



Published in final edited form as:

J Phys Act Health. 2017 October 01; 14(10): 766–772. doi:10.1123/jpah.2016-0438.

Childhood Socioeconomic Disadvantage, Occupational, Leisure-time, and Household Physical Activity, and Diabetes in Adulthood

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Abstract

Background—Regular physical activity is a key way to prevent disease. However, we have a limited understanding of the socioeconomic precursors and glucoregulatory sequelae of engaging in physical activity in different domains.

Methods—We examined the associations among lifecourse socioeconomic disadvantage, meeting the physical activity guidelines with leisure-time physical activity (LTPA), occupational physical activity (OPA), or household physical activity (HPA), and prediabetes and diabetes in the MIDUS (Midlife in the U.S.) national study (n=986).

Results—Childhood disadvantage was associated with lower odds of meeting the guidelines with LTPA (OR=0.75; 95% CI: 0.65; 0.86). Adulthood disadvantage was associated with higher odds of meeting the guidelines with OPA (OR=1.94; 95% CI: 1.49; 2.53). Importantly, while meeting the guidelines with LTPA was associated with lower odds of prediabetes and diabetes, we found no evidence for associations among OPA, HPA, and glucoregulation.

Conclusion—Current U.S. physical activity guidelines do not differentiate between physical activity for leisure or work, assuming that physical activity in any domain confers comparable health benefits. We documented important differences in the associations among lifetime socioeconomic disadvantage, physical activity domain, and diabetes, suggesting that physical activity domain potentially belongs in the guidelines, similarly to other characteristics of activity (e.g., type, intensity).

Keywords

exercise; chronic disease; health disparities; epidemiology; physical activity assessment; public health

Diabetes is a significant problem in the U.S. and accounts for substantial morbidity and mortality. Currently, 9.3% have diabetes and 37% have milder forms of hyperglycemia such as prediabetes that typically transition to overt diabetes ¹. The economic costs of diabetes are staggering: the total cost of diagnosed diabetes in 2012 was \$245 billion and care for individuals with diabetes accounted for more than 1 in 5 healthcare dollars ². The social determinants of type 2 diabetes and its risk factors are increasingly recognized: low socioeconomic status (SES), indexed by a variety of indicators across the life course,

consistently predicts higher risk for prediabetes and diabetes³⁻⁹. Therefore, understanding the pathways to diabetes in disadvantaged groups assumes increasing importance.

Physical activity is a critical cornerstone of diabetes prevention and management. Current U.S. Physical Activity guidelines provide specific recommendations about intensity, frequency, duration, and types of physical activity that confer health benefits¹⁰. Physical activity occurs in different domains (e.g., at work, around the house, for leisure) and the role of physical activity domain is currently understudied. Differentiating among leisure-time physical activity (LTPA), occupational physical activity (OPA), and household physical activity (HPA) has offered evidence that domain matters. For example, the association between LTPA and gluoregulation is widely studied and consistently shows a lower risk for type 2 diabetes and related glycemic parameters¹¹⁻¹⁷. The association between OPA and diabetes has received significantly less attention and mixed results are documented: some have found that OPA is associated with lower diabetes risk and mortality^{18,19}, while others have found no evidence for significant associations^{16,20}. While LTPA appears to be universally beneficial for cardiometabolic outcomes, engaging in OPA is often associated with worse health and higher mortality, which has been described as a “health paradox”²¹⁻²⁴. It is unknown whether OPA is associated with prediabetes and diabetes in a U.S. sample. Answering this question has significant implications: current physical activity guidelines suggest that physical activity goals could be met with LTPA, OPA, or HPA, effectively assuming that any kind of physical activity confers equal health benefits¹⁰. Further, rates of physical activity are patterned by SES: both childhood disadvantage and contemporaneous SES predict less frequent physical activity in adulthood²⁵⁻²⁷. Importantly, opportunities to engage in physical activity for leisure or work differ as a function of SES and higher physical activity at work often comes at the expense of leisure-time exercise²⁸⁻³¹. Therefore, it important to examine both the socioeconomic precursors and health correlates of engaging in physical activity in different domains.

Our study uses the MIDUS (Midlife in the U.S.) national study to first examine whether early life socioeconomic inequality affects physical activity in adulthood using a lifecourse approach and then investigate the links among physical activity domains and gluoregulation³². Our predictions about the influence of the “long arm” of childhood disadvantage on physical activity were informed by the *critical period model* and the *pathway model*. The critical period model suggests that exposure to stressful environments during childhood, such as low SES, may have lifelong effects on physiological systems³². The *lifecourse pathway model* further suggests that early-life circumstances influence adult morbidity through health behaviors such as physical activity^{33,34}. To summarize, we had two overarching goals: 1) examine the associations among lifecourse SES and engaging in physical activity in different domains in adulthood and 2) determine whether meeting the physical activity guidelines with LTPA, OPA, or HPA was associated with similar gluoregulatory benefits, such as lower odds of prediabetes and diabetes.

Methods

Sample

The National Survey of Midlife Development in the U.S. (MIDUS 1) began in 1995–96 as a national random digit dial sample of non-institutionalized, English-speaking adults representing every state in the United States. A final sample of 7108 participants ages 25–74 completed telephone and mail surveys in MIDUS 1. Approximately 9–10 years later, 4963 (75% response rate adjusted for mortality) were successfully contacted to participate in another phone interview and self-administered questionnaire (MIDUS 2 Survey). Participants who completed both MIDUS 1 and MIDUS 2 Survey were invited to be part of the MIDUS 2 Biomarker project. Biological data were collected from a subset of respondents (N = 1054) who agreed to an overnight visit at one of three General Clinical Research Centers (GCRCs) at University of Wisconsin-Madison, Georgetown, and University of California-Los Angeles from 2004–2009. Participants in MIDUS 2 Biomarker were compensated \$200 for their participation. The response rate was 43% among those eligible (adjusted for those who could not be reached), a rate somewhat lower than other epidemiological studies involving a clinic visit (e.g., 57% in the Cardiovascular Health Study)³⁵. However, the MIDUS protocol is demanding in requiring extensive travel for many participants and two full days of assessments. The biological sample was comparable with overall MIDUS 2 sample on most sociodemographic and health characteristics, although the participants were significantly better educated and less likely to smoke than nonparticipants³⁶. The study was approved by the institutional review board at each GCRC and informed written consent was obtained from all participants.

Further details of the study design, recruitment, and retention are available at midus.wisc.edu. The current study used data from MIDUS Survey (MIDUS 1 and 2) and MIDUS Biomarker (MIDUS 2). Of the 1054 participants who participated in the MIDUS 1 Survey, MIDUS 2 Survey, and MIDUS 2 Biomarker, 68 cases were excluded from the present analyses in three occasions: (a) having diabetes at MIDUS 1 (N=23) in order to avoid confounding by the influence of long-standing diabetes on physical activity, (b) missing information on diabetes in MIDUS 1 (N=32), or (c) missing data on any variable in the analysis (N=13). Thus, our final analytic sample included 986 participants.

Measures

Prediabetes/Diabetes—Fasting glucose and glycosylated hemoglobin A1c (HbA1c) samples were obtained during the overnight stay in a GCRC during MIDUS 2 Biomarker. Criteria from the American Diabetes Association were used to define presence of prediabetes (HbA_{1c} between 5.7–6.5% or fasting glucose between 100–126 mg/dl, and NOT taking diabetes medications) and diabetes (HbA_{1c} above 6.5%, fasting glucose above 126 mg/dl, or taking medications that lower glucose levels such as Metformin)³⁷. Fasting glucose was measured via an enzymatic assay photometrically on an automated analyzer (Roche Modular Analytics P). The HbA_{1c} assay was a colorimetric total-hemoglobin determination combined with an immunoturbidometric HbA_{1c} assay, carried out using a Cobas Integra Systems instrument (Roche Diagnostics)³⁸. The dependent variable was an ordered categorical variable with three levels: no diabetes, prediabetes, and diabetes.

Socioeconomic Status—SES disadvantage scores were created for childhood and adulthood. Information on childhood SES was collected retrospectively at the MIDUS 1 exam. This study relied on retrospective recall of childhood SES, which might produce some recall bias. However, the validity of recall of childhood SES is supported in twin studies³⁹, and if retrospective reports have caused any bias, it is likely to be an underestimation⁴⁰. Childhood socioeconomic disadvantage was computed by summing values on 3 indicators: financial level growing up (2 - worse off than others, 1 - about the same as others, 0 - better off than others), highest level of parental education (2 - less than high school, 1 - high school/GED, 0 - some college or higher), and childhood welfare status (2 - ever on welfare, 0 - never on welfare). Adulthood socioeconomic disadvantage was computed by summing values on 5 indicators obtained in MIDUS 1: education level (2 - high school/GED or less, 1 - some college/associate arts degree, 0 - bachelor's degree or higher), family-size adjusted income to poverty ratio (2 - less than 300%, 1-300 -599%, 0 – 600% or more), current financial situation (2 - worst possible, 1 - average, 0 - best possible), availability of money to meet basic needs (2 - not enough, 1 - just enough, 0 - more than enough), and difficulty level of paying bills (2 - very or somewhat difficult, 1 - not very difficult, 0 - not at all difficult). Within-person mean substitution was used in cases of missing data on childhood disadvantage where data was available on 2 out of 3 variables used in calculating the score and in cases of missing data on adulthood disadvantage where data was available on 4 out of 5 variables used in calculating the score. The socioeconomic disadvantage scores have been previously linked to diabetes, allostatic load, and neck bone strength^{41–43}.

Physical Activity—Physical activity data were collected as part of medical history data collection during the MIDUS 2 Biomarker GCRC visit. Respondents were first asked if they engaged in any type of regular physical activity for 20 minutes or more at least three times a week. Those who indicated 'no' were classified as non-exercisers. If a respondent answered 'yes,' they then provided specific type(s) of physical activity, and duration, frequency, and intensity (light, moderate, or vigorous) of each type of physical activity. Uniform definitions of what constituted light, moderate, and vigorous activity were provided to respondents. As per instructions in the physical activity guidelines, only moderate and vigorous physical activity was included in calculating the physical activity levels¹⁰. Data were converted to metabolic equivalents (METs) minutes per week (MMW) following established criteria: minutes per week of activity was multiplied by an intensity factor (moderate = 3; vigorous activities = 6)⁴⁴. The domain of activity (LTPA, OPA, or HPA) was determined by referencing the major activity categories within the Compendium of Physical Activity⁴⁴. OPA was determined by cross-referencing respondents' occupation indicated earlier in the MIDUS 2 survey. Specific activities that fit in the major categories of home activities and home repair were classified as HPA. All other activities were considered LTPA. Two of the study authors (J.M.B. and V.K.T) evaluated the domain of each activity independently and any discrepancies (~4% of activities coded) were resolved via discussion. Total physical activity was computed as the sum of LTPA, OPA, and HPA. Federal guidelines recommend that adults receive at least 150 minutes of moderate or vigorous physical activity each week, which is equivalent to 500 METs MMW⁴⁵. Therefore, we created binary variables reflecting whether federal recommendations were met (≥ 500 MMW) by total physical activity and by three types of physical activity (LTPA, OPA, and HPA).

Control Variables—Demographic covariates included age (in years), sex (male or female), and race/ethnicity (White or Other). Additional covariates included body mass index (BMI), alcohol intake (ranging from 0=every day to 5=never), currently smoking (yes or no), and depressive symptoms (0–49) ⁴⁶.

Statistical Analyses

First, descriptive statistics were generated. Means, standard deviations, and ranges for all continuous variables and proportions for categorical variables were examined. Binary logistic regression models were employed to examine prospective predictors of meeting physical activity guidelines. Initial models included MIDUS 1 sociodemographic factors (childhood socioeconomic disadvantage, age, race and sex) as predictors of meeting physical activity guidelines in MIDUS 2 (500 MMW). Adulthood socioeconomic disadvantage was included as an additional predictor in the follow-up models.

Ordinal logistic regression models were used to predict glucoregulatory status in MIDUS 2. The ordered logit model estimates one equation over all levels of the outcome variable (normal glycemia/prediabetes/diabetes) and the validity of the one-equation model is established via a test of the proportional odds assumption. We ascertained that the assumption was met ($p>.05$) in all ordinal models. Models 1–4 tested the associations between physical activity (LTPA, OPA, HPA) and glucoregulation (normal glycemia/prediabetes/diabetes), adjusting for age, race, sex, childhood socioeconomic disadvantage, and adulthood socioeconomic disadvantage. Models 1a, 2a, 3a, and 4a included additional adjustments for BMI, depressive symptoms, alcohol intake, and smoking.

Results

Descriptive statistics for all measures are presented in Table 1. The majority of participants in the current study showed evidence for hyperglycemia: overt diabetes was present in 123 participants (13%) and 479 met the criteria for pre-diabetes (49%). On average, participants were 55 years old, 93% were white, and 55% were female. Among individuals without prediabetes or diabetes, 46% met the physical activity guidelines with LTPA, compared to 27% of those with diabetes.

Is childhood socioeconomic disadvantage associated with physical activity in adulthood? Do the associations differ across physical activity domains?

Table 2 displays the associations observed between socioeconomic disadvantage and meeting physical activity guidelines. We found that childhood socioeconomic disadvantage was prospectively associated with lower odds of meeting physical activity guidelines using total activity (OR=0.79; 95% CI: 0.69; 0.90). The association was slightly attenuated but remained significant after controlling for adulthood socioeconomic disadvantage (Model 1a; OR = .83; 95% CI: .72; .94).

We then tested the associations among childhood socioeconomic disadvantage and physical activity in different domains. We found that both childhood socioeconomic disadvantage (OR=0.75; 95% CI: 0.65; 0.86) and adulthood socioeconomic disadvantage (OR=0.71; 95% CI: 0.62; 0.82) were associated with lower odds of meeting physical activity guidelines with

LTPA (Model 2a). We found no evidence that childhood socioeconomic disadvantage was associated with meeting physical activity goals with OPA. However, adulthood socioeconomic disadvantage was associated with higher odds of meeting guidelines with OPA (OR=1.94; 95% CI: 1.49; 2.53). Model 4 focused on meeting physical activity guidelines using HPA. We found that childhood socioeconomic disadvantage was associated with higher odds of meeting guidelines with HPA (OR=1.23; 95% CI: 1.01; 1.52). The association remained significant even after controlling for adulthood socioeconomic disadvantage (OR=1.26; 95% CI: 1.02; 1.56). We found no evidence that the association between disadvantage (childhood or adulthood) and LTPA, OPA, or HPA depended on age or sex (interaction terms $p>.05$).

Do the associations between physical activity and glucoregulation differ by domain (LTPA, OPA, and HPA)?

Table 3 shows the associations between physical activity and glucoregulation. We found that engaging in the recommended amount of physical activity with LTPA was associated with lower odds for prediabetes and diabetes (Model 1 OR=0.64; 95% CI: 0.49; 0.83), net of the influence of age, race, sex, childhood socioeconomic disadvantage, and adulthood socioeconomic disadvantage. The association remained significant after further adjusting for BMI, depressive symptoms, alcohol intake, and smoking (OR=0.74; 95% CI: 0.56; 0.96), and after including OPA and HPA (OR=0.73; 95% CI: 0.56; 0.96). There was no evidence that engaging in OPA or HPA was associated with glucoregulation (see Models 2 and 3). Further, there was no evidence that the association between physical activity (LTPA, OPA, or HPA) and glucoregulation depended on age or sex (interaction terms $p>.05$).

Follow-up analyses limited the sample to individuals who reported being currently employed in MIDUS 2 (N=661). While the coefficients and significance levels varied slightly, all associations were consistent with what we documented in Tables 2 and 3.

Discussion

Physical activity is a modifiable health behavior whose benefits for prevention of chronic disease cannot be overstated. We found evidence that combining physical activity across domains masks important variation in the socioeconomic precursors and glucoregulatory sequelae of physical activity. Consistent with the findings of recent systematic reviews, we found that socioeconomic disadvantage predicted lower physical activity in adulthood^{25–27}. However, once we examined physical activity by domain, different patterns of associations were observed between socioeconomic adversity and LTPA, OPA, and HPA. Childhood and adulthood socioeconomic disadvantage independently predicted lower LTPA in adulthood, suggesting a pervasive, lifecourse link between disadvantage and LTPA. Further, adulthood socioeconomic disadvantage was positively associated with meeting physical activity guidelines with OPA. Of note, while we confirmed that LTPA was associated with lower odds of prediabetes and diabetes, we found no evidence for associations between OPA, HPA, and glucoregulation.

This is the first study to determine the associations among socioeconomic disadvantage over the lifecourse, physical activity domain, and diabetes. Our findings regarding LTPA are

consistent with the large literature on the health benefits of physical activity. However, our findings that OPA and HPA were not associated with glucoregulation are novel and support the emerging literature that questions the health benefits of OPA. While current physical activity guidelines suggest that OPA is an option for meeting physical activity recommendations¹⁰, others have suggested that not differentiating among physical activity domains may be “a major error in public health recommendations” (p.771)⁴⁷. Some studies have found no significant associations between OPA and cardiovascular risk factors^{17,48,49} and others have documented positive associations with obesity and insulin resistance²², blood pressure⁵⁰, and mortality^{23,24,51}. Further adding to the complexity, other studies have documented that different activities involved in OPA have contrasting associations with health outcomes^{50,51}. Physical activity such as aerobic and strength training reduces diabetes risk through improved glucose uptake into active muscles and better insulin sensitivity⁵². In contrast to these health promoting movements usually associated with LTPA, OPA typically includes lifting heavy objects, standing for extended period of time, highly repetitive work, working with the hands lifted to shoulder height or higher, and working with the back twisted or bent forward⁵³, with limited control and opportunities to rest.

The key limitation of our study is the cross-sectional assessment of physical activity domain and glucoregulation which prevents us from examining the longitudinal patterns that would best inform our understanding of the temporality and directionality of associations between SES, physical activity, and glucoregulation. While the retrospective and self-reported assessment of childhood SES is another potential limitation, others have established the validity of recall³⁹. Further, our sample was comprised primarily of white participants, and it is important for future research to look at diverse populations, as minority groups, especially blacks, may derive fewer health benefits from higher SES compared to white adults⁵⁴. Nevertheless, our study provides important initial evidence that the domain in which physical activity is performed is closely linked to SES and might not always confer the assumed health benefits. Our final set of limitations pertains to our measures of diabetes: while we excluded participants who self-reported diabetes at MIDUS 1, we do not have biological data that could help ascertain glycemic status at MIDUS 1. Further, our analyses were modeled to capture known risk influences for type 2 diabetes, but we did not have information on whether participants with diabetes had type 1 or type 2 diabetes. Given that approximately 90–95% of individuals with diabetes have type 2 diabetes³⁷, our results are not significantly affected by this imprecision. Despite these caveats, our key findings that socioeconomic disadvantage shows different associations with physical activity across domains and importantly, that only LTPA is associated with better glucoregulation, are novel and help advance understanding of the social inequalities in type 2 diabetes. Future studies will benefit from more precise measures of physical activity, both in terms of specific domain (e.g., transportation, occupation) and objective characteristics of underlying physiological sequelae of physical activity. A notable strength of our study is that glycemic status was ascertained using biomarkers and allowed for investigating not only the odds of diabetes, but also prediabetes, a clinically relevant outcome that is an important step on the progression from normoglycemia to type 2 diabetes.

Better understanding the associations between physical activity domain and diabetes risk is critical for developing successful preventive efforts. Patients and providers will benefit from

recognizing that LTPA provides health benefits that might not be achieved by engaging in OPA and HPA. Individuals who engage in high OPA might assume that their work responsibilities provide health benefits, and encouraging them to add LTPA could be an important intervention target. Further, our central finding that early-life SES disadvantage propels individuals on unhealthy trajectories such as lower LTPA in adulthood suggests that policies addressing socioeconomic inequality among children may be an important route to alleviating socioeconomic health disparities in later life. These findings have important implications. Current U.S. physical activity guidelines have specific recommendations about intensity, frequency, duration, and type of physical activity that are associated with health benefits but do not currently differentiate physical activity domains¹⁰, and our findings suggest that physical activity domain also belongs in the guidelines. Ultimately, successful prevention of type 2 diabetes will depend on better understanding its preclinical progression, both in terms of identifying pre-disease pathways to morbidity and how they are contoured by antecedent factors following from one's socioeconomic standing.

Acknowledgments

Funding Source

This work was supported by a grant from the National Institute on Aging (P01-AG020166; Carol D. Ryff, Principal Investigator) to conduct a longitudinal follow-up of the MIDUS (Midlife in the US) investigation. The original study was supported by the John D. and Catherine T. MacArthur Foundation Research Network on Successful Midlife Development. Data collection was supported by the following grants: M01-RR023942 (Georgetown), M01-RR00865 (UCLA) from the General Clinical Research Centers Program, and 1UL1RR025011 (UW) from the Clinical and Translational Science Award (CTSA) program of the National Center for Research Resources, National Institutes of Health. The first author (VKT) of this study was supported by the National Institute on Aging (K01AG041179). No conflict of interest. The second author (CL) was supported by a career development grant from by the National Institute on Aging (K99AG052458). The third author (JMB) was supported by training grants from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (T32HD049302) and National Heart, Lung, and Blood Institute (T32HL07560).

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Table 1

Descriptive Statistics

	Full Sample (N=986)		No Diabetes ^a (N=384)		Prediabetes ^b (N=479)		Diabetes ^c (N=123)		Significant Differences	
	Mean (SD)	or % (N)	Mean (SD)	or % (N)	Mean (SD)	or % (N)	Mean (SD)	or % (N)		Range
SES disadvantage										
Childhood	1.87 (1.4)		1.67 (1.4)		2 (1.4)		1.96 (1.2)		0-6	ab
Adulthood (M1)	4.56 (2.6)		4.57 (2.6)		4.55 (2.6)		4.60 (2.5)		0-10	--
Physical Activity										
500 MMW Any Domain	52% (509)		58% (221)		50% (239)		40% (49)			ab, ac, bc
500 MMW Leisure	39% (385)		46% (178)		36% (174)		27% (33)			ab, ac, bc
500 MMW Occupational	9% (85)		9% (33)		9% (45)		6% (7)			--
500 MMW Household	10% (98)		9% (34)		10% (50)		11% (14)			--
Race										
White	93% (920)		95% (366)		93% (444)		89% (110)			
Other	7% (66)		5% (18)		7% (35)		11% (13)			
Age	55.24 (11.8)		50.7 (10.7)		57.37 (11.5)		61.07 (11.5)		34-84	ab, ac, bc
Sex										
Female	55% (542)		60% (229)		54% (257)		45% (56)			
Male	45% (444)		40% (155)		46% (222)		55% (67)			
Depressive Symptoms	7.87 (7.7)		8.03 (7.8)		7.63 (7.7)		8.34 (7.3)		0-49	--
Alcohol Intake	3.44 (1.6)		3.38 (1.60)		3.42(1.6)		3.75 (1.6)		0-5	--
Body Mass Index (BMI)	29.07 (5.9)		27.79 (5.4)		29.43 (5.9)		31.63 (6.3)		15-57	ab, ac, bc
Currently Smoking										
Yes	10% (101)		11% (41)		9% (44)		13% (16)			
No	90% (885)		89% (343)		91% (435)		87% (107)			

Table 2 Childhood Socioeconomic Disadvantage and Meeting Physical Activity Guidelines (500 MMW) in Adulthood (N=986)

	Total Physical Activity		Leisure Physical Activity		Occupational Physical Activity		Household Physical Activity	
	Model 1	Model 1a	Model 2	Model 2a	Model 3	Model 3a	Model 4	Model 4a
OR (95% CI)		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Childhood SES disadvantage	.79 (.69; .90)	.83 (.72; .94)	.69 (.60; .79)	.75 (.65; .86)	1.11 (.87; 1.40)	.95 (.74; 1.22)	1.23 (1.01; 1.52)	1.26 (1.02; 1.56)
Adulthood SES disadvantage		.83 (.72; .95)		.71 (.62; .82)		1.94 (1.49; 2.53)		.92 (.73; 1.15)

Note. All models adjust for age, sex, and race. Models 1a, 2a, 3a, and 4a also include adulthood socioeconomic disadvantage. The reported associations for childhood socioeconomic disadvantage and adulthood socioeconomic disadvantage are per 1 SD increment.

Physical Activity Domains and Odds of Prediabetes/Diabetes (N=986)

Table 3

	Model 1 ¹	Model 1a ² +Health Behaviors	Model 2 ¹	Model 2a ² +Health Behaviors	Model 3 ¹	Model 3a ² +Health Behaviors	Model 4 ¹	Model 4a ² +Health Behaviors
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Leisure-time Physical Activity	.64 (.49; .83)	.74 (.56; .96)	.92 (.59; 1.44)	.98 (.62; 1.55)			.63 (.49; .82)	.73 (.56; .96)
Occupational Physical Activity							.86 (.55; 1.35)	.94 (.59; 1.48)
Household Physical Activity					1.01 (.67; 1.53)	1.03 (.68; 1.56)	1.05 (.70; 1.59)	1.06 (.70; 1.61)

Note:

¹Models include age, race, sex, childhood socioeconomic disadvantage, and adulthood socioeconomic disadvantage.

²Models include age, race, sex, childhood socioeconomic disadvantage, adulthood socioeconomic disadvantage, BMI, depressive symptoms, currently smoking, and alcohol intake.

Physical activity domains are binary variables reflecting whether federal recommendations were met (< 500 MMW) by leisure, occupational, or household physical activity.