Active Transportation and Cardiovascular Disease Risk Factors in U.S. Adults

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Background: Evidence of associations between active transportation (walking and bicycling for transportation) and health outcomes is limited. Better understanding of this relationship would inform efforts to increase physical activity by promoting active transportation.

Purpose: This study examined associations between active transportation and cardiovascular disease risk factors in U.S. adults.

Methods: Using the 2007–2008 and 2009–2010 cycles of the National Health and Nutrition Examination Survey (NHANES), adults (N=9933) were classified by level of active transportation. Multivariable linear and logistic regression analyses controlled for sociodemographic characteristics, smoking status, and minutes/week of non-active transportation physical activity. Analyses were conducted in 2011.

Results: Overall, 76% reported no active transportation. Compared with no active transportation, mean BMI was lower among individuals with low (−0.9, 95% CI= −1.4, −0.5) and high (−1.2, 95% CI= −1.7, −0.8) levels of active transportation. Mean waist circumference was lower in the low (−2.2 cm, 95% CI= −3.2, −1.2) and high (−3.1 cm, 95% CI= −4.3, −1.9) active transportation groups. The odds of hypertension were 24% lower (AOR=0.76, 95% CI=0.61, 0.94) and 31% lower (AOR=0.69, 95% CI=0.58, 0.83) among individuals with low and high levels of active transportation, respectively, compared with no active transportation. High active transportation was associated with 31% lower odds of diabetes (AOR=0.69, 95% CI=0.54, 0.88). Active transportation was not associated with high-density lipoprotein level.

Conclusions: Active transportation was associated with more-favorable cardiovascular risk factor profiles, providing additional justification for infrastructure and policies that permit and encourage active transportation.

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Introduction

Nearly 40% of adults in the U.S. do not obtain the minimum 150 minutes/week of moderate physical activity recommended by the DHHS,[1,2] increasing their chances of acquiring cardiovascular disease risk factors such as obesity,[3,4] hypertension,[5] diabetes,[6,7] and serum lipid abnormalities.[8] Despite evidence of physical activity's health benefits, particularly for sedentary populations,[9] efforts to increase population levels of leisure-time or occupational physical activity have not achieved desired results. Active transportation (walking and bicycling for transportation) may provide an alternative opportunity for physical activity. By transforming routine daily living into an opportunity for physical activity, active transportation overcomes many of the traditional barriers to engaging in leisure-time or occupational physical activity.[10] Public policy and built environment interventions could increase levels of active transportation,[11,12] but justifying these efforts on the grounds of health promotion requires stronger evidence that active transportation, like other forms of physical activity, is associated with clinically meaningful health outcomes.

Numerous observational studies have demonstrated a protective effect of leisure-time physical activity on cardiovascular disease risk factors. However, studies[10,13] of

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active transportation have shown inconsistent effects. Further, studies conducted in Scandinavia,[14–24] Australia,[25] and Asia[26–28] may lack generalizability to U.S. adults because of different racial and ethnic composition, transportation policies and infrastructure, and cardiovascular disease risk profiles. Two U.S. studies focused only on adults aged 18–28 years[29] and aged 38–50 years.[30] Importantly, these studies[14–30] evaluated walking or bicycling to work or school and therefore fail to capture populations that are unemployed, do not attend school, or use active transportation for purposes other than commuting. Given these limitations, there is need for better understanding of the potential health benefits of active transportation in U.S. adults.

It was hypothesized that engaging in active transportation would be inversely associated with selected cardiovascular disease risk factors, independent of time spent in leisure-time and occupational physical activity. Because the greatest health benefits of physical activity accrue to sedentary individuals, it also was hypothesized that the associations would be stronger among individuals who did not meet physical activity recommendations through leisure-time and occupational physical activity.

Methods

Sample

The study employed a cross-sectional design using data from the 2007–2008 and 2009–2010 cycles of the National Health and Nutrition Examination Survey (NHANES), a stratified multistage probability sample of the non-institutionalized U.S. civilian population. Details of the complex survey design are described elsewhere.[31] Individuals aged ≥20 years who participated in both the questionnaire and Mobile Examination Center portions of the survey, were not pregnant, and did not report impaired mobility were included in the analysis. Impaired mobility was defined as using special equipment to walk or reporting much difficulty walking or being unable to walk one-quarter mile or up ten steps.

Measures

Outcomes of interest were cardiovascular disease risk factors for which physical activity has well-established protective effects, including BMI,[3,4] abdominal waist circumference,[3,4] hypertension,[5] diabetes,[6,7] and high-density lipoprotein (HDL) level.[8] BMI and abdominal waist circumference were treated as continuous variables; hypertension, diabetes, and HDL level were treated as dichotomous variables. Hypertension was defined as either self-reported use of pharmacologic therapy for high blood pressure, mean systolic blood pressure (SBP) ≥140 mmHg, or mean diastolic blood pressure (DBP) ≥90.[32,33] Diabetes was defined as either self-reported use of pharmacologic therapy for diabetes or a hemoglobin A1c (HbA1c) ≥6.5%.[34] Low HDL was defined as a serum HDL level <40 mg/dL.[35]

The primary independent variable was time spent in active transportation in a typical week. Participants were asked if they "walk or use a bicycle for at least 10 minutes continuously to get to and from places." If they responded affirmatively, they were asked on how many days in a typical week and for how many minutes on a typical day. Individuals who did not engage in active transportation were considered to have 0 minutes/week. For all others, minutes/week of active transportation were calculated by multiplying the minutes/day spent walking or bicycling for transportation by the number of days/week on which the activity was reported. Time spent in active transportation was categorized into three levels: none (0 minutes/week); low (1–149 minutes/week); or high (≥150 minutes/week). The cutoff reflects current recommendations for a minimum of 150 minutes/week of moderate physical activity and represented the approximate median of the distribution of those with nonzero values for time spent in active transportation.

Minutes per week of time spent in leisure-time physical activity and occupational physical activity were calculated using the same method. Because participants were asked independently about both moderate and vigorous leisure-time and occupational physical activity, time spent in vigorous activity was weighted by a factor of two in order to convert to moderate physical activity equivalents.[1] Time spent in leisure-time and occupational physical activity were summed to create a single variable. This variable was then categorized into five levels: 0 minutes/week; 1–149 minutes/week; 150–449 minutes/week; 450–899 minutes/week; 900–2249 minutes/week; or ≥2250 minutes/week, with cutoffs based on approximate quintiles of those with nonzero values for time spent in combined leisure-time and occupational physical activity. NHANES uses the WHO's Global Physical Activity Questionnaire, which has been evaluated for reliability and validity.[36]

Other covariates included age; gender; race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican-American, or other); education level (<high school, high school, or >high school); and smoking status (never, former, current). Ratio of family income to the federal poverty level (<1, 1–2.9, ≥3),[37] provided as a variable in the NHANES data set and used in prior studies of NHANES, was used to adjust for SES.

Data Analyses

First, descriptive statistics were used to characterize the sample by level of active transportation. Bivariate associations between sample characteristics and level of active transportation were examined using ANOVA and the χ^2 test for continuous and categoric variables, respectively. Second, unadjusted associations between level of active transportation and each of the five cardiovascular disease risk factors of interest were examined using ANOVA and the χ^2 test as appropriate.

Next, adjusted analyses of associations between level of active transportation and the cardiovascular disease risk factors were performed using linear regression for continuous outcomes (BMI and waist circumference) and logistic regression for dichotomous outcomes (hypertension, diabetes, and low HDL). All multivariable models were adjusted for sociodemographic variables, smoking status, and time spent in combined leisure-time and occupational physical activity.

Finally, in addition to analyses of the total sample, stratified analyses were conducted to assess whether associations between active transportation and cardiovascular disease risk factors differed in those who did and did not meet physical activity recommendations (at least 150 minutes/week of moderate physical activity) through combined leisure-time and occupational physical activity. Stratified analyses were performed in order to evaluate active transportation in an otherwise relatively sedentary popula-

Table 1. Description of the sample, % unless otherwise noted

Characteristic	Total sample (N=9933) No active transportation (*n*=7284; 76%)	Low active transportation (*n*=1129; 11%)	High active transportation (*n*=1520; 14%)	*p*-value[a]
Age (years; M±SE)	46±0.3	43±0.8	42±0.6	<0.001
Gender				0.001
Male	48	51	55	
Race/ethnicity				0.003
Mexican-American	12	15	19	
Non-Hispanic white	71	65	60	
Non-Hispanic black	10	13	12	
Other	6	8	8	
Education level				<0.001
<High school	16	18	28	
High school	25	22	17	
>High school	59	60	55	
Family income level, % FPL				<0.001
<100	10	15	20	
100 to <300	31	32	35	
≥300	51	45	37	
Unknown	8	9	8	
Smoking status				0.038
Never	56	55	56	
Former	24	23	21	
Current	21	22	23	
Time spent in combined leisure-time and occupational physical activity, minutes per week				<0.001
None	26	23	26	
1–149	13	14	6	
150–449	20	17	15	
500–899	14	15	15	
900–2249	16	18	20	
≥2250	12	13	19	

Note: All *n*s are unweighted and percentages are weighted; percentages may not sum to 100% because of rounding. No active transportation=0 minutes/week; low active transportation=1–149 minutes/week; high active transportation≥150 minutes/week.
[a]For ANOVA or χ^2 test
FPL, federal poverty level

tion that, based on prior research,[9] experiences the greatest benefit from participating in physical activity. All analyses were weighted to account for the complex survey design and were conducted using SAS 9.2 and SAS-Callable SUDAAN 9.0.3. Analyses were conducted in 2011. The study was exempted from review by the Yale University Human Investigation Committee.

Results

The final analytic sample included 9933 participants, 43% of whom did not meet physical activity recommendations based on combined leisure-time and occupational physical activity. Overall, 76% of individuals did not walk or bike for

Table 2. Unadjusted and adjusted[a] associations between level of active transportation and cardiovascular disease risk factors in unstratified and stratified[b] analyses

	BMI			Waist circumference, cm		
	Unadjusted			Unadjusted		
Level of active transportation	M±SE	p-value[c]	Adjusted β (95% CI)	M±SE	p-value[c]	Adjusted β (95% CI)
UNSTRATIFIED						
All included participants		<0.001			<0.001	
None	28.6±0.1		1 (ref)	97.9±0.3		1 (ref)
Low	27.6±0.2		−0.93 (−1.35, −0.51)	95.2±0.6		−2.22 (−3.25, −1.19)
High	27.3±0.3		−1.24 (−1.68, −0.79)	94.3±0.8		−3.08 (−4.28, −1.89)
STRATIFIED						
Did not meet physical activity recommendations		<0.001			<0.001	
None	29.3±0.2		1 (ref)	99.5±0.4		1 (ref)
Low	27.8±0.4		−1.48 (−2.34, −0.61)	95.3±0.9		−3.78 (−5.65, −1.90)
High	27.6±0.4		−1.73 (−2.47, −0.99)	94.4±1.0		−5.04 (−6.82, −3.26)
Met physical activity recommendations		0.011			0.007	
None	28.1±0.1		1 (ref)	96.9±0.3		1 (ref)
Low	27.5±0.3		−0.64 (−1.30, 0.02)	95.0±0.7		−1.32 (−2.71, 0.07)
High	27.2±0.3		−1.02 (−1.62, −0.42)	94.2±1.0		−2.17 (−3.74, −0.59)

Note: Active transportation: none=0 minutes/week; low=1–149 minutes/week; high=≥150 minutes/week.
[a]Adjusted for age, gender, race/ethnicity, education level, income, smoking status, and combined leisure-time and occupational physical activity
[b]Stratified by whether participants did or did not obtain ≥150 minutes/week of combined leisure-time and occupational physical activity
[c]*p*-value for ANOVA or χ^2 test
HDL, high-density lipoprotein

more than 10 minutes continuously for transportation in a typical week (i.e., no active transportation), and 19% of individuals engaged in no physical activity of any form.

Characteristics of the sample are shown in Table 1. Individuals who engaged in the highest level of active transportation, compared with those who engaged in no or low active transportation, were younger and more likely to be male, Mexican-American, lower income, and less than high-school educated. Level of active transportation was positively associated with time spent in combined leisure-time and occupational physical activity (Table 1). In unadjusted analyses, there were significant inverse associations of level of active transportation with mean BMI and mean abdominal waist circumference and with prevalence of both hypertension and diabetes (Table 2). No association was found between active transportation and prevalence of low HDL.

After adjustment for all covariates, mean BMI remained lower among individuals with low (−0.9, 95% CI= −1.4, −0.5) and high (−1.2, 95% CI= −1.7, −0.8) levels of active transportation versus no active transportation (Table 2). Similarly, mean abdominal waist circumference remained lower among those engaged in low (−2.2 cm, 95% CI= −3.2, −1.2) and high (−3.1 cm, 95% CI= −4.3, −1.9) levels of active transportation versus no active transportation (Table 2). The odds of having hypertension were 24% lower (AOR=0.76, 95% CI=0.61, 0.94) and 31% lower (AOR=0.69, 95% CI=0.58, 0.83) among individuals with low and high levels of active transportation, respectively, than individuals with no active transportation (Table 2). Compared with no active transportation, high active transportation was associated with 31% lower odds of having diabetes (AOR=0.69, 95% CI=0.54, 0.88); the odds of having diabetes among individuals with low active transportation also were reduced, but did not reach significance (Table 2).

Similar patterns were observed in stratified multivariable analyses (Table 2). Within the group that did not meet physical activity recommendations through combined leisure-time and occupational physical activity, increasing active transportation was associated with lower mean BMIs, smaller waist circumferences, and lower odds of both hypertension and diabetes. Further, even among the group that did meet physical activity recommendations through combined leisure-time and occupational physical activity, engaging in a high level of active transportation was associated with a lower mean BMI and smaller mean waist circumference. However, the magnitudes of these associations were smaller than those seen in the former group.

Table 2. *(continued)*

Hypertension			Diabetes			Low HDL		
Unadjusted			Unadjusted			Unadjusted		
%±SE	*p*-value[c]	AOR (95% CI)	%±SE	*p*-value[c]	AOR (95% CI)	%±SE	*p*-value[c]	AOR (95% CI)
	<0.001			<0.001			0.767	
30.3±0.9		1 (ref)	8.9±0.4		1 (ref)	21.3±0.7		1 (ref)
22.5±1.7		0.76 (0.61, 0.94)	6.5±0.7		0.77 (0.58, 1.02)	20.0±1.9		0.88 (0.67, 1.15)
20.2±1.5		0.69 (0.58, 0.83)	5.8±0.6		0.69 (0.54, 0.88)	21.7±1.4		0.88 (0.73, 1.06)
	<0.001			0.002			0.438	
36.3±1.1		1 (ref)	12.3±0.8		1 (ref)	21.2±1.1		1 (ref)
28.3±2.7		0.75 (0.57, 0.98)	9.7±1.1		0.83 (0.64, 1.07)	18.2±2.4		0.76 (0.53, 1.11)
23.2±1.9		0.58 (0.44, 0.76)	7.8±1.0		0.62 (0.45, 0.87)	19.9±2.2		0.77 (0.57, 1.05)
	<0.001			0.017			0.846	
26.5±1.3		1 (ref)	6.8±0.4		1 (ref)	21.3±0.8		1 (ref)
19.0±2.1		0.77 (0.58, 1.02)	4.6±1.0		0.71 (0.41, 1.24)	21.1±2.4		0.94 (0.68, 1.32)
18.7±1.9		0.77 (0.59, 1.02)	4.9±0.8		0.73 (0.52, 1.03)	22.5±2.1		0.94 (0.73, 1.20)

Discussion

Less than one quarter of U.S. adults in a nationally representative sample reported walking or bicycling for transportation in a typical week. After adjusting for potential confounders, engaging in active transportation was associated with lower BMI, smaller waist circumference, and lower odds of hypertension and diabetes. Based on the CIs, there were no differences between the associations of low and high levels of active transportation with the outcomes of interest. However, there was a trend toward higher levels of active transportation having stronger inverse associations with these four cardiovascular disease risk factors. After stratification of the sample into those who did or did not meet physical activity recommendations through a combination of leisure-time and occupational physical activity, the magnitudes of the associations were larger among the more sedentary group. However, even those who met physical activity recommendations had a significantly lower mean BMI and lower mean waist circumference when they also engaged in high levels of active transportation.

The present study's findings are interesting in light of evidence that fitness may be a more important determinant of cardiovascular risk than adiposity.[38] Although use of continuous and dichotomous dependent variables precludes direct comparison, the magnitude of associations between active transportation and BMI and waist circumference appeared small relative to its associations with hypertension and diabetes. Prior studies have demonstrated that fitness is associated with reductions in blood pressure[5,39] and improved glycemic control[40] independent of its effect on adiposity. No association was observed between active transportation and low HDL. Active transportation may not be of sufficient intensity to raise HDL levels.[41]

Active transportation is an untapped reservoir of opportunity for physical activity for many U.S. adults. A study using the National Household Transportation Survey found similar low utilization of active transportation, with only 19% of Americans aged ≥5 years reporting walking or bicycling for transportation.[42] In contrast to the U.S., many European countries experience high population levels of active transportation.[43] In Germany, the proportion of individuals reporting any walking or cycling for transportation are two and seven times greater than in the U.S., respectively.[12] These differences are in part due to policies, community planning, and infrastructure design that make active transportation appealing.[11,12,43,44] Implementing similar strategies in the U.S. could have important implications for individuals with time or financial constraints that prohibit leisure-time physical activity or with professions and work environments that are not conducive to occupational physical activity.

Although the cross-sectional study design precludes inferring a causal effect of active transportation on the outcomes of interest, the findings are consistent with prior longitudinal studies that demonstrate dose-dependent reductions in cardiovascular disease risk factors associated with physical activity.[4,5,7,45–47] The findings also are consistent with prior studies of U.S. adults that found inverse associations between active commuting and cardiovascular disease risk factors.[29,30] This suggests a potential role for active transportation in risk factor modification. Increasing levels of active transportation may have additive health benefits for individuals who are already physically active. However, the greatest impacts could accrue to the sedentary, highest-risk populations that are most sensitive to barriers to engaging in other forms of physical activity. Collectively, these findings suggest that public policy and built environment interventions to increase levels of active transportation in the U.S. may be justified on the grounds of health promotion. Additionally, these strategies could help reduce morbidity and mortality linked to motor vehicle emissions, including cardiopulmonary disease[48,49] and global climate change.[50,51]

Strengths and Limitations

The present study has several strengths, including use of a sample representative of the U.S. adult population, assessment of active transportation for any purpose rather than just for commuting, use of objective measurements of cardiovascular disease risk factors, adjustment for contributions of other forms of physical activity, and a large sample size. Nonetheless, this study does have limitations. The cross-sectional design prohibits attributing causality to the associations between active transportation and investigated cardiovascular disease risk factors. However, excluding participants with impaired mobility reduced the potential for reverse causation; individuals with disabilities related to any of the outcomes of interest might not have been able to engage in active transportation (e.g., an individual with an amputation due to diabetes who, therefore, was unable to walk or bike without difficulty).

Confounding could occur if individuals who engage in active transportation are more likely to make other healthy lifestyle choices. To address this possibility, time spent in non–active transportation physical activity and smoking status were included in multivariable models. The sample also was restricted to those who did not meet physical activity recommendations through combined leisure-time and occupational physical activity in the stratified analyses. Interestingly, there was evidence to refute a positive correlation between active transportation and other healthy behaviors.

First, smoking status did not differ substantially across levels of active transportation. Second, analysis of data from the 2007–2008 NHANES cycle, which included information on self-reported diet quality, revealed no association between active transportation and diet quality (data not shown). Third, active transportation was more common among demographic groups that tend to engage in less leisure-time physical activity,[2,52,53] which may reflect their concentration in urban areas and lower rates of car access. These groups' high levels of combined leisure-time and occupational physical activity may be due to employment in more physically demanding professions.[53–55]

The analysis did not adjust for rural, suburban, or urban location or geographic region because of restricted access to geographic variables. Systematic differences in cardiovascular disease risk factor profiles by region or degree of rurality could have caused confounding if these geographic factors also influenced levels of active transportation (e.g., due to weather, cultural norms, or inconvenience). Additionally, time spent in physical activity was based on self-report, which is known to overestimate accelerometer-based measurements of physical activity.[1] However, there is little reason to suspect systematic misreporting among certain groups that would lead to bias. It was not possible to estimate the intensity of active transportation without knowledge of the relative contribution of walking and biking to time spent in active transportation.

Conclusion

Evidence for the diverse health benefits associated with active transportation is mounting. Despite this knowledge, levels of active transportation in the U.S. remain low, largely because of policies and built environments that discourage its use. This study provides support for the value of active transportation in reducing the prevalence of important cardiovascular disease risk factors, including obesity, hypertension, and diabetes. Interventions to promote the use of active transportation in the U.S. should be pursued.

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