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Physical activity in youth and cardiovascular disease risk in later-life: Mediation by mid-life factors in a large cohort of Swedish adults

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ABSTRACT

Objective: The aims were to investigate the association between youth physical activity and the risk of cardiovascular disease (CVD) later in life in men and women and whether mid-life lifestyle-associated factors, including exercise, smoking, Body Mass Index (BMI), and cardiorespiratory fitness (VO_2max), mediate this association.
Methods: Data from 269,431 Swedish participants (52 % men) who participated in occupational health profile assessments between 1995 and 2023 were included. Youth physical activity was self-reported as overall participation in school-based physical education and physical activity outside school before age 20. CVD incidence was obtained from national registers. Mediation analyses assessed mid-life lifestyle-associated factors' influence on the association.
Results: Compared to those reporting no physical education participation, participation in only physical education was associated with a 18 % lower risk for CVD later in life (HR = 0.82, 95 % CI 0.70,0.95). Participating in additional physical activity outside school yielded varying risk estimates (HR = 0.78, 95 % CI 0.67,0.90 for one to two times/week; HR = 0.84, 95 % CI 0.73,0.97 for three to five times/week). VO_2max, BMI, and smoking mediated 16 %–32 % of the association. In the single mediation model, cardiorespiratory fitness explicitly mediated the association in those who participated in physical education and at least one weekly sessions of physical activity outside school.
Conclusion: Youth refraining from participating in physical education class could be considered a risk group for later-life CVD. Mediation analyses suggest that engaging in only physical education or with additional physical activity outside school in youth, may confer more healthy behaviour in mid-life, which explain the lower CVD risk.

1. Introduction

Cardiovascular diseases (CVD) remain the leading global cause of mortality, accounting for 20.5 million deaths in 2021 and contributing to millions of years of life lost due to disability (Lindstrom et al., 2022). A significant proportion of global CVD cases can be attributed to modifiable risk factors, such as smoking, an unhealthy diet, obesity, and insufficient physical activity (Roth et al., 2020; World Heart Federation, 2023). While adults show a strong dose-response relationship between higher levels of especially moderate-to-vigorous physical activity and reduced CVD risk (Kraus et al., 2019; Li and Siegrist, 2012), recent findings indicate that also early-life physical activity may have lasting effects on CVD risk factors later in life (Da Silva et al., 2023; Fernandes and Zanesco, 2015; Kallio et al., 2021), raising questions about the relative importance of different life stages for CVD prevention. In particular, evidence from Ekblom-Bak et al. (2018) suggests that higher amounts of physical activity during childhood and adolescence, including school-based physical education, are associated with reduced CVD risk factors and sustained physical activity into adulthood, potentially due to sensitive developmental periods (Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents, 2011).

Current guidelines recommend children and adolescents engage at least 60 min/day in moderate-to-vigorous physical activity to achieve health benefits (Bull et al., 2020). Meanwhile, physical education, a compulsory school subject in Sweden from ages six–16 (Swedish National Agency for Education, 2022), is essential in promoting physical activity in youth (Pate et al., 2006) and could contribute to the

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recommended physical activity levels. Yet, the long-term health effects of school-based physical education is limited (Ekblom-Bak et al., 2018), and the potential mediating role of mid-life lifestyle factors remains understudied. With most youths failing to meet the physical activity recommendations (Guthold et al., 2020; Nyberg et al., 2020) alongside declining cardiorespiratory fitness (Ekblom et al., 2011; Väisänen et al., 2021) and a persistently high prevalence of lifestyle-related factors linked to both CVD risk (NCD Risk Factor Collaboration (NCD-RisC), 2017; López-Bueno et al., 2024) and physical activity (Leech et al., 2014; Paavola et al., 2004), understanding the relationship between youth physical activity and CVD is increasingly relevant.

This study utilizes a large Swedish national cohort of men and women from the working population to address two key aims: (1) Investigate the association between self-reported youth physical activity and the risk of CVD later in life in men and women, and (2) explore the potential mediating effect of mid-life lifestyle-associated factors, including exercise, smoking, body mass index (BMI), and cardiorespiratory fitness on this association.

2. Methods

2.1. Data material and population

This large-scale prospective cohort study used an exploratory design to link exposure data from the Health Profile Assessment (HPA) database with outcome data from Swedish national registers to track individuals over time. HPAs have been conducted within Swedish health services since the 1970s, with data stored digitally from 1990. Participation is voluntary and free and is offered to employees of companies or organizations affiliated with occupational or other health services. An HPA includes a questionnaire on physical activity and lifestyle habits, a physical examination with anthropometric measurements, an estimated maximal oxygen uptake (VO_2max) test via submaximal ergometer cycling, and a detailed interview with an HPA coach. An HPA may be offered on a single occasion to the employee or on multiple occasions for follow-up. The HPA database is managed by the HPI Health Profile Institute (Stockholm, Sweden), which oversees method standardization, HPA coach training, and software development for data collection.

A total of 572,985 HPAs (both first-time and follow-up tests) with data on self-reported youth physical activity (defined as physical activity before 20, see below) were available in the database. Limited HPAs were available before 1995, which introduced a selection bias. After excluding HPAs conducted before 1995 ($n = 1919$) and after 2022-12-30 (end of follow-up in national registers for outcomes, $n = 1037$), those 20 years old or younger at the HPA ($n = 1565$), participants with missing data on the covariates (sex ($n = 0$), age (n = 1), exercise ($n = 3094$), estimated VO_2max ($n = 124{,}223$), smoking ($n = 3150$), BMI ($n = 6322$), and education ($n = 2154$)), follow-up tests ($n = 170{,}901$), and participants with incidence cases before the HPA ($n = 1699$), the resulting sample consisted of 269,431 participants (see Supplement Fig. 1). The ethics were granted at the Stockholm Ethics Review Board (Dnr 2015/1864–31/2 and 2016/9–32) and complied with the Declaration of Helsinki.

2.2. Exposure

Physical activity before 20 years of age (hereafter referred to as physical activity before 20) was self-reported at the HPA in mid-life (age 20–70), answering to the statement using one out of five alternatives: *Prior to the age of 20, I …* (1) *Did not participate in physical education,* (2) *Participated only in physical education*, (3) *Participated in physical education and one-two times/week of physical activity outside of school hours,* (4) *Participated in physical education and three-five times/week of physical activity outside school hours* or (5) *Participated in physical education class and at least six times/week of physical activity outside school hours*.

2.3. Morbidity and mortality outcomes

Participants were followed from their HPA to the first CVD event, or until 2022-12-30. The incident cases with CVD were derived from the Swedish national cause of death registry and the national in-hospital registry as Ischemic heart disease (I20–25), Cardiac arrest (I46) and Stroke (I60-I66) according to the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10). Cases recorded with earlier versions, i.e. ICD-9 or ICD-8, had been translated into ICD-10.

2.4. Mediators and other covariates

In mid-life, exercise level was self-reported by answering the following statement that fit into the five alternatives: *I exercise for the purpose of maintaining/improving my physical fitness, health, and well-being…* (1) *Never,* (2) *Sometimes,* (3) *one-two times/week,* (4) *three-five times/week* or (5) *At least six times/week*. Smoking was assessed by answering the statement "*I smoke…*" with the five alternatives (1) *At least 20 cigarettes/day,* (2) *11–19 cigarettes/day,* (3) *one-10 cigarettes/day,* (4) *Occasionally* or (5) *Never*. BMI was calculated by dividing body mass by body height in meters squared (kg/m^2), both of which were assessed during the HPA with a calibrated scale with lightweight clothing close to 0.5 kg and a stadiometer. Cardiorespiratory fitness (VO_2max) was assessed as estimated maximal oxygen uptake (in mL/min/kg), obtained through a submaximal exercise test on a cycle ergometer and calculated according to Åstrand and Ryhming (1954) and Åstrand et al. (1960). The Åstrand test has previously shown a low coefficient of variation, i.e. variation on a group level between the estimated and directly measured VO_2max. Björkman et al. (2016) showed that the mean difference was 0.07 l/ min (95 % CI 0.06–0.21) on the group level. Educational level was classified using the Swedish educational classification (2000) and divided into four categories: (1) Primary education ($\leq$9 years), (2) Secondary education (10–12 years), (3) Tertiary education (13–14 years), and (4) Higher education ($\geq$15 years).

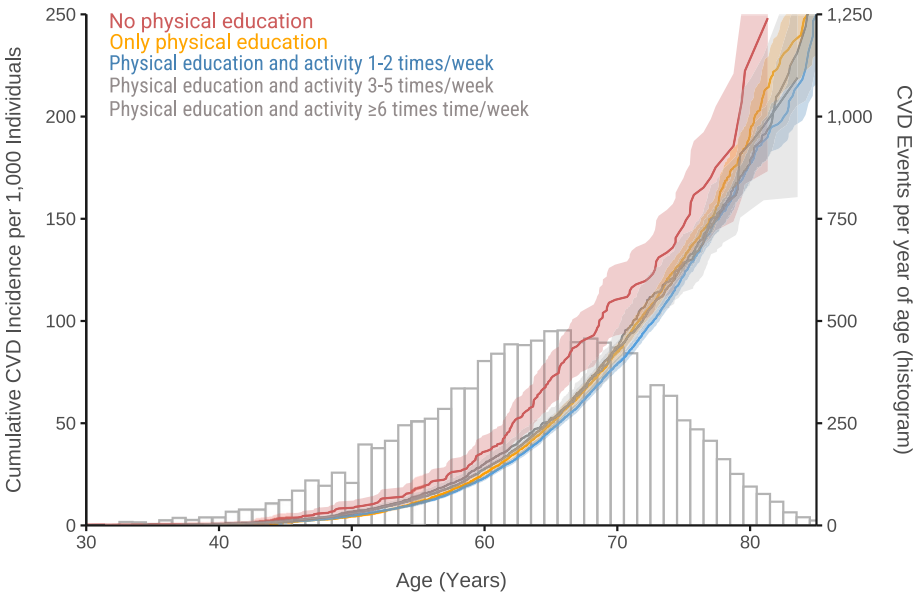
2.5. Statistics

For all survival analyses, risk time began at age 20 and ended at the first occurrence of CVD incidence, mortality, or end of study, which established the time scale as age in survival analyses. Cox regressions and mediation analyses used calendar time (2023-year when 20 years old) to adjust for year of birth, accounting for potential cohort effects and changes in exposure or risk factors over time. Age at the HPA controls for when in life the HPA was conducted.

For Fig. 1, cumulative CVD incidence per 1000 person-years was estimated using the Santo Nieto method (Nieto and Coresh, 1996), expressed as (1 − Survival Probability) × 1000. Poisson regression assessed physical activity before 20-CVD associations with incidence rates (IR) per 1000 person-years. The model was sex-adjusted to address sex differences in CVD risk and the different proportions of men and women across physical activity before 20 strata.

The proportional hazards assumption of the Cox model was assessed using Schoenfeld residuals. Sex differences across physical activity before 20 levels were assessed using Cox models with physical activity before 20-sex interaction terms, presenting contrasts as hazard ratios. Sex-specific incidence rates derived from risk time-adjusted Poisson models. Two Cox models were fitted with sequential adjustments: (1) physical activity before 20, (2) + calendar time, sex, age at the time of the HPA, VO_2max, BMI, smoking, and exercise. Given its role as a proxy for unmeasured confounding, education was included in a sensitivity analysis to assess robustness of the model. As estimates remained stable, Model 2 (excluding education) was retained for mediation analysis, consistent with our theoretical framework.

Causal mediation analysis examined VO_2max, BMI, smoking, and exercise as mediators between physical activity before 20 and CVD



	N	Incidence	IR (95% CI)	HR (95% CI)
No physical education	3,305	191	36.70 (29.00-46.40)	1 (ref)
Only physical education	49,142	2,446	32.90 (31.00-34.80)	0.81 (0.70-0.94)
Physical education and activity 1-2 times/week	94,435	3,674	23.10 (21.90-24.40)	0.74 (0.64-0.85)
Physical education and activity 3-5 times/week	98,435	3,706	17.60 (16.20-19.00)	0.81 (0.70-0.94)
Physical education and activity ≥6 times time/week	24,114	758	15.10 (12.30-18.40)	0.84 (0.72-0.99)

Fig. 1. Survival analysis with cumulative incidence, incidence rate and hazard ratio of cardiovascular disease events or death due to cardiovascular disease per 1000 person-years adjusted for sex in Swedish adults who performed a Health Profile Assessment between 1995 and 2023.
Note. Abbreviations: CVD, cardiovascular disease.

outcomes, estimating natural indirect effects (hereafter referred to as indirect effects), natural direct effects (direct effects), and total effects. Multiple mediation models included all mediators whereas individual models examined unique contributions. All models adjusted for sex, age and calendar time, with individual models controlling for concurrent mediators (except VO_2max and BMI due to overlap). Exercise (categories one-two vs three-five) and smoking (categories one-three vs four-five) were binary, and VO_2max and BMI remained continuous. Mediation used Cox regression for outcomes and logistic/linear regression for mediators. Confidence intervals derived from 1000 bootstrap samples.

The Cox proportional hazards models in the mediation model are multiplicative, therefore the sum of direct and indirect effects may not equal the total effect. Asymmetry in confidence intervals (CI) can result from the distribution of hazard ratios, which may be non-symmetrical, and from bootstrapping methods used to estimate intervals when distributions deviate from normality.

Statistical analysis used R (version 4.4.2) and the packages CMAverse (Shi et al., 2021), Tidyverse (Jiang and VanderWeele, 2015), and AdjustedCurves (Denz et al., 2023).

Table 1
Self-reported physical activity levels before age 20 among Swedish adults, recorded at the Health Profile Assessment between 1995 and 2023.

	No physical education (ref) (n = 3305)	Only physical education (n = 49,142)	Physical education + physical activity one-two times/week (n = 94,435)	Physical education + physical activity three-five times/week (n = 98,435)	Physical education + physical activity ≥ six times/week (n = 24,114)
	N (%)/mean (SD)	N (%)/mean (SD)	N (%)/mean (SD)	N (%)/mean (SD)	N (%)/mean (SD)
Men	1578 (48)	18,980 (39)	42,709 (45)	61,888 (63)	17,030 (71)
Age (years)	43.70 (11.30)	45.50 (10.90)	43.40 (11.10)	40.90 (10.90)	39.70 (10.60)
Body mass index (kg/m^2)	26.10 (4.50)	25.70 (4.30)	25.40 (4.10)	25.60 (3.90)	25.70 (3.80)
VO_2max (ml/kg/min)	33.80 (9.40)	33.50 (9.00)	35.80 (9.60)	38.00 (10.20)	39.90 (10.80)
Exercise (< one time(s)/week)	1417 (43)	20,501 (42)	32,586 (35)	30,055 (31)	6152 (26)
Smoking (≥ one cigarette(s)/day)	527 (16)	6536 (13)	10,319 (11)	9157 (9.3)	1618 (6.7)
High education (≥15 years)	734 (22)	9764 (20)	25,442 (27)	26,017 (26)	6832 (28)

Note. Abbreviations: SD, Standard deviation; VO_2max, maximal oxygen consumption.

3. Results

Table 1 provides an overview of the sample characteristics in relation to physical activity before the age of 20. Individuals who reported higher physical activity levels in youth had better lifestyle outcomes in mid-life, including lower BMI, higher VO_2max, regular exercise, and less smoking. The proportion of men and women who reported no physical education were similar. Fewer women reported higher levels of physical activity in youth, and those who reported high physical activity were also younger and had higher education than those who reported no physical education.

During a median follow-up of 14 years (Q1-Q3 11–18 years), 10,216 participants (3.8 % of the study population) experienced a first-time incidence CVD event. Of these individuals, 930 (0.9 % of the cases) experienced a fatal outcome.

Compared with the reference group (no physical education), participating in only physical education was associated with a lower HR of CVD later in life (Table 2 and Fig. 1). This association remained after adjusting for calendar time, sex, age, BMI, VO_2max, exercise and smoking (Model 2). Similar results were found in those reporting participation in physical education and additional physical activity outside school, in the fully adjusted model (Table 2). In analyses stratified by sex, women who engaged in additional physical activity outside school one–five times/week had a significantly lower HR compared to those reporting no physical education, while for men, physical education alone or with additional physical activity outside school one–two times/week was associated with reduced CVD risk after full adjustments.

Part of the association between physical activity before 20 and CVD incidence risk was mediated by mid-life lifestyle-associated factors (see Supplement Fig. 2. for the directed acyclic graph). The single mediation models presented the following point estimates for the indirect effect: 0.98 (95 % CI 0.97,0.99) for smoking and 0.98 (95 % CI 0.98,0.99) for BMI in the group who participated in only physical education, and 0.95 (95 % CI 0.95,0.96) for VO_2max (ml/min/kg), 0.97 (95 % CI 0.96,0.0.98) for smoking, and 0.97 (95 % CI 0.97,0.98) for BMI in the group participating in physical education and additional physical activity outside school ≥ one times/week compared to those with no physical education. A similar pattern was seen for the percentage mediated (Fig. 2). The indirect effects of combining BMI, VO_2max, exercise, and smoking at the HPA explained 16 % (95 % CI 8 %,49 %) of the total effect in those who participated in only physical education and 32 % (95 % CI 20 %,67 %) of the total effect in those participating in physical education and additional physical activity outside school ≥ one times/week (Fig. 2).

4. Discussion

In a cohort of 269,431 Swedish men and women, those reporting participation in school-based physical education before age 20 had a 18 % lower risk of fatal and non-fatal CVD later in life compared to those who did not participate in physical education, even after adjusting for central confounders. Reporting additional weekly sessions of physical activity outside school yielded varying risk estimates: one-two weekly sessions were associated with an additional decrease in risk (22 %), while three-five weekly sessions were associated with a slightly less decrease (16 %). Women participating in physical education and additional weekly sessions of physical activity outside of school had a 25 %–26 % reduced risk, while men had a 19 %–20 % reduced risk by participating in only physical education or with one-two weekly sessions of physical activity outside of school. Subsequent mediation analyses using a multiple mediation model indicated that lifestyle-associated factors in mid-life could explain 16 % and 32 % of the risk reduction for those who participated in only physical education and physical education with additional physical activity outside school compared to not participating in physical education. Single mediation models showed that BMI (7 %) and smoking (9 %) mediated part of the effect among those who only participated in physical education. In participants who combined physical education with additional physical activity outside school ≥one times/week, VO_2max (16 %), BMI (10 %), and smoking (12 %) emerged as key mediators.

Previous studies have primarily focused on the relationship between physical activity in youth and CVD risk factors (Kallio et al., 2021; Raitakan et al., 1994). One study has examined the association between physical activity in adolescence and the incidence of CVD in later life (Saint-Maurice et al., 2019) and reported a 12 % lower risk of CVD-related mortality (HR = 0.86, 95 % CI 0.81,0.92) in individuals with self-reported 7.0 h/week of leisure-time physical activity between 15 and 18 years of age followed by low levels of leisure-time physical activity throughout adulthood. However, their analysis did not include physical education participation in adolescence. Moreover, physical activity was self-reported based on leisure-time moderate-to-vigorous physical activity between ages 15 and 18, utilizing a shorter time span and a different physical activity measurement. Despite these differences, the present study found similar risk estimates for those engaging in physical education and additional physical activity outside school one-five times/week.

A dose-response relationship between physical activity and CVD risk is commonly shown in prospective cohort studies of adult populations (Kraus et al., 2019; Li and Siegrist, 2012). By contrast, this study found that physical education participation combined with one–five weekly sessions of physical activity outside of school was linked to the greatest risk reduction, while the benefit of additional three-five sessions of physical activity outside of school on CVD risk were lower. Furthermore, there was no difference in risk between those participating in physical education and additional physical activity outside school ≥six times/week compared to those not participating in physical education. The latter finding could potentially be explained by burnout and injuries from high sports participation, which could cause attrition in youth

Table 2
Hazard ratios with 95 % confidence intervals for the association between physical activity before 20 and cardiovascular disease among Swedish adults (1995–2023).

	No physical education class (ref) (n = 3305)	Only physical education class (n = 49,142)		Physical education class + physical activity one-two times/week (n = 94,435)		Physical education class + physical activity three-five times/week (n = 98,435)		Physical education class + physical activity ≥ six times/week (n = 24,114)	
All									
Model 1	1	0.71	(0.61–0.82)	0.72	(0.62–0.83)	0.97	(0.84–1.12)	1.06	(0.91–1.24)
Model 2	1	0.82	(0.70–0.95)	0.78	(0.67–0.90)	0.84	(0.73–0.97)	0.90	(0.77–1.06)
Women									
Model 1	1	0.76	(0.59–0.97)	0.67	(0.52–0.86)	0.71	(0.56–0.92)	0.77	(0.56–1.05)
Model 2	1	0.80	(0.62–1.02)	0.73	(0.57–0.94)	0.75	(0.58–0.96)	0.84	(0.61–1.15)
Men									
Model 1	1	0.82	(0.69–0.99)	0.78	(0.65–0.93)	0.86	(0.72–1.03)	0.88	(0.72–1.06)
Model 2	1	0.82	(0.68–0.98)	0.80	(0.67–0.96)	0.88	(0.73–1.05)	0.92	(0.76–1.12)

Note. Hazard ratios with 95 % confidence intervals. Model 1: Unadjusted. Model 2: Adjusted for model 1 + calendar time, sex, age, body mass index, VO_2max, exercise, and smoking.

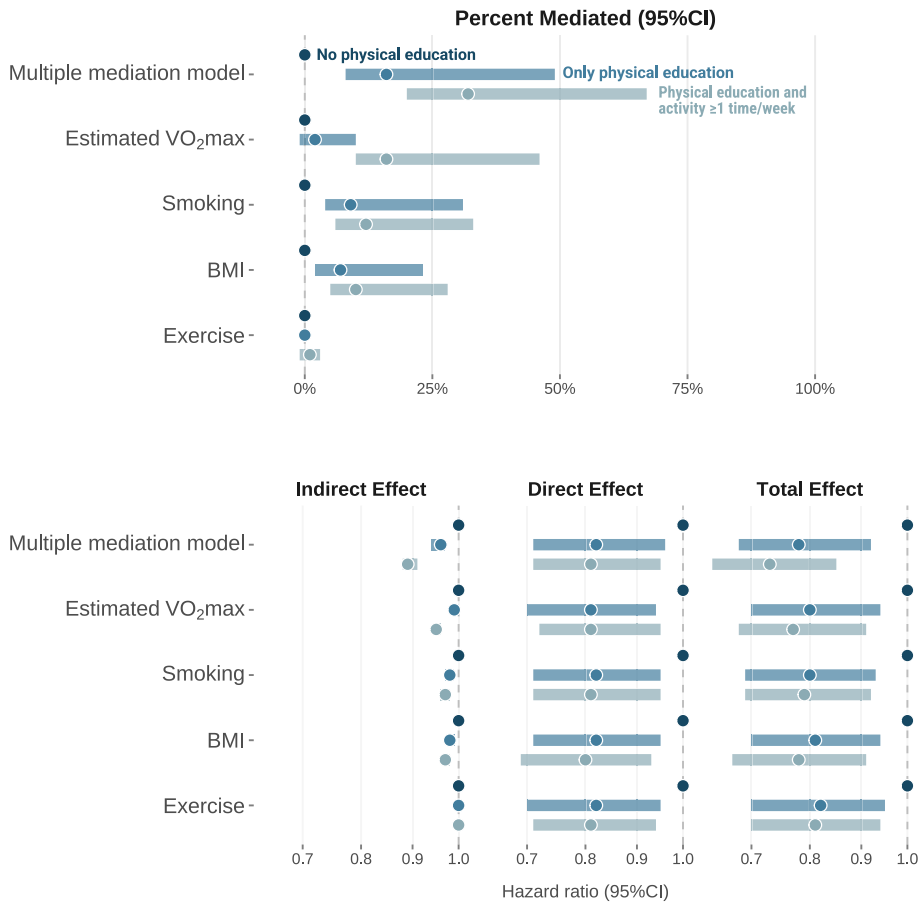


Fig. 2. Mediation analyses with percentage mediated, indirect, direct and total effect of estimated VO_2max, smoking, body mass index, and exercise in Swedish adults who performed a Health Profile Assessment between 1995 and 2023.

Note. The figure consists of 10 mediator models with the exposure groups: no physical education (reference), physical education only, and physical education and additional physical activity ≥one times/week, and the cardiovascular disease outcome for four different mediators. All models are adjusted for sex, age, and calendar time. The multiple mediation model includes all mediating variables. The Indirect effect reflects the effect of the exposure on the outcome through the mediator/s, while the Direct effect reflects the effect of the exposure on the outcome that does not operate through the mediator(s). The Total effect is the combined effect of both pathways. The Percentage mediated represents the proportion of the total effect attributed to the indirect effect. Abbreviations: BMI, body mass index; VO_2max, maximal oxygen consumption.

sports and reduced physical activity in adulthood (Brenner et al., 2024). However, a more likely explanation is that the operationalization of physical activity, with "No physical education" serving as a proxy for the absence of physical activity in youth, represents different behaviours rather than increasing intensities of the same activity. For example, reasons for not participating in physical education might differ from not engaging in physical activity outside school. Although physical education is a compulsory subject in Swedish schools, there are students who truant, meaning that they do not participate without a valid reason. In the current study, 3305 of 269,431 (1.2 %) reported not participating in physical education and lacked data on why. However, a previous study identified multiple reasons for not participating, including medical conditions, low self-confidence, dissatisfaction with physical ability, negative perceptions of physical education, and social pressures (Larsson, 2003). The current study found that not participating in physical education was associated with an elevated risk of CVD later in life compared to those who participated. While Larsson stated that health issues were not the primary reason, they may still contribute to this association. As such, the current study's results suggest that those who did not participate in physical education represent a vulnerable group, potentially at greater risk of poor health later in life.

HPA cohort data have previously shown that school-based physical education participation and additional physical activity outside school were associated with exercising ≥one times/week (OR range: 1.17–2.21), having normal/high VO_2max (OR range: 1.23–1.98), and obesity (OR range: 0.81–0.70) up to 70 years of age compared to those who did not participate in physical education (Ekblom-Bak et al., 2018). The current study extends those findings by identifying VO_2max, smoking, and BMI as mediators between participation in school-based physical education and additional physical activity outside school and later-life CVD risk. While VO_2max did not significantly mediate the association in the "only physical education" group, the variable was a significant mediator in the group engaging in both physical education and additional physical activity outside school, further suggesting different mechanisms may underlie early-life physical activity's impact on CVD risk depending on the type of physical activity. Considering the tracking of physical activity from youth into adulthood in this cohort (Ekblom-Bak et al., 2018), physical activity performed outside of school may offer greater long-term benefits for maintaining an active lifestyle into mid-life. Therefore, the established link between moderate-to-vigorous physical activity in adulthood and higher cardiorespiratory fitness (Milanović et al., 2015; Skinner et al., 2000), provides a plausible explanation for how VO_2max could mediate this relationship. Nonetheless, mid-life exercise did not mediate the association between youth physical activity and CVD in the present study, warranting additional research into this relationship.

4.1. Strengths and limitations

This study used a large, diverse sample with data collected over a long period (1995–2023). Key strengths include objective measures of morbidity, mortality, BMI, and estimated VO_2max. With its broad set of lifestyle factors and long follow-up, the study fills some research gaps in the current literature. However, several limitations exist. The voluntary nature of the HPA may have led to a selection bias favouring healthier individuals. Since it is only available to employed individuals, findings may not apply to the unemployed. Recent results from Ekblom-Bak et al. (2024) indicate that the cohort does not fully represent the Swedish workforce by overrepresenting those with a high educational level, single income source, the middle-aged, and those born in Sweden. Furthermore, the categorization of self-reported physical activity before 20 limits direct comparison to the recommendations. Concerning physical education, changes in the curricula over time (Jingstål and Forsberg, 2013) mean that participants had varying school-based physical activity experiences. Lastly, since the physical activity before 20 was retrospectively self-reported, the data may be subject to recall bias.

5. Conclusion

This study investigated patterns and relationships of lifestyle-related factors to better understand the long-term impact of physical activity during youth. Using exploratory analyses, it is the first to identify that individuals who did not participate in physical education before age 20 may represent a risk group for CVD later in life. This association was partly mediated by lifestyle-related factors, suggesting that individuals engaging in physical education only or with additional physical activity outside school in youth, may confer more healthy behaviour in mid-life, which explain the lower CVD risk. Further research should examine a wider range of youth factors to assess whether the association reflects other underlying conditions. Additionally, utilizing cohorts with more CVD cases are necessary to improve reliability and reduce the risk of type II errors.

Ethical Statement

The ethics board granted ethics at the Stockholm Ethics Review Board (Dnr 2015/1864–31/2 and 2016/9–32), and the study complied with the Declaration of Helsinki.

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Declaration of generative AI and AI-assisted technologies

During the preparation of this work, author(s) used ChatGPT to improve language and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

CRediT authorship contribution statement

Frida Söderström: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Elin Ekblom-Bak:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Sofia Paulsson:** Writing – review & editing, Data acquisition. **Daniel Väisänen:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Formal analysis, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:
Sofia Paulsson is employed at the Health Profile Institute.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2025.108416.

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