Calculation of the PAIs

We consider the PAIs to be a convenient and practical index. The PAIs were calculated for each subject and activity by dividing EE by either BW (EE/BW; kcal·min^{-1}/kg), L-RMR (EE/L-RMR; kcal·min^{-1}/kcal·min^{-1}), S-RMR (EE/S-RMR; kcal·min^{-1}/kcal·min^{-1}), or FFM (EE/FFM; kcal·min^{-1}/kg). Therefore, the EE/L-RMR for lying and the EE/S-RMR for sitting quietly were equal to 1.00.

Statistical analysis

The data are presented as means±SD, unless otherwise stated. Differences were considered to be statistically significant if the P value was less than 0.05. We regarded a PAI as an appropriate adjustment for body size when there was no significant correlation between the PAI and BW. The independent associations between the PAIs and BW were tested using a general linear model (GLM) that examined the effects of age, sex, and sex–BW interaction, given that men have a greater body weight than women. In addition, the activity styles may also be related to age and sex, although the L-RMR, S-RMR, and FFM measured in the present study already reflected the effects of age and sex. Therefore, the effects of age and sex were considered in the relationship between all the PAIs and BW. If the sex–BW interaction term was not statistically significant in the GLM, the interaction term was excluded in the subsequent analyses, and the errors in the PAIs caused by size were estimated from the regression models using the average age and a fixed value for sex (0.5). If the interaction term was significant, the errors were estimated in a similar way, but for each sex. The errors were calculated as percentages of the predicted PAIs for an average BW ($PAIs_{(ave.)}$). For example, error (%)$=B\times x/PAIs_{(ave.)}\times 100$, where B is the regression coefficient of the relationship between PAI and BW from GLM adjusted for age and sex and x is the difference from average BW. All the statistical analyses were performed using SPSS Version 15.0J for Windows (SPSS, Inc., Chicago, IL, USA).

Results

The majority of the 78 subjects weighed between 40–80 kg, although 2 subjects weighed more than 100 kg and were outside the 98th percentile BMI for the Japanese population. As L-RMR or S-RMR data for five subjects were not obtained, these subjects were excluded from all the analyses. The physical characteristics of the remaining 71 subjects are summarized in Table 1.

The means, SDs, and coefficients of variations of PAI for all activities are presented in Table 2. Several data are missing due to difficulties in adequately collecting expired gas in the steady state or performing the activity following the prescribed speed and duration. We confirmed in respective activities there was no bias with respect to age, BW, or BMI. S-RMR/L-RMR was 1.09±0.05 in males and 1.12±0.08 in females. Although mean PAI was different between the sexes in some activities, the sex–BW interaction term was not statistically significant for any activity except EE/FFM-walking at 70 m/min with a 3-kg load. Therefore, all the analyses included all data from both sexes. The relationships between the PAIs and BW are summarized in Table 3 and the percentage differences in PAIs caused by a 10 kg deviation from average BW are summarized in Table 4. EE/BW correlated significantly with BW in all sedentary activities. For these activities, there were −5% to −6% (5% to 6%) differences in EE/BW values when the BW was more than 10 kg above or below average (60 kg). EE/L-RMR correlated significantly with BW for walking up stairs, walking at 70 m/min, and walking at 100 m/min. For these activities, there were +3% to 5% (−3% to −5%) differences in EE/L-RMR values when the BW exceeded or was below the average by 10 kg. EE/S-RMR correlated significantly with BW for vacuuming, lifting and carrying a small load, and for the majority of the ambulant activities. For these activities, there were +3% to 6% (−3 to −6%) differences in EE/S-RMR values when BW exceeded or was below the average by 10 kg. EE/FFM correlated significantly with BW for walking up stairs only. For this activity, there was +3.7% (−3.7%) differences in EE/FFM values when BW exceeded or was below the average by 10 kg.

Discussion

In the present study, the mean values of PAIs were significantly different between the sexes for some activities.

Table 1 Characteristics of the subjects

	All (N=71)		Male (N=34)	Female (N=37)	
	Means±SD	Range	Means±SD	Means±SD	*p*-value
Age (years)	43±13	21–66	43±14	43±13	0.850
Height (cm)	163.7±8.1	149.8–183.9	169.6±6.1	158.2±5.5	<0.001*
Body weight (kg)	60.0±10.5	40.3–86.1	65.3±9.6	55.2±9.0	<0.001*
BMI (kg/m^2)	22.3±3.0	16.7–32.3	22.6±2.4	22.1±3.4	0.450
Fat-free mass	45.2±8.5	32.2–62.0	51.9±6.3	38.9±4.7	<0.001*
Body fat (%)	24.7±6.7	11.0–37.8	20.0±4.5	28.9±5.4	<0.001*

BMI: (body mass index)

* Significant difference between sexes (Student's *t*-test)

Table 2 The means of respective physical activity indexes for all activities

2-a. The means of EE/BW for all activities

	EE/BW (kcal·min⁻¹/kg)						
	All			Male		Female	
	N	Mean±SD	CV	N	Mean±SD	N	Mean±SD
Sedentary activities							
lying quietly	71	0.0148±0.0016	10.8	34	0.0154±0.0015*	37	0.0143±0.0015
sitting quietly	71	0.0164±0.0017	10.3	34	0.0168±0.0016*	37	0.0160±0.0017
working at the computer	69	0.0181±0.0019	10.8	32	0.0187±0.0020*	37	0.0175±0.0017
Lifestyle activities							
vacuuming	69	0.0481±0.0096	19.9	34	0.0492±0.0099	35	0.0470±0.0092
hanging laundry	71	0.0367±0.0053	14.3	34	0.0378±0.0055	37	0.0358±0.0049
washing dishes	69	0.0293±0.0046	15.8	34	0.0301±0.0047	35	0.0285±0.0045
carrying a small load	71	0.0715±0.0108	15.1	34	0.0744±0.0106*	37	0.0688±0.0104
Ambulant activities							
walking up stairs	68	0.1228±0.0093	7.6	32	0.1262±0.0090*	36	0.1197±0.0086
downstairs	71	0.0512±0.0082	16.1	34	0.0534±0.0090*	37	0.0492±0.0071
walking (55 m/s)	69	0.0502±0.0064	12.7	32	0.0516±0.0070	37	0.0489±0.0056
walking (70 m/s)	69	0.0590±0.0071	12.0	33	0.0598±0.0079	36	0.0583±0.0062
walking (100 m/s)	71	0.0759±0.0115	15.1	34	0.0771±0.0129	37	0.0748±0.0100
walking (70 m/s) with a 3 kg load	71	0.0689±0.0090	13.1	34	0.0688±0.0105	37	0.0690±0.0076
jogging (140 m/s)	62	0.1557±0.0188	12.1	34	0.1624±0.0196*	28	0.1475±0.0143

2-b. The means of EE/L-RMR for all activities

	EE/L-RMR (kcal·min⁻¹/kcal·min⁻¹)						
	All			Male		Female	
	N	Mean±SD	CV	N	Mean±SD	N	Mean±SD
Sedentary activities							
lying quietly	—		—		—		
sitting quietly	71	1.11±0.07	6.3	34	1.09±0.05*	37	1.12±0.08
working at the computer	69	1.23±0.11	8.6	32	1.22±0.10	37	1.23±0.11
Lifestyle activities							
vacuuming	69	3.28±0.72	21.9	34	3.21±0.71	35	3.35±0.72
hanging laundry	71	2.50±0.40	16.0	34	2.47±0.40	37	2.52±0.40
washing dishes	69	2.00±0.35	17.4	34	1.95±0.30	35	2.04±0.39
carrying a small load	71	4.85±0.79	16.2	34	4.86±0.83	37	4.85±0.75
Ambulant activities							
walking up stairs	68	8.40±0.82	9.8	32	8.29±0.81	36	8.50±0.83
downstairs	71	3.46±0.50	14.4	34	3.46±0.49	37	3.46±0.51
walking (55 m/s)	69	3.40±0.46	13.4	32	3.35±0.44	37	3.45±0.47
walking (70 m/s)	69	4.00±0.54	13.6	33	3.88±0.55	36	4.11±0.52
walking (100 m/s)	71	5.15±0.82	15.8	34	5.02±0.85	37	5.27±0.78
walking (70 m/s) with a 3 kg load	71	4.68±0.68	14.6	34	4.47±0.68*	37	4.87±0.64
jogging (140 m/s)	62	10.51±1.26	12.0	34	10.58±1.38	28	10.42±1.11

Table 2 Continued

2-c. The means of EE/S-RMR for all activities

	EE/S-RMR ($kcal \cdot min^{-1}/kcal \cdot min^{-1}$)						
	All			Male		Female	
	N	Mean±SD	CV	N	Mean±SD	N	Mean±SD
Sedentary activities							
lying quietly	71	0.91±0.06	6.1	34	0.92±0.05	37	0.89±0.06
sitting quietly		—			—		—
working at the computer	69	1.11±0.08	7.1	32	1.12±0.07	37	1.10±0.09
Lifestyle activities							
vacuuming	69	2.96±0.63	21.4	34	2.95±0.68	35	2.97±0.59
hanging laundry	71	2.26±0.37	16.2	34	2.26±0.37	37	2.25±0.37
washing dishes	69	1.80±0.32	17.6	34	1.79±0.27	35	1.81±0.36
carrying a small load	71	4.39±0.69	15.7	34	4.46±0.74	37	4.32±0.64
Ambulant activities							
walking up stairs	68	7.60±0.74	9.8	32	7.60±0.73	36	7.59±0.76
downstairs	71	3.13±0.47	14.9	34	3.18±0.48	37	3.09±0.46
walking (55 m/s)	69	3.08±0.43	14.0	32	3.08±0.43	37	3.08±0.44
walking (70 m/s)	69	3.62±0.50	13.9	33	3.57±0.52	36	3.67±0.48
walking (100 m/s)	71	4.66±0.76	16.3	34	4.61±0.80	37	4.71±0.73
walking (70 m/s) with a 3 kg load	71	4.23±0.62	14.7	34	4.11±0.64	37	4.34±0.59
jogging (140 m/s)	62	9.50±1.10	11.6	34	9.72±1.29	28	9.23±0.77

2-d. The means of EE/FFM for all activities

	EE/FFM ($kcal \cdot min^{-1}/kg$)						
	All			Male		Female	
	N	Mean±SD	CV	N	Mean±SD	N	Mean±SD
Sedentary activities							
lying quietly	71	0.0197±0.0018	9.2	34	0.0193±0.0017	37	0.0201±0.0019
sitting quietly	71	0.0218±0.0019	8.6	34	0.0210±0.0017*	37	0.0225±0.0018
working at the computer	69	0.0242±0.0026	10.6	32	0.0236±0.0026	37	0.0247±0.0025
Lifestyle activities							
vacuuming	69	0.0643±0.0140	21.7	34	0.0617±0.0135	35	0.0669±0.0141
hanging laundry	71	0.0491±0.0081	16.6	34	0.0474±0.0074	37	0.0507±0.0086
washing dishes	69	0.0391±0.0071	18.0	34	0.0376±0.0061	35	0.0406±0.0077
carrying a small load	71	0.0954±0.0153	16.0	34	0.0935±0.0153	37	0.0972±0.0153
Ambulant activities							
walking up stairs	68	0.1646±0.0161	9.8	32	0.159±0.0143*	36	0.1698±0.0159
downstairs	71	0.0684±0.0118	17.2	34	0.0669±0.0117	37	0.0698±0.0119
walking (55 m/s)	69	0.0671±0.0100	14.9	32	0.0645±0.0092*	37	0.0693±0.0103
walking (70 m/s)	69	0.0789±0.0116	14.7	33	0.0750±0.0104*	36	0.0824±0.0116
walking (100 m/s)	71	0.1016±0.0180	17.7	34	0.0966±0.0171*	37	0.1061±0.0178
walking (70 m/s) with a 3 kg load	71	0.0923±0.0154	16.7	34	0.0862±0.0139*	37	0.0979±0.0148
jogging (140 m/s)	62	0.2040±0.0223	10.9	34	0.2035±0.0265	28	0.2045±0.0162

EE: energy expenditure, BW: body weight, L-RMR: lying resting metabolic rate, S-RMR: sitting resting metabolic rate, FFM: fat-free mass, CV: coefficient of variation.

* $p<0.05$ vs. male group (Student's *t*-test)

Table 3 Results from the general linear model with physical activity index as the dependent variable and body weight, age, and sex as the independent variables

	EE/BW (kcal·min^{-1}/kg)			EE/L-RMR (kcal·min^{-1}/kcal·min^{-1})			EE/S-RMR (kcal·min^{-1}/kcal·min^{-1})			EE/FFM (kcal·min^{-1}/kg)		
	Regression coefficient[1] (Estimate±SE)	Age, sex[2)]	Average EE/BW[3)]	Regression coefficient[1] (Estimate±SE)	Age, sex[2)]	Average EE/BMR[3)]	Regression coefficient[1] (Estimate±SE)	Age, sex[2)]	Average EE/BMR[3)]	Regression coefficient[1] (Estimate±SE)	Age, sex[2)]	Average EE/FFM[3)]
Sedentary activities												
lying quietly	−0.000079±0.000016**	age, sex	0.0149	—		—	0.000±0.001		0.91	−0.000020±0.000024		0.0197
sitting quietly	−0.000094±0.000017**	age, sex	0.0164	−0.001±0.001		1.11	—		—	−0.000032±0.000022	sex	0.0218
working at the computer	−0.000091±0.000022**	sex	0.0181	0.000±0.001	age	1.22	0.001±0.001	age	1.11	−0.000018±0.000029	age	0.0241
Lifestyle activities												
vacuuming	−0.000016±0.000123	age	0.0480	0.015±0.009	age	3.26	0.016±0.008*	age	2.95	0.000252±0.000173	age, sex	0.0636
hanging laundry	−0.000099±0.000062	age, sex	0.0368	0.006±0.004	age	2.49	0.007±0.004	age	2.26	0.000088±0.000089	age, sex	0.0491
washing dishes	−0.000075±0.000057	age	0.0293	0.005±0.004	age	1.99	0.006±0.004	age	1.79	0.000068±0.000084	age	0.0394
carrying a small load	−0.000139±0.000132	age, sex	0.0717	0.016±0.009	age	4.85	0.017±0.008*	age	4.39	0.000233±0.000175	age	0.0953
Ambulant activities												
walking up stairs	−0.000070±0.000119	sex	0.1230	0.035±0.010**	sex	8.37	0.035±0.009**		7.58	0.000598±0.000178*	age, sex	0.1637
downstairs	−0.000189±0.000103	sex	0.0513	0.006±0.006	age	3.46	0.007±0.006	age	3.13	0.000050±0.000147	age	0.0683
walking (55 m/s)	−0.000119±0.000083	sex	0.0503	0.011±0.006	age	3.40	0.011±0.005*	age	3.08	0.000146±0.000123	age, sex	0.0670
walking (70 m/s)	−0.000121±0.000091		0.0590	0.013±0.006*	age, sex	3.99	0.035±0.009**		7.58	0.000213±0.000135	age, sex	0.0785
walking (100 m/s)	−0.000096±0.000149		0.0760	0.021±0.010*	age, sex	5.14	0.021±0.009*	age	4.66	0.000335±0.000210	age, sex	0.1012
walking (70 m/s) with a 3 kg load	−0.000186±0.000113	age	0.0689	0.012±0.007	age, sex	4.67	0.013±0.007	age, sex	4.22	0.000159±0.000168	age, sex	0.0920
jogging (140 m/s)	−0.000339±0.000242	sex	0.1547	0.031±0.018		10.51	0.031±0.015*		9.47	0.000343±0.000308	0.2038	

EE: energy expenditure, BW: body weight, L-RMR: lying resting metabolic rate , S-RMR: sitting resting metabolic rate, FFM: fat-free mass, SE: standard error.

[1] Regression coefficient: Relationship between physical activity indices and body weight from general linear models (GLM) adjusted for age and sex.

[2] Age, sex: Significance of age and sex in the GLM. ($P<0.05$)

[3] Average physical activity indices: Physical activity index of average body weight (60.0 kg) from GLM adjusted for age (43 y) and sex (0.5).

* $P<0.05$, ** $P<0.001$: There was a significant correlation between the index and body weight.

Table 4 The errors (%) in physical activity indices caused by a 10 kg above average body weight (60.0 kg)[1].

Activities	EE/BW (kcal·min^{-1}/kg)	EE/L-RMR (kcal·min^{-1}/kcal·min^{-1})	EE/S-RMR (kcal·min^{-1}/kcal·min^{-1})	EE/FFM (kcal·min^{-1}/kg)
Sedentary activities				
lying quietly	−5.3	—		
sitting quietly	−5.7		—	
working at the computer	−5.0			
Lifestyle activities				
vacuuming			5.3	
hanging laundry				
washing dishes				
carrying a small load			3.9	
Ambulant activities				
walking up stairs		4.2	4.6	3.7
downstairs				
walking (55 m/s)			3.6	
walking (70 m/s)		3.3	4.6	
walking (100 m/s)		4.1	4.6	
walking (70 m/s) with a 3 kg load				
jogging (140 m/s)			3.2	

EE: energy expenditure, BW: body weight, L-RMR: lying resting metabolic rate, S-RMR: sitting resting metabolic rate, FFM: fat-free mass.
[1] The discrepancies were calculated as follows;
The error (%)=B×x/PAIs(ave.)×100
B is the regression coefficient of the relationship between physical activity index and body weight from general linear models (GLM) adjusted for age and sex.
x is the difference from average body weight (60.0 kg).
$PAI_{(ave.)}$: Physical activity index for average body weight (60.0 kg) from GLM adjusted for age and sex.
Data are presented only for the significant relationship between physical activity index and body weight.
This table shows when x is +10 kg (70 kg). If x is 10 kg below average, the values of the discrepancies change from plus to minus or from minus to plus.

However, gender did not influence the correlation between PAI and BW in any activity except for EE/FFM-walking at 70 m/min with a 3-kg load. Therefore, we were able to combine the data for both sexes in most of the analyses.

Our results showed that the EE/BW was not appropriate for adjusting for body size in sedentary activities. In contrast, EE/L-RMR and EE/S-RMR were appropriate for sedentary activities, but inappropriate for the other activities. The EEs of sedentary activities were not weight-dependent and increased less than body weight. In contrast, the EEs of other activities were weight-dependent as they increased with increasing BW, whereas the observed L-RMR and S-RMR increased less with increasing BW. Therefore, EE/BW values in non-weight-dependent activities decreased and EE/L-RMR and EE/S-RMR values in weight-dependent activities increased with increasing BW. When we used EE/BW to evaluate the intensity of non-weight-dependent activities, this caused about a 20% higher estimate for 40 kg than for 80 kg BWs for the same activity. When we used EE/L-RMR or EE/S-RMR values to estimate the intensity of weight-dependent activities, this caused a 12% to 20% lower estimate for 40 kg than 80 kg BWs.

It has been reported that EE/RMR (including EE/BMR) was inappropriate for evaluation of intensity of some activities in girls and adults (Kriyan et al., 2006; Spadano et al., 2003; Haggarty et al., 1997). These researchers suggested it was necessary to take BW into consideration when using the BMR-multiple approach to estimate EE. Kuriyan et al., (2006) considered the relationship between EE/BMR, BW, and BMI. They found in three walking activities that BMI caused a 3% to 16% overestimation of EE/BMR in underweight men (BMI 16.0–18.3 kg/m^2, BW 42.3–49.8 kg) and a 3% to 11% underestimation of EE/BMR in overweight men (BMI 25.2–33.0 kg/m^2, BW 51.0–92.3 kg) when EE was estimated using the EE/BMR value for normal weight (BMI 19.1–24.3 kg/m^2, BW 46.6–66.5 kg) men. A similar tendency was observed by Haggarty et al., (1997) who showed that EE/BMR increased in a hyperbolic manner as weight increased, and that the rate of increase in EE/BMR became larger as intensity of activity rose. However, in our study the error in EE/BMR caused by BW for jogging was smaller than the difference for walking activities. This could be due to the fact that the EE of high intensity activities such as jogging was influenced not only by body size, but also by physical fitness (Margaria et al., 1963).

Our study indicated that S-RMR is undifferentiated from L-RMR in some cases. While the relationship between EE/L-RMR and BW was similar to the relationship between EE/S-RMR and BW, the errors caused by BW were more likely to be observed and be larger in EE/S-RMR than in EE/L-RMR. This discrepancy was probably caused by differences in the relationship between L-RMR, RMR, and BW. The difference in relationship was not statistically significant, although RMR increased less with BW compared to L-RMR.

On the other hand, EE/FFM was appropriate except for the ambulant activity of walking up stairs. We found that size-independent comparisons could be made using FFM. Moreover, previous studies succeeded in comparing physical activity using EE/FFM even between obese and nonobese adult subjects (Meijer et al., 1992) and between children and adolescents (Ekelund et al., 2004; Vermorel et al., 2005). On the basis of these results it appears that FFM has characteristics of both BW and RMRs.

Daily life consists of various kinds of activities. The average intensity of daily activity is evaluated as TEE/BW, TEE/L-RMR, or TEE/S-RMR. Some previous papers have suggested that TEE/BW (Lawrence, 1988; Margaria et al., 1963) and TEE/BMR (Goran, 1995; Carpenter et al., 1995; Goran, 2005) produced spurious differences when subjects of different size were compared across the range of TEE levels. We consider that the maximum difference from average BW was no more than±10% for a daily lifestyle in the normal BW group. For example, for an 80-kg person sitting quietly for 24 hours, the intensity of daily activity calculated using TEE/BW is about a 10% underestimation of the true intensity of daily activity. As daily activities consisted of various activities, including weight-dependent activities, the estimation errors caused by BW for particular activities become smaller than 10%. It seems unimportant that a 10% estimation error (at a maximum) can be caused by using PAIs, as intra-individual variation in TEE is approximately±10% in free-living activities for some weeks (Goran et al., 1993). In addition, there are unavoidable differences in methodology when using a physical activity record and physical activity recall. Comparing the unavoidable differences reported in a previous study (Conway et al., 2002) to the differences in our data, our maximum estimation error of 10% was about 1/3 that of the TEE estimated from the physical activity record and only 1/10 that of the TEE estimated from physical activity recall. Thus, our estimation errors in TEE appear to be considerably smaller than the other error factors. Moreover, use of PAIs may reduce errors when the intensity of daily activity is estimated using TEE/L-RMR and TEE/S-RMR to calculate physical activity levels.

It is important to note that a two-step procedure is required to predict physical activity level in general situations (Goran, 2005). In many cases, RMRs are predicted from an equation that often is based on BW. For example, the basal metabolism per unit body weight (BMR/BW) was included in the Dietary Reference Intakes for Japanese, 2010 (Ministry of Health, Labour, and Welfare, Japan, 2009). However, BMR/BW correlated negatively with BW (Takahashi et al., 2007). As BMR corresponded to L-RMR in the present study, there will be an estimation error when BMR/BW is used in the estimate of BMR. According to our study, −5% to 6% errors may occur in BMR values when the BW is more than 10 kg above average. In addition, it is also necessary to consider the effect of the errors in estimations of RMRs. As the measurement error of body weight is considerably smaller than the prediction error of BMR or RMR, different effects of the errors would occur when using the predicted values.

This study had several limitations. The coefficient of variation tended to be large, especially for lifestyle activities. This was attributed to the fact that we prescribed only the duration of the activities and did not strictly prescribe the motion of activities. In addition, we did not obtain information on the motion for each activity of each subject, and accordingly could not examine the effects of inter-individual differences. Other limitations included the fact that the methodology for determining body composition in our study was not sophisticated, as we estimated FFM using bioelectrical impedance analysis. Therefore, the results for EE/FFM would include the predictive error associated with the measurement method (Korth et al., 2007). Another limitation is that we did not take into account aerobic fitness, although we considered the influence of this factor was small, as subjects who were not athletes performed each activity for only several minutes.

In conclusion, although BW influenced EE/BW in sedentary activities and also the three alternative indices in other activities, the error in the estimate of total EE using any of these indices should be considerably less than±10% for body weights within the normal range. The PAIs are simple calculations and make it easy to compare the intensities of activity and to estimate EEs using activity diaries, recall, and direct observation data. It is most important in future studies to consider the size of the error effects of the indices. It will then be possible to properly compare physical activity among different body sizes.

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METs in Adults While Playing Active Video Games: A Metabolic Chamber Study

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ABSTRACT

MIYACHI, M., K. YAMAMOTO, K. OHKAWARA, and S. TANAKA. METs in Adults While Playing Active Video Games: A Metabolic Chamber Study. *Med. Sci. Sports Exerc.*, Vol. 42, No. 6, pp. 1149–1153, 2010. **Purpose**: Active video game systems controlled through arm gestures and motions (Nintendo Wii Sports) and video games controlled through force plate (Wii Fit Plus) are becoming increasingly popular. This study was performed to determine the energy expenditure (EE) during Wii Fit Plus and Wii Sports game activities. **Methods**: Twelve adult men and women performed all the activities of Wii Sports (five activities: golf, bowling, tennis, baseball, and boxing) and Wii Fit Plus (63 activities classified as yoga, resistance, balance, and aerobic exercises). Each activity was continued for at least 8 min to obtain a steady-state EE. Because EE was assessed in an open-circuit indirect metabolic chamber consisting of an airtight room (20,000 or 15,000 L), subjects were freed of apparatus to collect expired gas while playing the games. MET value was calculated from resting EE and steady-state EE during activity. **Results**: The mean MET values of all 68 activities were distributed over a wide range from 1.3 METs (Lotus Focus) to 5.6 METs (single-arm stand). The mean MET values in yoga, balance, resistance, and aerobic exercise of Wii Fit Plus and Wii Sports were 2.1, 2.0, 3.2, 3.4, and 3.0 METs, respectively. Forty-six activities (67%) were classified as light intensity (<3 METs), and 22 activities (33%) were classified as moderate intensity (3.0–6.0 METs). There were no vigorous-intensity activities (>6.0 METs). **Conclusions**: Time spent playing one-third of the activities supplied by motion- and gesture-controlled video games can count toward the daily amount of exercise required according to the guidelines provided by the American College of Sports Medicine and the American Heart Association, which focus on 30 min of moderate-intensity daily physical activity 5 $d \cdot wk^{-1}$. **Key Words:** ENERGY EXPENDITURE, HUMAN CALORIMETER, METABOLIC EQUIVALENTS, Wii

BASIC SCIENCES

Adults in developed countries are currently recommended to take more than a half hour of moderate to vigorous physical activity each day (6). However, many individuals spend many hours sitting in front of their TV playing video games. More than half of American adults (53%) play video games, and about one in five adults (21%) play every day or almost every day (9). This type of sedentary behavior is causally linked to chronic diseases and obesity (5,13).

The active video game systems controlled through arm gestures and motions (Wii Sports; Nintendo Inc., Kyoto, Japan) as well as the video games controlled through force plate (Wii Fit Plus; Nintendo Inc.) are becoming increasingly popular. These systems may attenuate a sedentary lifestyle and permit video game enthusiasts to increase their energy expenditure (EE), which is associated with prevention of obesity and lifestyle-related diseases (7,10). Several studies indicated that playing new-generation active computer games involves significantly greater EE than playing sedentary computer games but does not use as much energy as playing sport itself (3,4,8). The energy spent while playing active Wii Sports games was not of sufficiently high intensity to contribute toward the recommended daily amount of exercise (3,4,8). However, EE for these activities may have been underestimated because measurements were obtained using the Intelligent Device for Energy Expenditure and Activity (IDEEA) system (3) or indirect calorimeter with a facemask connected directly to an analyzer (4,8). The IDEEA does not detect arm or trunk movements well, considering the principle for physical activity evaluation (4,15), and therefore may underestimate EE. During measurement of EE with a facemask, the subjects' movements were tightly restricted (4,8). This may result in misleading conclusions regarding whether sufficient EE can be obtained while playing any mode of Wii Sports or Wii Fit Plus. Therefore, further research is needed to understand the energy load of the new modes of computer interaction and game play.

The present study was performed to determine EE and MET during various modes of activity in Wii Sports and Wii Fit Plus software using an open-circuit indirect metabolic chamber. The metabolic chamber can correctly

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measure whole-body EE and MET intensities while subjects are freely playing the game.

METHODS

Subjects. Twelve Japanese men (n = 7) and women (n = 5) participated in this study. All subjects were adults (25–44 yr) and were free of chronic diseases that could affect metabolism or daily physical activity. They had not engaged in regular intensive sports or physical activity for the past year. Informed consent was obtained from all subjects. The study protocol was approved by the ethical committee of the National Institute of Health and Nutrition.

Experimental design. Each subject completed metabolic chamber measurement under three different protocols on three different days: sitting rest, Wii Fit Plus balance and resistance exercises, Wii Fit Plus yoga and aerobic exercises, and Wii Sports. The order of these protocols was randomly assigned for each subject. Resting metabolic rate was evaluated immediately before performing activities of Wii Fit Plus balance and resistance exercises in the morning. Subjects abstained from meals and drink, except water, for at least 5 h before entering the metabolic chamber. Weight, height, and body composition analyzed by bioelectrical impedance were measured immediately before each session.

Wii Fit Plus software contains various activities consisting of 18 modes of yoga, 15 modes of resistance exercise, 16 modes of balance exercise, and 14 modes of aerobic exercise. Wii Sports software includes five activities: golf, bowing, tennis, baseball, and boxing. Each activity was continued for at least 8 min to obtain the steady-state EE separated by appropriate rest periods. Although game lengths of each activity were initially from 1 to 4 min, personal skills, fitness, and type of game resulted in fluctuations in the game lengths. The games in all activities were restarted immediately over and over again for 8 min. All subjects began each activity at the beginner level, and they performed these in an active fashion.

Metabolic chamber. The open-circuit indirect metabolic chamber used consisted of an airtight room (20,000 or 15,000 L) equipped with a bed, a desk, a chair, a TV with a video game player, a telephone, and a toilet. Thus, subjects were freed of apparatus to collect expired gas while playing the games. The temperature and the relative humidity in the room were controlled at 25°C and 55%, respectively. The oxygen (O_2) and carbon dioxide (CO_2) concentrations of the air supply and exhaust were measured by mass spectrometry. For each experiment, the gas analyzer (ARCO-1000A-CH; Arco System, Kashiwa, Japan) was initially calibrated using a certified gas mixture and atmospheric air. The flow rate exhausted from the chamber was measured by pneumotachography (FLB1; Arco System). The flowmeter was calibrated before each measurement, and the flow rate was maintained at 60 $L \cdot min^{-1}$ ambient temperature pressure (ATP). O_2 consumption and CO_2 production ($\dot{V}O_2$ and $\dot{V}CO_2$, respectively) were determined from the flow rate of exhaust from the chamber and the concentrations of the inlet and outlet air of the chamber, respectively (12). EE was estimated from $\dot{V}O_2$ and $\dot{V}CO_2$ using Weir's (14) equation. The accuracy and the precision of our metabolic chamber for measuring EE as determined by the alcohol combustion test were 99.2% ± 0.7% (mean ± SD) over 6 h and 99.2% ± 3.0% over 30 min (2).

Each activity was continued for at least 8 min. The metabolic chamber continuously analyzed O_2 and CO_2 concentrations for each gas and flow rate five times per minute and calculated EE for each minute. The EE increased progressively in the first 2–3 min of each activity, and then steady-state EE was obtained from 3 to 8 min. Therefore, we defined the mean value of EE for the last 5 min as steady-state EE of each activity. This increase in EE within a few minutes and the subsequent steady-state EE indicated that our metabolic chamber method has sufficient sensitivity. MET value was calculated from resting and steady-state EE during the activity.

Data calculation and analysis. All data are expressed as the means ± SD. Data were analyzed using one-way repeated-measures ANOVA with corrected *post hoc* paired t-test. We used the Statistical Package for the Social Sciences for Windows (SPSS Inc., Chicago, IL) for statistical analyses, and $P < 0.05$ was taken to indicate statistical significance.

RESULTS

The characteristics of the study subjects were as follows: age = 34 ± 6 yr, height = 167.4 ± 7.6 cm, body weight = 64.3 ± 15.0 kg, and percent fat = 22.3% ± 3.9%. Figure 1 shows the MET intensities during gaming. There were no significant differences in MET values between men and women. Therefore, mean MET values of each activity were calculated from the data of both sexes combined. The mean MET values of all 68 activities were distributed over a wide range from 1.3 METs (Lotus Focus: balance exercise) to 5.6 METs (single-arm stand: resistance exercise). The mean MET values in yoga, balance, resistance, and aerobic exercise of Wii Fit Plus and Wii Sports were 2.1 ± 0.6, 2.0 ± 0.6, 3.2 ± 1.2, 3.4 ± 0.9, and 3.0 ± 0.9 METs, respectively. The MET values of yoga and balance exercise were significantly lower than those of resistance and aerobic exercise of Wii Fit Plus or Wii Sports. Forty-six activities (67%) were classified as light intensity (<3 METs), and 22 activities (33%) were classified as moderate intensity (3.0–6.0 METs). There was no activity with intensity >6.0 METs.

The MET values of playing Wii Sports versions of activities were markedly lower than those of actual sports activities reported previously as follows (1): golf = 3.0–4.5 METs, bowling = 3.0, tennis = 5.0–7.0 METs, baseball = 5.0 METs, and boxing = 6.0–12.0 METs. However, the MET values of the Wii Fit Plus versions of yoga and

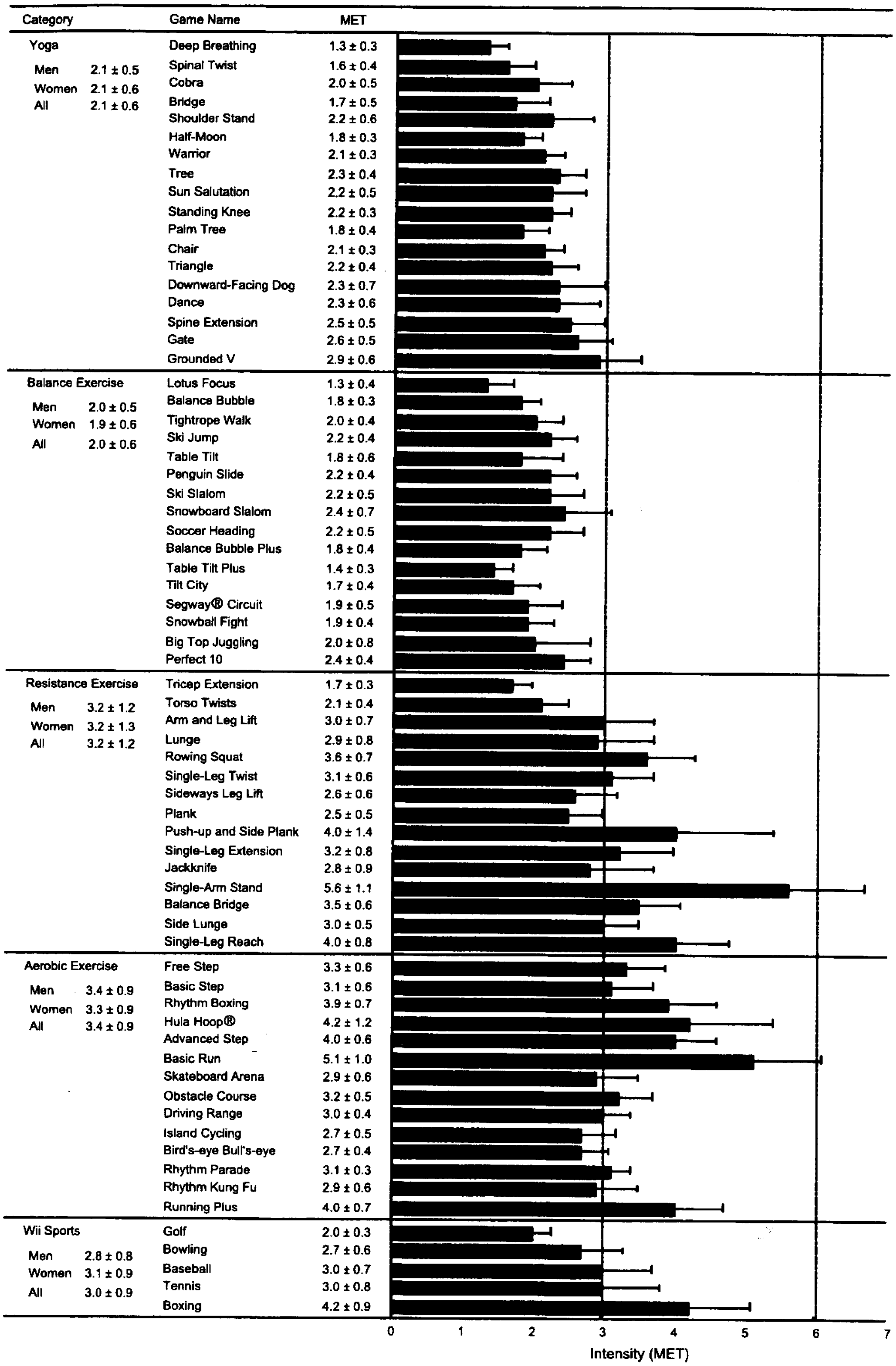

FIGURE 1—Mean values ± SD of METs while playing Wii Fit Plus and Wii Sports.

resistance exercise were similar to actual yoga (2.5 METs) and resistance exercise (3.0 METs) (1).

DISCUSSION

We determined EE and MET values during Wii Sports and Wii Fit Plus game activities using an open-circuit indirect metabolic chamber. The main findings of the present study were as follows. First, the mean MET values in yoga, balance, resistance, and aerobic exercise of Wii Fit Plus and Wii Sports were 2.1, 2.0, 3.2, 3.4, and 3.0 METs, respectively. Second, 46 activities (67%) were classified as light intensity (<3 METs), and 22 activities (33%) were classified as moderate intensity (3.0–6.0 METs). There were no vigorous-intensity activities (>6.0 METs). These findings suggest that time spent playing one-third of the activities supplied by motion- and gesture-controlled video games can partially count toward the daily amount of exercise required according to the guidelines provided by the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) (6).

The ACSM or AHA physical activity guidelines (6) focus on 30 min of moderate-intensity daily physical activity 5 $d \cdot wk^{-1}$ or vigorous-intensity aerobic activity for a minimum of 20 min for 3 $d \cdot wk^{-1}$. Moderate and vigorous physical activities were generally defined as intensities of 3.0–6.0 and >6.0 METs, respectively (6). Twenty-two (33%) of the 68 activities in Wii Fit Plus and Wii Sports were classified as moderate-intensity activities on the basis of MET intensity. Taken together, the observations of the present study suggest that the time spent playing Wii Fit Plus or Wii Sports can partially count toward the daily amount of exercise required according to the guidelines provided by the ACSM and the AHA (6). On the other hand, Graves et al. (3) concluded that Wii Sports games were not sufficiently vigorous to meet the guidelines for daily physical activity in children. We speculate that this discrepancy may be associated with differences in age of subjects and of measurement methods in EE and MET values (15).

Wii Sports gaming or Wii Fit Plus aerobic exercise involved less EE than authentic sports or exercises (1) because playing these active video games involved little horizontal locomotion. However, these light to moderate activities may contribute to increased EE, and even the small energy gap induced by the increased EE may be effective for prevention of weight gain (7). Furthermore, there were no moderate- or vigorous-intensity activities in Wii Fit Plus yoga and balance exercise. However, we should emphasize that yoga and balance exercise are effective in improving flexibility and in fall prevention, respectively (11). In addition, active computer games stimulated positive activity behaviors: the players were on their feet, and they moved in all directions while performing basic motor control and fundamental movement skills that were not evident during seated gaming. Given the current prevalence of overweight and obesity, such positive behaviors should be encouraged.

The strength of the present study is that the metabolic chamber method could replicate the conditions under which the subjects play the games in their home because subjects were free from apparatus used to measure EE when playing the game. In fact, the MET values of Wii Sports activities in our study were slightly higher than those in previous reports using the IDEEA system (3) or indirect calorimeter (4,8). On the other hand, the limitations of this study were that the sample size was small and the results were applicable only to healthy adults and to the Wii Fit Plus and Wii Sports computer games, which are more active than other Wii games.

CONCLUSIONS

We determined the MET values of Wii Sports and Wii Fit Plus game activities under free-living conditions using an open-circuit indirect metabolic chamber in healthy adults. Time spent playing one-third of the activities supplied by Wii Sports and Wii Fit Plus can count toward the daily amount of exercise required according to the guidelines provided by the ACSM and the AHA, which focus on 30 min of moderate-intensity daily physical activity 5 $d \cdot wk^{-1}$. Further research is needed to investigate the efficacy of the games on health promotion.

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The results of the present study do not constitute endorsement by the authors and the American College of Sports Medicine.

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Original Article

Association between Perceived Neighborhood Environment and Walking among Adults in 4 Cities in Japan

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ABSTRACT

Background: Recent research highlights the importance of environment as a determinant of physical activity; however, evidence among Japanese is sparse. The aim of this study was to examine the association between perceived neighborhood environment and neighborhood walking for multiple purposes among Japanese.

Methods: We conducted a population-based, cross-sectional study of 1461 Japanese adults (age: 48.2 ± 14.1 years, men: 44.8%). Neighborhood environment and walking were assessed by a validated questionnaire. The odds ratio of active walkers was calculated in relation to environmental characteristics after adjustment for age, sex, and other potential confounders.

Results: Participants were more likely to walk when they perceived that there was high residential density (odds ratio, 1.47; 95% confidence interval, 1.11–1.96), fair land use mix–diversity (1.37, 1.04–1.81), good walking/cycling facilities (1.56, 1.19–2.04), and attractive aesthetics (1.49, 1.14–1.95). Environmental factors associated with walking differed with respect to the purpose for walking. The environmental characteristics associated with walking for daily errands and with walking for commuting were similar, and included residential density and land use mix. Walking for leisure was associated with walking/cycling facilities, aesthetics, and traffic safety. Stratified analyses showed some sex-specific associations. Among women, there was an unexpected inverse association of leisure walking with both residential density and land use mix–diversity.

Conclusions: The association between neighborhood environment and walking differed by walking purpose. The results were generally consistent with those of studies conducted in Western countries, except for the association of high residential density and good land use mix–diversity with less leisure walking in women. These results suggest possible targets for environmental interventions to promote walking.

Key words: active transport; neighborhood environment; physical activity; policy; walking

INTRODUCTION

Regular physical activity reduces the risk of mortality, and the incidence of cardiovascular diseases, diabetes, and some cancers.[1–3] However, a large part of the population is not physically active in Japan and in many other countries.[4,5] Thus, physical activity promotion is a public health priority.[6] Data on physical activity determinants and correlates are needed as a basis for developing effective interventions. Many studies have focused on individual demographics and psychobehavioral factors.[7] However, recent progress in research suggests that certain environmental characteristics, such as residential density, access to destinations, walking facilities, aesthetics, safety, and access to exercise facilities are related to physical activity.[7–13] Interventions that target individuals have only a minimal impact on the physical activity levels of whole populations[14,15]; however, changes to the environment are believed to have a long-term and substantial impact.[16]

Although there is accumulating evidence on the association between physical activity and environment, the relevant studies have been mostly limited to Western countries, in particular the United States and Australia[12]; only a few have been undertaken in Japan.[17–19] Evidence from study settings—including Japan—where the environment, culture, and physical activity patterns differ from those of Western

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countries, is thus valuable. Indeed, evidence from Japan could support or refute the generalizability of previous studies conducted in Western countries, and/or add new findings regarding associations between environment and physical activity. Also, data from Japanese are needed for the development of physical activity interventions in Japan.

We previously reported associations of environment with physical activity, using a convenience sample of Japanese adults.[18] In that previous study, environmental characteristics were associated with physical activity, but the findings were limited by the use of simple measures that could not differentiate the purposes for walking. In the present cross-sectional study, we used a random community sample from 4 Japanese cities and measured walking as the outcome. Because environmental correlates are specific to the type and purpose of physical activity,[11,20] the aim of this study was to examine environmental correlates of neighborhood walking and its components, including walking for daily errands, walking for leisure, and commuting on foot.

METHODS

Participants and data collection

This cross-sectional study was conducted from February 2007 through January 2008. A total of 4000 residents aged 20 to 69 years and living in 4 Japanese cities (Koganei, Tsukuba, Shizuoka, Kagoshima) were randomly selected from the registry of residential addresses and stratified by sex, age (20–29, 30–39, 40–49, 50–59, and 60–69 years), and city of residence, so that the sample included 2000 subjects of each sex, 800 subjects of each age category, and 1000 subjects from each city. As a result, the addresses of 100 subjects of a specific sex, a specific age category, and a specific city were obtained. Four cities were chosen so as to include various environmental conditions. Koganei is in the Tokyo metropolitan area and Tsukuba is a university town located 50 km northeast of Tokyo. Shizuoka and Kagoshima are located in central and western Japan, respectively, and are the capital cities of prefectures that include both urban and relatively rural areas. For data collection, a questionnaire was sent to and collected from participants via postal mail. To increase the response rate, invitation letters that described the content of the study were sent to all 4000 subjects 2 weeks before the survey. During the survey period, a call center was established to answer the questions of the subjects. Nonrespondents were mailed 2 additional requests to join the survey. If a participant submitted an incomplete survey, we asked that the survey be completed again. Ultimately, of the 4000 subjects identified, 1508 (37.7%) responded to the survey. After data cleaning, valid data were obtained from 1461 participants (final response rate: 36.5%). All participants signed an informed consent document before answering the questionnaire, and the study received prior approval from the Tokyo Medical University Ethics Committee.

Assessment of perceived neighborhood environment

On the self-administered questionnaire, the Neighborhood Environment Walkability Scale–Abbreviated Japanese Version (NEWS–AJ) was used as the environmental measure.[21–23] The NEWS questionnaire was originally developed in the United States to evaluate several neighborhood environmental factors believed to be related to physical activity undertaken for multiple purposes. It has been used in various countries.[24–26] The NEWS–AJ consists of 54 questions that assess 8 neighborhood environmental factors: (1) residential density, (2) land use mix–diversity, (3) land use mix–access, (4) street connectivity, (5) walking and cycling facilities, (6) aesthetics, (7) traffic safety, and (8) crime safety. Several of these factors are related to the concept of walkability, which is the ability to walk from one's home to nearby destinations. "Neighborhood" in this questionnaire meant the area within a 15-minute walk from a participant's residence. A sample of the questions used is shown in the Appendix. Scores on the 8 subscales were calculated by using a standardized scoring manual.[27] Higher scores indicate a more favorable environment for walking. The score for residential density was calculated as the sum of the weighted score of 5 items.[27] Land use mix–diversity was based on the reported walking distance to a list of 23 possible destinations, including shops, services, and recreation facilities. As for the other variables, scores were estimated as the mean of scale items that used a 4-point rating scale (1 = strongly disagree, 4 = strongly agree), including reverse coding of selected items. The psychometric properties of the questionnaire and the process by which it was translated into Japanese were reported in a previous study.[23] The test–retest reliabilities of the 8 subscales were from $r = 0.76$ to $r = 0.96$.

Assessment of walking

For the assessment of physical activity, a self-administered questionnaire was used. The questionnaire asked participants about their walking frequency (days/week), and average walking duration each day (min/day), with respect to 6 purposes: walking for daily errands, walking for leisure, commuting on foot to work, commuting on foot to school, walking during work, and walking for other purposes. The questionnaire instructed participants to consider all walks that involved at least 5 minutes of continuous activity. Walking time (min/week) was calculated as the product of walking frequency and duration. In this study, 4 variables were examined: (1) neighborhood walking (sum of the duration of 4 types of walking, walking for daily errands, walking for leisure, commuting on foot to work, and commuting on foot to school, min/week), and 3 specific types of walking, namely, (2) walking for daily errands (min/week), (3) walking for leisure (min/week), and (4) commuting on foot to work (min/week). We examined these 3 specific types of walking because they were expected to occur in the participant's neighborhood.

Although commuting to school was also expected to occur in the neighborhood, we excluded this variable from the specific analyses because the present sample included only 31 participants (2.1%) who walked to school. The Spearman correlation coefficient between total walking time (the sum of 6 types of walking time) calculated from the questionnaire and step counts per day, as assessed by accelerometer in a part of the present study sample ($n = 783$), was 0.30 ($P < 0.001$).

Sociodemographic and other variables

The sex and age of each participant were obtained from the registry of residential addresses of each city. Information on employment status, years of education, height, weight, and self-rated health was obtained by self-report. Body mass index (BMI) was calculated from self-reported weight and height. Self-rated health was measured with a single item that asked participants to rate their health: participants chose the most suitable answer from a 5-point scale—excellent, very good, good, fair, and poor—for the statement, "In general, would you say that your health is...?".

Statistical analyses

To examine the association between the neighborhood environment as the independent variable and walking as the dependent variable, odds ratios for active walkers were calculated using logistic regression models. For the analysis, the scores for the 8 environmental variables were converted into tertiles (high/middle/low for residential density and good/fair/poor for the other 7 variables). For each of the 4 walking variables, participants were classified into 2 groups. For neighborhood walking, participants were divided into 2 groups by using the median: ≤90 min/week or >90 min/week. Regarding walking for daily errands, walking for leisure, and commuting on foot to work, the proportions of participants who reported walking for these purposes were less than 50%. Thus, participants were divided into 2 groups for each of these purposes: those who walked for a given purpose and those who did not. In the analyses of commuting on foot to work, we used data only from employed participants ($n = 1083$). To calculate odds ratios, the environmental factors expected to be associated with lower levels of walking were used as references ("low" for residential density and "poor" for the other 7 variables), ie, an odds ratio higher than 1.00 indicates the association of an activity-supportive environmental characteristic with active walking. Odds ratios were adjusted by age, sex, location of residence, employment status, educational level, BMI, and self-rated health. Statistical significance was considered to be present when $P < 0.05$. All analyses were conducted by using SPSS version 15.0 for Windows (SPSS Inc., Tokyo, Japan).

RESULTS

Table 1 shows the characteristics of the participants. In the overall sample, 44.8% were men. The mean age ± standard deviation (SD) was 48.2 ± 14.1 years. The sample included participants of Tsukuba (25.1%), Koganei (26.9%), Shizuoka (26.1%), and Kagoshima (21.9%). The proportion of overweight participants (BMI ≥25 kg/m²) was 26.5% of men and 12.4% of women. The proportions of participants who

Table 1. Characteristics of participants

	Overall $n = 1461$		Men $n = 654$		Women $n = 807$	
	n	%	*n*	%	*n*	%
Age, years						
≤29	221	15.1	82	12.5	139	17.2
30–39	212	14.5	84	12.8	128	15.9
40–49	307	21.0	136	20.8	171	21.2
50–59	327	22.4	160	24.5	167	20.7
60+	394	27.0	192	29.4	202	25.0
mean ± SD	48.2 ± 14.1		49.6 ± 13.7		47.1 ± 14.3	
Location of residence						
Tsukuba	366	25.1	177	27.1	189	23.4
Koganei	393	26.9	172	26.3	221	27.4
Shizuoka	382	26.1	168	25.7	214	26.5
Kagoshima	320	21.9	137	20.9	183	22.7
Education, years						
≤12	600	41.1	268	41.0	332	41.1
13+	861	58.9	386	59.0	475	58.9
Employment status						
Employed	1083	74.1	559	85.5	524	64.9
Not employed	378	25.9	95	14.5	283	35.1
BMI, kg/m²						
≥25	273	18.7	173	26.5	100	12.4
<25	1188	81.3	481	73.5	707	87.6
Mean ± SD	22.4 ± 3.2		23.4 ± 3		21.5 ± 3.1	
Self-rated health						
Excellent	20	1.4	9	1.4	11	1.4
Very good	182	12.5	78	11.9	104	12.9
Good	577	39.5	245	37.5	332	41.1
Fair	603	41.3	281	43.0	322	39.9
Poor	79	5.4	41	6.3	38	4.7
Neighborhood walking[a]						
No	417	28.9	217	33.4	200	25.2
Yes	1026	71.1	432	66.6	594	74.8
Mean ± SD[b], min/week	209 ± 185		203 ± 176		214 ± 191	
Walking for daily errands						
No	837	57.3	468	71.6	369	45.7
Yes	624	42.7	186	28.4	438	54.3
Mean ± SD[b], min/week	121 ± 126		91 ± 101		134 ± 133	
Walking for leisure						
No	949	65.0	438	67.0	511	63.3
Yes	512	35.0	216	33.0	296	36.7
Mean ± SD[b], min/week	180 ± 168		194 ± 180		170 ± 157	
Commuting on foot to work						
No	1038	71.0	426	65.1	612	75.8
Yes	423	29.0	228	34.9	195	24.2
Mean ± SD[b], min/week	111 ± 90		123 ± 99		98 ± 76	
Commuting on foot to school						
No	1430	97.9	641	98.0	789	97.8
Yes	31	2.1	13	2.0	18	2.2
Mean ± SD[b], min/week	106 ± 77		114 ± 83		101 ± 75	

[a]Neighborhood walking was defined as the sum of walking for daily errands, walking for leisure, commuting on foot to work, and commuting on foot to school.
[b]Mean ± SD indicates walking time for participants who did each type of walking.

Table 2. Number and proportion of participants in each environmental category

	Range of category[a]	Overall n = 1461		Men n = 654		Women n = 807	
		n	%	n	%	n	%
Residential density (5–805)[b]							
High	259<	432	29.8	178	27.5	254	31.8
Medium	184<, ≤259	514	35.5	234	36.1	280	35.0
Low	≤184	502	34.7	236	36.4	266	33.3
Mean ± SD		248 ± 96		242 ± 93		252 ± 98	
Land use mix–diversity (1–5)[b]							
Good	3.41<	471	32.8	214	33.3	257	32.4
Fair	2.57<, ≤3.41	483	33.7	211	32.9	272	34.3
Poor	≤2.57	481	33.5	217	33.8	264	33.3
Mean ± SD		2.95 ± 0.87		2.94 ± 0.84		2.96 ± 0.88	
Land use mix–access (1–4)[b]							
Good	3.14<	479	33.1	204	31.6	275	34.3
Fair	2.57<, ≤3.14	484	33.4	213	33.0	271	33.8
Poor	≤2.57	485	33.5	229	35.4	256	31.9
Mean ± SD		2.87 ± 0.63		2.85 ± 0.63		2.90 ± 0.64	
Street connectivity (1–4)[b]							
Good	3.00<	436	30.3	192	29.8	244	30.7
Fair	2.70<, ≤3.00	540	37.6	233	36.2	307	38.7
Poor	≤2.70	462	32.1	219	34.0	243	30.6
Mean ± SD		2.80 ± 0.73		2.76 ± 0.77		2.83 ± 0.7	
Walking/cycling facilities (1–4)[b]							
Good	2.40<	473	32.8	195	30.3	278	34.9
Fair	1.80<, ≤2.40	457	31.7	219	34.0	238	29.9
Poor	≤1.80	510	35.4	230	35.7	280	35.2
Mean ± SD		2.20 ± 0.65		2.17 ± 0.63		2.22 ± 0.67	
Aesthetics (1–4)[b]							
Good	2.80<	557	38.6	233	36.1	324	40.6
Fair	2.30<, ≤2.80	443	30.7	198	30.7	245	30.7
Poor	≤2.30	443	30.7	214	33.2	229	28.7
Mean ± SD		2.48 ± 0.67		2.42 ± 0.66		2.52 ± 0.66	
Traffic safety (1–4)[b]							
Good	3.00<	496	34.2	197	30.4	299	37.3
Fair	2.50<, ≤3.00	548	37.8	263	40.6	285	35.5
Poor	≤2.50	406	28.0	188	29.0	218	27.2
Mean ± SD		2.67 ± 0.54		2.63 ± 0.55		2.70 ± 0.54	
Crime safety (1–4)[b]							
Good	3.17<	585	40.3	267	41.2	318	39.6
Fair	2.83<, ≤3.17	445	30.7	211	32.6	234	29.1
Poor	≤2.83	421	29.0	170	26.2	251	31.3
Mean ± SD		2.97 ± 0.46		2.98 ± 0.45		2.96 ± 0.47	

[a]Classification of categories was by tertiles.
[b]Figures in parentheses indicate score ranges.

reported neighborhood walking, walking for daily errands, walking for leisure, and commuting on foot to work were 71.1%, 42.7%, 35.0%, and 29.0%, respectively.

Table 2 shows the mean scores and SDs for the 8 environmental variables. The tertiles of these variables are also indicated, and participants were categorized into 3 groups.

Table 3 shows the odds ratios for active walkers by environmental factor in the overall sample. Four environmental variables (high residential density, fair land use mix–diversity, good walking/cycling facilities, and good aesthetics) were significantly associated with neighborhood walking. Participants were more likely to walk when they perceived that there was high residential density (odds ratio, 1.47; 95% confidence interval, 1.11–1.96), fair land use mix–diversity (1.37, 1.04–1.81), good walking/cycling facilities (1.56, 1.19–2.04), and good aesthetics (1.49, 1.14–1.95). Regarding walking for particular purposes, there were specific associations between environment and walking. Active walking for daily errands was associated with 6 categories in 4 environmental variables: high residential density, good and fair land use mix–diversity, good and fair land use mix–access, and good street connectivity. In contrast, the environmental factors that were significantly associated with walking for leisure were different, and included good walking/cycling facilities, good and fair aesthetics, and good and fair traffic safety. The results regarding commuting on foot to work were similar to those for walking for daily errands: 3 environmental variables were significant—high residential density, good land use mix–diversity, and good land use mix–access.

Analyses stratified by sex (men, Table 4; women, Table 5) revealed some differences between men and women. Walking for daily errands and commuting on foot to work were associated with a higher number of environmental variables in women than in men. In men, there was no significant association between environment and commuting on foot to work. In the analyses of walking for leisure, the associations between environment and walking also differed by sex. Among men, those who perceived good and fair walking/cycling facilities, good aesthetics, and good traffic safety tended to walk for leisure; among women, high residential density, good land use mix–diversity, and good and fair aesthetics were significantly associated with this type of walking. An interesting unexpected result was that women who reported high residential density and good land use mix–diversity walked less for leisure.

DISCUSSION

In the present study, the perceived environmental features of a neighborhood were associated with walking in that neighborhood. In addition, the environmental variables associated with walking differed with regard to the purpose for walking, which was consistent with previous studies.[10,11] Walking for transportation (ie, errands and commuting to work) was associated with neighborhood walkability, as defined by high residential density, mixed land use, and good street connectivity. Walking for leisure was associated with the quality of pedestrian facilities, neighborhood aesthetics, and traffic safety.

Because sex differences in the associations between environment and physical activity have not been widely studied, those observed in the present study are of particular interest. Sex-specific analyses revealed significant associations between environment and commuting on foot to work only in women. The reasons for this are unclear. One possible reason is that women are more likely to work within walking

Table 3. Odds ratios for active walkers by environmental factors (all respondents)

	Neighborhood walking n = 1443			Walking for daily errands n = 1461			Walking for leisure n = 1461			Commuting on foot to work n = 1083[e]		
	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[b] (95% CI)	P value
Residential density												
High	57.6 (246/427)	1.47 (1.11, 1.96)	0.008	54.4 (235/432)	2.09 (1.56, 2.81)	<0.001	33.8 (146/432)	0.94 (0.70, 1.26)	0.677	51.1 (162/317)	1.99 (1.41, 2.81)	<0.001
Medium	49.4 (252/510)	1.12 (0.85, 1.46)	0.424	41.8 (215/514)	1.30 (0.98, 1.72)	0.067	35.4 (182/514)	1.02 (0.78, 1.35)	0.868	38.8 (149/384)	1.26 (0.90, 1.76)	0.171
Low	43.6 (216/495)	1.00		33.9 (170/502)	1.00		35.3 (177/502)	1.00		27.3 (102/373)	1.00	
Land use mix–diversity												
Good	54.1 (251/464)	1.19 (0.89, 1.60)	0.238	48.4 (228/471)	1.69 (1.25, 2.30)	<0.001	34.8 (164/471)	0.93 (0.68, 1.27)	0.643	47.6 (162/340)	1.51 (1.06, 2.16)	0.023
Fair	55.0 (264/480)	1.37 (1.04, 1.81)	0.027	46.2 (223/483)	1.53 (1.14, 2.05)	0.004	37.9 (183/483)	1.17 (0.88, 1.57)	0.278	39.1 (140/358)	1.05 (0.74, 1.49)	0.769
Poor	41.2 (195/473)	1.00		34.1 (164/481)	1.00		32.6 (157/481)	1.00		29.6 (108/365)	1.00	
Land use mix–access												
Good	56.2 (266/473)	1.33 (1.00, 1.78)	0.053	52.2 (250/479)	2.11 (1.56, 2.84)	<0.001	37.0 (177/479)	1.01 (0.75, 1.36)	0.944	47.6 (157/330)	1.68 (1.18, 2.38)	0.004
Fair	51.1 (247/483)	1.17 (0.89, 1.55)	0.257	43.8 (212/484)	1.55 (1.16, 2.06)	0.003	35.1 (170/484)	1.00 (0.75, 1.34)	0.988	38.0 (139/366)	1.14 (0.81, 1.60)	0.441
Poor	42.9 (204/475)	1.00		33.0 (160/485)	1.00		33.0 (160/485)	1.00		30.9 (116/376)	1.00	
Street connectivity												
Good	50.6 (219/433)	1.01 (0.77, 1.34)	0.924	47.0 (205/436)	1.43 (1.07, 1.91)	0.015	36.5 (159/436)	1.05 (0.79, 1.40)	0.750	36.7 (115/313)	0.98 (0.70, 1.39)	0.929
Fair	52.1 (279/536)	1.11 (0.85, 1.45)	0.440	45.0 (243/540)	1.28 (0.97, 1.68)	0.080	34.3 (185/540)	1.03 (0.79, 1.36)	0.811	44.1 (179/406)	1.31 (0.95, 1.80)	0.097
Poor	47.6 (215/452)	1.00		37.0 (171/462)	1.00		34.6 (160/462)	1.00		33.8 (117/346)	1.00	
Walking/cycling facilities												
Good	55.8 (261/468)	1.56 (1.19, 2.04)	0.001	46.9 (222/473)	1.26 (0.96, 1.65)	0.100	39.1 (185/473)	1.47 (1.11, 1.93)	0.006	42.0 (144/343)	1.36 (0.99, 1.88)	0.059
Fair	50.9 (230/452)	1.22 (0.93, 1.60)	0.150	43.1 (197/457)	1.13 (0.86, 1.49)	0.381	35.0 (160/457)	1.21 (0.92, 1.61)	0.177	41.4 (139/336)	1.19 (0.86, 1.65)	0.298
Poor	44.3 (223/503)	1.00		39.2 (200/510)	1.00		31.0 (158/510)	1.00		33.2 (129/389)	1.00	
Aesthetics												
Good	57.8 (318/550)	1.49 (1.14, 1.95)	0.004	48.1 (268/557)	1.28 (0.97, 1.69)	0.079	43.4 (242/557)	2.22 (1.66, 2.97)	<0.001	40.8 (162/397)	1.03 (0.74, 1.42)	0.882
Fair	46.7 (204/437)	0.99 (0.75, 1.31)	0.942	41.5 (184/443)	1.04 (0.78, 1.39)	0.774	34.3 (152/443)	1.57 (1.16, 2.12)	0.004	38.0 (127/334)	0.90 (0.65, 1.27)	0.561
Poor	43.6 (191/438)	1.00		37.7 (167/443)	1.00		25.1 (111/443)	1.00		36.1 (122/338)	1.00	
Traffic safety												
Good	54.0 (263/487)	1.02 (0.77, 1.35)	0.895	43.3 (215/496)	0.87 (0.65, 1.17)	0.356	39.3 (195/496)	1.48 (1.10, 2.00)	0.009	41.8 (150/359)	1.08 (0.77, 1.51)	0.675
Fair	49.1 (265/540)	0.93 (0.71, 1.22)	0.591	43.4 (238/548)	0.99 (0.75, 1.31)	0.949	36.7 (201/548)	1.39 (1.04, 1.86)	0.025	36.9 (146/396)	0.92 (0.66, 1.28)	0.631
Poor	46.4 (188/405)	1.00		41.1 (167/406)	1.00		27.3 (111/406)	1.00		36.1 (116/321)	1.00	
Crime safety												
Good	50.4 (293/581)	1.03 (0.79, 1.36)	0.816	43.2 (253/585)	1.05 (0.8, 1.39)	0.721	36.6 (214/585)	1.07 (0.81, 1.42)	0.618	40.5 (169/417)	1.22 (0.87, 1.69)	0.245
Fair	51.6 (225/436)	1.14 (0.86, 1.52)	0.366	42.7 (190/445)	1.05 (0.79, 1.41)	0.721	35.5 (158/445)	1.14 (0.85, 1.53)	0.375	37.1 (125/337)	0.91 (0.65, 1.28)	0.590
Poor	47.8 (199/416)	1.00		42.5 (179/421)	1.00		32.3 (136/421)	1.00		36.6 (118/322)	1.00	

Abbreviations: OR, odds ratio; CI, confidence interval.
[a]Odds ratios were calculated after adjustment for age, sex, location of residence, employment status, education, BMI, and self-rated health.
[b]Odds ratios were calculated after adjustment for age, sex, location of residence, education, BMI, and self-rated health.
[c]For the 4 respective categories, an active walker was defined as a respondent who reported neighborhood walking >90 min/week, walking for daily errands, walking for leisure, or walking to work.
[d]Figures in parentheses indicate (number of active walkers/number of participants in category).
[e]Commuting on foot to work was examined only among the 1083 participants who were employed.

Table 4. Odds ratios for active walkers by environmental factors (men)

	Neighborhood walking $n = 649$			Walking for daily errands $n = 654$			Walking for leisure $n = 654$			Commuting on foot to work $n = 559$[e]		
	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[b] (95% CI)	P value
Residential density												
High	54.2 (96/177)	1.47 (0.95, 2.27)	0.083	36.5 (65/178)	1.74 (1.09, 2.76)	0.020	37.6 (67/178)	1.56 (0.99, 2.47)	0.056	48.4 (75/155)	1.33 (0.81, 2.18)	0.264
Medium	42.9 (100/233)	0.87 (0.58, 1.31)	0.503	29.5 (69/234)	1.20 (0.77, 1.88)	0.419	28.2 (66/234)	0.84 (0.54, 1.30)	0.439	43.7 (86/197)	1.18 (0.74, 1.88)	0.486
Low	40.8 (95/233)	1.00		22.0 (52/236)	1.00		33.5 (79/236)	1.00		31.2 (63/202)	1.00	
Land use mix–diversity												
Good	50.5 (107/212)	1.36 (0.87, 2.14)	0.180	29.0 (62/214)	1.21 (0.73, 1.99)	0.457	36.9 (79/214)	1.53 (0.95, 2.48)	0.081	48.3 (86/178)	1.34 (0.79, 2.27)	0.280
Fair	51.2 (108/211)	1.67 (1.09, 2.58)	0.019	35.5 (75/211)	1.70 (1.07, 2.71)	0.026	33.6 (71/211)	1.58 (1.00, 2.51)	0.052	44.0 (80/182)	1.20 (0.73, 1.97)	0.475
Poor	35.0 (75/214)	1.00		21.2 (46/217)	1.00		28.6 (62/217)	1.00		29.6 (56/189)	1.00	
Land use mix–access												
Good	51.5 (104/202)	1.37 (0.88, 2.13)	0.162	35.8 (73/204)	1.88 (1.17, 3.02)	0.009	35.8 (73/204)	1.41 (0.88, 2.26)	0.155	48.2 (81/168)	1.07 (0.64, 1.80)	0.784
Fair	46.9 (100/213)	1.11 (0.73, 1.67)	0.633	29.6 (63/213)	1.42 (0.90, 2.24)	0.135	34.3 (73/213)	1.23 (0.79, 1.91)	0.369	37.5 (69/184)	0.71 (0.44, 1.16)	0.175
Poor	39.4 (89/226)	1.00		21.8 (50/229)	1.00		29.3 (67/229)	1.00		36.8 (74/201)	1.00	
Street connectivity												
Good	43.8 (84/192)	0.83 (0.54, 1.26)	0.381	27.6 (53/192)	1.05 (0.66, 1.66)	0.831	33.3 (64/192)	1.01 (0.65, 1.58)	0.965	36.6 (59/161)	0.71 (0.43, 1.16)	0.173
Fair	48.7 (113/232)	1.08 (0.72, 1.62)	0.701	33.5 (78/233)	1.42 (0.92, 2.18)	0.111	32.2 (75/233)	1.20 (0.78, 1.84)	0.415	46.3 (94/203)	1.06 (0.67, 1.68)	0.803
Poor	44.7 (96/215)	1.00		25.1 (55/219)	1.00		33.3 (73/219)	1.00		38.0 (71/187)	1.00	
Walking/cycling facilities												
Good	50.5 (98/194)	1.72 (1.13, 2.61)	0.011	29.7 (58/195)	1.10 (0.71, 1.71)	0.677	38.5 (75/195)	1.90 (1.22, 2.95)	0.005	42.7 (70/164)	1.25 (0.78, 2.00)	0.363
Fair	48.6 (106/218)	1.46 (0.98, 2.19)	0.066	31.1 (68/219)	1.16 (0.76, 1.77)	0.499	33.8 (74/219)	1.56 (1.01, 2.40)	0.045	43.2 (80/185)	1.07 (0.67, 1.71)	0.762
Poor	38.8 (88/227)	1.00		26.1 (60/230)	1.00		27.0 (62/230)	1.00		36.6 (74/202)	1.00	
Aesthetics												
Good	53.7 (124/231)	1.41 (0.93, 2.12)	0.102	33.9 (79/233)	1.36 (0.88, 2.11)	0.163	39.1 (91/233)	1.76 (1.13, 2.74)	0.013	46.3 (93/201)	1.24 (0.77, 1.99)	0.370
Fair	41.3 (81/196)	0.94 (0.62, 1.44)	0.785	26.3 (52/198)	0.96 (0.61, 1.51)	0.853	32.8 (65/198)	1.42 (0.90, 2.25)	0.128	38.2 (65/170)	0.97 (0.60, 1.58)	0.910
Poor	40.8 (87/213)	1.00		25.7 (55/214)	1.00		26.6 (57/214)	1.00		35.4 (64/181)	1.00	
Traffic safety												
Good	50.0 (97/194)	1.26 (0.81, 1.95)	0.303	26.4 (52/197)	0.76 (0.47, 1.21)	0.245	38.6 (76/197)	1.65 (1.03, 2.64)	0.039	44.2 (72/163)	1.19 (0.72, 1.97)	0.487
Fair	47.5 (124/261)	1.18 (0.78, 1.78)	0.426	30.0 (79/263)	0.95 (0.62, 1.46)	0.817	35.4 (93/263)	1.48 (0.95, 2.32)	0.086	40.4 (90/223)	1.04 (0.65, 1.66)	0.877
Poor	38.3 (72/188)	1.00		28.7 (54/188)	1.00		23.9 (45/188)	1.00		35.7 (60/168)	1.00	
Crime safety												
Good	42.9 (114/266)	0.83 (0.55, 1.27)	0.400	25.8 (69/267)	0.67 (0.43, 1.05)	0.081	35.6 (95/267)	1.35 (0.85, 2.13)	0.201	40.5 (92/227)	1.00 (0.62, 1.62)	0.999
Fair	49.5 (103/208)	1.10 (0.71, 1.70)	0.682	28.9 (61/211)	0.77 (0.49, 1.21)	0.261	35.1 (74/211)	1.47 (0.92, 2.37)	0.108	38.0 (68/179)	0.71 (0.43, 1.18)	0.191
Poor	45.0 (76/169)	1.00		32.4 (55/170)	1.00		26.5 (45/170)	1.00		41.9 (62/148)	1.00	

Abbreviations: OR, odds ratio; CI, confidence interval.
[a]Odds ratios were calculated after adjustment for age, sex, location of residence, employment status, education, BMI, and self-rated health.
[b]Odds ratios were calculated after adjustment for age, sex, location of residence, education, BMI, and self-rated health.
[c]For the 4 respective categories, an active walker was defined as a respondent who reported neighborhood walking >90 min/week, walking for daily errands, walking for leisure, or walking to work.
[d]Figures in parentheses indicate (number of active walkers/number of participants in category).
[e]Commuting on foot to work was examined only among the 559 participants who were employed.

Table 5. Odds ratios for active walkers by environmental factors (women)

	Neighborhood walking $n = 794$			Walking for daily errands $n = 807$			Walking for leisure $n = 807$			Commuting on foot to work $n = 524$[e]		
	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[a] (95% CI)	P value	% of active walkers[c,d]	OR[b] (95% CI)	P value
Residential density												
High	60.0 (150/250)	1.49 (1.02, 2.18)	0.038	66.9 (170/254)	2.35 (1.60, 3.43)	<0.001	31.1 (79/254)	0.64 (0.43, 0.96)	0.029	53.7 (87/162)	3.29 (1.97, 5.49)	<0.001
Medium	54.9 (152/277)	1.35 (0.93, 1.95)	0.111	52.1 (146/280)	1.32 (0.92, 1.90)	0.127	41.4 (116/280)	1.12 (0.77, 1.62)	0.566	33.7 (63/187)	1.45 (0.87, 2.40)	0.153
Low	46.2 (121/262)	1.00		44.4 (118/266)	1.00		36.8 (98/266)	1.00		22.8 (39/171)	1.00	
Land use mix–diversity												
Good	57.1 (144/252)	1.10 (0.74, 1.63)	0.643	64.6 (166/257)	2.14 (1.44, 3.17)	<0.001	33.1 (85/257)	0.63 (0.41, 0.95)	0.027	46.9 (76/162)	1.77 (1.07, 2.94)	0.026
Fair	58.0 (156/269)	1.21 (0.84, 1.76)	0.310	54.4 (148/272)	1.38 (0.95, 1.99)	0.092	41.2 (112/272)	0.96 (0.65, 1.40)	0.822	34.1 (60/176)	1.01 (0.61, 1.67)	0.960
Poor	46.3 (120/259)	1.00		44.7 (118/264)	1.00		36.0 (95/264)	1.00		29.5 (52/176)	1.00	
Land use mix–access												
Good	59.8 (162/271)	1.35 (0.91, 1.98)	0.131	64.4 (177/275)	2.28 (1.55, 3.35)	<0.001	37.8 (104/275)	0.78 (0.52, 1.16)	0.216	46.9 (76/162)	2.83 (1.67, 4.80)	<0.001
Fair	54.4 (147/270)	1.22 (0.84, 1.78)	0.298	55.0 (149/271)	1.63 (1.12, 2.36)	0.010	35.8 (97/271)	0.80 (0.54, 1.17)	0.249	38.5 (70/182)	1.98 (1.19, 3.29)	0.008
Poor	46.2 (115/249)	1.00		43.0 (110/256)	1.00		36.3 (93/256)	1.00		24.0 (42/175)	1.00	
Street connectivity												
Good	56.0 (135/241)	1.19 (0.81, 1.75)	0.364	62.3 (152/244)	1.78 (1.22, 2.60)	0.003	38.9 (95/244)	1.08 (0.73, 1.59)	0.704	36.8 (56/152)	1.28 (0.77, 2.13)	0.336
Fair	54.6 (166/304)	1.14 (0.80, 1.63)	0.478	53.7 (165/307)	1.20 (0.85, 1.71)	0.307	35.8 (110/307)	0.97 (0.67, 1.40)	0.857	41.9 (85/203)	1.61 (1.01, 2.57)	0.048
Poor	50.2 (119/237)	1.00		47.7 (116/243)	1.00		35.8 (87/243)	1.00		28.9 (46/159)	1.00	
Walking/cycling facilities												
Good	59.5 (163/274)	1.53 (1.07, 2.18)	0.020	59.0 (164/278)	1.35 (0.95, 1.91)	0.091	39.6 (110/278)	1.24 (0.87, 1.79)	0.239	41.3 (74/179)	1.54 (0.97, 2.43)	0.065
Fair	53.0 (124/234)	1.08 (0.75, 1.57)	0.669	54.2 (129/238)	1.09 (0.76, 1.57)	0.636	36.1 (86/238)	1.02 (0.70, 1.49)	0.928	39.1 (59/151)	1.40 (0.87, 2.26)	0.171
Poor	48.9 (135/276)	1.00		50.0 (140/280)	1.00		34.3 (96/280)	1.00		29.4 (55/187)	1.00	
Aesthetics												
Good	60.8 (194/319)	1.59 (1.10, 2.30)	0.013	58.3 (189/324)	1.24 (0.87, 1.77)	0.239	46.6 (151/324)	2.83 (1.90, 4.22)	<0.001	35.2 (69/196)	0.79 (0.49, 1.27)	0.335
Fair	51.0 (123/241)	1.02 (0.7, 1.5)	0.914	53.9 (132/245)	1.10 (0.76, 1.60)	0.613	35.5 (87/245)	1.69 (1.11, 2.57)	0.014	37.8 (62/164)	0.87 (0.54, 1.42)	0.578
Poor	46.2 (104/225)	1.00		48.9 (112/229)	1.00		23.6 (54/229)	1.00		36.9 (58/157)	1.00	
Traffic safety												
Good	56.7 (166/293)	0.82 (0.56, 1.20)	0.317	54.5 (163/299)	0.95 (0.65, 1.37)	0.768	39.8 (119/299)	1.26 (0.85, 1.87)	0.248	39.8 (78/196)	0.95 (0.59, 1.53)	0.835
Fair	50.5 (141/279)	0.72 (0.49, 1.04)	0.083	55.8 (159/285)	1.02 (0.70, 1.47)	0.928	37.9 (108/285)	1.23 (0.83, 1.82)	0.299	32.4 (56/173)	0.80 (0.49, 1.30)	0.372
Poor	53.5 (116/217)	1.00		51.8 (113/218)	1.00		30.3 (66/218)	1.00		36.6 (56/153)	1.00	
Crime safety												
Good	56.8 (179/315)	1.23 (0.85, 1.76)	0.272	57.9 (184/318)	1.41 (0.99, 2.01)	0.059	37.4 (119/318)	0.96 (0.67, 1.40)	0.844	40.5 (77/190)	1.35 (0.85, 2.16)	0.208
Fair	53.5 (122/228)	1.14 (0.78, 1.66)	0.504	55.1 (129/234)	1.28 (0.88, 1.86)	0.190	35.9 (84/234)	0.98 (0.66, 1.44)	0.909	36.1 (57/158)	1.02 (0.63, 1.66)	0.930
Poor	49.8 (123/247)	1.00		49.4 (124/251)	1.00		36.3 (91/251)	1.00		32.2 (56/174)	1.00	

Abbreviations: OR, odds ratio; CI, confidence interval.
[a]Odds ratios were calculated after adjustment for age, sex, location of residence, employment status, education, BMI, and self-rated health.
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[e]Commuting on foot to work was examined only among the 524 participants who were employed.