Causal Structure Related to Reduced Car Use Considering Attitudes for Healthy Lifestyles in a Provincial City without Sufficient Public Transport

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Abstract: The present study aimed to identify the causal structure among the factors related to reduced use of automobiles in Tokushima, a provincial city in Japan with insufficient service of public transport. Particularly, we focused on the factors that promote cycling or walking for health rather than driving a car. We examined the individual relationships among the factors with generalized linear regression models based on the results of a questionnaire survey for drivers. we also identified the causal structure among those factors by means of structural equation modeling. The results of our analysis indicated the information about health and the global environment as important factors in reducing automobile use. However, interest in the information is affected by the intention to improve personal lifestyle. With respect to the factors behind these findings, we confirmed that dissatisfaction with sleeping hours or working hours leads to stress in daily life.

Keywords: Concern for health, Physical activity, Time of daily activities, Healthy mobility, Structural equation modeling

1. INTRODUCTION

In provincial cities of Japan, the amount of physical activity attained through walking and cycling is low owing to the great dependence on automobiles. The growth of motorization may be considered as one cause of an increase in lifestyle-related diseases. Thus, daily physical activities can be improved by walking or cycling instead of traveling by car.

However, it has been reported that many residents of some provincial cities in Japan travel by car even over easily walkable distances (Kong et al., 2011). The urban structure of Japanese provincial cites is not as compact as that of developed countries in Europe (Matsunaka et al., 2013). The railway and the tramway stations in some provincial cities in Japan are not closer to the pedestrian space than in developed countries of Europe. Furthermore, automobiles are comfortable and convenient for travel in such cities in Japan. Accordingly, residents become dependent on cars: they find that it is not easy to lead their daily lives without automobiles. In terms of transport policies to reduce private car usage, public acceptance of the importance of environmental considerations has been emphasized (Nilsson and Kuller, 2000).

Conversely, it has been found that health-related motivation affects decision making with regard to changing transport modes (Grant-Muller et al., 2001). Since the beginning of this century in Europe, transport policies for walking and cycling have been proposed from the viewpoint of promoting health (WHO Regional Office for Europe, 2005). For example, with daily commuting in Copenhagen, cyclists have been found to be the victims in 72% of cases of all-cause mortality (Andersen et al., 2000). In three Norwegian cities, a cost-benefit analysis of developing bicycle paths and sidewalks has been conducted by taking into consideration the external cost of car use, health effects, and traffic safety (Saelensminde, 2004). Based on a review of those studies, one proposed approach to transport plans considers health aspects (Cavill et al., 2008). The health effects of walking and cycling have been determined under proposed methodological guidance (Kahlmeier et al., 2010). Measures to promote cycling should be adequately promoted (Broach et al., 2012). In a review of the literature, Cohen et al. (2014) examined both the impact of transport decisions and benefit of sustainable transport on health. The review recommended that such evidence be used to shape and support healthy transport development.

In terms of attitudes about cycling, such factors as convenience, “pro-bike” policies, physical determinants, and exogenous restrictions have been identified as significant factors in a covariance structure analysis (Fernandez-Heredia et al., 2014). Exogenous restrictions consist of danger, vandalism, and auxiliary facilities; they are perceived to interfere with cycling. Conversely, convenience in terms of flexibility and efficiency is regarded as the most important promoting factor. In terms of walking behavior, it has been reported that walkability within an individual’s activity space, rather than in the local neighborhood, is more strongly associated with overall physical activity and use of transport (Howell et al., 2017).

In the field of behavioral science, one study using a conceptual model called the trans theoretical model has integrally examined the attendant behavioral changes (Prochaska and Velicer, 1997). The model features support procedures that correspond to the exercise readiness of human subjects. The model may also be applied to encourage exercise toward maintaining health. With such an approach to promoting healthy activities, appropriate support should be given according to an individual’s lifestyle and health awareness.

Toward reducing the use of cars in Tokushima, a provincial city with insufficient service of public transport, the present study aimed to identify the factors that promote cycling or walking for health rather than going by car. It also attempted to determine the causal structure among the various factors, taking into consideration aspects of daily life in such a city. For that purpose, we conducted a questionnaire survey for health activities among drivers in that city to determine details related to lifestyle, timing of living activities, current degree of stress, and intention to reduce automobile use. Based on the results of that survey, we applied generalized linear regression models to specify the individual relationships among such factors as reducing car use, concern about health information and global warming, healthy daily activities, and dissatisfaction with daily life. We developed a hypothesis about the causal structure based on the identified relations among the factors. We applied structural equation modeling to verify the causal structure among those factors.

2. QUESTIONNAIRE SURVEY ABOUT HEALTHY ACTIVITY IN DAILY LIFE

We conducted a questionnaire survey about healthy activity in daily life. We created a database based on the responses to that survey about health concerns, dissatisfaction with daily life, and reducing car use.

2.1 Design of survey components

We carried out the survey among drivers in Tokushima, a provincial city in Japan, using the Internet. The questionnaire survey consisted of a preliminary survey, automobile user survey, and follow-up survey. The purpose of the preliminary survey was to select target samples for the automobile user survey. The items in the preliminary survey are summarized in Table 1.

The questions addressed daily driving area, health concerns, and number of hours exercise a week. We conducted the preliminary survey in November 2015 and obtained 500 samples.

Table 1. Preliminary survey items

No.	Survey item	Alternatives	Percentage
P1	Daily driving	None	16
		Driving only within urban area	67
		Driving outside urban area	17
P2	Health concerns	None	1
		Few	4
		Neutral	14
		Yes	48
		Very much	33
P3	Weekly exercise	None	43
		Up to 5 hours	51
		More than 5 hours	6

Public transport services are insufficient in Tokushima; thus, it is impractical for residents facing long driving distances to make a modal shift to healthier mobility, such as walking and cycling. Long-distance drivers are unsuitable as targets for reducing car usage for health reasons. Thus, for the automobile user survey, we excluded subjects who drove outside urban area more than 25km away from the city center of Tokushima as well as individuals who did not drive automobiles.

Drivers with little interest in health would be unlikely to refrain from using their cars following advice about health matters. Therefore, we excluded from the automobile user survey subjects who answered “None” or “Few” to the question about having health concerns.

Residents who exercise on a daily basis do not need to refrain from using their cars for health reasons. If subjects exercise 5 or more hours a week, they are getting sufficient physical activity. We therefore excluded from the automobile user survey participants who exercised 5 or more hours a week.

As a result, the sample in the automobile user survey comprised car drivers who had insufficient daily exercise. Therefore, it should be noted that the sample is extracted from a target limited to 50% of the total population. We conducted the automobile user survey in December 2015. The items in that survey appear in Table 2.

The questionnaire survey consisted of 19 items. We classified the survey items into eight groups: individual attributes; attitude to health; attitude to global environment; daily life behavior; daily outdoor behavior; daily exercise; concern about merit of walking or cycling; and intention to reduce car use.

Responses about health attitudes are shown in Fig. 1; responses about attitude to global environment appear in Fig. A1. In terms of daily life behavior, the following are presented: eating habits in Fig. A2; daily sleeping hours in Fig. A3; daily working hours in Fig. A4; and dissatisfaction with daily life in Fig. 2. Similarly, with respect to daily outdoor behavior, the following are shown: number of days going out walking a week in Fig. A5; number of walking hours a day in Fig. A6; number of cycling days a week in Fig. A7; and number of cycling hours a day in Fig. A8. With regard to daily exercise, the number of days exercise a week appears in Fig. A9 and number of exercise hours a week in Fig. A10.

For the item concern about merit of walking or cycling, we designed the information to suit car users. we provided information about health or the problem of global warming to promote cycling or walking instead of driving a car. The information about the merit of walking or cycling used for question 18 appears in Table 3. we offered five kinds of information: [1] risk of lifestyle-related disease; [2] local rate of active transport modes; [3] reduction in CO_2 emissions; [4] walking; and [5] cycling.

Table 2. Questionnaire items in the automobile user survey

Item groups	No.	Survey item	Alternatives	Percentage
Individual attributes	1	Sex	male	61
	2	Age	20s	4
			30s	20
			40s	30
			50s	24
			60s	19
			70s	3
	3	Employment	Employed	70
	4	Main commuting mode	Car	59
			Other transport modes	15
			Do not commute	26
Attitude to health	5[1]	Concern for health	See Fig. 1	
	5[2]	Anxiety over health		
	5[3]	Intention to improve lifestyle		
	5[4]	Active intention to exercise		
Attitude to global environment	6[1]	Concern about global warming	See, Fig. A1	
	6[2]	Realize necessity to reduce CO_2 emissions		
Daily life behavior	7[1]	Breakfast every morning	See , Fig. A2	
	7[2]	Balanced diet		
	7[3]	Refrain from excessive drinking		
	8[1]	Number of sleeping hours	See , Fig. A3	
	8[2]	Number of working hours	See , Fig. A4	
	9[1]	Dissatisfaction with sleeping hours	See Fig. 2	
	9[2]	Dissatisfaction with working hours		
	10	Stress in daily life		
Daily outdoor behavior	11	Number of days going out walking	See, Fig. A5	
	12	Number of walking hours a day	See, Fig. A6	
	13	Number of days going out cycling	See, Fig. A7	
	14	Cycling hours a day	See, Fig. A8	
Daily exercise	15	Number of exercise days a week	See, Fig. A9	
	16	Number of exercise hours a week	See , Fig. A10	
	17	Type of activity, multiple choices allowed	Walking	37
			Jogging	10
			Cycling	7
			Ball game	14
			Other	14
Concern about merit of walking or cycling	18[1]	Concern about risk of lifestyle-related disease	Yes	32
	18[2]	Concern about local rate of active transport modes	Yes	16
	18[3]	Concern about reducing CO_2 emissions	Yes	14
	18[4]	Concern about walking	Yes	32
	18[5]	Concern about cycling	Yes	20
Intention to reduce car use	19	Do you intend to reduce your use of the car in your daily life?	Very much so	8
			Yes	35
			Neutral	22
			No	24
			Definitely not	11

All five types of information about the merits of walking and cycling are taken based on existing facts. We prepared the first information about the risk of lifestyle-related disease with reference to the results of two cohort studies: one on developing hypertension (Hayashi et al., 1999) and one on the risk of developing type 2 diabetes (Laaksonen et al., 2005). We provided the second item to draw attention to the fact if many other locals commute by bicycle or on foot, it is possible for the subjects to do likewise. This may be regarded as the psychological effect of others' actions. We presented information about the local rate of using active transport modes with reference to the results of a person-trip survey in Tokushima by Ministry of Land, Infrastructure, Transport and Tourism of Japan. In Tokushima, 16% of commuters do so on bicycle and 10% on foot, totaling 26%. However, it has been reported that the proportion of CO_2 emissions by car usage among all activities in Tokushima is 17%; thus, we presented information about reducing CO_2 emissions as the third item. We set the discharge rate of CO_2 from vehicles as 2.3 kg CO_2 per liter and average efficiency of fuel consumption as 15 km per liter. Further, we wished to promote the health merits of cycling and walking, and so we provided information about those physical activities.

Table 3. Information about the merits of walking and cycling

[1] Risk of lifestyle-related disease Risk of lifestyle-related disease increases unless commuting is done using active transport modes, such as cycling and walking.
[2] Local rate of active transport modes In Tokushima, one in four residents commute by bicycle or on foot.
[3] Reduction in CO_2 emissions If you commute to work once a week by cycling or walking, there will be on average a 3.5% reduction in CO_2 emissions from all activities.
[4] Walking If you make a 2-km round-trip on foot once a week, you can consume 16% of the required physical activity amount.
[5] Cycling If you make a 5-km round-trip once a week by bike, you can consume 14% of the required physical activity amount.

After the questions about the subjects' interest in the above types of information, we asked about the intention to reduce automobile use. we asked the participants, "It is healthier to use a bicycle or walk instead of going by automobile. Do you intend to reduce your use of the car in your daily life?"

In January 2016, we conducted the follow-up survey, using the same participants as in the automobile user survey. After providing information about the merits of walking or cycling in the automobile user survey, we queried about changes in travel behavior and exercise in the follow-up survey. The items in the follow-up survey consisted of three kinds of travel behavior change a week with respect to driving a car, walking, and cycling. Examples included making a change when commuting, change when shopping, change with trips for other purposes, increased travel time when walking or cycling, and increased exercise time.

2.2 Implementation of questionnaire survey

For the automobile user survey, we selected 249 individuals from participants in the preliminary survey. Our focus was on automobile users; accordingly, 61% of the subjects were male. With respect to age-group, participants in their 40s were the most frequent, accounting for 30%.

Health consciousness among drivers is considered an important factor toward reducing automobile usage. The responses we obtained for intentions regarding health (i.e., concerns and anxiety with respect to health, intention to improve lifestyle, and active exercise intentions) are presented in Fig. 1.

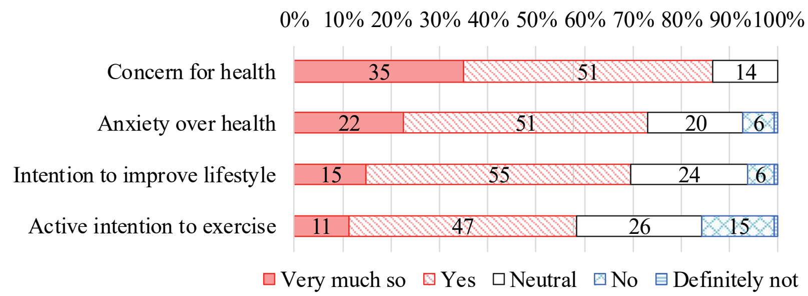

Figure 1. Responses about health attitudes

Regarding concern for health, we found the proportion of positive responses to be over 80%. The proportion of positive responses decreased in the following order: anxiety about health; improved intention with respect to lifestyle; and active intention to undertake exercise.

The response rates for dissatisfaction with daily life (such as dissatisfaction with sleeping hours, dissatisfaction with working hours, and stress in daily life) appear in Fig. 2. We found that the rate of dissatisfaction with working hours was lower than that with sleeping hours. Over 25% of the subjects in this study experienced stress in their daily lives; that was a higher rate than those for dissatisfaction with sleeping (21%) and working hours (13%).

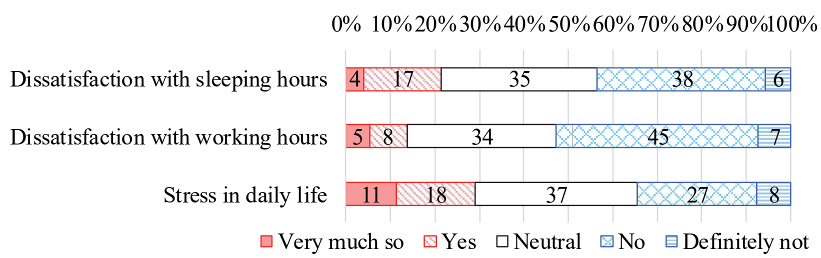

Figure 2. Dissatisfaction with daily life

The proportion of subjects who were interested in information about health and global warming appear in Table 2. The responses for concern about the risk of lifestyle-related disease and concern about walking were both 32%: that is higher than other concerns. The responses about the intention to reduce automobile use are also presented in Table 2. In response to the question about health and the global environment, 8% of participants stated that it was their definite intention to reduce their use of motor vehicles. In addition, 35% replied in the affirmative, indicating a weak intention to reduce such usage. Thus, we were able to demonstrate that the intention to reduce automobile use can be created by providing information about health and global warming.

The responses about the intention to reduce automobile usage in the light of different concerns appear in Fig. 3. We observed the highest responses about reducing automobile usage among individuals who stated that they were concerned about all types of information. There was particularly high concern about reducing CO_2 emissions: the proportion of respondents who stated “strongly agree” was, at 24%, the highest. With respect to positive responses regarding concerns about physical activities, that for cycling was the highest: 78%.

In the follow-up survey, we obtained responses from the same 249 participants in the automobile user survey. In terms of affirmative responses about travel behavior, we found that 1.6% of respondents stated they would make changes with commuting, 3.6% with shopping, and 0.8% with trips for other purposes. Thus, 6% of the subjects affirmed that they would change their travel behavior from driving a car to walking or cycling. We are therefore able to demonstrate that providing simple information about the merits of walking or cycling in the automobile user survey could lead the participants to modify their travel behavior.

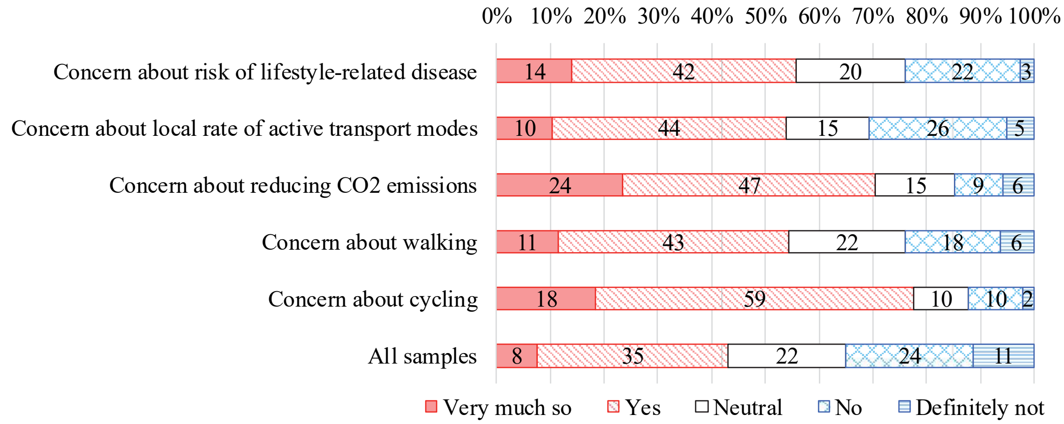

Figure 3. Intention to reduce car use

3. RELATION AMONG FACTORS

By means of a generalized linear regression model, we analyzed the survey results about the relations among such factors as reduced car usage, concerns about health and global warming, healthy daily activities, and dissatisfaction with daily life.

3.1 Factors related to reduced car use

In the follow-up survey, we observed reduced automobile usage as an affirmative response for travel behavior change. We identified the factors related to this reduction by means of a binary logit model. We used the items from the questionnaire survey as explanatory variables. We estimated the coefficient parameters by means of the maximum likelihood method, and we selected the explanatory variables based on the Akaike information criterion (AIC). The result with the binary logit model for reduced car use appears in Table 4.

Table 4. Results of the binary logit model for reduced car usage

Variables	Coeff.	t-stat.
Constant term	-6.101	-4.27 *
Intention to reduce car use	0.799	2.12 *
Number of days going out walking	0.350	2.60 *
Number of working hours	0.261	1.98 *
Age 20s	2.088	1.85
Age 30s	1.723	1.80
Age 40s	1.226	1.35
Balanced diet	0.537	1.35
Dissatisfaction with working hours	-1.170	-2.32 *
Stress in daily life	-1.181	-2.46 *
Main commuting mode: car	-2.799	-3.06 *

*:5% statistically significant

The coefficient parameter of the intention to reduce car usage was statistically significant. We also found the coefficient parameter for the number of days going out walking to be statistically significant. Thus, we were able to confirm that by providing information, we could change the commuting practice of driving a private car to walking or cycling. Conversely, the coefficient parameters for both car commuting and stress in daily life were negative and statistically significant. Commuting by car constitutes a lifestyle in which there is dependency on the automobile. We were also able to confirm that stress in daily life affects change in travel behavior. However, dissatisfaction with working hours was negative; the parameter for working hours was positive. Thus, the relationship among the factors for reducing car usage is not simple: a complex structure should be assumed.

We classified the responses concerning intention to reduce automobile usage into five categories. Then, we identified the factors related to such intention using an ordered logit model. we determined the coefficient parameter of the explanatory variable and threshold parameter for intercepts by means of the maximum likelihood method. Except for five items of concern for the merits of walking or cycling, we selected the explanatory variables based on the AIC. The estimated results with the ordered logit model for the intention to reduce automobile use appear in Table 5.

Table 5. Results with the ordered logit model for intention to reduce automobile use

Variables	Model 1		Model 2	
	Coeff.	t-stat.	Coeff.	t-stat.
Concern about risk of lifestyle-related disease (dummy)	0.579	2.15 *	0.623	2.37 *
Concern about local rate of active transport modes (dummy)	-0.331	-0.97	-	-
Concern about reducing CO2 emissions (dummy)	0.774	1.90	0.803	2.05 *
Concern about walking (dummy)	0.147	0.52	-	-
Concern about cycling (dummy)	1.306	3.53 *	1.243	3.67 *
Number of days going out walking	0.061	0.97	-	-
Number of days going out cycling	0.198	2.33 *	0.205	2.51 *
Number of working hours	-0.091	-2.11 *	-0.086	-2.01 *
Age 50s (dummy)	-0.433	-1.58	-0.399	-1.46
Age 70s (dummy)	1.213	1.69	1.412	2.02 *
Employed(dummy)	0.778	2.19 *	0.694	1.99 *
Intercepts:				
Definitely not | No	-1.780	-5.16 *	-1.839	-5.48 *
No | Neutral	-0.196	-0.63	-0.264	-0.89
Neutral | Yes	0.883	2.81 *	0.805	2.67 *
Yes | Very much so	3.559	8.53 *	3.470	8.50 *
			*:5% statistically significant	
AIC:		705		702

In Table 5, the coefficient parameters for concern about the merits of walking or cycling are presented in model 1. The parameters for concern about local rate of active transport modes and concern about walking were not statistically significant. Thus, in model 2, we removed those variables and number of days going out walking.

With model 2, the coefficient parameters for concern about risk of lifestyle-related disease, concern about reducing CO_2 emissions, and concern about cycling were statistically significant. The coefficient parameters for number of days going out cycling were also statistically significant; thus, we were able to confirm that daily cycling activity influences the intention to reduce automobile usage. Conversely, since the coefficient parameter for number of working hours was negative and statistically significant, working long hours reduces the intention to shift from car use to walking or cycling. Furthermore, the parameter for the threshold between "no" and "neutral" was not statistically significant; thus, the categories of "no" and "neutral" did not differ.

3.2 Factors related to concern for information about health and global warming

We found that information about the merits of walking or cycling affected the intention to reduce automobile use. Therefore, we identified the factors that affect interest in that information using the binary logit model in terms of such variables as concern about risk of lifestyle-related disease, concern about reducing CO_2 emissions, and concern about cycling. We selected the explanatory variables based on the AIC. First, we analyzed the factors for concern about risk of lifestyle-related disease; the results of the binary logit model appear in Table 6. We identified the coefficient parameters for intention to improve lifestyle and number of days going out walking as statistically significant factors. Participants with high intention to improve their lifestyle also had high interest in information about risk of lifestyle-related disease. Individuals who often went out walking were also interested in the risk of such disease.

Table 6. Results with binary logit model for concern about risk of lifestyle-related disease

Variables	Coeff.	t-stat.
Constant term	-1.028	-5.91 *
Intention to improve lifestyle	0.452	2.78 *
Number of days going out walking	0.142	2.35 *

*:5% statistically significant

Second, we analyzed the factors regarding concern about reducing CO_2 emissions, and the results of the binary logit model are presented in Table 7. The coefficient parameters of the four variables identified as factors related to concern about reducing CO_2 emissions were statistically significant. We found that positive attitudes about the necessity to reduce CO_2 emissions affected concern for information about reducing CO_2 emissions. However, participants who often went out cycling were also interested in such reduction.

Table 7. Results with binary logit model for concern about reducing CO_2 emissions

Variables	Coeff.	t-stat.
Constant term	-3.847	-5.94 *
Employed	1.784	2.85 *
Necessity to reduce CO_2 emissions	0.844	3.66 *
Number of days going out cycling	0.355	3.58 *

*:5% statistically significant

Third, we analyzed the factors related to concern about cycling, and the results of the binary logit model appear in Table 8. The coefficient parameters of four variables were also statistically significant and identified as factors related to concern about cycling. If participants were interested in information about the risk of lifestyle-related disease and reducing CO_2 emissions, they were also interested in information about cycling. Subjects with concern for health also had concern about cycling.

Table 8. Results with binary logit model for concern about cycling

Variables	Coeff.	t-stat.
Constant term	-2.373	-8.47 *
Age 20s (dummy)	1.507	2.37 *
Concern about risk of lifestyle-related disease	1.226	3.42 *
Concern about reducing CO_2 emissions	1.252	2.89 *
Concern for health	0.659	2.89 *

*:5% statistically significant

3.3 Analysis of factors related to healthy daily activity

We confirmed that daily outdoor behavior affected concern about the merits of walking or cycling. About half of the participants went out walking daily (Fig. A5). However, over 70% of subjects did not go out cycling daily (Fig. A7). Using the binary choice model, we identified the factors that influence daily outdoor behavior in terms of such variables as number of days going out walking and number of days going out cycling. We selected the explanatory variables based on the AIC, and we excluded variables about concern for information about health and global warming.

We analyzed the factors about the number of days going out walking, and the results of the binary choice model are presented in Table 9. The coefficient parameters for active intention to exercise and stress in daily life as well as some individual attributes were statistically significant; We identified those as factors for going out walking daily. Therefore, active intention to exercise improves with the number of days going out walking. Conversely, stress in daily life reduced that number of days. Car commuters and females had fewer days of going out walking.

Table 9. Results with binary logit model for number of days going out walking

Variables	Coeff.	t-stat.
Constant term	0.300	1.43
Main commuting mode: car	-1.064	-7.72 *
Female	-0.631	-4.40 *
Middle age	-0.974	-4.75 *
Age 60s	-1.095	-4.61 *
Active intention to exercise	0.409	5.73 *
Stress in daily life	-0.244	-3.53 *

*:5% statistically significant

We analyzed the factors related to going out cycling daily, and the results of the binary choice model appear in Table 10. The coefficient parameters for number of days going out walking and some individual attributes were statistically significant; we identified them as factors for going out cycling daily. The number of days going out cycling tended to increase with the number of days going out walking. Car commuters and females had fewer days of both going out cycling and walking. Conversely, employed participants often tended to go out cycling.

Table 10. Results with binary logit model for number of days going out cycling

Variables	Coeff.	t-stat.
Constant term	-2.081	-10.62 *
Main commuting mode: car	-2.383	-10.96 *
Female	-0.482	-2.51 *
Employed	1.284	6.31 *
Number of days going out walking	0.122	3.67 *

*:5% statistically significant

As well as daily outdoor behavior, daily exercise is important as a healthy daily activity. The number of participants who exercised on a daily basis was greater than the number who went out walking or cycling (Fig. A9). We attempted to identify the factors that affected exercise time other than commuting trips. There was a gradual decrease in the number of subjects with the number of exercise hours a week (Fig. A10). Accordingly, we applied a

Weibull regression model as the generalized linear model. We chose the explanatory variables based on the AIC. The estimated results of the Weibull regression model for number of exercise hours a week are presented in Table 11.

Table 11. Results of Weibull regression model for number of exercise hours a week

Variables	Coeff.	t-stat.
Constant term	2.000	7.80 *
Active intention to exercise	1.305	4.68 *
Balanced diet	0.794	2.96 *
Shape parameter ρ	1.346	25.17 *

*:5% statistically significant

We calculated the chi-square value for the statistical test to be 34.47; thus, we confirmed that the Weibull distribution was suitable for the distribution of number of exercise hours a week. The coefficient parameters for the constant term and scale parameter were statistically significant. Therefore, the distribution of number of exercise hours can be described using the Weibull distribution. However, the coefficient parameters for active intention to exercise and balanced diet were statistically significant and identified as factors for exercise. Thus, increasing the intention to exercise may lead to a rise in exercise time. we also found that participants who maintained a balanced diet spent a long time exercising.

3.4 Factors related to dissatisfaction with daily life

We observed that stress in daily life reduced daily outdoor behavior. For stress in daily life, we identified the factors using the ordered logit model. We selected the explanatory variables based on the AIC, and we excluded variables that had already been analyzed as objective variables. The results of the ordered logit model for stress in daily life are presented in Table 12. The coefficient parameters for dissatisfaction with sleeping hours and dissatisfaction with working hours were statistically significant and confirmed as stress factors. Both sleeping hours and working hours are basic factors in life; thus, dissatisfaction with either leads to stress in daily life. However, participants with anxiety about health may suffer stress in their daily life. In terms of individual attributes, we found that car commuters had higher stress than other subjects. That was probably the result of traffic congestion when commuting. All the parameters for the thresholds were statistically significant.

Table 12. Results of ordered logit model for stress in daily life

Variables	Coeff.	t-stat.
Main commuting mode: car	0.608	2.46 *
Anxiety over health	0.591	4.27 *
Dissatisfaction with sleeping hours	0.434	2.90 *
Dissatisfaction with working hours	0.700	4.39 *
Intercepts:		
Definitely not | No	-2.677	-9.14 *
No | Neutral	-0.447	-2.20 *
Neutral | Yes	1.506	6.74 *
Yes | Very much so	2.945	10.38 *

*:5% statistically significant

In terms of both sleeping hours and working hours as causes of stress in daily life, we determined the factors related to dissatisfaction using the ordered logit model. The results of the ordered logit model for dissatisfaction with sleeping hours appear in Table 13. We found that dissatisfaction decreased with the number of sleeping hours. Thus, participants having insufficient sleep time were highly dissatisfied. We identified the coefficient parameters for number of exercise hours a week and middle age as statistically significant factors. It was evident that exercise relieved dissatisfaction with sleeping hours.

Table 13. Results of ordered logit model for dissatisfaction with sleeping hours

Variables	Coeff.	t-stat.
Number of sleeping hours	-0.993	-6.73 *
Middle age	1.121	3.59 *
Number of exercise hours a week	-0.005	-2.30 *
Intercepts:		
Definitely not | No	-9.435	-8.01 *
No | Neutral	-6.176	-5.77 *
Neutral | Yes	-4.203	-4.06 *
Yes | Very much so	-2.138	-2.05 *

*:5% statistically significant

The results of the ordered logit model for dissatisfaction with working hours are presented in Table 14. We confirmed that dissatisfaction increased with the number of working hours. In addition, we identified the coefficient parameters for dissatisfaction for sleeping hours and middle age as statistically significant factors. Thus, if participants were dissatisfied with their sleeping hours, their dissatisfaction with working hours increased. Middle-aged subjects were satisfied with working hours, though they had high dissatisfaction with their sleeping hours.

Table 14. Results of ordered logit model for dissatisfaction with working hours

Variables	Coeff.	t-stat.
Number of working hours	0.194	4.83 *
Middle age	-0.007	-3.04 *
Dissatisfaction with sleeping hours	1.126	7.21 *
Intercepts:		
Definitely not | No	-2.354	-6.02 *
No | Neutral	1.275	3.67 *
Neutral | Yes	3.587	8.69 *
Yes | Very much so	4.883	9.99 *

*:5% statistically significant

4. STRUCTURAL EQUATION MODELING

We assumed that the causal structure related to reduced car use would be based on the identified relations among the factors, and we verified that using structural equation modeling.

4.1 Hypothesis of causal structure

With the analyses, we were able to identify both the factors related to reducing car use and individual relationships among those factors. From those findings, we were able to infer the causal structure of the factors related to reduction of automobile use. For example, we supposed that reduced car use was the result of a travel behavior change influenced by both the intention to reduce such use and the number of days going out walking. Similarly, we concluded that both concern for information about health and global warming and number of days going out cycling affected the intention to reduce automobile use. Further, we observed that the intention to reduce car use declined with an increase in the number of working hours. In that way, we determined causal relations among the latent variables based on the results of our analysis.

In addition to the relations based on the analysis results using the generalized linear regression model, we inferred that concern for health was affected by the following: anxiety over health; intention to improve lifestyle; active intention to exercise; balanced diet; and concern for information about health and global warming. we suppose that dissatisfaction with sleeping hours increases anxiety over health and that a balanced diet reduces anxiety. However, anxiety over health may be assumed to affect intention to improve lifestyle and decrease active intention to exercise. Furthermore, active intention to exercise may be supposed to increase with intention to improve lifestyle, which is affected by attitude to global environment. Moreover, dissatisfaction with working hours may be assumed to decrease the tendency to have a balanced diet. Our hypothesis for the causal structure is presented in Fig. 4. The latent variable of attitude to the global environment comprises two observed variables: concern about global warming and necessity to reduce CO_2 emissions. Similarly, the two observed variables of number of days exercise a week and number of exercise hours a week constitute the latent variable of exercise time. Each other latent variable consists of only one observed variable.

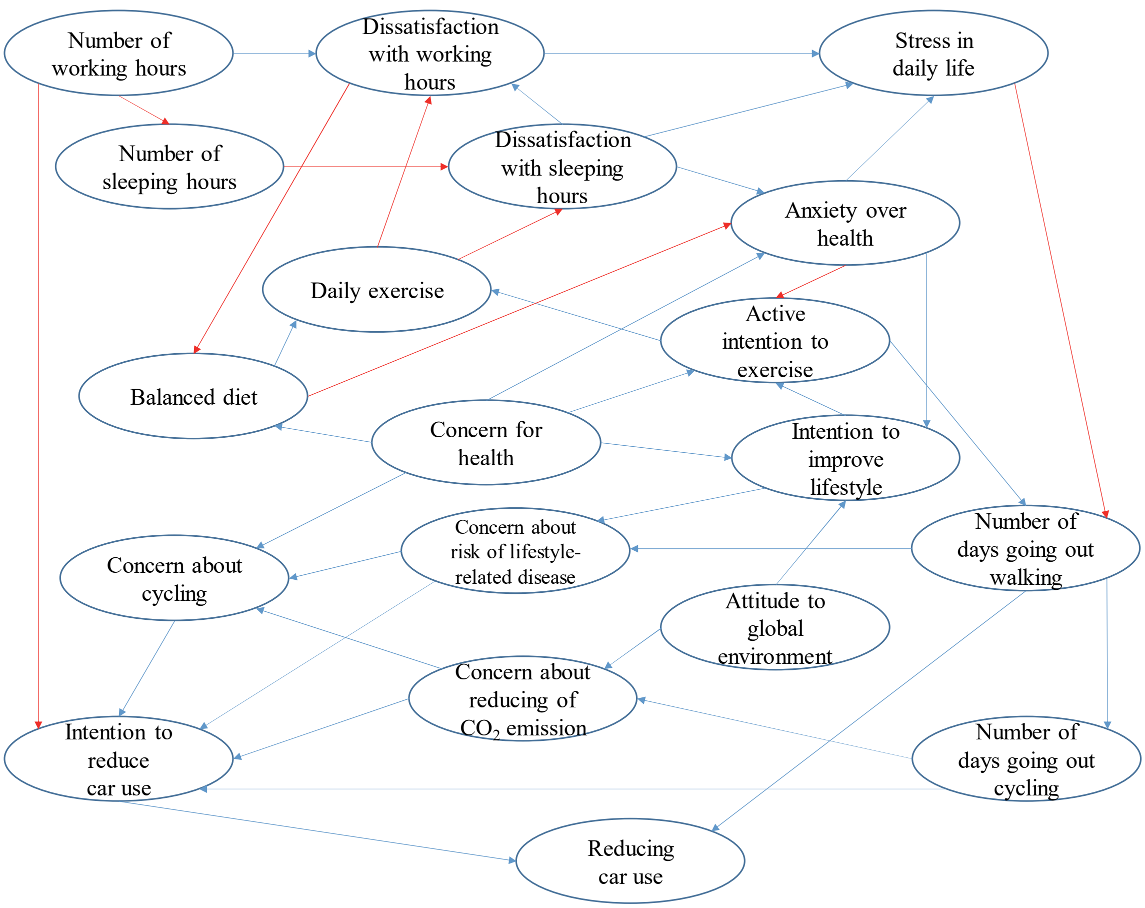

Figure 4. Hypothesis of causal structure

The observed variables of hours of active life and exercise are specified as continuous variables. Similarly, we defined the numbers of days of outdoor behavior as continuous variables. Conversely, the variables of concern for information about health and the global warming are given as dummy variables. Except for these items, we converted the items with five answers to the observed variables using a Likert scale.

4.2 Validation of casual structure

We validated the hypothesis of the causal structure related to intention to reduce automobile use by means of statistical analysis. We estimated the coefficient parameters in the structure equation model using the maximum likelihood method based on the data from the 249 participants in the questionnaire survey. The estimated parameters converged normally after 35 iterations. The statistical indexes for the proposed model appear in Table 15.

Table 15. Summary of statistical indexes for the proposed model

Number of observations	249	Loglikelihood and Information Criteria:	
		Loglikelihood of the proposed model	-6724
Model test of the proposed model:		Loglikelihood of unrestricted model	-6616
Chi-square statistic	217	Number of free parameters	66
Degrees of freedom	165	Akaike (AIC)	13581
P-value (Chi-square)	0.004	Bayesian (BIC)	13813
Model test of the unrestricted model:		Sample-size adjusted Bayesian (BIC)	13604
Chi-square statistic	1587	Root Mean Square Error of Approximation:	
Degrees of freedom	210	RMSEA	0.036
P-value	0.000	lower bound of 90 Percent Confidence Interval	0.021
The proposed model versus the unrestricted model:		upper bound of 90 Percent Confidence Interval	0.048
Comparative Fit Index (CFI)	0.962	P-value RMSEA <= 0.05	0.974
Tucker-Lewis Index (TLI)	0.952	Standardized Root Mean Square Residual:	0.058

From the result of the chi-square test, we could not confirm whether the proposed model had sufficient fitness. However, the value of both the comparative fit index and Tucker-Lewis index were greater than 0.95; thus, the fitness of the proposed model could be confirmed as good. The index of the root mean square error of approximation was less than 0.05. The upper bound of the 90% confidence interval was also less than 0.05. Therefore, the proposed model displayed good data fit.

The estimated results of the coefficient parameters for the measurement model are presented in Table 16.

Table 16. Estimated parameters for the coefficient of the measurement model

Latent variables	Observed variables	Standardized estimeted value	t-stat.
Attitude to global environment	Concern about global warming	0.966	27.01 **
	Realize necessity to reduce CO_2 emissions	0.940	26.60 **
Daily exercise	Number of exercise days a week	0.747	13.85 **
	Number of exercise hours a week	0.705	13.04 **

*:5% statistically significant, **:1% statistically significant

The relations among the latent and observed variables are described in the measurement model. In terms of the latent variable of attitude to the global environment, both observed variables "concern about global warming and necessity to reduce CO_2 emissions" were statistically significant. Both standardized estimated values of the coefficient parameters were roughly the same. Similarly, regarding the latent variable of exercise time, the observed variables "number of days exercise a week and number of exercise hours a week" were statistically significant. The difference between the estimated values of the coefficient parameters of those variables was not large. Therefore, we considered that those latent variables were constituent concepts that integrated similar observation variables.

The estimated results of the coefficient parameters for the structural equation model and covariance appear in Table 17.

Table 17. Estimated parameters for coefficient of structural equation model and covariance

Explained latent variables	Explanatory latent variables	Standardized estimeted value	t-stat.
Number of sleeping hours	Number of working hours	-0.287	-4.94 **
Dissatisfaction with working hours	Number of working hours	0.284	5.57 **
	Dissatisfaction with sleeping hours	0.447	9.31 **
Dissatisfaction with sleeping hours	Number of sleeping hours	-0.473	-9.84 **
	Daily exercise	-0.190	-2.98 **
Stress in daily life	Dissatisfaction with working hours	0.284	4.68 **
	Dissatisfaction with sleeping hours	0.199	3.20 **
	Anxiety over health	0.254	4.75 **
Anxiety over health	Concern for health	0.325	5.51 **
	Dissatisfaction with sleeping hours	0.156	2.60 **
	Balanced diet	-0.128	-2.05 *
Intention to improve lifestyle	Concern for health	0.292	5.20 **
	Anxiety over health	0.299	5.49 **
	Attitude to global environment	0.153	2.70 **
Balanced diet	Concern for health	0.273	4.83 **
	Dissatisfaction with working hours	-0.241	-4.17 **
Active intention to exercise	Intention to improve lifestyle	0.440	7.97 **
	Concern for health	0.317	5.77 **
	Anxiety over health	-0.185	-3.31 **
Daily exercise	Active intention to exercise	0.470	7.72 **
	Balanced diet	0.289	4.40 **
Number of days going out walking	Active intention to exercise	0.176	2.93 **
	Stress in daily life	-0.204	-3.41 **
Number of days going out cycling	Number of days going out walking	0.225	3.74 **
Concern about risk of lifestyle-related disease	Intention to improve lifestyle	0.179	2.95 **
	Number of days going out walking	0.155	2.54 *
Concern about reducing CO_2 emissions	Attitude to global environment	0.221	3.68 **
	Number of days going out cycling	0.221	3.76 **
Concern about cycling	Concern for health	0.176	3.02 **
	Concern about risk of lifestyle-related disease	0.220	3.81 **
	Concern about reducing CO_2 emissions	0.220	3.82 **
Intention to reduce car use	Concern about risk of lifestyle-related disease	0.160	2.75 *
	Concern about reducing CO_2 emissions	0.161	2.71 *
	Concern about cycling	0.221	3.74 **
	Number of days going out cycling	0.150	2.58 *
	Number of working hours	-0.123	-2.18 *
Reducing car use	Intention to reduce car use	0.385	7.20 **
	Number of days going out walking	0.119	2.07 *

*:5% statistically significant, **:1% statistically significant

Covariances:

Concern for health	Attitude to global environment	0.234	3.81 **
Concern for health	Number of working hours	-0.107	-1.71
Attitude to global environment	Number of working hours	-0.105	-1.63

The relations among the latent variables are described in the structural equation model. From the estimation results, we were able to confirm that dissatisfaction with working and sleeping hours affected stress in daily life. The number of days going out walking decreased in response to stress; the number of days going out walking affected the number of days going out cycling. Concern for health was directly related to concern about cycling; it indirectly influenced concern about risk of lifestyle-related disease. Furthermore, the number of days going out walking affected concern about risk of lifestyle-related disease; the number of days going out cycling influenced concern about cycling. Moreover, the concern for information about health and global warming as well as the number of days going out cycling affected the intention to reduce automobile use. Finally, reduced car use as a result of travel behavior change was influenced by both the intention to reduce car use and number of days going out walking.

Thus, it may be concluded that appropriate information about the time spent engaged in various activities may be effective in reducing automobile use. In addition, appropriately managing sleeping hours, working hours, and exercise time and promoting concern for health also lead to such reduction.

5. CONCLUDING REMARKS

Toward reducing automobile use in a provincial city with insufficient service of public transport, we conducted a questionnaire survey of residents who may refrain from driving for their health. By means of a generalized linear regression model, we analyzed the results to identify the relations among factors for healthy activities in daily life. We verified the causal structure related to reduced automobile use using structural equation modeling. The findings of our study may be summarized as follows.

First, we confirmed that both the intention to reduce car use and daily active walking influence the change from car driving to walking or cycling. However, the relationship among the factors for reducing car use is not simple: a complex structure should be assumed.

Second, we found that information about risk of lifestyle-related disease, reducing CO_2 emissions, and cycling was a factor that promoted cycling or walking rather than driving. Daily cycling promotes the intention to reduce automobile use. Conversely, long working hours hinder such intention. Therefore, to reduce car use, it is important to provide information about health and the global environment as well as about properly managing working hours.

Third, among factors related to interest in information about health and the global environment, we identified the intention to improve lifestyle and positive attitudes about the necessity to reduce CO_2 emissions. Such interest produces concern about cycling. Number of days going out walking influences concern about risk of lifestyle-related disease; the number of days going out cycling affects concern about cycling.

Fourth, we found that dissatisfaction with working hours was positive with respect to number of working hours and that dissatisfaction with sleeping hours was negative with respect to number of sleeping hours; however, exercise reduced dissatisfaction with sleeping or working hours. Dissatisfaction with sleeping or working hours and anxiety over health led to stress in daily life. Stress in daily life decreased the number of days going out walking, but the active intention to exercise increased that number. The number of days going out walking tended to increase with the number of days going out cycling.

Future research should be in the form of a large-scale social study of a whole urban area. It should examine residents who intend to reduce automobile use and present information about health and global environment to determine their effects.

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APPENDICES

See Figures A1, A2, A3, A4, A5, A6, A7, A8, A9 and A10.

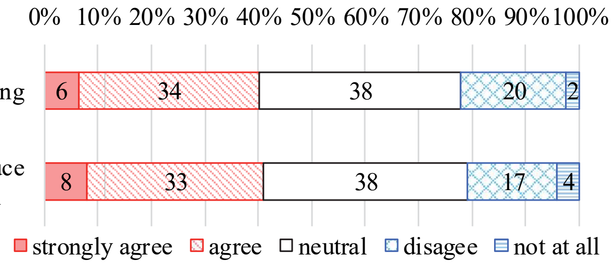

Figure A1. Attitudes to global warming

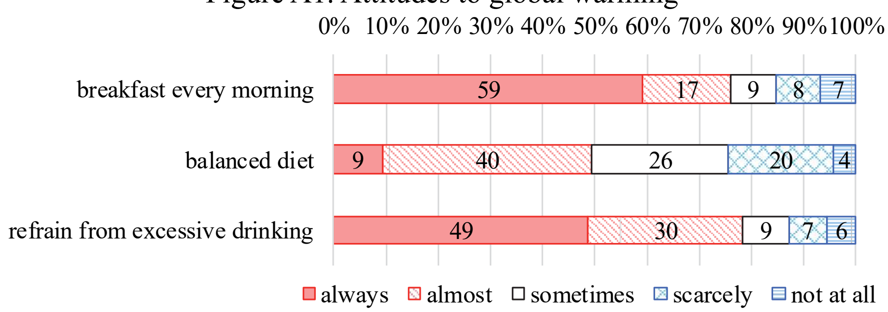

Figure A2. Eating habits

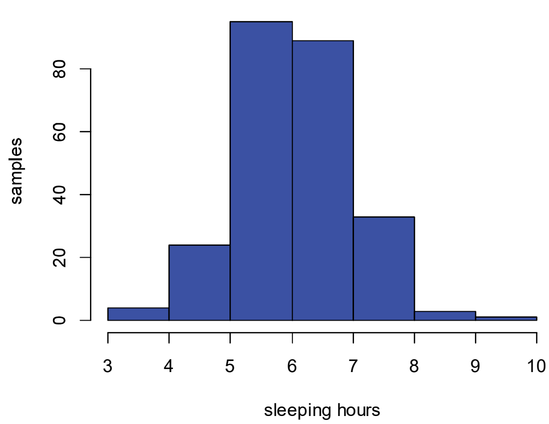

Figure A3. Daily sleeping hours

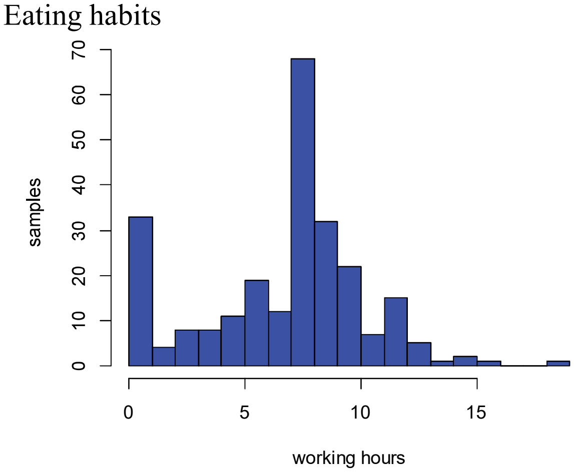

Figure A4. Daily working hours

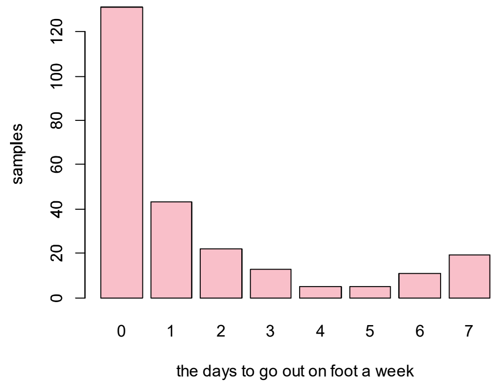

Figure A5. Number of days going out walking a week

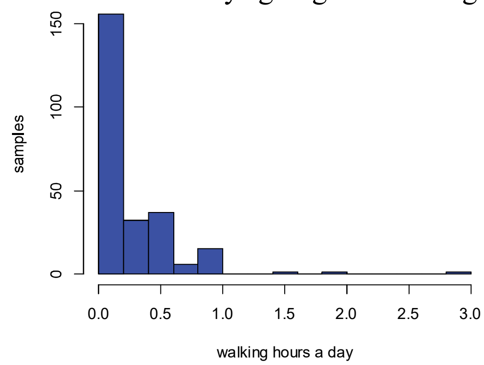

Figure A6. Number of walking hours a day

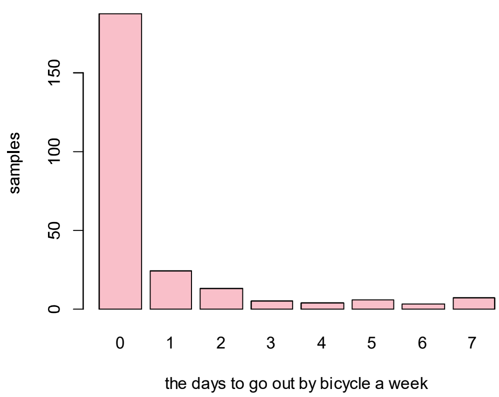

Figure A7. Number of cycling days a week

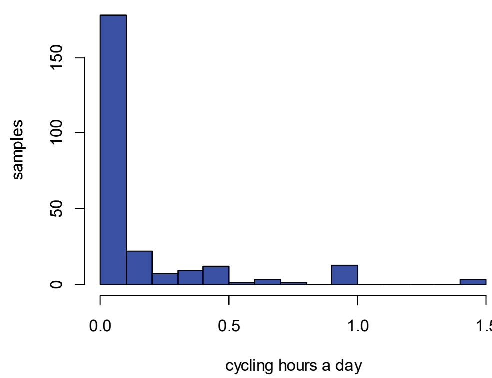

Figure A8. Number of cycling hours a day

Figure A9. Number days exercise a week

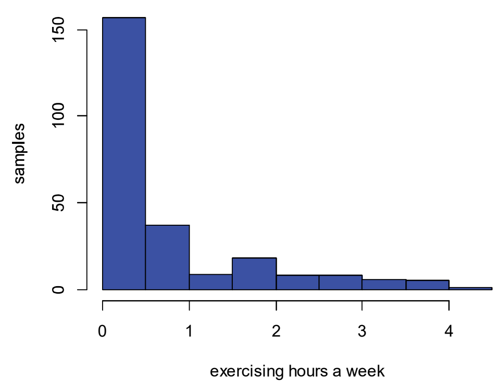

Figure A10. Number of exercise hours a week