with musculoskeletal pain in adolescents: A cross sectional study. *Braz J Phys Ther* 2022;26:100452.
- 161 Joergensen AC, Strandberg-Larsen K, Andersen PK, et al. Spinal pain in pre-adolescence and the relation with screen time and physical activity behavior. *BMC Musculoskelet Disord* 2021;22:393.
- 162 Wirth B, Knecht C, Humphreys K. Spine day 2012: spinal pain in Swiss school children—epidemiology and risk factors. *BMC Pediatr* 2013;13:159.
- 163 Jung KS, et al. The Study on the Correlation between Low Back Pain and Life Habit, Obesity in High School Students. *J Orient Rehabil Med* 2010;20:185–95.
- 164 Toyran M, Ozmert E, Yurdakök K. Television viewing and its effect on physical health of schoolage children. *Turk J Pediatr* 2002;44:194–203.
- 165 Bélanger RE, Akre C, Berchtold A, et al. A U-Shaped Association Between Intensity of Internet Use and Adolescent Health. *Pediatrics* 2011;127:e330–5.
- 166 New world bank country classifications by income level: 2021-2022 the world. The World Bank; 2021. Available: <https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2021-2022>
- 167 Aartun E, Hartvigsen J, Boyle E, et al. No associations between objectively measured physical activity and spinal pain in 11-15-year-old Danes. *Eur J Pain* 2016;20:447–57.
- 168 Aartun E, Boyle E, Hartvigsen J, et al. The most physically active Danish adolescents are at increased risk for developing spinal pain: a two-year prospective cohort study. *BMJ Open Sport Exerc Med* 2016;2:e000097.
- 169 Brink Y, Crous LC, Louw QA, et al. The association between postural alignment and psychosocial factors to upper quadrant pain in high school students: A prospective study. *Man Ther* 2009;14:647–53.
- 170 Brink Y, Louw Q, Grimmer K, et al. The relationship between sitting posture and seated-related upper quadrant musculoskeletal pain in computing South African adolescents: A prospective study. *Man Ther* 2015;20:820–6.
- 171 Siivola SM, Levoska S, Latvala K, et al. Predictive Factors for Neck and Shoulder Pain: A Longitudinal Study in Young Adults. *Spine (Phila Pa 1986)* 2004;29:1662–9.
- 172 Smith A, Beales D, O'Sullivan P, et al. Low Back Pain With Impact at 17 Years of Age Is Predicted by Early Adolescent Risk Factors From Multiple Domains: Analysis of the Western Australian Pregnancy Cohort (Raine) Study. *J Orthop Sports Phys Ther* 2017;47:752–62.
- 173 Szita J, Boja S, Szilagyai A, et al. Risk factors of non-specific spinal pain in childhood. *Eur Spine J* 2018;27:1119–26.
- 174 Szpalski M, Gunzburg R, Balagué F, et al. A 2-year prospective longitudinal study on low back pain in primary school children. *Eur Spine J* 2002;11:459–64.
- 175 Rosa BN da, Noll M, Candotti CT, et al. Risk Factors for Back Pain among Southern Brazilian School Children: A 6-Year Prospective Cohort Study. *Int J Environ Res Public Health* 2022;19:8322.
- 176 Noll M, Candotti CT, da Rosa BN, et al. Back pain and its risk factors in Brazilian adolescents: a longitudinal study. *Br J Pain* 2021;15:16–25.
- 177 Jones GT, Watson KD, Silman AJ, et al. Predictors of Low Back Pain in British Schoolchildren: A Population-Based Prospective Cohort Study. *Pediatrics* 2003;111:822–8.
- 178 De Vitta A, Noll M, Monfort-Pañego M, et al. Thoracic Spine Pain in High School Adolescents: A One-Year Longitudinal Study. *Healthcare (Basel)* 2023;11:196:09.
- 179 Vitta A de, Bento TPF, Cornelio GP, et al. Incidence and factors associated with low back pain in adolescents: A prospective study. *Braz J Phys Ther* 2021;25:864–73.
- 180 Brink Y, Louw Q, Grimmer K. Do changes in psychosocial factors, lifestyle factors and sitting posture influence the likelihood of musculoskeletal pain in high school computer users? *Physiotherapy Res Intl* 2020;25:e1865.
- 181 Aunger J, Wagnild J. Objective and subjective measurement of sedentary behavior in human adults: A toolkit. *Am J Hum Biol* 2022;34:e23546.
- 182 Gill JM, Chico TJ, Doherty A, et al. Potential impact of wearables on physical activity guidelines and interventions: opportunities and challenges. *Br J Sports Med* 2023;57:1223–5.