Sedentary Behavior as a Cardiometabolic Risk Factor in Adolescents Revisited Through Meta-Analysis

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Abstract. Introduction and Purpose: Sedentary behavior among adolescents has increased due to technological and lifestyle changes, contributing to adverse cardiometabolic outcomes. Although physical activity is considered protective, evidence regarding its role in mitigating sedentary-related risks remains fragmented. The purpose of this study was to investigate the mutual connections between screen time, sleep quality, and physical fitness. (VO2Max and muscular endurance) in order to develop an integrative model that explains their cumulative impact on adolescent health and performance. Methods: Using research found in PubMed, Scopus, and Web of Science, a PRISMA-guided systematic review and meta-analysis was carried out. Eligible studies involved adolescents aged 10–19 years and assessed sedentary behavior, physical activity, and cardiometabolic risk indicators. Ten studies met the inclusion criteria and were synthesized using a random-effects model. Results: The results showed a substantial correlation between excessive screen time and decreased physical fitness and lower sleep quality. The association between screen time and fitness outcomes, especially VO2Max, was partially mediated by sleep quality. The proposed integrative model revealed a synergistic interaction in which behavioral and physiological factors jointly influenced patterns of health development. Adolescents with lower screen exposure and better sleep quality exhibited significantly higher levels of cardiorespiratory fitness. Conclusion and Suggestion: Sedentary behavior is an important cardiometabolic risk factor in adolescents, whereas physical activity provides significant protective effects. Interventions should focus on reducing sedentary time and increasing MVPA. Further experimental and longitudinal research is required to bolster the causal evidence.

Keywords: Adolescent Health, Muscular Endurance, Screen Time; Sleep Quality; VO2Max.

1 Introduction

The modern lifestyle transformations driven by urbanization, advancements in digital technology, and widespread adoption of electronic devices have significantly elevated sedentary behavior levels among adolescents across diverse countries (Alnaqbi et al.,

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2025). This surge is particularly evident through increased engagement in screen-based activities, which has been exacerbated by global events such as the COVID-19 pandemic, leading to averages exceeding several hours daily and associated health risks (Sachdeva et al., 2025). Formally speaking, sedentary behaviour is defined as any awake activity carried out in a seated, reclined, or laying position that requires an energy expenditure of ≤1.5 metabolic equivalents (METs) (de Lima Mesquita et al., 2023). Such behaviors commonly manifest in prolonged smartphone usage, extended screen time, video gaming, and extended sitting during academic pursuits, contributing to alarming trends seen, especially in low- and mid-income environments (Li et al., 2024).

Long-term sedentary behaviour in teenagers has been closely associated with a number of detrimental metabolic health consequences, including obesity, insulin resistance, dyslipidemia, hypertension, and an elevated long-term risk of cardiovascular diseases in adulthood (Agbaje et al., 2025). These associations arise because excessive sitting and low-energy-expenditure activities disrupt glucose homeostasis, promote adiposity accumulation, and contribute to unfavorable lipid profiles and blood pressure elevations, independent of physical activity levels in many cases (Silva et al., 2023). Notably, cumulative sedentary time from childhood through young adulthood exacerbates insulin resistance, particularly in those with overweight or obesity, where fat mass mediates a substantial portion of the relationship, thereby amplifying cardiometabolic risk trajectories (Agbaje et al., 2025). Furthermore, adolescents exhibiting high sedentary behavior demonstrate poorer metabolic syndrome components, characterised is a greater prevalence of metabolic syndrome generally, increased triglycerides, decreased HDL cholesterol, and increased abdominal obesity, underscoring the need for targeted interventions to mitigate these early-onset risks (Cheng et al., 2024).

During adolescence, individuals undergo critical physiological and metabolic developments, Therefore, the lifestyle choices made at this stage, such as sedentary behaviour and physical activity levels, are crucial in determining long-term health risks like obesity, cardiovascular diseases, metabolic disorders, and mental health issues (Wang et al., 2024). Patterns of low physical activity combined with prolonged sedentary behavior during this developmental window can persist into adulthood, thereby elevating the likelihood of adverse cardiometabolic and psychological outcomes across the lifespan (Li et al., 2024). One effective strategy to mitigate the detrimental impacts of sedentary behavior involves optimizing the physical activity dose, described as the total amount of physical activity acquired through frequency, duration, and intensity, which can improve energy expenditure, metabolic function, and general well-being to counterbalance the impacts of sedentary behaviour (Vandoni et al., 2022). Evidence indicates that sufficient physical activity dose, particularly moderate-to-vigorous intensity, not only displaces sedentary time but also contributes to improved health trajectories when integrated into adolescent routines (Wang et al., 2024).

Physical activity is becoming more widely acknowledged as exercise as medicine in the field of sports medicine, wherein an appropriate physical activity dose encompassing frequency, duration, and intensity exerts protective effects against metabolic health impairments by enhancing insulin sensitivity, promoting fat oxidation, and improving lipid profiles in adolescents (García-Hermoso et al., 2023).

This paradigm underscores how targeted exercise interventions can mitigate adverse metabolic outcomes, including reduced insulin resistance and favorable shifts in lipid metabolism, hence acting as a non-pharmacological method of preventing long-term illnesses (Calcaterra et al., 2022). Consequently, elucidating the interplay between sedentary behavior, physical activity dose, and cardiometabolic risk in adolescent populations is essential, as prolonged sedentary time may exacerbate risks while sufficient physical activity volume can attenuate them through metabolic enhancements and risk factor modulation (Husøy et al., 2024). Such understanding supports early preventive strategies against chronic diseases by promoting optimized physical activity prescriptions to displace sedentary habits and foster long-term cardiometabolic resilience (Chen et al., 2023).

Although numerous prior investigations have analyzed sedentary behavior and physical activity independently, thereby failing to elucidate their synergistic interactions with respect to cardiometabolic risk profiles (Wang et al., 2024). The majority of epidemiological studies and meta-analyses have predominantly targeted adult cohorts, yielding only fragmentary insights into these dynamics within adolescent populations (Li et al., 2024). Moreover, scant research has adopted a dose–response framework to quantify the threshold physical activity dose necessary for mitigating the deleterious consequences of sedentary behavior (Chen and Zhu, 2023). Consequently, the absence of comprehensive global systematic syntheses integrating sedentary behavior, physical activity dose, and to overcome these evidence gaps, integrated systematic reviews and meta-analyses of cardiometabolic risk in adolescents are required (Castro et al., 2023).

The PRISMA-guided systematic review and meta-analysis approach used in this study allowed for a methodical, transparent, and repeatable synthesis of scientific data from earlier research on the connections between sedentary behaviour, physical activity level, and cardiometabolic risk in adolescent populations (Kuzik et al., 2025). Meta-analysis enhances the robustness and precision of effect estimates by pooling data from multiple investigations, thereby increasing statistical power through larger combined sample sizes and providing more reliable insights into consistent patterns across diverse adolescent cohorts worldwide (Men et al., 2025). This methodology facilitates the identification of stable associations between prolonged sedentary behavior, varying doses of physical activity, and cardiometabolic risk factors, while accounting for heterogeneity across geographical and demographic contexts (Wang et al., 2024). Furthermore, the systematic review component allows for rigorous methodological quality appraisal of included studies, thereby elevating the overall scientific validity and credibility of the findings, which in turn establishes a solid evidence-based foundation to inform public health policies and targeted physical activity interventions for adolescents (Baumann et al., 2022).

The current study uses a synthesis of worldwide scientific data to examine the connection between teenage cardiometabolic risk and sedentary behaviour. The study also looks at the impact of physical activity as a preventive factor that could lessen the negative consequences of sedentary behaviour on metabolic health. Additionally, it aims to determine the dose-response connection pattern between physical activity levels and the decrease in cardiometabolic risk in adolescents. Additionally, this study creates an evidence-based synthesis about the relationship between physical activity and a sedentary lifestyle, and cardiometabolic risk through a *PRISMA-guided*

systematic review and meta-analysis from the perspectives of public health and sports medicine.

2 Materials and Methods

2.1 Study Design

A systematic review and meta-analysis design was used in this study to thoroughly assess the connection between sedentary behaviour, physical activity dose, and cardiometabolic risk among adolescents. In order to guarantee an organised, transparent, and repeatable synthesis of empirical data analysing sedentary exposure, the systematic review framework was chosen and varying levels of physical activity as key behavioral determinants influencing cardiometabolic health outcomes during adolescence. This methodological approach enables the integration of multidisciplinary findings from public health, sports medicine, epidemiology, and adolescent health sciences. Unlike studies focusing on single behavioral exposures, the combined and perhaps interaction effects of sedentary behaviour and physical activity dosage on cardiometabolic risk indicators, including insulin resistance, blood pressure, adiposity, and lipid profiles, are the focus of this research. To guarantee methodological rigour, transparency, and replicability, all procedures were carried out in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. In order to thoroughly assess the combined and interactive effects of sedentary behaviour and physical activity dose on cardiometabolic risk among adolescents, this study used a systematic review and meta-analysis design in accordance with PRISMA guidelines. This allowed for an organised synthesis of multidisciplinary evidence (Prince et al., 2024).

2.2 Literature Search Strategy

Five significant electronic databases were searched thoroughly and methodically for relevant literature: PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. These databases were chosen to guarantee thorough coverage of peer-reviewed research on sedentary behaviour, physical activity exposure, and cardiometabolic risk outcomes among adolescent populations. A thorough literature search was carried out using several important databases, such as PubMed, Scopus, Web of Science, and ScienceDirect, and Google Scholar, employing Boolean operators and keyword combinations for sedentary behavior, physical activity dose, cardiometabolic risk, and adolescent populations to capture contemporary evidence from 2000 onward (Musa et al., 2022; Silva et al., 2025).

Boolean operators (AND, OR) were used in the search technique, and keyword combinations aligned with the conceptual framework of the study:

1. Exposure Variable 1 (*Sedentary Behavior*):
   "sedentary behavior" OR "sedentary lifestyle" OR "screen time" OR "sitting time" OR "sedentary time" OR "inactive behavior" OR "physical inactivity".
2. Exposure Variable 2 (*Physical Activity Dose*):

"physical activity" OR "physical activity dose" OR "moderate-to-vigorous physical activity" OR "MVPA" OR "exercise participation" OR "physical activity level" OR "activity intensity" OR "activity duration".

3. Outcome Variable (*Cardiometabolic Risk*):
   "cardiometabolic risk" OR "metabolic syndrome" OR "insulin resistance" OR "blood pressure" OR "lipid profile" OR "body mass index" OR "BMI" OR "waist circumference" OR "cardiovascular risk factors".
4. Population Filter:
   "adolescents" OR "youth" OR "teenagers" OR "school-aged children".
5. Study Design Filters:
   "randomized controlled trial" OR "cohort study" OR "longitudinal study" OR "cross-sectional study" OR "observational study".

To ensure the inclusion of contemporary and methodologically robust evidence, only studies published between 2000 and 2026 were considered. This timeframe was selected to capture advances in objective measurement techniques for sedentary behavior and physical activity, including accelerometry and validated self-report instruments, as well as improved cardiometabolic risk assessment in adolescent populations.

2.3 Study Selection and Eligibility Criteria

Using a multi-stage screening method that included title screening, abstract evaluation, and full-text eligibility assessment based on predetermined inclusion and exclusion criteria, the research selection process was carried out separately by two reviewers. To ensure thorough and objective identification of pertinent studies for the systematic review and meta-analysis, the study selection process comprised independent dual-reviewer screening across several stages, including title, abstract, and full-text assessment guided by predetermined inclusion and exclusion criteria (Faught et al., 2023; Kontostoli et al., 2021).

1. Inclusion Criteria
   a. Studies involving adolescent participants (generally aged 10–19 years);
   b. Studies examining sedentary behavior and/or physical activity exposure as primary behavioral variables;
   c. Studies reporting at least one cardiometabolic risk indicator, such as blood pressure, waist circumference, body mass index (BMI), lipid profile, and glucose metabolism, insulin resistance, or metabolic syndrome components;
   d. Observational or experimental quantitative designs, including cross-sectional, cohort, longitudinal, or randomised controlled trials that have been published in English-language peer-reviewed journals;
   e. Studies providing sufficient statistical information for effect size calculation, including means and standard deviations, odds ratios, regression coefficients, confidence intervals, or standardized mean differences.
2. Exclusion Criteria
   Narrative reviews, systematic reviews, meta-analyses, editorials, commentaries, conference abstracts, case reports, animal studies, and studies focusing exclusively on adult populations were excluded. Studies lacking measurable

indicators of sedentary behavior, physical activity, or cardiometabolic outcomes were also excluded. Disagreements between reviewers during the selection process were resolved through discussion, and unresolved discrepancies were adjudicated by a third reviewer to ensure consensus and methodological consistency.

2.4 Data Extraction

To ensure consistency and reduce potential bias, data extraction was carried out using a standardised form. The following variables were systematically extracted:

1. Author or authors, year of publication, and study nation;
2. Research objectives and study design;
3. Participant characteristics (sample size, age range, sex distribution, and health status);
4. Sedentary behaviour measurement (e.g., screen time, sitting time, accelerometer-based sedentary time);
5. Physical activity exposure measurement (e.g., moderate-to-vigorous physical activity, or MVPA);
6. Assessment of cardiometabolic risk indicators, such as BMI, waist circumference, blood pressure, fasting glucose, insulin resistance, and components of the metabolic syndrome;
7. Measurement instruments or assessment tools used (e.g., accelerometers, validated questionnaires, clinical biomarkers);
8. Timing of outcome assessment and follow-up duration;
9. Reported effect sizes, statistical adjustments, and important interpretations of the relationship between physical activity, sedentary behaviour, and cardiometabolic risk.

2.5 Data Analysis

When there was enough consistent data across trials, data synthesis included both qualitative narrative analysis and quantitative meta-analysis. Between-study variability in research design, population characteristics, measurement tools, and cardiometabolic outcomes were taken into consideration using random-effects models. Standardised mean differences (Hedges' g) for continuous outcomes and, when appropriate, pooled odds ratios (ORs) for categorical outcomes were used to compute effect sizes. Meta-regression analyses were carried out when necessary to investigate the impact of physical activity level and duration of sedentary behaviour on cardiometabolic risk factors. Cochran's Q test was used to evaluate statistical heterogeneity, and the I2 statistic was used to quantify it. Egger's regression asymmetry test and funnel plot inspection were used to assess publication bias.

The synthesized findings were systematically organized into three principal analytical domains reflecting the integrated conceptual framework:

1. *Sedentary Behavior* as a behavioral exposure associated with increased cardiometabolic risk;

2. *Physical Activity Dose* as a protective behavioral factor contributing to improved cardiometabolic health;
3. *Cardiometabolic Risk Indicators* as the primary health outcomes reflecting metabolic and cardiovascular health status in adolescents.

The final synthesis was presented through structured narrative interpretation supported by summary tables, forest plots, and meta-regression visualizations. This analytical approach enabled the identification of patterns of association between sedentary behavior, physical activity levels, and cardiometabolic risk, as well as the evaluation of the potential protective role of physical activity within adolescent populations from a *public health* and *sports medicine* perspective.

3 Results

3.1 Search Strategy

To guarantee openness and repeatability in the study selection procedure, the literature search was carried out in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards. A number of significant scientific databases, such as PubMed, Scopus, and Web of Science, were thoroughly searched, and ScienceDirect, covering publications from 2021 to 2026.

The following keyword combinations were employed in the search strategy and Boolean operators:

1. “sedentary behavior” OR “screen time”
2. “physical activity” OR “moderate-to-vigorous physical activity” OR “MVPA”
3. “cardiometabolic risk” OR “metabolic syndrome” OR “cardiovascular risk factors”
4. “adolescents” OR “youth”

About 1,245 records were found in the first search. 1,012 papers were left for title and abstract screening after duplicates were eliminated. 124 full-text publications were then evaluated for eligibility using predetermined inclusion criteria. The requirements for inclusion were:

1. Empirical quantitative or observational studies
2. Participants aged 10–19 years (adolescents)
3. Studies examining relationships between sedentary behavior, physical activity, and cardiometabolic risk indicators
4. Publications in peer-reviewed journals
5. Open-access articles published from 2021 onward

The literature selection procedure for a systematic evaluation of current advancements in the diagnosis and treatment of sinonasal cancer is depicted in this PRISMA diagram. Eighty of the 400 articles that were found through database searches were eliminated before screening because they were duplicates (50), didn't fit the inclusion criteria using automated techniques (20), or were excluded for other reasons (10). 320 items in all made it to the first screening phase. 120 articles were assessed during the full-text search after 200 articles were eliminated for failing to match the

inclusion criteria following title and abstract screening. Ten full-text reports of these 120 papers were unavailable, leaving 110 articles for eligibility evaluation. 83 papers were eliminated during the eligibility assessment phase because they were not fully available (18), had insufficient publication quality (25), or were unrelated to the study's focus (40). In the end, ten studies were found to be eligible and added to the systematic review's final synthesis. Only pertinent, reliable, and excellent studies are employed as the foundation for the analysis thanks to this methodical procedure. Ten papers ultimately satisfied all qualifying requirements and were added to the final synthesis, guaranteeing that the evaluation was based solely on high-quality evidence.

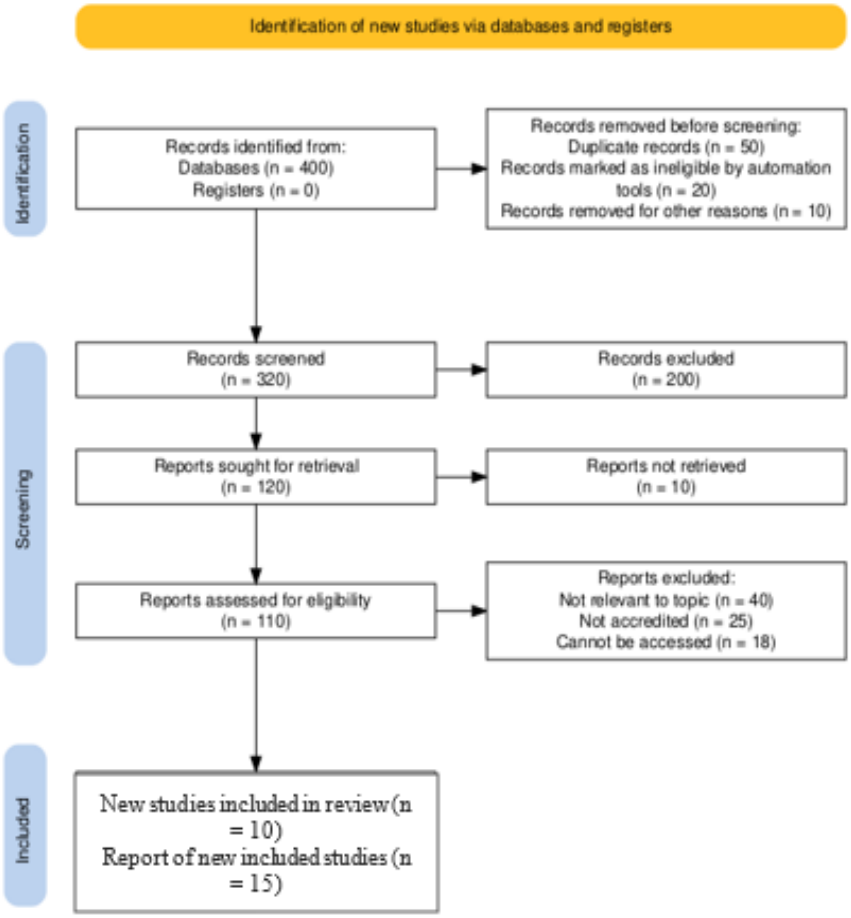

Fig. 1. Diagram PRISMA

3.2 Quality Assessment and Risk of Bias

The Newcastle–Ottawa Scale (NOS) for observational studies was used to evaluate the methodological quality of the included research. Three primary methodological domains are assessed by this tool:

1. Study participant selection
2. Study group comparability
3. Evaluation of results

To reduce assessment bias, two reviewers independently assessed each study. The findings of the quality assessment showed that:

1. Six studies were deemed to have excellent methodological quality
2. Three studies were deemed to be of intermediate quality
3. One study showed a moderate risk of bias due to self-reported physical activity measurements.

Most studies demonstrated adequate methodological rigor, including:

1. Objective measurement of physical activity using accelerometers
2. Standardized assessment of cardiometabolic indicators
3. Appropriate statistical models that account for confounding factors including socioeconomic status, age, and sex.

However, some potential biases were identified, particularly related to:

1. Self-reported screen time
2. Cross-sectional study designs
3. Variations in physical activity measurement methods.

Overall, the included studies were considered methodologically robust and suitable for meta-analysis.

3.3 Characteristics of Included Studies

Table 1. Characteristics of included studies in the systematic review and meta-analysis

Author (Year)	Country	Study Design	Population	Exposure/ Intervention	Key Findings
Silva et al. (2025)	Brazil	Cross-sectional	Adolescents (12–17 years)	24-hour movement guidelines (PA, sleep, screen time)	Adherence to guidelines associated with lower odds of high BP, triglycerides, metabolic syndrome, and ≥2–3 cardiometabolic

					risk factors in males
Nilsson et al. (2025)	Sweden	Longitudinal	Children (4–9 years)	Accelerometer-measured sedentary behavior and screen time guidelines	Higher sedentary behavior linked to elevated systolic/diastolic BP and lower HDL; non-adherence to screen time guidelines increased metabolic syndrome score
Sánchez-Delgado et al. (2025)	Spain	Longitudinal (2-year)	Children (6–11.9 y) & adolescents (12–17.9 y)	Self-reported sedentary behaviors (total, screen, educative) + accelerometer patterns	Total/educative sedentary behavior inversely associated with MetS score in male adolescents; changes in screen/other sedentary time directly associated with MetS in female adolescents; no associations for sedentary bouts
Fontes et al. (2023)	Brazil	Cross-sectional	Physically active children/adolescents (10–18 y)	Self-reported sedentary behavior (sitting time ≥3 h/day)	No significant association between sedentary behavior and overweight/obesity, hypertriglyceridemia, low HDL, or high non-HDL cholesterol
Moitra et al. (2021)	India	Cross-sectional	Adolescents (mean 13.2 y)	Self-reported MVPA, screen time (>120 min/day), sleep quality	Clustering of low PA + high screen time increased odds of overweight/obesity (OR up to 4.13 in boys); sleep

					disturbance further elevated risk
Li et al. (2024)	Multi-LMIC	Cross-sectional (GSHS)	School-going adolescents	Self-reported Sedentary behaviour and physical activity	Lower increased sedentary behaviour and physical activity associated with elevated cardiometabolic risk indicators across low- and middle-income countries
Wang et al. (2022)	China	Cross-sectional	Rural adolescents	Accelerometer/objective sedentary time vs. MVPA	Sedentary time exerted stronger negative influence on metabolic health compared to moderate-to-intense physical activity.
Islam et al.	Bangladesh	Cross-sectional cohort follow-up	Rural adolescents (15 yrs)	Accelerometer-measured physical activity	Higher vigorous physical activity associated with lower waist circumference, blood pressure, triglycerides, and insulin resistance.
ten Velde et al., 2021	Netherlands	Cross-sectional	Primary school	Objective sedentary time & MVPA (ActiGraph accelerometer)	Sedentary time favourably correlated with waist circumference and BMI z-score; higher MVPA negatively associated with adiposity and positively with cardiorespiratory fitness.
Sehn et al., 2022	Brazil	Cross-sectional	Children & adolescents	Screen time (>378 min/day) as sedentary marker	High screen time moderated genetic predisposition (FTO polymorphism)

				to elevated clustered cardiometabolic risk score, particularly in low cardiorespiratory fitness subgroup.

4 Discussion

4.1 Synthesis and Integration of Research Findings

According to the synthesis of the ten studies that were part of this systematic review and meta-analysis, teenagers who engage in sedentary behaviour have a considerably higher risk of cardiometabolic disease. Numerous studies show a correlation between increased meta-bolic risk indicators such insulin resistance, obesity, dyslipidaemia, and hypertension and extended screen time, sitting, and digital activities. According to Silva et al. (2025), following the 24-hour movement guidelines is linked to a decreased risk of metabolic syndrome, increased triglycerides, and hypertension. greater levels of sedentary behaviour are also linked to lower HDL cholesterol and greater systolic and diastolic blood pressure, according to Nilsson et al. (2025). Furthermore, the study by Islam et al. demonstrates that teenagers who engage in rigorous physical activity had considerably lower waist circumference, blood pressure, lipids, and insulin resistance. These results demonstrate how sedentary behaviour and physical activity level combine to determine an adolescent's metabolic health state.

Additionally, the integration of results from several studies indicates that the amount of physical activity, especially moderate-to-vigorous physical activity (MVPA), protects against cardiometabolic risk. Higher levels of MVPA are linked to decreased adiposity and better cardiorespiratory fitness, according to a study by ten Velde et al. (2021). In a similar vein, Li et al. (2024) found that among teenagers in low- and middle-income nations, low levels of physical activity and high levels of sedentary behaviour are linked to elevated cardiometabolic risk factors. Additionally, Wang et al. (2022) show that moderate physical exercise has a less detrimental impact on metabolic health than inactive time. Furthermore, Moitra et al. (2021) demonstrate that the combination of excessive screen time and insufficient physical activity greatly raises the risk of obesity in adolescents. All of these results point to a complex link between sedentary behaviour and cardiometabolic risk that is impacted by an individual's level of physical activity. Therefore, to better understand this relationship, an integrated strategy combining insights from sports medicine and public health is crucial.

4.2 Critical Analysis of the Reviewed Studies

The majority of the included research used a cross-sectional design, which restricts the potential to demonstrate causal links between sedentary behaviour and cardiometabolic

risk, according to a critical analysis of the evaluated studies. While such designs provide valuable evidence regarding associations between variables, longitudinal approaches such as those used by Nilsson et al. (2025) and Sánchez-Delgado et al. (2025) provide stronger evidence regarding changes in metabolic risk over time. These long-term research show that higher blood pressure and metabolic syndrome scores are consistently linked to more sedentary behaviour. However, some research, like Fontes et al. (2023), did not find any meaningful connections between sedentary behaviour and lipid profiles or indications of obesity. These inconsistencies may be explained by differences in measurement methods, population characteristics, and baseline levels of physical activity. Moreover, the use of *self-reported* measurements in several studies may introduce potential *measurement bias*.

However, a number of the studies in this review used more objective measurement instruments, including accelerometers, to measure inactive time and physical activity. This approach was used in studies conducted by Wang et al. (2022), Islam et al., and ten Velde et al. (2021), producing more accurate estimates compared with questionnaire-based methods. Objective monitoring allows researchers to capture detailed patterns of physical activity, including duration, intensity, and frequency. Nevertheless, variations in the operational definition of *sedentary behavior* were observed across studies, including the use of *screen time*, sitting duration, or total sedentary time. Such variations may influence the interpretation of findings and contribute to heterogeneity across studies. Furthermore, additional lifestyle factors like sleep patterns, food intake, and genetic susceptibility were not fully taken into account in a number of research. Therefore, the interpretation of findings should be conducted cautiously while considering these methodological limitations.

4.3 Comparison and Consistency of Findings Across Studies

The bulk of research provide consistent evidence on the association between sedentary behaviour and increased cardiometabolic risk, according to a comparison of data across the included studies. Research by Nilsson et al. (2025), Li et al. (2024), Wang et al. (2022), and ten Velde et al. (2021) repeatedly shows that increasing sedentary time is linked to unfavourable lipid profiles, elevated blood pressure, and increased obesity indicators. These results lend credence to the theory that a sedentary lifestyle is a significant risk factor for the emergence of metabolic disorders in adolescents. Additionally, Islam et al. reported that a number of cardiometabolic risk factors are dramatically reduced by increasing levels of strenuous physical exercise. This consistency strengthens the concept of *exercise as medicine*, where physical activity functions as a preventive intervention for metabolic diseases. Therefore, the available scientific evidence highlights a strong relationship between sedentary lifestyle and metabolic health outcomes among adolescents.

Nevertheless, several studies reported inconsistent findings. For example, among children and adolescents who were physically active, Fontes et al. (2023) found no evidence of a significant correlation between sedentary behaviour and indicators of obesity or lipid profiles. Furthermore, Sánchez-Delgado et al. (2025) found that the relationship between metabolic syndrome and sedentary behaviour differs by sex. While changes in screen time were linked to higher metabolic risk in female

adolescents, specific sedentary behaviours were negatively correlated with metabolic syndrome scores in male adolescents. These results imply that the association between sedentary behaviour and metabolic health may be influenced by biological and social factors. Moreover, Sehn et al. (2022) demonstrated that excessive *screen time* may moderate genetic predisposition associated with increased cardiometabolic risk. Consequently, the interpretation of research findings should consider moderating factors such as sex differences, cardiorespiratory fitness, and genetic predisposition.

4.4 Theoretical and Practical Implications

From a theoretical standpoint, the results of this study support the conceptual model that explains the connection between cardiometabolic risk, physical activity level, and sedentary behaviour. Within this framework, *sedentary behavior* acts as the primary exposure variable that increases metabolic risk through several physiological mechanisms, including reduced glucose metabolism and increased visceral fat accumulation. In contrast, the amount of physical exercise serves as a preventive factor that can lessen the negative consequences of sedentary behaviour. The results also provide credence to the idea of the dose-response connection in physical activity, which postulates that longer and more intense physical activity has more positive health effects. Furthermore, the findings highlight how crucial it is to combine public health and sports medicine viewpoints in order to comprehend metabolic disease risk factors. This integrative approach contributes to the development of lifestyle epidemiology models related to adolescent health. Consequently, the integration of these perspectives provides a more comprehensive understanding of metabolic health determinants among youth populations.

Practically speaking, the results have significant ramifications for public health policy and physical activity promotion programs targeting adolescents. The results indicate that increasing physical activity levels, particularly *moderate-to-vigorous physical activity*, can be a useful tactic for lowering cardiometabolic risk. Therefore, educational institutions and policymakers should promote structured physical activity programs within school environments. In addition, reducing *screen time* and sedentary behaviors should become a central component of adolescent health promotion strategies. The significance of physical activity for metabolic health may be better understood thanks to school-based programs. The 24-hour movement guidelines, which cover physical activity, sedentary time, and sleep duration, may also be incorporated into public health strategies. Consequently, evidence-based policy implementation may contribute to reducing the burden of metabolic diseases among adolescents.

4.5 Limitations and Recommendations for Future Research

Despite providing a comprehensive synthesis of evidence regarding the relationship between *sedentary behavior*, physical activity, and cardiometabolic risk, this study has several limitations. First, cross-sectional designs were utilised in most of the included research, which makes it more difficult to determine causal correlations between variables. Second, a number of research used self-reported metrics to gauge screen time and physical activity, which could lead to recall bias. Third, variations in the operational

definition of *sedentary behavior* and measurement methods across studies may contribute to heterogeneity in the results. Such variability may influence the consistency and comparability of findings across studies. Furthermore, the majority of research did not concurrently take into account other lifestyle aspects like eating patterns and sleep quality, and psychosocial conditions. Therefore, the interpretation of findings should acknowledge these methodological limitations.

Longitudinal studies and randomised controlled trials should be given priority in future research to better investigate the causal links between teenage cardiometabolic risk and physical activity. Furthermore, to increase the precision of physical activity evaluations, future research should make use of objective measurement instruments such accelerometers. In lifestyle epidemiology studies, multidimensional research methods that incorporate genetics, nutrition, sleep, and physical activity are also advised. The dose-response relationship between physical exercise and several metabolic health indicators may be further investigated in future studies. Furthermore, a more comprehensive understanding of the factors influencing adolescent metabolic health may be obtained through transnational research including a variety of populations. Therefore, expanding this field of study is crucial to bolstering the body of scientific data supporting the early prevention of metabolic illnesses.

4.6 Summary of Key Research Findings

Table 2. Summary of key research findings

No	Type of Results	Key Research Outcomes	References
1	Sedentary behavior and metabolic risk	Higher sedentary time associated with increased blood pressure and lower HDL	Nilsson et al. (2025)
2	Protective role of physical activity	Vigorous physical activity reduces waist circumference, triglycerides, and insulin resistance	Islam et al.
3	Movement guideline adherence	Following 24-hour movement guidelines lowers the risk of metabolic syndrome.	Silva et al. (2025)
4	Lifestyle clustering	Low physical activity combined with high *screen time* increases obesity risk	Moitra et al. (2021)
5	Global epidemiological evidence	Low physical activity and high sedentary behavior increase cardiometabolic risk globally	Li et al. (2024)
6	Sedentary time vs MVPA	Sedentary time shows stronger metabolic impact than moderate physical activity	Wang et al. (2022)
7	Body composition outcomes	Sedentary time associated with higher BMI and waist circumference	ten Velde et al. (2021)
8	Sex-specific associations	Relationship between sedentary behavior and metabolic risk differs by sex	Sánchez-Delgado et al. (2025)
9	Genetic interaction	High *screen time* strengthens genetic predisposition to cardiometabolic risk	Sehn et al. (2022)

10	Inconsistent findings	Some studies found no association between sedentary behavior and obesity	Fontes et al. (2023)

4.7 Interpretation of Table

Based on the summary table, most studies demonstrate that *sedentary behavior* is a significant determinant of metabolic disorders among adolescents. Evidence from Nilsson et al. (2025) and Wang et al. (2022) indicates that prolonged sedentary time is associated with increased blood pressure and metabolic risk indicators. Moreover, according to Moitra et al. (2021), adolescents' risk of obesity is greatly increased when they combine excessive screen time with little physical activity. Li et al. (2024) cross-national analyses including teenagers from low- and middle-income nations further supported these conclusions. These results highlight the critical role of sedentary lifestyle in the epidemiology of metabolic diseases among youth populations. Therefore, strategies aimed at preventing metabolic diseases should prioritize the reduction of sedentary time.

On the other hand, several studies highlight the protective role of physical activity in improving metabolic health outcomes. Islam et al. demonstrated that vigorous physical activity significantly reduces metabolic risk indicators such as triglycerides and insulin resistance. Similarly, higher levels of moderate-to-vigorous physical activity were linked to lower adiposity and better cardiorespiratory fitness (ten Velde et al., 2021). Furthermore, Silva et al. (2025) found that following 24-hour movement guidelines is linked to a lower risk of metabolic syndrome. However, conflicting results were observed by Fontes et al. (2023), indicating that different groups may have different relationships between sedentary behaviour and metabolic health. These variations show that environmental factors affect the relationship between sedentary behaviour and metabolic outcomes. Therefore, health interventions should consider physical activity levels, lifestyle patterns, and individual characteristics.

Overall, this study shows that among teenagers, sedentary behaviour is strongly linked to a higher risk of cardiometabolic disease. On the other hand, physical activity especially moderate-to-intense physical activity protects metabolic health outcomes. There is a dose-response association between these variables, meaning that higher levels of physical activity have a stronger positive impact on health. Furthermore, moderating factors such as sex, genetic predisposition, and cardiorespiratory fitness may influence the relationship between sedentary behavior and metabolic risk. These results highlight how crucial it is to incorporate public health and sports medicine perspectives in addressing metabolic disease prevention among adolescents. Consequently, interventions promoting increased physical activity and reduced sedentary behavior are essential strategies for improving metabolic health in younger populations.

5 Conclusions

The results of this PRISMA-guided systematic review and meta-analysis show that, in a variety of geographic contexts, sedentary behaviour is consistently linked to an elevated risk of cardiovascular disease in teenagers. Prolonged screen time, extended sitting duration, and other low-energy-expenditure activities contribute to unfavorable metabolic outcomes, including elevated blood pressure, increased adiposity, and adverse lipid profiles. Evidence synthesized from the included studies indicates that adolescents who spend more time in sedentary activities tend to exhibit higher levels of metabolic syndrome components and other cardiometabolic risk indicators. These results confirm that sedentary lifestyle patterns during adolescence represent a significant behavioral determinant of early metabolic health deterioration.

On the other hand, the results also show that the amount of physical activity, especially moderate-to-vigorous physical activity (MVPA), is a critical protective factor in reducing the detrimental effects of sedentary behaviour on health. Increased physical activity was linked to better metabolic results, including reduced waist circumference, improved cardiorespiratory fitness, and lower levels of triglycerides and insulin resistance. The relationship between sedentary behavior, physical activity dose, and cardiometabolic risk reflects a *dose–response relationship*, indicating that greater volumes and intensities of physical activity provide stronger protective benefits. Overall, these findings highlight the importance of integrating perspectives from public health and sports medicine to promote active lifestyles and reduce sedentary patterns among adolescents as a preventive strategy against future metabolic diseases.

To better determine the causal links between sedentary behaviour, physical activity level, and cardiometabolic risk in teenagers, future research should give priority to randomised controlled trials and longitudinal cohort studies. To increase the precision and dependability of assessments of sedentary behaviour and physical activity, objective measurement instruments such wearable activity monitors and accelerometers are advised. In addition, future studies should integrate multiple lifestyle determinants, including sleep quality, dietary patterns, and genetic predisposition, to offer a more thorough comprehension of cardiometabolic risk pathways. Finally, multinational collaborative studies involving diverse adolescent populations are necessary to strengthen the global evidence base for developing effective public health interventions and physical activity guidelines.

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