Prospective Associations between Sedentary Lifestyle and BMI in Midlife

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Abstract

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Objective: A strong positive cross-sectional relationship between BMI and a sedentary lifestyle has been consistently observed in numerous studies. However, it has been questioned whether high BMI is a determinant or a consequence of a sedentary lifestyle.

Research Methods and Procedures: Using data from four follow-ups of the University of North Carolina Alumni Heart Study, we examined the prospective associations between BMI and sedentary lifestyle in a cohort of 4595 middle-aged men and women who had responded to questionnaires at the ages of 41 (standard deviation 2.3), 44 (2.3), 46 (2.0), and 54 (2.0).

Results: BMI was consistently related to increased risk of becoming sedentary in both men and women. The odds ratios of becoming sedentary as predicted by BMI were 1.04 (95% confidence limits, 1.00, 1.07) per 1 kg/m^2 from ages 41 to 44, 1.10 (1.07, 1.14) from ages 44 to 46, and 1.12 (1.08, 1.17) from ages 46 to 54. Controlling for concurrent changes in BMI marginally attenuated the effects. Sedentary lifestyle did not predict changes in BMI, except when concurrent changes in physical activity were taken into account ($p < 0.001$). The findings were not confounded by preceding changes in BMI or physical activity, age, smoking habits, or sex.

Discussion: Our findings suggest that a high BMI is a determinant of a sedentary lifestyle but did not provide unambiguous evidence for an effect of sedentary lifestyle on weight gain.

Key words: physical activity, cohort study, University of North Carolina Alumni Heart Study, BMI, adults

Introduction

With obesity reaching epidemic proportions, knowledge of modifiable risk factors for weight gain is pivotal for public health interventions to successfully target this problem. A candidate for one such risk factor is lack of physical activity, i.e., sedentary lifestyle. A strong inverse cross-sectional relationship between BMI and a sedentary lifestyle has been consistently observed in numerous studies. This has predominantly been attributed to the effects of physical activity on BMI (1–4). However, observational studies have yielded mixed results, which may, to some extent, be attributed to different conceptual and methodological approaches. Recently, two observational studies have suggested that a high BMI is a determinant rather than a product of a sedentary lifestyle, which could serve as an alternative explanation to the cross-sectional association between BMI and sedentary lifestyle (5,6). If a high BMI can be considered both a determinant and a product of sedentary lifestyle, then the relationship between BMI and sedentary lifestyle is an instance of bidirectional causation. That the temporal sequence is unknown implies that we cannot determine whether or not concurrent changes in one variable are possible causes of changes in the other. The implications of bidirectional causation on statistical modeling in the study of obesity and sedentary lifestyle have been discussed previously. Petersen et al. and Bak et al. (5,6) have argued that changes in physical activity between two points in time should not be included in the regression analysis because changes may have occurred after the change in the dependent variable (i.e., BMI or obesity) and

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may, in fact, even be caused by changes in the dependent variable, leading to reverse causality. For that reason, the authors argue that a valid interpretation of temporal sequence requires that only measures of physical activity assessed before the changes in weight occurs are included. However, in these studies, the time interval between baseline and follow-up were so long that the associations between physical activity and BMI changes may have been diluted by changes in both, including regression to the mean tendencies. Moreover, changes in both before the baseline may have created spurious associations due to such regression to the mean tendencies. The aim of this study was to examine the prospective associations between BMI and a sedentary lifestyle over fairly close follow-up waves in a cohort of middle-aged adults and to examine to what extent controlling for preceding and concurrent changes in physical activity and BMI influences the results.

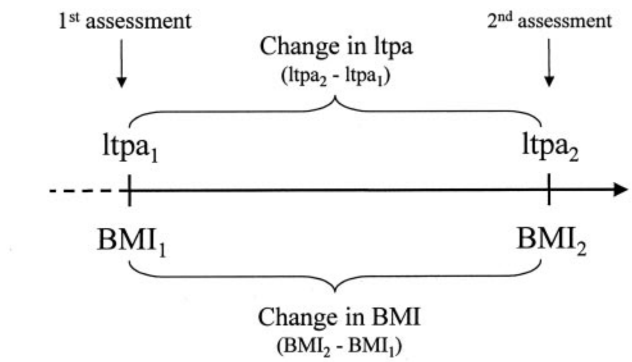
Research Methods and Procedures

The University of North Carolina Alumni Heart Study (UNCAHS)[1] is a longitudinal study of 4595 men and women who attended University of North Carolina in Chapel Hill during the period 1964 to 1966. The UNCAHS cohort was born primarily from 1940 to 1949. The cohort was followed up with regards to a variety of lifestyle and psychosocial variables in yearly and biyearly waves from 1987 onwards. This paper will use data collected from four surveys, collected in 1987, 1989, 1992, and 2001. The response rate to the 1987 questionnaire was 75.9%. The corresponding response rates for the 1989, 1992, and 2002 questionnaires were 76.3%, 71.2%, and 60.4%. Data and data collection have been described in greater detail elsewhere (7).

Measurements

Information on body mass and leisure time physical activity (ltpa) was assessed four times: at the approximate ages 41 (standard deviation: 2.3), 44 (2.3), 46 (2.0), and 54 (2.0). BMI (kilograms per meter squared) was calculated from self-reported height and weight. At age 41 (1987), information on ltpa was assessed by the question: How many hours a week, on average, do you exercise or play sports for fun or to keep in shape, not counting job or housework activities? At age 44 (1989), the question was: On average, how many hours of exercise do you get a week? Respondents were asked to report the number of hours spent weekly on sports and physical fitness activities and the weekly number of hours spent on normal activities at work and household chores. For comparability, only hours spent on sports and physical activity were included. At ages 46

[1] Nonstandard abbreviations: UNCAHS, University of North Carolina Alumni Heart Study; ltpa, leisure time physical activity.



	Dependent variable	Independent variables
"Baseline"	Change in $ltpa_{1-2}$	BMI_1 + covariates*
	Change in BMI_{1-2}	BMI_1 + $ltpa_1$ + covariates
"Concurrence"	Change in $ltpa_{1-2}$	BMI_1 **+ change in BMI_{1-2}** + covariates*
	Change in BMI_{1-2}	BMI_1 + $ltpa_1$ **+ change in $ltpa_{1-2}$** + covariates

* $ltpa_1$ was not included as a independent variable because all subjects included in this regression analysis were non-sedentary at 1st assessment

Figure 1: Schematical representation of the analytic models: baseline and concurrence.

(1991) and 54 (2000), the scale for rating physical activity for use with the Houston Non-exercise $V\text{O}_2$ Test was administered (8). The scale is measured on an eight-category ordinal scale, with zero representing no physical activity. To ensure comparability across waves, each of these variables was recoded into a binary variable, reflecting a sedentary lifestyle. At ages 41 and 44, respondents who reported 0 hours of ltpa per week were classified as sedentary. At ages 46 and 54, having a sedentary lifestyle was defined as belonging to the category: do not participate regularly in programmed recreation sport or heavy physical activity. Covariates include smoking status (current, former, never), age, and sex.

Statistical Analysis

The analytical strategy was to compare the observed effects of BMI and ltpa as assessed in two different analytical models, termed baseline and concurrence. The baseline model does not include changes in the independent variables during the time interval where changes in the outcome variable are recorded. The concurrence model adjusts for changes in the independent variables that occur concurrently with changes in the outcome variable. The models are schematically represented in Figure 1.

In analysis of the effect of sedentary lifestyle on BMI, change in BMI from one follow-up to the next was used as outcome in linear regression models; for example, change in BMI from first to second assessment was calculated as: [BMI at the second assessment] − [BMI at the first assessment] and so forth. Distributional assumptions, linearity, and model fit of linear regressions were assessed by examining the residuals.

Table 1. Characteristics at ages 41, 44, 46, and 56; the UNCAHS

Variable	Age 41 (*N* = 841, women; *N* = 3754, men)		Age 44 (*N* = 734, women; *N* = 3016, men)		Age 46 (*N* = 678, women; *N* = 2583, men)		Age 54 (*N* = 516, women; *N* = 1946, men)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Women								
Age	40.68	3.01	43.19	3.06	45.14	2.92	54.23	3.14
BMI (kg/m^2)	22.76	4.34	23.14	4.35	23.95	4.78	25.39	5.32
Change in BMI since last assessment			0.47	1.77	1.02	1.78	1.46	2.46
Obese (%)	6.54		7.22		9.10		14.66	
Becoming obese since last assessment (%)			2.32		3.05		6.85	
Sedentary lifestyle (%)	18.31		21.39		30.92		26.95	
Becoming sedentary since last assessment (%)			13.22		18.81		12.91	
Current smokers (%)	15.81		15.12		14.45		15.89	
Former smokers (%)	34.36		34.33		32.74		33.53	
Men								
Age	40.47	1.92	42.98	1.96	44.96	1.87	53.93	1.70
BMI	25.21	3.27	25.45	3.36	25.87	3.47	26.97	4.01
Change in BMI since last assessment			0.35	1.31	0.54	1.49	1.09	1.99
Obese (%)	7.33		8.06		10.85		18.15	
Becoming obese since last assessment (%)			2.39		4.46		8.93	
Sedentary lifestyle (%)	13.21		17.22		17.26		22.51	
Becoming sedentary since last assessment (%)			9.75		10.13		14.04	
Current smokers (%)	17.50		15.82		16.18		15.11	
Former smokers (%)	38.01		38.86		38.64		40.24	

UNCAHS, University of North Carolina Alumni Heart Study; SD, standard deviation.

Analyses of dichotomous outcome variables sedentary lifestyle or obesity were carried out by logistic regression models, for which we excluded respondents who were already sedentary or obese, respectively, at the beginning of the interval in which the risk (expressed as odds ratios) of becoming sedentary or obese was estimated; for example, a subject was considered to have become sedentary at the third assessment only if he had been non-sedentary at the second assessment and sedentary at the third assessment.

When several BMI assessments were used as independent variables, we entered BMI at the beginning at the interval in which the risk of change in ltpa was assessed as a continuous variable into the regression equation. Other measures of BMI were entered as change in BMI from one assessment to the next. This strategy was chosen to avoid problems of collinearity between BMI measures. For example, in the logistic regression analysis where a dichotomous variable indicating whether or not a subject became sedentary from the second to the third assessment is used as outcome variable, two continuous BMI variables were included: BMI at the second assessment and change in BMI from first to second assessment (i.e., [BMI at second assessment] − [BMI at first assessment]). Previous assessments of BMI and ltpa were included as potentially confounding or effect-modifying variables where such assessments were available; for example, change in BMI from ages 46 to 54 was adjusted for ltpa and BMI at ages 41, 44, and 46. Statistically significant refers to inference based on statistic tests or corresponding confidence intervals with a 5% type I error rate per test.

Results

Table 1 shows the sample characteristics at each of the four assessments. Table 2 shows the cross-sectional associations between sedentary lifestyle and BMI at each of the four points of assessment. As is evident from Table 2, sedentary lifestyle and BMI are strongly and significantly associated at all four assessments.

Table 2. Cross-sectional associations between sedentary lifestyle and BMI (kg/m^2), 95% confidence limits in parentheses; the UNCAHS

Variable	*N*	Mean	95% confidence limits	*p**
BMI at age 41				
Non-sedentary	3945	24.63	(24.52, 24.73)	
Sedentary	650	25.60	(25.24, 25.97)	
Difference in BMI		−0.98	(−1.28, −0.68)	<0.001
BMI at age 44				
Non-sedentary	3226	24.84	(24.72, 24.96)	
Sedentary	524	25.93	(25.52, 26.34)	
Difference in BMI		−1.09	(−1.42, −0.75)	<0.001
BMI at age 46				
Non-sedentary	2543	25.17	(25.04, 25.30)	
Sedentary	632	26.66	(26.27, 27.05)	
Difference in BMI		−1.49	(−1.82, −1.16)	<0.001
BMI at age 54				
Non-sedentary	1805	26.11	(25.94, 26.29)	
Sedentary	552	28.37	(27.90, 28.83)	
Difference in BMI		−2.25	(−2.66, −1.85)	<0.001

UNCAHS, University of North Carolina Alumni Heart Study.
* Test of the null hypothesis: difference in BMI equal to zero.

Table 3 shows the regression analysis of BMI as predicted by sedentary lifestyle. The baseline models show that there was no association of sedentary lifestyle at the beginning of the interval with subsequent gain in BMI. Point estimates range from 0.05 to 0.07 kg/m^2 and are all non-significant. However, including concurrent changes into the regression equation significantly changes the estimates. Compared with respondents who were non-sedentary throughout the interval, respondents who were sedentary throughout the interval experienced an excess mean gain of 0.43 kg/m^2 from ages 41 to 44, an excess mean gain of 0.47 kg/m^2 from ages 44 to 46, and an excess mean gain of 0.73 kg/m^2 from ages 46 to 54. This corresponds to mean yearly excess gains of 0.14, 0.23, and 0.09 kg/m^2. Respondents who became sedentary had excess mean gains in BMI of 0.18, 0.55, and 0.48 kg/m^2 (mean yearly excess gains of 0.06, 0.28, and 0.06 kg/m^2) when compared with those were non-sedentary throughout the interval. Respondents who became non-sedentary experienced a smaller gain in BMI than those who were non-sedentary throughout the interval. The excess gains were −0.36, −0.07, and −0.33 kg/m^2 in the three age intervals (mean yearly excess gains of −0.12, −0.03, and −0.04 kg/m^2). Adjustment for putative confounders and preceding changes in ltpa and BMI did not change these results. Table 4 shows the corresponding analysis using obesity as an outcome. In these analyses, sedentary lifestyle was only borderline statistically significantly associated with obesity from ages 44 to 46, where a sedentary lifestyle was associated with 1.71-fold [95% confidence limits, 1.02, 2.84] in odds. Although all other estimates were insignificant, point estimates generally suggested that a sedentary lifestyle was a risk factor for the development of obesity.

Table 5 shows the results of the logistic regression analysis of sedentary lifestyle as predicted by BMI. When using the baseline only approach, BMI was associated with increased risk of becoming sedentary in all three age intervals. An elevation of 1 kg/m^2 in BMI at age 41 conferred a statistically significant increase in odds of becoming sedentary from ages 41 to 44 of 4% (95% confidence interval, 0% to 7%). The corresponding increases in odds were 10% (6% to 14%) from ages 44 to 46 and 13% (9% to 18%) from ages 45 to 54. Including concurrent changes in BMI did not change the effect of BMI at a particular age. However, increase in BMI was independently associated with risk of becoming sedentary. An increase of 1 kg/m^2 in BMI between assessments was associated with increases in odds of becoming sedentary of 9% (1% to 18%) from ages 41 to 44, 21% (13% to 31%) from ages 44 to 46, and 12% (5% to 20%) from ages 46 to 54. Adjustment for putative confounders and preceding changes in ltpa and BMI did not change these results. The same pattern was observed when

Table 3. Linear regression of sedentary lifestyle as a predictor of excess gain in BMI (kg/m^2) from ages 41 to 44, 44 to 46, and 46 to 54 using concurrence and baseline approaches, 95% CLs in parentheses; the UNCAHS

Baseline				Concurrence				
Variable	**β (95% CL)**	**β/yr (95% CL)**	***p***	**Variable**	**β (95% CL)**	**β/yr (95% CL)**	***p***	
Ages 41 to 44† (*n* = 3740)								
Sedentary	0.05 (−0.08, 0.18)	0.02 (−0.03, 0.06)	0.47	Sedentary	0.43 (0.26, 0.60)	0.14 (0.09, 0.20)	<0.0001	<0.0001*
Non-sedentary	0 (reference)			Become non-sedentary	−0.36 (−0.55, −0.17)	−0.12 (−0.18, −0.06)	<0.001	
				Become sedentary	0.18 (0.03, 0.32)	0.06 (0.01, 0.11)	0.02	
				Non-sedentary	0 (reference)			
Ages 44 to 46‡ (*n* = 2998)								
Sedentary	0.05 (−0.10, 0.20)	0.03 (−0.05, 0.10)	0.50	Sedentary	0.47 (0.26, 0.68)	0.23 (0.13, 0.34)	<0.0001	<0.0001*
Non-sedentary	0 (reference)			Become non-sedentary	−0.07 (−0.25, 0.12)	−0.03 (−0.13, 0.06)	0.48	
				Become sedentary	0.55 (0.38, 0.72)	0.28 (0.19, 0.36)	<0.0001	
				Non-sedentary	0 (reference)			
Ages 46 to 54§ (*n* = 2070)								
Sedentary	0.07 (−0.17, 0.32)	0.01 (−0.02, 0.04)	0.55	Sedentary	0.73 (0.40, 1.07)	0.09 (0.05, 0.13)	<0.0001	<0.0001*
Non-sedentary	0 (reference)			Become non-sedentary	−0.33 (−0.65, −0.01)	−0.04 (−0.08, 0.00)	0.04	
				Become sedentary	0.48 (0.21, 0.75)	0.06 (0.03, 0.09)	<0.001	
				Non-sedentary	0 (reference)			

CL, confidence limit; UNCAHS, University of North Carolina Alumni Heart Study.
* *p* value of likelihood ratio test (3 *df*).
† Adjusted for smoking habits and sex.
‡ Adjusted for smoking habits, sex, sedentary lifestyle at age 41, and change in BMI from ages 41 to 44.
§ Adjusted for smoking habits and sex, sedentary lifestyle at ages 41 and 44, and change in BMI from ages 41 to 44 and 44 to 46.

Table 4. Logistic regression of sedentary lifestyle as a predictor of obesity (BMI > 30 kg/m^2) from ages 41 to 44, 44 to 46, and 46 to 54 using concurrence and baseline approaches, 95% CLs in parentheses; the UNCAHS

Baseline				Concurrence			
Variable	**OR (95% CL)**	**OR/yr (95% CL)**	***p***	**Variable**	**OR (95% CL)**	**OR/yr (95% CL)**	***p***
Ages 41 to 44† (*n* = 3486, events = 89)							
Sedentary	1.51 (0.80, 2.76)	1.15 (0.93, 1.41)	0.20	Sedentary	1.97 (0.83, 4.35)	1.25 (0.95, 1.65)	0.10
Non-sedentary	1 (reference)			Become non-sedentary	1.26 (0.51, 2.85)	1.08 (0.81, 1.44)	0.59
				Become sedentary	1.35 (0.59, 2.84)	1.11 (0.85, 1.43)	0.44
				Non-sedentary	1 (reference)		0.41*
Ages 44 to 46‡ (*n* = 2792, events = 125)							
Sedentary	1.71 (1.02, 2.84)	1.31 (1.01, 1.69)	0.04	Sedentary	2.17 (1.00, 4.56)	1.47 (1.01, 2.15)	0.05
Non-sedentary	1 (reference)			Become non-sedentary	1.53 (0.81, 2.81)	1.24 (0.91, 1.69)	0.18
				Become sedentary	1.12 (0.46, 2.48)	1.06 (0.70, 1.60)	0.79
				Non-sedentary	1 (reference)		0.18*
Ages 46 to 54§ (*n* = 1867, events = 172)							
Sedentary	0.8 (0.47, 1.35)	0.97 (0.91, 1.04)	0.41	Sedentary	1.42 (0.70, 2.84)	1.05 (0.96, 1.14)	0.32
Non-sedentary	1 (reference)			Become non-sedentary	0.6 (0.28, 1.20)	0.94 (0.86, 1.03)	0.16
				Become sedentary	1.58 (0.94, 2.64)	1.06 (0.99, 1.13)	0.08
				Non-sedentary	1 (reference)		0.07*

CL, confidence limit; UNCAHS, University of North Carolina Alumni Heart Study.
* *p* value of likelihood-ratio test (3 *df*).
† Adjusted for smoking habits and sex.
‡ Adjusted for smoking habits, sex, sedentary lifestyle at age 41, and change in BMI from ages 41 to 44.
§ Adjusted for smoking habits and sex, sedentary lifestyle at ages 41 and 44, and change in BMI from ages 41 to 44 and 44 to 46.

Table 5. Logistic regression of BMI (kg/m^2) as predictor of sedentary lifestyle from ages 41 to 44, 44 to 46, and 46 to 54 using concurrence and baseline approaches, 95% CLs in parentheses; the UNCAHS

Baseline				Concurrence			
Variable	**OR (95% CL)**	**OR/yr (95% CL)**	***p***	**Variable**	**OR (95% CL)**	**OR/yr (95% CL)**	***p***
Ages 41 to 44† (*n* = 3216, events = 390)							
BMI	1.04 (1.00, 1.07)	1.01 (1.00, 1.02)	0.03	BMI	1.04 (1.01, 1.07)	1.01 (1, 1.02)	0.02
				Gain in BMI	1.09 (1.01, 1.18)	1.03 (1, 1.06)	0.02
Ages 44 to 46‡ (*n* = 2452, events = 355)							
BMI	1.10 (1.06, 1.14)	1.05 (1.03, 1.07)	<0.0001	BMI	1.08 (1.04, 1.12)	1.04 (1.02, 1.06)	<0.0001
				Gain in BMI	1.21 (1.13, 1.31)	1.10 (1.06, 1.14)	<0.0001
Ages 46 to 54§ (*n* = 1679, events = 280)							
BMI	1.13 (1.09, 1.18)	1.02 (1.01, 1.02)	<0.0001	BMI	1.12 (1.07, 1.17)	1.01 (1.01, 1.02)	<0.0001
				Gain in BMI	1.12 (1.05, 1.20)	1.01 (1.01, 1.02)	<0.001

CL, confidence limit; UNCAHS, University of North Carolina Alumni Heart Study.
* *p* value of likelihood-ratio test (3 *df*).
† Adjusted for smoking habits and sex.
‡ Adjusted for smoking habits, sex, sedentary lifestyle at age 41, and change in BMI from ages 41 to 44.
§ Adjusted for smoking habits and sex, sedentary lifestyle at ages 41 and 44, and change in BMI from ages 41 to 44 and 44 to 46.

Table 6. Logistic regression of obesity (BMI > 30 kg/m^2) as predictor of sedentary lifestyle from ages 41 to 44, 44 to 46, and 46 to 54 using concurrence and baseline approaches, 95% CLs in parentheses; the UNCAHS

Baseline				Concurrence				
Variable	**OR (95% CL)**	**OR/yr (95% CL)**	***p***	**Variable**	**OR (95% CL)**	**OR/yr (95% CL)**	***p***	
Ages 41 to 44† (*n* = 3216, events = 390)								
Obese	1.51 (0.98, 2.26)	1.15 (1.00, 1.32)	0.06	Obese	1.64 (1.03, 2.52)	1.18 (1.02, 1.37)	0.03	0.21*
Not obese	1 (reference)	1 (reference)		Become not obese	1.04 (0.31, 2.68)	1.01 (0.71, 1.44)	0.93	
				Become obese	1.25 (0.60, 2.37)	1.08 (0.86, 1.35)	0.52	
				Not obese	1 (reference)	1 (reference)		
Ages 44 to 46‡ (*n* = 2452, events = 355)								
Obese	2.23 (1.46, 3.34)	1.49 (1.22, 1.83)	<0.001	Obese	2.38 (1.53, 3.64)	1.54 (1.25, 1.91)	<0.0001	<0.0001*
Not obese	1 (reference)	1 (reference)		Become not-obese	1.81 (0.40, 5.87)	1.34 (0.70, 2.54)	0.37	
				Become obese	2.29 (1.38, 3.69)	1.51 (1.18, 1.93)	<0.001	
				Not obese	1 (reference)	1 (reference)		
Ages 46 to 54§ (*n* = 1679, events = 280)								
Obese	1.83 (1.13, 2.9)	1.08 (1.02, 1.14)	0.01	Obese	2.34 (1.41, 3.81)	1.11 (1.05, 1.18)	<0.001	<0.001*
Not obese	1 (reference)	1 (reference)		Become not obese	0.73 (0.11, 2.61)	0.96 (0.80, 1.16)	0.68	
				Become obese	2.05 (1.32, 3.14)	1.09 (1.04, 1.15)	<0.01	
				Not obese	1 (reference)	1 (reference)		

CL, confidence limit; UNCAHS, University of North Carolina Alumni Heart Study.

* *p* value of likelihood-ratio test (3 *df*).

† Adjusted for smoking habits and sex.

‡ Adjusted for smoking habits, sex, sedentary lifestyle at age 41, and change in BMI from ages 41 to 44.

§ Adjusted for smoking habits and sex, sedentary lifestyle at ages 41 and 44, and change in BMI from ages 41 to 44 and 44 to 46.

obesity was considered as a determinant of becoming sedentary, although dichotomization of the BMI variable likely reduced power (see Table 6).

Discussion

In this study, we found BMI to be consistently related to increased risk of becoming sedentary regardless of whether concurrent or preceding changes in BMI were included as covariates. Sedentary lifestyle was not associated with increased gains in BMI when assessed prospectively in the baseline model but was associated when changes in sedentary lifestyle occurring between baseline and follow-up were also included in the concurrent model. With regards to the findings of this study, our analysis of the effect of a sedentary lifestyle on BMI confirms the results of the existing studies of this association. The studies conducted by Bak et al. and Petersen et al. (5,6) were carried out in Danish study populations, and this study extends the findings to another, but similar, population, i.e., middle-aged white Americans. The effect of BMI at baseline was not substantially changed by whether or not concurrent changes in BMI were taken into account. The findings of this study suggest that a high BMI is a determinant of a sedentary lifestyle but did not provide unambiguous evidence for an effect of sedentary lifestyle on weight gain.

This study was conducted using a prospective observational design with four follow-ups over a 14-year period. Compared with the previous studies, the multiple follow-ups and the short time period between follow-ups are major strengths of this study. A potentially important weakness of this study is the change in the method of assessment of physical activity across waves. These changes increase the risk of misclassification of physical activity, which may bias our findings toward inconsistency, but generally the results appeared to be almost independent of whether the measurements of physical activity were highly or less highly comparable across the waves being evaluated. On the other hand, the consistent findings despite these methodological differences may also be seen as strength of the study. The multiple follow-ups allow for testing the hypothesis at several points in time and the relatively short follow-up time is an advantage when studying effects with short latency times. This design would generally be considered highly valid for studying the effect of risk factors over time. However, in some cases of bidirectional causation, observational studies may have inherent weaknesses. Although we recognize these methodological issues, we will contend that these phenomena can be studied this way. Because either analytical model can be contested and might introduce bias, a balanced interpretation requires a presentation of the results from each of the models. As noticed earlier, the findings are only suggestive as to the size of the true effect of BMI on sedentary lifestyle and vice versa due to limitations in design. It is also important to recognize that sedentary lifestyle and BMI are not measured with the same precision and that the asymmetry in our findings may, in part, be due to this.

The apparently conflicting findings with regards to the effect of sedentary lifestyle on BMI are also in line with the existing findings of the literature. From studies using physical activity at baseline as predictor of change in BMI or weight results are mixed. Several have reported no association (5,6,9), whereas others have reported protective effects of physical activity at baseline (10,11). A study by Bild et al. (12) found reported increased weight gain in the highly physically active compared with less active study participants. In studies controlling for concurrent changes in physical activity, increases in physical activity are predominantly associated with decreases in weight (13–20), and this is in line with our findings. We suggest that part of the explanation for the positive findings when the concurrence approach is used is bias caused by reverse causation.

Because the relationship between BMI and a sedentary lifestyle is of great importance to public health, we suggest that this association be studied in further detail. Anthropometric measures other than weight and height should be included, e.g., waist circumference, waist-to-hip ratio, and fat-free body mass. These measures may be more appropriate in describing the physiological effect of a sedentary lifestyle on body composition. Unfortunately, randomized trials addressing the concerns of external validity do not seem to be feasible. Compliance to the high amount of exercise to possibly prevent weight gain over a substantial follow-up period (21) may be difficult to achieve. The size of the study populations of such trials and the necessary duration of follow-up for making inferences to weight gain would make the trials very costly. Therefore, observational epidemiological studies with even better control over putative confounders and the interplay between preceding and subsequent changes in both physical activity and body weight and composition are worthwhile.

Conclusion

Our findings suggest that a high BMI is a determinant of a sedentary lifestyle but do not unambiguously support that sedentary lifestyle has an effect on later BMI changes.

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