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Moderate-to-vigorous intensity physical activity from young adulthood to middle age and metabolic disease: A 30-year population-based cohort study

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Abstract

Objectives: To determine the association between moderate-to-vigorous intensity physical activity (MVPA) trajectories (course over age and time) through the adult life course and onset of metabolic disease (diabetes and dyslipidemia).

Methods: We analyzed prospective community-based cohort data of 5,115 participants in the CARDIA study, who were Black and White men and women aged 18–30 years at baseline (1985–1986) at four urban sites, collected through 30 years of follow-up. Individualized MVPA trajectories were developed for each participant using linear mixed models.

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Contributors: J.M.N. conducted the literature search, interpreted findings, and wrote, revised, and edited the manuscript. E.V. conceptualized the study, analyzed data, and edited the manuscript. K.P.G., S.S., A.K.G., K.B.D. conceptualized the study, interpreted the data, and provided critical revisions on the manuscript. A.E.M., J.S.R., and J.P.R. provided critical revisions on the manuscript. All authors approved the final draft.

Competing Interests: The authors have no conflicts of interest to report.

Patient and Public Involvement: Patients or the public were not involved in the design, conduct, reporting, or dissemination plans of our research.

Ethics Approval: The institutional review boards at each study site approved all study procedures. All participants provided written informed consent. The University of California, San Francisco institutional review board deemed this secondary data analysis project exempt (IRB 18–26523).

Results: Lower estimated MVPA score at age 18 was associated with a 12% (95% confidence interval [CI] 6%, 18%) higher odds of incident diabetes, a 4% (95% CI 1%, 7%) higher odds of incident low HDL, and a 6% (95% CI 2%, 11%) higher odds of incident high triglycerides. Each additional annual 1-unit reduction in the MVPA score was associated with a 6% (95% CI 4%, 9%) higher annual odds of diabetes incidence and a 4% (95% CI 2%, 6%) higher annual odds of high triglyceride incidence. Analyzing various MVPA trajectory groups, participants who were in the most active group at age 18 (over 300 min/week), but with sharp declines in midlife, had higher odds of high LDL and low HDL incidence, compared to those in the most active group at age 18 with subsequent gains.

Conclusion: Given recent trends in declining MVPA across the life course and associated metabolic disease risk, young adulthood is an important time period for interventions to increase and begin the maintenance of MVPA.

Keywords

physical activity; exercise; diabetes; cholesterol; triglycerides; trajectories

Introduction

Metabolic disease, including type 2 diabetes and dyslipidemia (low high-density lipoprotein cholesterol [HDL-C], high low-density lipoprotein cholesterol [LDL-C], and high triglycerides) are established risk factors for cardiovascular disease (CVD) [1–3], the leading cause of mortality in the USA [4]. Despite our understanding of the general benefits of moderate-to-vigorous intensity physical activity (MVPA) on preventing type 2 diabetes [5] and dyslipidemia [6–8], there is a paucity of longitudinal data regarding the specific trajectories (the course over age and time) of MVPA during young adulthood and the association of MVPA trajectory groups with adult-onset CVD. In particular, there is a need to understand how MVPA in young adulthood affects incidence of metabolic disease.

Young adulthood may set the baseline for later life physical activity trajectories and, thus, be an important time window for intervention [9,10]. The 2018 US Department of Health and Human Services (HHS) Physical Activity Guidelines recommend a minimum of 150 minutes of moderate-intensity physical activity per week for adults 18–65 years [11,12]. The Physical Activity Guidelines Scientific Report noted that young adults have unique growth and developmental needs similar to adolescents, who are recommended to have 60 minutes per day (420 minutes per week) of MVPA [11]. However, there was insufficient literature on physical activity and health outcomes in young adulthood to confirm current guidance or to support a change to the current approach [11]. Thus, the optimal dose and trajectory patterns of MVPA, particularly in young adulthood, to prevent metabolic disease remains unknown [13,14].

The objective of this study was to determine the independent associations between the young adult level of MVPA and subsequent changes in MVPA through the transition to midlife and incidence of metabolic disease (diabetes, high LDL-C, low HDL-C, high triglycerides, dyslipidemia). Second, we examined if specific MVPA trajectory patterns were associated with metabolic disease onset.

Methods

Study Population

The Coronary Artery Risk Development in Young Adults (CARDIA) study is a prospective cohort study that recruited Black and White young adults at baseline from 1985 to 1986. Participants (N=5115) were recruited from four urban locations (Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA) and have been followed-up for more than 30 years (years 2, 5, 7, 10, 15, 20, 25, 30 with 90%, 86%, 81%, 77%, 74%, 72%, 72%, and 71% retention, respectively). The cohort of participants was designed to be diverse in approximately equal parts by sex, race (Black and White), age (18–24 years and 25–30 years at baseline), and educational level (high school or less or higher than high school) within each center. After conducting the baseline examination, one participant requested to be excluded from all further analyses. Further details about the study design have been previously published [15]. The institutional review boards at each study site approved all study procedures. All participants provided written informed consent.

Measures

Physical Activity:

Self-reported MVPA was assessed by the interviewer-administered CARDIA Physical Activity History Questionnaire at each of the nine examinations [16,17]. Participants were asked about the frequency of participation in 13 different activity categories (8 of vigorous and 5 of moderate intensity) within the leisure time and occupational physical activity domains over the prior 12 months. Each activity's intensity was expressed as metabolic equivalents of task (METs), where one MET is defined as the energy utilized at rest (approximately an oxygen consumption of 3.5 mL/1kg of body weight/minute).Vigorous intensity activities (≥6 METs) included running, racquet sports, bicycling faster than 10 miles per hour, swimming, vigorous exercise classes, sports (e.g. basketball, football), heavy lifting, carrying or digging on the job, and home activities, such as snow shoveling and lifting heavy objects. Moderate intensity activities (3–5 METs) included non-strenuous sports (e.g. softball), walking, bowling/golf, home maintenance (e.g., gardening, raking), and calisthenics [18]. Each activity was assigned a frequency based on whether it was performed for ≥1 hour or during any 1 month in the past year, the number of months it was performed at that level, and the number of months it was performed on a frequent basis. Intensity scores (3–8 METs) and duration thresholds (2–5 hours per week) were assigned to each activity; activities above these levels of participation was considered frequent [17]. An MVPA score was computed by multiplying the frequency (number of months) of participation by the intensity (METs) of the activity with a weighting factor for the months of more frequent participation [19]. The MVPA score was the sum of all activities expressed in exercise units (EUs). For reference, an MVPA score of 300 EU estimates the HHS recommendations of approximately 150 minutes of moderate-intensity activity per week [12,20]. Given recent evidence that occupational physical activity does not improve health and may be detrimental, constituting an occupational paradox [21], we excluded the occupational physical activity question (lifting, carrying, or digging on the job) from the MVPA score. Convergent validity of the CARDIA Physical Activity History questionnaire

has been established using report-based measures, including physical activity diaries and detailed quantitative recall questionnaires [16,19,22] and accelerometers [22–24]. It has also been indirectly validated by showing expected relations with physical fitness and measures of body fat [19,25,26], and has demonstrated adequate test-retest reliability [19].

Diabetes:

Blood was drawn and processed at the central laboratory according to standard procedures at each of the nine CARDIA examinations. Glucose was assayed using the hexokinase method. Diabetes was defined as a fasting glucose ≥126 mg/DL or on diabetic medications but not pregnant for exams before May 2011 [15,17]. Diabetes was defined as fasting glucose ≥126 mg/DL, 2-hour glucose tolerance test ≥200 mg/DL, hemoglobin A1c (HbA1c) ≥6.5%, or being on diabetic medications but not pregnant for exams after May 2011.

Cholesterol:

Fasting lipid measures were measured at each of the nine examinations. Total cholesterol was measured enzymatically and defined as high if levels were ≥240 mg/DL [15]. Triglycerides were measured enzymatically and defined as high if levels were ≥200 mg/DL [15]. HDL cholesterol was determined after precipitation with dextran sulfate-magnesium chloride and defined as low if levels were <35 mg/DL for males or <45 mg/DL for females [27]. LDL cholesterol was calculated using the Friedewald equation and defined as high if levels were ≥160 mg/DL [28]. Dyslipidemia was defined as triglycerides ≥150 mg/DL or HDL <35 mg/DL for males, or triglycerides ≥150 mg/DL or HDL <45 mg/DL for females.

Covariates:

Age (years), race (Black or White), sex (male or female), smoking status (never, former, or current smoker), alcohol use (mL of alcohol consumed/day), educational attainment (highest grade of school completed), family history of diabetes or CVD (yes or no), medical history, and medications were reported through a questionnaire. The use of diabetes or dyslipidemia medications was assessed by self-report at each examination. Body mass index (BMI) was calculated based on measured height and weight at each examination.

Statistical Analysis

Summarizing physical activity.

MVPA trajectories were modeled among all CARDIA participants. We developed a linear mixed model (LMM) for repeated measures of MVPA in order to generate succinct summaries of exercise patterns over time. The MVPA slopes use all observations of the MVPA scores prior to metabolic disease onset in order to use as much of the data for each participant as possible and to stabilize the best linear unbiased predictions. The LMM included fixed effects for a four-level categorization of sex and race, with age as continuous, and their interactions, as well as random effects for participant and age, with unstructured covariance. Our inclusion of these covariates, along with observed outcomes, makes the LMM assumption of missingness at random more plausible, though this assumption is not ultimately verifiable. From the fixed and random effects estimates provided by this model, we calculated expected MVPA level at age 18 and annual change for each participant.

For ease of interpretation, we changed the sign of both summaries, so as to capture the associations of lower level and faster decline in MVPA with increased metabolic risk.

Modeling the association of lower MVPA with incident metabolic disease.

Unadjusted cumulative incidence of metabolic diseases (diabetes, high LDL-C, low HDL-C, high TG, high TC, or dyslipidemia) by sex and race/ethnicity were estimated using Kaplan-Meier methods. The data for each participant were then expanded to include a record for each age between study entry and either metabolic disease onset, which was assumed to occur at the first visit at which it was detected, or at censoring by the end of the study of loss to follow-up. Pooled logistic models were used to estimate the independent associations of the expected MVPA at age 18 and subsequent annual change with onset of metabolic disease, adjusting for potential confounders, including sex, race, family history of diabetes or CVD, years of education, smoking status, alcohol use, and BMI (smoking status, alcohol use, and BMI were time varying, with the last observation carried forward), which have been adjusted for in prior analyses of physical activity and CVD risk (directed acyclic graphs are shown in the supplemental appendix) [17,29]. We scaled estimated MVPA score at age 18 from high to low per 100 Exercise Units, corresponding to 0.45 SDs, for ease of interpretation. We kept annual reduction in total MVPA per one Exercise Unit, corresponding to 0.23 SDs. We tested if BMI category or sex and race modified the effect of MVPA (level and change) on incident metabolic disease. Pooled logistic models estimated the associations of meeting various MVPA thresholds at age 18 (<150, 150–300, 300–600, >600 EU) in combination with annual change categories (gain, loss of <2.5 EU/year, of loss >2.5 EU/year) and onset of metabolic disease, adjusting for confounders (sample sizes shown in supplemental Appendix A). We used Stata 16.0 (Statacorp, College Station, TX) for all analyses.

Results

Table 1 shows the baseline demographic and health characteristics of 5,114 participants included in the sample. The sample was 51.6% Black and 45.5% male. Demographic and health characteristics of the sample at baseline are shown in Table 1. Average MVPA declines from young adulthood in all race and sex groups, particularly in Black men (Figure 1). Incidence of diabetes and cholesterol outcomes by race and sex are presented in Supplemental Figures A–E.

Table 2 shows pooled logistic regression model estimates for the associations of the two MVPA summaries (estimated MVPA level at age 18 and subsequent declines in MVPA) with metabolic disease onset. Model 2.1 adjusted for age only, whereas Model 2.2 adjusted for age, race, sex, education, family history, smoking status, alcohol, and BMI. In the fully adjusted model (Model 2.2), lower estimated MVPA score (per 100 units) at age 18 was associated with a 12% (95% confidence interval [CI] 6%, 18%) higher odds of incident diabetes, a 4% (95% CI 1%, 7%) higher odds of incident low HDL, a 6% (95% CI 2%, 11%) higher odds of incident high triglycerides, and a 3% (95% CI 0%, 6%) higher odds of incident dyslipidemia. Each additional annual 1-unit reduction in the MVPA score was associated with a 6% (95% CI 4%, 9%) higher annual odds of diabetes incidence, a 4%

(95% CI 2%, 6%) higher annual odds of high triglyceride incidence, and a 2% (95% CI 0%, 3%) higher annual odds of dyslipidemia incidence. Pooled logistic regression model estimates stratified by BMI category (Appendix B) and race and sex (Appendix c) are shown in the online appendix.

Associations between various MVPA thresholds at age 18 combined with categories of subsequent annual change in MVPA and onset of metabolic disease are shown in Table 3. In fully-adjusted models treating MVPA as additive (Model 3.1), reductions in MVPA in midlife (compared to gains in MVPA) were associated with onset of all metabolic disease outcomes for any given MVPA threshold level at age 18. In fully-adjusted models allowing MVPA categories to interact (Model 3.2), certain MVPA combinations are notable. For instance, among participants with over twice the minimum recommended MVPA level (>600 EU) at age 18, those with steep subsequent losses (>2.5 EU/year) had 4.74 higher odds (95% CI 1.55–14.50) of low HDL incidence and 3.22 higher odds (95% CI 1.23–8.47) of high LDL than those with gains in MVPA. In addition, participants with 300–600 EU at age 18 and subsequent gains in MVPA did not have higher odds of most metabolic disease onset compared to participants with >600 EU at age 18 and subsequent gains in MVPA.

Discussion

In this prospective cohort study with 30 years of follow-up, we found that a high level of MVPA in young adulthood is a critical starting point for maintaining lifetime metabolic health. Young adult MVPA is associated with lower incidence of diabetes, low HDL-C, and high triglycerides, independent of MVPA levels across later adulthood. Maintaining high levels of MVPA in the adult life course is also important; for any given young adult MVPA set point, decline in MVPA through the adult life course is also associated with incident diabetes and high triglycerides.

These findings add to prior literature on physical activity and metabolic disease [5–8] by leveraging a large longitudinal cohort with 30 years of follow-up data to develop MVPA trajectories throughout the life course. Using these individualized trajectories, we find independent associations with the young adult level of MVPA and subsequent declines in the later adult level of MVPA with diabetes and high triglycerides. It is notable that both estimated MVPA level and slope were independently associated with diabetes and triglyceride onset, even after adjusting for a number of potential confounders.

Our findings indicate that young adult MVPA levels provide protection from subsequent metabolic disease, independent of MVPA levels up through midlife. Thus, young adulthood is an important period for intervention to ensure adequate MVPA levels. Furthermore, our findings indicate that protective levels of activity are higher than the currently recommended minimum. This is an important finding since the HHS Physical Activity Guidelines Scientific Committee Report noted there was insufficient literature on physical activity to inform guidelines in young adults [11]. Physical activity typically declines in the transition from adolescence to young adulthood due to educational, economic, and social transitions [9,10,30]. For instance, young adults may have fewer opportunities for team or organized sports when they transition to the workforce or college, compared to adolescents, who have

physical activity requirements and more opportunities for organized team sports in school [31]. The transition to parenthood may also displace leisure time for physical activity [32].

The MVPA trajectory analysis also identified notable MVPA patterns by race and sex through the life course. For instance, Black women have the lowest MVPA levels through the adult life course. Although Black men start with high average levels of MVPA in young adulthood, their levels persistently decline throughout the adult life course, similar to findings from the National Health and Nutrition Examination Surveys (NHANES) [33]. Physical activity interventions and messaging may particularly focus on Black women through adulthood and preventing declines in Black men. We also found that Black adults have higher diabetes incidence throughout the life course compared to White adults, similar to findings in NHANES [4,34].

Clinical and public health implications

We find that reductions in MVPA during midlife are associated with an increased incidence of metabolic disease across several outcomes. Public health campaigns and clinicians should focus messaging on maintaining adequate levels of MVPA and preventing declines throughout the adult life course. It is also noteworthy that young adults who were in the most active group at age 18 (over 300 min/week), but had sharp declines in MVPA in midlife, had higher odds of high LDL and low HDL incidence, compared to those in the most active group at age 18 and subsequent gains. Young adults may be more willing to take on immediate risk (e.g. not being physically active) if they perceive the outcome is too far into the future, a concept referred to as temporal discounting [35]. Young adults may respond to messaging that promotes optimizing health beyond just the need to avoid risk [36].

Limitations and strengths

Limitations and strengths of this study should be noted. While we adjusted for several potential confounders including age, race, sex, education, family history, smoking status, alcohol, and BMI (and behavioral and BMI covariates were time-varying), there is the possibility of unmeasured confounders, such as neighborhood or genetic factors [37]. In addition, mixed models can produce biased effect estimates in the presence of time-varying confounding affected by prior exposure, which would require causal methods to adjust for this potential bias, such as inverse probability weighting [38]. There may be attenuation bias due to measurement error in MVPA and residual confounding due to measurement error in some confounders such as smoking and alcohol. There was a possibility of selection bias due to censoring, including losses-to-follow-up and competing risks. MVPA was measured simultaneously with other proposed confounders in one visit, which may lead to over-adjustment bias (adjustment for mediators rather than confounders). MVPA was based on self-report and may be subject to information and prevarication bias, and it did not collect information regarding activity intensity. Nonetheless, the same questionnaire was used across the 30-year follow-up period, which is a distinct strength. Because we scaled the estimated MVPA score at age 18 per 100 Exercise Units for ease of interpretation, the odds ratios for the two MVPA estimates (level at age 18 and annual reduction) are not standardized and should be interpreted in different scales. The sampling design of CARDIA

was not representative of all races or ethnicities in the US, which may limit generalizability; however, the study specifically focused on participants identifying as Black or White race [15]. Given the larger proportion of the sample with metabolic disease by age 60, the number of eligible participants in the analysis drops with age.

Conclusion

In conclusion, MVPA level in young adulthood and declines in later adulthood are each significantly and independently associated with later life metabolic disease onset. Public health and clinical programs should emphasize, prioritize, and develop interventions to promote MVPA in young adulthood, the time when individuals establish a MVPA set point. Future research could examine the mechanisms and mediators by which MVPA may be related to metabolic disease, such as insulin sensitivity. Regardless of young adult MVPA level, interventions to sustain or increase MVPA across adulthood remain another priority for lifetime metabolic health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data Availability Statement:

Data are available upon request and data use agreement with the CARDIA Study (https://www.cardia.dopm.uab.edu/).

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Key Messages

What are the findings?

- In this prospective longitudinal study with regular 30-year follow-up, we found that low young adult moderate-to-vigorous intensity physical activity was associated with higher odds of diabetes, high triglycerides, and low HDL incidence.
- Reductions in moderate-to-vigorous intensity physical activity during midlife are associated with an increased incidence of metabolic disease.

How might it impact on clinical practice in the future?

- Given recent trends in declining moderate-to-vigorous intensity physical activity across the life course and associated metabolic disease risk, young adulthood and midlife are important time periods for interventions to increase and maintain moderate-to-vigorous intensity physical activity.

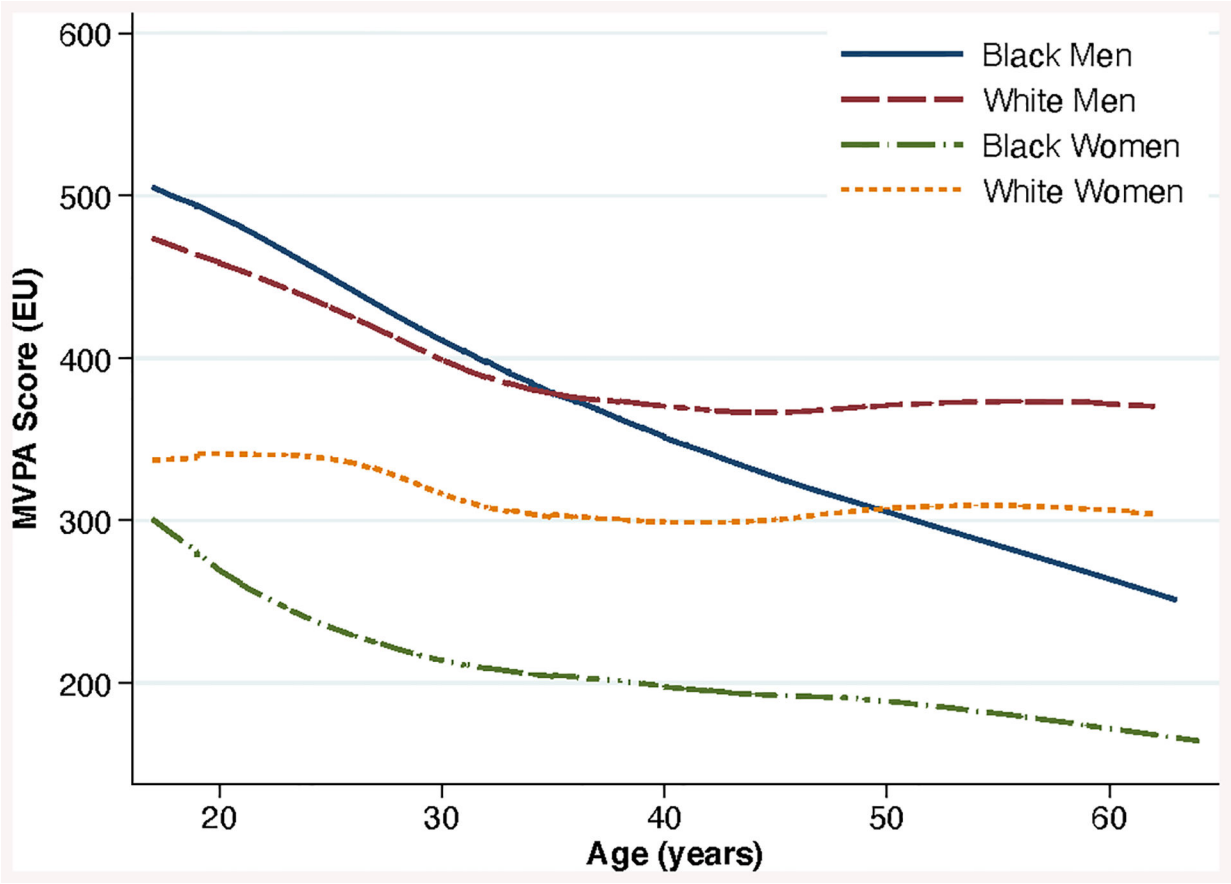

Figure 1.

Average moderate-to-vigorous intensity physical activity (MVPA) trajectories, by race and sex

Note: A total MVPA score of 300 exercise units (EU) approximates the Health and Human Services recommendations of 150 minutes of moderate-intensity activity.

Table 1.

Baseline demographic and health characteristics of participants in the Coronary Artery Risk Development in Young Adults (CARDIA) Study

	Total	White women	Black women	White men	Black men	
N	**5,114**	**1,307**	**1,480**	**1,170**	**1,157**	
Baseline demographic characteristics	**Median (IQR) / n (%)**	**Median (IQR) / n (%)**	**Median (IQR) / n (%)**	**Median (IQR) / n (%)**	**Median (IQR) / n (%)**	**p-value**
Age (years)	25.0 (22.0–28.0)	26.0 (23.0–28.0)	24.0 (21.0–28.0)	26.0 (23.0–28.0)	24.0 (21.0–28.0)	<0.001
Highest grade of school completed	13.0 (12.0–16.0)	15.0 (12.0–16.0)	13.0 (12.0–14.0)	15.0 (12.0–16.0)	12.0 (12.0–14.0)	<0.001
Family history of diabetes	800 (15.6%)	166 (12.7%)	319 (21.6%)	131 (11.2%)	184 (15.9%)	<0.001
Family history of cardiovascular disease	1,022 (20.0%)	250 (19.1%)	310 (20.9%)	227 (19.4%)	235 (20.3%)	0.62
Body mass index (BMI)	23.4 (21.2–26.4)	22.0 (20.3–24.6)	24.2 (21.2–28.9)	23.7 (21.9–26.0)	23.7 (21.7–26.4)	<0.001
<18.5 kg/m^2	237 (4.6%)	91 (7.0%)	95 (6.4%)	20 (1.7%)	31 (2.7%)	
18.5 to <25 kg/m^2	3,091 (60.6%)	921 (70.7%)	728 (49.4%)	741 (63.5%)	701 (60.8%)	
25–30 kg/m^2	1,170 (23.0%)	195 (15.0%)	337 (22.8%)	334 (28.6%)	304 (26.4%)	
>30 kg/m^2	599 (11.8%)	95 (7.3%)	315 (21.4%)	72 (6.2%)	117 (10.1%)	
Smoking status						<0.001
Never	2,856 (56.2%)	685 (52.7%)	885 (60.1%)	670 (57.8%)	616 (53.8%)	
Former	676 (13.3%)	261 (20.1%)	127 (8.6%)	182 (15.7%)	106 (9.3%)	
Current	1,546 (30.4%)	355 (27.3%)	461 (31.3%)	307 (26.5%)	423 (36.9%)	
Alcohol (mL of alcohol consumed per day)	5.4 (0.9–15.5)	4.8 (0.9–12.1)	1.8 (0.0–6.9)	11.1 (3.7–23.2)	10.2 (2.0–25.2)	<0.001
MVPA score at enrollment (EU)	312.0 (168.0–528.0)	306.0 (183.0–502.0)	207.0 (90.0–348.0)	396.0 (228.0–612.0)	408.0 (235.0–656.0)	<0.001
Estimated MVPA score at age 18 (EU)	313.4 (208.1–477.5)	297.7 (204.5–431.6)	209.9 (138.6–303.9)	395.8 (271.6–545.4)	445.2 (305.8–611.9)	<0.001
Estimated MVPA score at age 18 (EU), mean (SD)	361.8 (209.5)	330.6 (168.9)	240.8 (144.6)	428.8 (205.9)	484.2 (229.8)	<0.001
Annual reduction in MVPA score (EU)	2.3 (0.3–4.8)	1.2 (−0.7–3.1)	1.6 (0.3–3.3)	2.2 (0.1–4.5)	5.5 (3.4–8.0)	<0.001
Annual reduction in MVPA score (EU), mean (SD)	2.6 (4.0)	1.2 (3.3)	1.8 (3.2)	2.3 (4.0)	5.8 (4.1)	<0.001
Diabetes	32 (0.6%)	7 (0.5%)	14 (1.0%)	6 (0.5%)	5 (0.4%)	0.29
High LDL cholesterol	1,096 (21.7%)	260 (20.0%)	298 (20.4%)	298 (25.9%)	240 (21.0%)	0.001
LDL cholesterol	106.0 (87.0–127.0)	102.0 (85.0–123.0)	107.0 (88.0–129.0)	109.0 (89.0–129.0)	106.0 (85.0–127.0)	<0.001
Low HDL cholesterol	1,853 (36.6%)	539 (41.5%)	672 (46.1%)	403 (34.7%)	239 (20.9%)	<0.001
HDL cholesterol	52.0 (44.0–61.0)	55.0 (47.0–64.0)	54.0 (46.0–64.0)	45.0 (40.0–53.0)	52.0 (44.0–61.0)	<0.001
High triglycerides	925 (18.3%)	203 (15.6%)	130 (8.9%)	378 (32.6%)	214 (18.7%)	<0.001
Triglycerides	62.0 (45.0–84.0)	62.0 (45.0–81.5)	56.0 (42.0–75.0)	72.0 (52.0–103.0)	60.0 (45.0–82.0)	<0.001

	Total	White women	Black women	White men	Black men	
N	**5,114**	**1,307**	**1,480**	**1,170**	**1,157**	
Baseline demographic characteristics	**Median (IQR) / n (%)**	**Median (IQR) / n (%)**	**Median (IQR) / n (%)**	**Median (IQR) / n (%)**	**Median (IQR) / n (%)**	**p-value**
Dyslipidemia[a]	2,633 (52.0%)	690 (53.2%)	775 (53.1%)	689 (59.3%)	479 (41.8%)	<0.001

IQR = Interquartile range; EU = Exercise units; MVPA = Moderate-to-vigorous intensity physical activity

A total MVPA score of 300 exercise units (EU) approximates the Health and Human Services recommendations of 150 minutes of moderate-intensity activity per week.

[a]Dyslipidemia is defined as triglycerides≥150 mg/DL or HDL<35 mg/DL for males or HDL<45 mg/DL for females.

Table 2.

Associations between moderate-to-vigorous intensity physical activity (MVPA) trajectories and onset of metabolic disease in the CARDIA Study

	Model 2.1 (adjusted for age)[a]			Model 2.2 (fully adjusted)[b]		
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**
Diabetes						
Lower MVPA score (per 100 Exercise Units) at age 18	1.26	1.19, 1.33	<0.001	1.12	1.06, 1.18	<0.001
Annual reduction in MVPA score (per 1 Exercise Unit)	1.14	1.12, 1.17	<0.001	1.06	1.04, 1.09	<0.001
High LDL cholesterol						
Lower MVPA score (per 100 Exercise Units) at age 18	0.99	0.96, 1.02	0.65	0.99	0.95, 1.02	0.49
Annual reduction in MVPA score (per 1 Exercise Unit)	1.01	1.00, 1.02	0.09	1.00	0.99, 1.02	0.58
Low HDL cholesterol						
Lower MVPA score (per 100 Exercise Units) at age 18	1.16	1.13, 1.19	<0.001	1.04	1.01, 1.07	0.019
Annual reduction in MVPA score (per 1 Exercise Unit)	1.00	0.99, 1.02	0.43	1.01	1.00, 1.03	0.09
High triglycerides						
Lower MVPA score (per 100 Exercise Units) at age 18	1.02	0.98, 1.05	0.40	1.06	1.02, 1.11	0.008
Annual reduction in MVPA score (per 1 Exercise Unit)	1.05	1.03, 1.06	<0.001	1.04	1.02, 1.06	<0.001
Dyslipidemia [c]						
Lower MVPA score (per 100 Exercise Units) at age 18	1.08	1.06, 1.11	<0.001	1.03	1.00, 1.06	0.034
Annual reduction in MVPA score (per 1 Exercise Unit)	1.02	1.01, 1.03	<0.001	1.02	1.00, 1.03	0.026

Note: We scaled estimated MVPA score at age 18 from high to low per 100 Exercise Units, corresponding to 0.45 SDs, for ease of interpretation. We kept annual reduction in MVPA per one Exercise Unit, corresponding to 0.23 SDs

[a]Model 2.1 includes: estimated MVPA level at age 18, additional annual reduction in MVPA, and age. Separate models are presented for each outcome (diabetes, high LDL, low HDL, high triglycerides, dyslipidemia).

[b]Model 2.2 includes: estimated MVPA level at age 18, additional annual reduction in MVPA, age, race, sex, education, family history of diabetes or cardiovascular disease, smoking status, alcohol, and body mass index. Separate models are presented for each outcome (diabetes, high LDL, low HDL, high triglycerides, dyslipidemia).

[c]Dyslipidemia is defined as triglycerides≥150 mg/DL or HDL<35 mg/DL for males or HDL<45 mg/DL for females.

Table 3.

Associations between moderate-to-vigorous intensity physical activity (MVPA) thresholds at age 18, expected annual reduction of MVPA categories, and onset of metabolic disease in the CARDIA Study

	Diabetes			High LDL			Low HDL			High TG			Dyslipidemia		
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**
Model 3.1 treating MVPA as additive, fully adjusted[a]															
Expected MVPA at age 18[a]															
>600 EU		reference			reference			reference			reference			reference	
300–600 EU	1.12	0.86, 1.48	0.40	1.11	0.90, 1.36	0.32	1.35	1.10, 1.65	0.003	0.97	0.79, 1.21	0.81	1.23	1.06, 1.32	0.005
150–300 EU	1.24	0.93, 1.65	0.15	0.95	0.76, 1.19	0.64	1.11	0.90, 1.38	0.33	1.01	0.80, 1.28	0.93	1.06	0.90, 1.24	0.49
0–150 EU	1.50	1.03, 2.17	0.034	0.78	0.57, 1.05	0.09	0.80	0.61, 1.06	0.12	1.02	0.72, 1.44	0.90	0.83	0.65, 1.05	0.12
Expected annual reduction in MVPA score															
Gain		reference			reference			reference			reference			reference	
Reduction 0–2.5 EU/year	1.80	1.38, 2.35	<0.001	3.49	2.80, 4.35	<0.001	4.27	3.54, 5.15	<0.001	1.98	1.58, 2.47	<0.001	3.30	2.83, 3.85	<0.001
Reduction >2.5 EU/year	1.74	1.35, 2.25	<0.001	2.11	1.70, 2.62	<0.001	1.97	1.63, 2.38	<0.001	1.50	1.20, 1.87	<0.001	1.90	1.63, 2.22	<0.001
Model 3.2 allowing MVPA categories to interact, fully adjusted[a]															
>600, gain		reference			reference			reference			reference			reference	
>600, loss <2.5 EU/year	1.14	0.18, 7.08	0.89	1.59	0.49, 5.19	0.44	1.85	0.47, 7.34	0.38	3.03	0.85, 10.78	0.09	2.31	0.77, 6.94	0.13
>600, loss >2.5 EU/year	2.12	0.52, 8.71	0.30	3.22	1.23, 8.47	0.018	4.74	1.55, 14.50	0.006	3.14	0.98, 10.04	0.054	4.95	1.86, 13.18	0.001
300–600, gain	0.81	0.18, 3.56	0.78	0.78	0.28, 2.20	0.64	0.61	0.18, 2.08	0.43	1.17	0.35, 3.92	0.80	1.18	0.42, 3.26	0.76
300–600, loss <2.5 EU/year	1.83	0.44, 7.63	0.41	5.11	1.95, 13.34	<0.001	10.84	3.57, 32.87	<0.001	3.72	1.16, 11.93	0.027	8.69	3.27, 23.12	<0.001
300–600, loss >2.5 EU/year	2.53	0.63, 10.26	0.19	3.38	1.30, 8.80	0.012	6.01	1.99, 18.19	0.001	3.16	0.99, 10.04	0.051	6.16	2.33, 16.34	<0.001
150–300, gain	1.48	0.35, 6.17	0.59	1.46	0.54, 3.91	0.45	2.69	0.87, 8.28	0.09	2.26	0.70, 7.32	0.18	2.81	1.04, 7.57	0.041
150–300, loss <2.5 EU/year	3.11	0.76, 12.68	0.11	5.04	1.93, 13.15	<0.001	10.66	3.52, 32.25	<0.001	4.48	1.40, 14.35	0.011	9.6	3.62, 25.50	<0.001
150–300, loss >2.5 EU/year	2.16	0.53, 8.84	0.28	1.95	0.74, 5.17	0.18	2.35	0.76, 7.23	0.14	2.34	0.72, 7.57	0.16	2.71	1.01, 7.29	0.047
<150, gain	2.40	0.56, 10.25	0.24	2.02	0.73, 5.62	0.18	3.88	1.23, 12.21	0.02	3.48	1.03, 11.74	0.044	4.22	1.55, 11.53	0.005
<150, loss <2.5 EU/year	3.03	0.74, 12.49	0.12	3.25	1.22, 8.67	0.018	5.76	1.87, 17.71	0.002	3.34	1.01, 11.04	0.048	5.23	1.94, 14.14	0.001
<150, loss >2.5 EU/year	1.35	0.22, 8.22	0.75	0.43	0.05, 3.76	0.45	1.15	0.1, 7.20	0.88	1.21	0.19, 7.71	0.84	1.44	0.29, 7.05	0.66

A total MVPA score of 300 exercise units (EU) approximates the Health and Human Services recommendations of 150 minutes of moderate-intensity activity per week.

[a]Covariates: age, race, sex, education, family history of cardiovascular disease, smoking status, alcohol, and body mass index.