The Road to Obesity or the Path to Prevention: Motorized Transportation and Obesity in China

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Abstract

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Objective: Dependence on motorized forms of transportation may contribute to the worldwide obesity epidemic. Shifts in transportation patterns occurring in China provide an ideal opportunity to study the association between vehicle ownership and obesity. Our objective was to determine whether motorized forms of transportation promote obesity.

Research Methods and Procedures: A multistage random-cluster sampling process was used to select households from eight provinces in China. Data were included on household vehicle ownership and individual anthropometric and sociodemographic status. Cross-sectional data (1997) from 4741 Chinese adults aged 20 to 55 years were used to explore the association between vehicle ownership and obesity. Cohort data (1989 to 1997) from 2485 adults aged 20 to 45 years in 1989 (59% follow-up) were used to measure the impact of vehicle acquisition on the odds of becoming obese.

Results: Our main outcome measure was current obesity status and the odds of becoming obese over an 8-year period. In 1997, 84% of adults did not own motorized transportation. However, the odds of being obese were 80% higher ($p < 0.05$) for men and women in households who owned a motorized vehicle compared with those who did not own a vehicle. Fourteen percent of households acquired a motorized vehicle between 1989 and 1997. Compared with those whose vehicle ownership did not change, men who acquired a vehicle experienced a 1.8-kg greater weight gain ($p < 0.05$) and had 2 to 1 odds of becoming obese.

Discussion: Encouraging active forms of transportation may be one way to protect against obesity.

Key words: **China, motorized transportation, weight gain**

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Introduction

Inactivity is associated with a range of adverse health outcomes, not the least of which is obesity. In the United States, an increase in the prevalence of overweight in both children and adults has continued unabated over the last two or three decades (1,2), and recent data suggest over 10% of children and 50% of adults are overweight (3). The direct economic cost of illness in the U.S. due to lack of physical activity has been conservatively estimated at 24 billion dollars and the cost of obesity at 70 million dollars (4). Moreover, obesity is second only to smoking as a contributor to mortality (5).

Advances in technology and transportation are considered key explanations for greater inactivity in the population (6). Labor-saving devices have eliminated many of the back-breaking tasks of agricultural- and industrial-sector occupations and reduced the time it takes to complete them (7). These occupational sectors have also shrunk in size, with more people working in service industry occupations (8). Occupations in this sector tend to be sedentary, promoting weight gain (9). Technology has also created opportunity for increasingly sedentary leisure time. For example, television viewing has been associated with an increase in the prevalence of obesity in the U.S. and the United Kingdom (10,11). Dependence on motorized forms of transportation is also likely to have increased inactivity by reducing the need for more active forms of transportation. However, despite a growing emphasis on altering land use and transport systems to encourage physical activity (12–14), evidence implicating changes from active to passive forms of transportation as a cause of obesity is difficult to find. One reason is that in affluent countries there is virtually no variation in the type of transportation used. In the U.S., 86% of all person trips are by private motorized vehicle and ownership is well over 60% (15,16). Conversely, in China, data from 1997 indicate that only 16% of households owned motorized forms of transportation and economics, city design, and land use limit the personal choice involved in vehicle ownership. This offers an ideal opportunity to determine whether motorized forms of transportation promote obesity, and if so, to encourage continued dependence on active forms of transportation as an effective obesity prevention strategy.

Research Methods and Procedures

The China Health and Nutrition Survey (CHNS) is a longitudinal survey of health and nutrition in China, conducted jointly by the China Academy of Preventive Medicine and the University of North Carolina at Chapel Hill. The initial survey was in 1989 and included eight provinces (Shangdong, Jiangsu, Hunan, Hubei, Henan, Guizhou, Guangxi, and Liaoning). Follow-up surveys were conducted in 1991, 1993, and 1997, although the Liaoning province did not participate in the 1997 survey. The survey is not nationally representative, but the provinces vary considerably in geography, stage of economic development, and health status. This variation was achieved using a multistage, random-cluster sampling process. Four counties were selected within each of the above provinces. Within each county or urban area, neighborhoods were randomly selected from suburbs, townships, and villages. Twenty randomly selected households were targeted within each neighborhood. Health workers visited each survey household with questionnaires on sociodemographics, health, and nutrition that were directed at both the household and individual level. Further details about the CHNS have been published (17).

Cross-sectional survey respondents included 5247 of 6180 (85%) nonpregnant adults aged 20 to 55 years from the 1997 survey. Five hundred and six participants were excluded because they were missing energy-intake or work-related physical-activity data, which left a sample of 4741. The questions were asked as part of a 3-day dietary recall that was separate from the main survey questionnaire and had a higher respondent burden. We also followed a cohort of 2485 individuals from 1989 to 1997, representing 59% of 4213 nonpregnant adults aged 20 to 45 years who had weight and height data collected at baseline. Those lost to follow-up did not differ to those remaining in the study with respect to the primary outcome (weight status) or to the exposure (vehicle ownership). However, they were significantly more likely to be male, reside in an urban area, and be in the highest third of income. They were also younger.

Obesity was defined as a body mass index (BMI) $\geq$25 kg/m^2, in accordance with new weight status cut-offs for Asian populations proposed by the International Obesity Taskforce and the World Health Organization (18). This is considerably lower that the definition used for the U.S. population (BMI $\geq$ 30 kg/m^2). Height was measured without shoes to the nearest 0.2 cm, using a portable stadiometer. Weight was measured without shoes and with light clothing to the nearest 0.1 kg, using a calibrated beam scale. High waist circumference was defined at $\geq$90 cm for men and $\geq$80 cm for women (18). Waist circumference was not measured in 1989. Vehicle ownership was defined at the household level based on four categories: no vehicle, nonmotorized vehicle only (bicycles and tricycles), motorized vehicle only (motorcycles and cars), and both motorized and nonmotorized vehicles. Questions on work-related physical activity were used to create a three-level work-related activity variable: light (e.g., receptionist), moderate (e.g., electrician), and heavy (e.g., farmer). In the 1997 survey, questions on five categories of leisure-time activity (martial arts, dance, team sports, jogging/swimming, and court sports) were used to create a binary variable based on whether or not an individual participated in one of these activities at least 12 times in the previous year. Dietary-intake data were collected by nutritionists using 24-hour recalls collected over 3 consecutive days, and condiments and added oils were measured and weighed over the same days. A weekend day was not necessarily included. Daily-energy intake and fat intake were calculated using 1991 Chinese Food Composition Tables.

In the cross-sectional analysis, differences in the odds of being obese according to vehicle ownership were calculated in Stata (Version 7.0; Stata Corp., College Station, TX) using generalized estimation equations (GEE). We assumed a binomial distribution and used a logit link function and an exchangeable working correlation matrix. Clustering by household was accounted for in the model and we adjusted for age (continuous in the range 20 to 55 years), work (light, moderate, heavy), leisure activity (participation in at least one of five activities such as martial arts), energy intake (kilocalories, continuous), smoking status (smoker, ex-smoker, or nonsmoker), alcohol consumption in the past year (yes/no), per capita income (low, medium, high) with the income deflated to 1.0 for rural Liaoning province for 1988, educational attainment (primary, secondary, tertiary), household ownership of a computer (yes/no) and TV (yes/no), and urban or rural residence. In the cohort analysis, differences in the odds of becoming obese according to the acquisition of a motorized vehicle were calculated using the same method, but for this analysis we adjusted for baseline age, weight, education, urban residence, and change in work-related activity (i.e., heavy to moderate), energy intake, smoking status, alcohol consumption, income, and television ownership. Alternative models were run where energy intake was divided into fat and nonfat components to determine the specific impact of dietary fat (not shown). Dietary fat was an important contributor to weight gain and obesity, but it did not confound the association between vehicle ownership and these outcomes differently from models where energy was not partitioned.

Table 1. Individual, household, and community characteristics according to type of vehicle owned by the household in 1997

		Type of vehicle*			
Characteristics	**All participants**	**No vehicle**	**Nonmotorized**	**Motorized only**	**Motorized and nonmotorized**
Individual					
n (%)	4741 (100)	768 (16)	3197 (67)	106 (2)	670 (14)
Men (%)	48.9	49.3	48.6	50.0	50.0
Age (years)	37.7 (9.8)	37.5 (10.4)	38.0 (9.7)	33.6 (8.3)	36.8 (9.4)
Body mass index (kg/m^2)	22.3 (3.1)	21.7 (3.1)	22.3 (3.0)	22.2 (3.2)	23.1 (3.3)
Waist circumference (cm)	76.8 (9.1)	75.5 (8.6)	76.7 (8.9)	75.2 (9.9)	78.6 (9.9)
Smokers (%)	32.9	35.9	31.6	41.5	33.9
Drank alcohol in past year (%)	38.0	36.3	37.7	41.5	41.0
Daily-energy intake (kcal)	2584 (802)	2707 (673)	2579 (813)	2578 (617)	2470 (882)
Daily-fat intake (kcal)	708 (460)	696 (366)	695 (491)	739 (404)	778 (400)
Heavy work-related physical activity (%)	53.2	62.9	55.9	44.7	30.9
Active leisure (%)	3.4	3.4	2.6	2.8	7.2
Highest income tertile (%)	32.2	25.8	28.8	32.1	55.5
Technical college/university education (%)	6.4	5.3	6.3	5.7	8.4
Household					
Own computer (%)	2.0	1.3	1.6	1.9	4.8
Own TV (%)	91.4	76.2	93.4	97.2	98.8
Community					
Urban (%)	28.1	23.7	27.1	26.4	38.2

* Nonmotorized vehicles, bicycles and tricycles; motorized vehicles, motorcycles and cars.
Numbers in parentheses are SD except where specified.

Results

In 1997, only 16% of households in China had motorized transportation. Two-thirds of households had nonmotorized forms of transportation and 16% had no vehicles (Table 1). As the mode of transportation shifted from walking (no vehicle) to cycling to driving, BMI (p for trend < 0.001) and waist circumference (p for trend < 0.001) increased. Declines in daily-energy intake and heavy work-related physical activity accompanied this trend, as did increases in fat intake, income, tertiary education, leisure-time activity, computer and TV ownership, and urban residence (p for trend < 0.001 in each case). Those who exclusively owned motorized transportation were a small but unique group that we do not discuss further but include in our models.

Household ownership of a motorized vehicle was associated with greater odds of prevalent obesity in men and women and a high (≥90 cm) waist circumference in men (Figure 1). We adjusted for age, work and leisure activity, energy intake, smoking status, alcohol consumption, income, education, household ownership of a computer and TV, and urban residence and found the odds of being obese were 70% greater [odds ratio, (OR) 1.70; 95% CI, 1.08 to 2.67] in men and 85% greater in women (OR, 1.85; 95% CI, 1.21 to 2.81) compared with those who did not own a vehicle. Women from households that owned nonmotorized

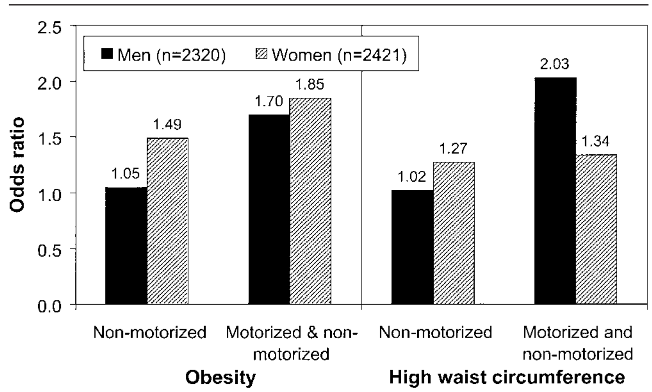

Figure 1: Odds of being obese or having a high waist circumference according to household vehicle ownership in 1997.

Table 2. Baseline characteristics of men and women according to type of vehicle acquired by the household between 1989 and 1997*

		Vehicle ownership		
Characteristics	**Overall**	**No change**	**Acquired nonmotorized vehicle†**	**Acquired motorized vehicle†**
Men				
n (%)	818 (100)	661 (81)	50 (6)	107 (13)
Age (years)	33.5 (6.7)	33.7 (6.7)	33.5 (6.2)	31.9 (7.1)
Weight (kg)	57.9 (7.3)	57.8 (7.2)	54.4 (5.6)	59.6 (7.9)
Body mass index $\geq$ 25 kg/m^2	4.8	4.8	2.0	5.6
Heavy work-related activity (%)	56.2	56.7	68.0	47.7
Daily energy intake (kcal)	2904 (758)	2928 (777)	3068 (725)	2681 (596)
Daily fat intake (kcal)	530 (354)	532 (366)	418 (239)	568 (314)
Smoker (%)‡	70.4	70.3	74.0	69.1
Drank alcohol in past year (%)‡	70.7	71.1	70.0	68.2
Highest income tertile (%)	31.2	29.5	18.1	47.7
Tertiary education (%)	5.1	5.9	2.0	1.9
Households owning at least one TV (%)	58.4	58.4	30.0	72.0
Urban (%)	28.0	27.4	20.0	35.5
Women				
n (%)	1009 (100)	816 (81)	67 (7)	126 (12)
Age (years)	33.9 (6.3)	34.1 (6.2)	34.0 (5.6)	32.1 (7.3)
Weight (kg)	52.1 (7.1)	52.2 (7.2)	50.5 (5.8)	52.4 (6.4)
Body mass index $\geq$ 25 kg/m^2	11.1 (31.4)	11.4	10.4	9.5
Heavy work-related activity (%)	53.3	53.4	70.1	43.6
Daily-energy intake (kcal)	2588 (659)	2601 (666)	2793 (747)	2397 (507)
Daily-fat intake (kcal)	461 (296)	461 (300)	401 (240)	490 (294)
Smoker (%)	1.5	1.7	0.0	1.0
Drank alcohol in past year (%)	14.0	13.8	19.4	11.9
Highest income tertile (%)	31.5	31.4	20.9	38.1
Tertiary education (%)	3.6	3.4	3.0	4.8
Households owning at least one TV (%)	60.2	59.3	38.8	77.7
Urban (%)	23.5	23.4	20.9	25.4

* Excludes those (~2%) who experienced a decline number of vehicles owned.
† Nonmotorized vehicles, bicycles and tricycles; motorized vehicles, motorbikes and cars.
‡ 1991.
Numbers in parentheses are SDs except where specified.

forms of transportation also had higher odds of prevalent obesity (OR, 1.49; 95% CI, 1.06 to 2.09), and household ownership of motorized transportation was associated with 2 to 1 odds for high waist circumference in men (OR, 2.03; 95% CI, 1.24 to 3.34).

These cross-sectional observations are suggestive of an important positive association between vehicle ownership and obesity, but they are not helpful for indicating causality. To clarify this issue, we investigated how the acquisition of a motorized vehicle influenced the odds of weight gain and becoming obese.

Thirteen percent of households acquired a motorized vehicle over the 8-year period from 1989 to 1997 (Table 2). Men from households that acquired a motorized vehicle (107 participants) experienced an 18% increase in obesity prevalence (p = 0.003 unadjusted, compared with no-change group). This compared with a 2% increase among those who acquired a nonmotorized form of transportation (50 participants) and an 8% increase among the group who had no change in vehicle ownership (661 participants). The equivalent increases in obesity for women (13%, 9%, and 13%, respectively) were not significantly different. We excluded 28 participants who lost or sold a vehicle. At baseline, those who acquired a motorized vehicle were younger ($p < 0.05$, men and women), heavier ($p < 0.05$, men), and had a lower daily-energy intake ($p < 0.01$, men and women). Fat intake was not significantly different. They were less likely to engage in heavy work-related activity ($p < 0.05$, women) but more likely to have high income ($p < 0.01$, men), have at least one TV in the household ($p < 0.01$, men and women), and to live in an urban area compared with those who had no change in vehicle ownership. These differences were more obvious for men than women.

Motorized vehicle acquisition was an important predictor of weight gain in men. Compared with those who had no change in vehicle ownership and excluding all those who were obese at baseline, men in households who acquired a motorized vehicle experienced a 1.8 kg (95% CI, 0.82 to 2.83) greater weight gain after adjustment for confounders (Figure 2). The unadjusted weight gain was 2.2 kg. Baseline secondary (1.04 kg; 95% CI, 0.30 to 1.78) and tertiary (3.62 kg; 95% CI, 1.94 to 5.31) vs. primary education, decline in work-related physical activity (1.27 kg; 95% CI, 0.41 to 2.13), energy intake (0.49 kg/1000 kcal; 95% CI, 0.16 to 0.83), and an increase in per capita income (0.24 kg/1000 yuan; 95% CI, 0.03 to 0.46) were also significant predictors of weight gain. Being older at baseline (−0.06 kg; 95% CI, −0.12 to −0.01) predicted weight loss. A separate model partitioning energy intake into fat and nonfat components did not alter the association between weight gain and vehicle acquisition but did emphasis the importance of increasing dietary fat on weight gain (1.0 kg/1000 kcal from fat; 95% CI, 0.37 to 1.67). Women from households who acquired a motorized vehicle gained 0.4 kg, a gain that remained nonsignificant after adjustment for confounders. However, higher weight at baseline predicted significant weight loss (−0.05 kg; 95% CI, −0.1 to −0.01), whereas lower intensity activity at work (0.92 kg; 95% CI, 0.15 to 1.68) and higher income (0.32 kg/1000 yuan; 95% CI, 0.14 to 0.49) predicted weight gain. Urban residence (0.70 kg; 95% CI, −0.08 to 1.48) was also an important predictor of weight gain in women.

Individuals who were underweight at baseline would benefit from gaining weight, and therefore, an increase in weight in this population does not pose a threat to public health unless it represents a shift from normal or overweight status to obesity. For this reason we investigated the odds of becoming obese according to household vehicle acquisition. Compared with no change in vehicle ownership, the acquisition of a motorized vehicle was associated with greater

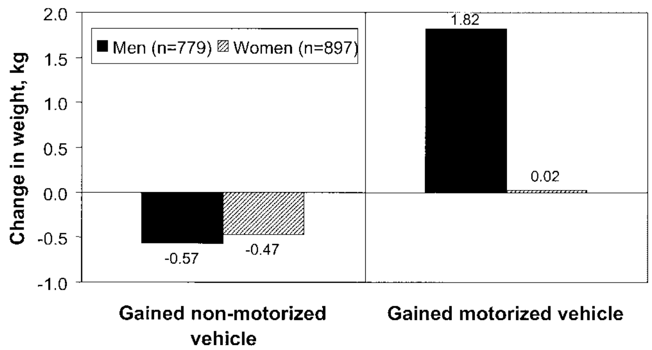

Figure 2: Change in weight with the acquisition of nonmotorized or motorized transportation: 1989 to 1997.

odds of becoming obese in men (Figure 3). An unadjusted model ($n = 988$) yielded odds of 2.35 (95% CI, 1.45 to 3.82) to 1 of becoming obese with motorized vehicle acquisition. These odds were attenuated somewhat by adjustment for confounders, but they remained significant (OR, 2.16; 95% CI, 1.09 to 4.27). Men who acquired nonmotorized transportation between 1989 and 1997 were at lower odds (OR, 0.30; 95% CI, 0.07 to 1.25 unadjusted; OR, 0.46; 95% CI, 0.06 to 3.70 adjusted) of becoming obese than those who had no change in vehicle ownership, but the difference was not significant. Interestingly, motorized vehicle acquisition did not increase the odds of becoming obese for women, regardless of adjustment.

Discussion

In this study, using both cross-sectional and cohort data, household ownership of motorized transportation was associated with obesity in men and women, and the acquisition of a motorized vehicle increased the odds of becoming obese in men. Furthermore, these associations persisted after adjustment for an array of environmental, behavioral, and biological factors known to influence weight.

To our knowledge, this is the first study to look directly at the impact of motorized transportation on weight. Transportation is most commonly mentioned in the literature as a barrier to effective nutrition-exercise intervention programs and not as an independent risk factor for obesity (19,20). Only a handful of studies relate transportation and obesity. One cross-sectional study of 290 adults in Bahrain found that ownership of a car was positively associated with obesity (21). In the U.S., long-haul truck drivers are known to be at risk for sleep apnea and other obesity-related disorders. (22,23)

Despite this lack of evidence, the relationship we observed between mode of transportation and obesity is an intuitive one, and one with an obvious etiologic pathway. The health benefits of walking and other forms of aerobic exercise for weight control have been well-established in an

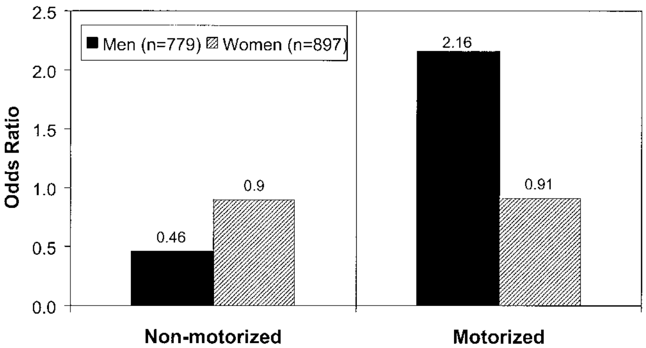

Figure 3: Odds of becoming obese according to household vehicle acquisition: 1989 to 1997.

experimental context (24,25). Walking has also been demonstrated to be beneficial to health in free-living contexts (26,27). Motorization contributes to obesity by replacing active forms of transportation, such as walking or cycling, with passive forms. Ecological data also support our observations. First, the proliferation of motorized transportation in affluent countries has coincided with the increasing prevalence of obesity (16). Second, countries that emphasize active forms of transportation, such as Holland, have lower levels of obesity than countries that don't, such as the U.S. (28).

Cities in China tend to have the high population density and mixed land uses (i.e., people work in walking or cycling distance from home) that are conducive to nonmotorized forms of transportation (16). Moreover, as we have shown, bicycling and walking remain the dominant forms of transportation. A cost of continued economic development, however, seems to be worsening conditions for cyclists and pedestrians, as cities make way for motorized forms of transportation (29). One reason could be that cars have become a symbol of economic success, and this may partly explain our observation that motorized vehicle acquisition led to weight gain in men but not women. We did not have a measure of vehicle use, but it is likely that men were the predominant users of motorized vehicles whereas women were more likely to use nonmotorized vehicles. No developing country data exist on gender differences in vehicle use. However, gender differences in the incidence of fatal automobile crashes in the U.S. can be attributed to greater exposure among men (30). With evidence that declines in work-related physical activity are related to weight gain in China, coupled with increases in dietary-fat intake (9,31), people will need to adopt more active leisure-time activities and maximize their opportunities for incidental physical activity (e.g., walking to work or shops). Increased automobile dependence does not need to be an inevitable consequence of economic development. China has the opportunity to develop their traditional dependence on nonmotorized vehicles into an obesity prevention strategy. This will require preserving existing policies and infrastructure that support nonmotorized transportation and avoiding changes in urban form and transportation systems that encourage motorized transportation. Ironically, the U.S. and other countries are now putting considerable effort into recreating the type of active transportation environment that China currently has (32,33).

Our study has some limitations. The data are not nationally representative. We did not have data on waist circumference at the onset of study, and future analyses need to test the impact of vehicle acquisition on the distribution of body fat. It is likely that there is a lag time between acquisition of a motorized vehicle and the onset of obesity. However, so few people acquired a motorized vehicle between 1989 and 1993 that we were unable to demonstrate this. Also, we did not adequately address the issue of endogeneity (34). People may choose their mode of transportation based on reasons related to their weight. We think this is unlikely in China, especially compared with the U.S., but to truly address this issue, a prospective, randomized control trial is needed where weight change is monitored in people randomly assigned to receive a motor vehicle or to maintain their no-vehicle status.

Encouraging active forms of transportation may be one way to protect against the obesity epidemic. There are numerous economical and environmental advantages to limiting automobile dependence. These data suggest there may also be advantages in terms of public health.

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