Accelerometers with a DC (direct current) response are capable of measuring acceleration due to movement and gravitational acceleration [17]. Therefore, filter processing that removes gravitational acceleration is performed to detect dynamic movements and gravitational acceleration is used to discriminate static postures such as lying and standing. Although the discrimination of posture is important in understanding behavior patterns, it is also necessary to determine what kinds of activities a person is performing under sitting or standing conditions. We hypothesized that information from the gravitational acceleration signal may contribute not only to discrimination of posture but also to classification of physical activity into locomotive or household activity, because household activities tend to involve a change in inclination of the upper body in addition to movement.

The purpose of this study was to develop a new algorithm for quick and accurate classification of physical activity into either locomotive or household activity using a triaxial accelerometer and to compare the accuracy of the algorithm with a previously proposed method.

2. Methods

2.1. Subjects

Sixty-six volunteers (31 men and 35 women) participated in this study. The subjects were separated randomly into a validation group ($n = 44$) and a cross-validation group ($n = 22$). Physical characteristics of the subjects are shown in Table 1. Before measurements, the purpose and procedure of the study were explained in detail. Written informed consent was obtained from all subjects. When we recruited subjects, participants were excluded from the study if they had any contraindications to exercise or if they were physically unable to complete the activities. This study protocol was approved by the Ethical Committee of the National Institute of Health and Nutrition in Japan.

2.2. Protocol

Before testing, height and weight were measured with subjects in light clothing without shoes using a stadiometer and a physician's scale. Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively. Body mass index was calculated as weight (kg) divided by height squared (m^2).

All 66 subjects performed 12 sequences of normal daily movements in a controlled laboratory setting while wearing a triaxial accelerometer on the left side of the waist. The testing procedure was the same for all subjects. Participants performed each activity for 3–7 min with a break of a few minutes between each activity. The selected activities were personal computer (PC) work, laundry, dishwashing, moving a small load (5 kg), vacuuming, slow walking (3.3 km/h), normal walking (4.2 km/h), brisk walking (6.0 km/h), normal walking while carrying a bag (3 kg) in the hand, jogging (8.4 km/h) on a track, and ascending and descending stairs at personal normal speed (Table 2). These activities were chosen as representative activities of daily life and were based on our observations for 3 days in free-living conditions. The preliminary study was performed using the activity records of 93 subjects living in the Tokyo metropolitan area.

2.3. Triaxial accelerometer device

In order to perform this experiment, we used a triaxial accelerometer device with 4 GB of memory (Omron Healthcare, Kyoto, Japan) consisting of a MEMS-based accelerometer (LIS3LV02DQ; ST-Microelectronics) which responds to both acceleration due to movement and gravitational acceleration. The sensor is built in a plastic case designed to be clipped onto a waist belt. The device measures 80 mm × 20 mm × 50 mm and weighs 60 g, including batteries. During the experiment, the device was attached at waist level on the left side using an elastic belt. A commercial device (Omron Healthcare, Active Style Pro HJA-350IT) has been developed from the device used in the present study.

Table 1
Physical characteristics of subjects.

	Men	Women	Total
Validation group			
n	21	23	44
Age (years)	42.2 ± 14.4	43.0 ± 13.1	42.6 ± 13.7
Height (cm)	170.2 ± 5.8	159.3 ± 5.4	164.5 ± 7.8
Weight (kg)	68.3 ± 15.1	55.6 ± 9.8	61.6 ± 14.1
BMI (kg/m^2)	23.4 ± 4.2	21.9 ± 3.7	22.6 ± 4.0
Cross-validation group			
n	10	12	22
Age (years)	41.9 ± 14.3	42.0 ± 11.4	42.0 ± 12.8
Height (cm)	170.2 ± 7.5	156.9 ± 5.2	162.9 ± 9.2
Weight (kg)	68.2 ± 11.9	54.9 ± 7.6	61.0 ± 11.8
BMI (kg/m^2)	23.4 ± 3.2	22.3 ± 2.9	22.8 ± 3.1

Values are means ± SD; BMI, body mass index.

Table 2
Household and locomotive activities performed in this study.

PC work: typing with a personal computer (7 min)
Laundry: carrying clothes from a laundry basket and hanging up clothes (6 min)
Dishwashing: washing the dishes (6 min)
Moving a small load: lifting a small load of 5 kg and unloading it after a few steps (5 min)
Vacuuming: cleaning the floor with a vacuum cleaner (6 min)
Slow walking: walking at 55 m/min around a track (6 min)
Normal walking: walking at 70 m/min around a track (5 min)
Brisk walking: walking at 100 m/min around a track (5 min)
Walking while carrying a bag: walking at 70 m/min around a track while carrying a bag of 3 kg (5 min)
Jogging: jogging at 140 m/min around a track (4 min)
Ascending stairs: walking up stairs at a self-selected speed (3 min)
Descending stairs: walking down stairs at a self-selected speed (3 min)

2.4. Analysis of acceleration signal

Anteroposterior (x-axis), mediolateral (y-axis), and vertical (z-axis) accelerations were obtained from the triaxial accelerometer during each activity at a sampling rate of 32 Hz. The acceleration data are expressed relative to g ($1\ g = 9.81\ m/s^2$). With a 12-bit analog-to-digital converter, the maximum scaling of the acceleration data was $\pm 6\ g$ (resolution: 0.003 g). The acceleration data were uploaded to a personal computer. The signals obtained from the triaxial accelerometer were processed as follows. Each of the three signals from the triaxial accelerometer was passed through a second-order Butterworth high-pass filter to remove the gravitational acceleration component from the signal. The cut-off frequency was chosen based on frequency analysis of movements conducted. The power spectrum of each direction was calculated by fast Fourier transform (FFT) for a temporal window that contained 256 samples of the signal. This was normalized to the maximum power of each window, and the normalized power spectrums of the three directions were composited. We calculated the integral of the absolute value of the accelerometer output of each of the three axes using acceleration signals (X, Y, Z) over a 10-s time interval. The interval size was determined based on physiological aspects and the processing performance of the CPU; it has been reported that the use of 10-s epochs does not result in a significant underestimation of high-intensity activity relative to 5-s epochs whereas longer epochs do [18]. Then, the calculated horizontal acceleration in the X–Y plane (horizontal acceleration filtered, HAF) and the calculated total three-dimensional acceleration (total acceleration filtered, TAF) were determined. In addition, total acceleration using an unfiltered acceleration signal (total acceleration unfiltered, TAU) was calculated. Finally, the ratios of unfiltered to filtered total acceleration (TAU/TAF) and of filtered vertical acceleration (VAF) to HAF (VAF/HAF), as proposed by Midorikawa et al. [16], were calculated. When TAU/TAF was calculated, the phases of TAU and TAF were matched in consideration of the phase shift of the high-pass filter. The acceleration signals from six 10-s epochs in the middle of each activity were processed to various acceleration output variables.

2.5. Statistical analysis

Statistical analyses were carried out using SPSS Version 14.0 for Windows (SPSS, Inc., Chicago, IL). All results are shown as the mean ± SD. $P < 0.05$ was considered statistically significant.

To assess the cut-off value for classification of household and locomotive activities, receiver-operating characteristic (ROC) curve analysis was applied to the acceleration data. We calculated the sensitivities and specificities using the TAU/TAF and VAF/HAF ratios. The sensitivity was multiplied by the specificity, and the point with the maximum product of sensitivity and specificity was considered to be the most valid discrimination cut-off value. The triaxial accelerometer signals from the validation group were used to identify the optimum cut-off value of parameters to classify physical activity. This cut-off value was then applied to the cross-validation group and the accuracy of discrimination was evaluated.

3. Results

FFT analysis showed that for locomotive activities, peak power appeared at a frequency of 1.0 Hz or more and the frequency of the peak increased with an increase in walking pace. For household

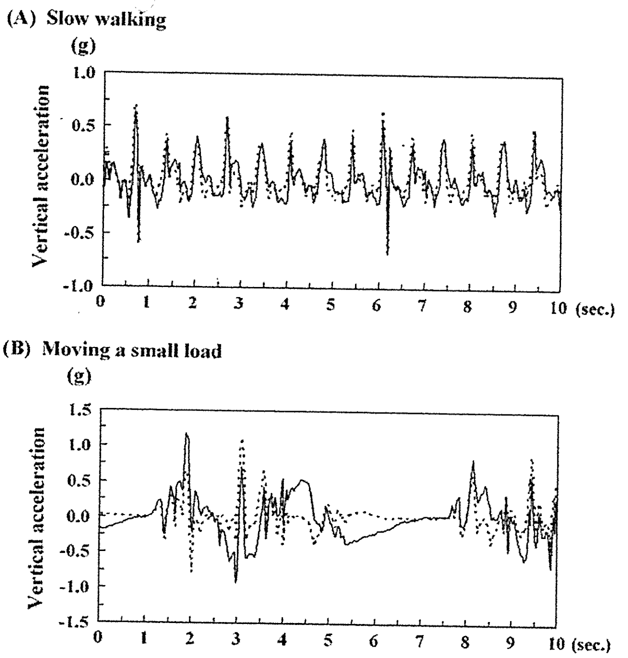

Fig. 1. Typical examples of a vertical acceleration signal during slow walking (A) and while moving a small load (B). Dotted line is before high-pass filtering, and solid line is after high-pass filtering.

activities, peak power appeared at 1.0 Hz or less and the mean frequency of the peak was 0.29 ± 0.19 Hz. Therefore, the cut-off frequency for the high-pass filter was set at 0.7 Hz (mean + 2SD).

Fig. 1 shows typical examples of a vertical acceleration signal before and after high-pass filtering during slow walking (Fig. 1A) and moving a small load (Fig. 1B). TAU during moving a small load (0.34 g) was larger than that during slow walking (0.23 g). TAF during both physical activities was similar (0.22 g and 0.22 g, respectively). Therefore, TAU/TAF during moving a small load (1.55) was larger than that during slow walking (1.04).

Fig. 2A shows TAU/TAF in the validation group. As in the case illustrated in Fig. 1, the average TAU/TAF during locomotive activities was 1.03 ± 0.03 (range 0.96–1.12). In contrast, the average TAU/TAF during household activities was 2.46 ± 0.73 (range 1.19–5.53). The product obtained by multiplying the sensitivity and specificity from the TAU/TAF data was 1.0 when TAU/TAF was between 1.13 and 1.19. Therefore, the discrimination cut-off value was set at 1.16, which is the mid-point for the TAU/TAF data. When the discrimination cut-off value derived from the validation group was applied to the cross-validation group, the percentage of correct discrimination was over 95.5% (Table 3).

The VAF/HAF ratio in the validation group is shown in Fig. 2B. The average VAF/HAF during locomotive activities was 1.13 ± 0.36 (range 0.56–2.58) and that during household activities was 0.55 ± 0.13 (range 0.32–0.99). The largest product of sensitivity and specificity using the VAF/HAF data was 0.74. Table 3 shows the results from applying the discrimination cut-off value to the cross-validation group. Vacuuming, doing laundry, dishwashing, and normal walking while carrying a bag were correctly classified by the VAF/HAF cut-off ratio. Percentages of correct discrimination for other activities ranged from 63.6% to 95.5%.

4. Discussion

Our major finding in this study is that locomotive and household activities can be accurately classified from the analysis of both unfiltered and filtered acceleration signals. We used the ratio of TAU/TAF to classify physical activities into either

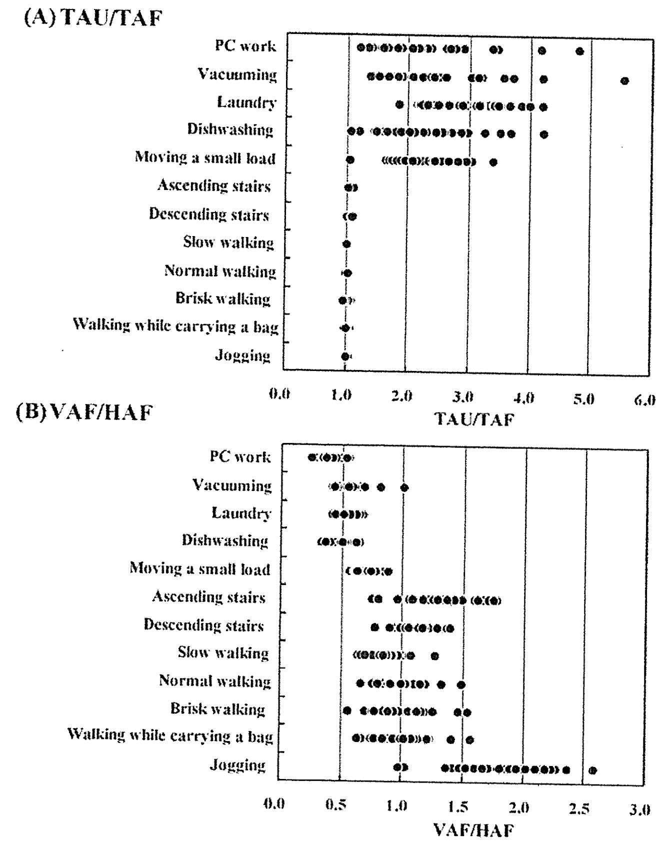

Fig. 2. The ratio of unfiltered to filtered total accelerations (TAU/TAF) (A) and the ratio of filtered vertical to filtered horizontal accelerations (VAF/HAF ratio) (B) during each activity in the validation group ($n = 44$).

locomotive or household activities. The TAU/TAF ratios obtained during locomotive activities (around 1.0) and household activities (>1.0) were entirely different. Since the distinction between locomotive, household and light activities is important for accurate estimation of energy expenditure using an accelerometer, various classification methods have been proposed in previous studies [16,19]. Light activities can be discriminated from locomotive or household activities by using only total acceleration, because a lower total acceleration is observed for light activities than for the other two types of activities [16]. However, locomotive and household activities could not be clearly distinguished by a previously reported method [19]. It is very important to estimate EE accurately, including the proportion of time spent in household activities throughout the day, which is a large component of NEAT.

Table 3
Percentage of correct discrimination in cross-validation group ($n = 22$).

	TAU/TAF (%)	VAF/HAF (%)
PC work	100	100
Vacuuming	100	100
Laundry	100	100
Dishwashing	100	100
Moving a small load	100	63.6
Ascending stairs	100	90.9
Descending stairs	95.5	90.9
Slow walking	95.5	81.8
Normal walking	95.5	95.5
Brisk walking	100	95.5
Normal walking while carrying a bag	100	100
Jogging	100	100

TAU/TAF, ratio of unfiltered to filtered total acceleration; VAF/HAF, ratio of vertical to horizontal acceleration.

Therefore, our findings are very pertinent to future research in this area.

The compendium of physical activities [20] is a common source of information regarding the intensities of various activities. The EEs of both normal walking and vacuuming are similar according to the compendium listings, whereas in this study the total acceleration for vacuuming was 1/4 that for normal walking. These results are consistent with previous reports that household activities have a higher oxygen cost, at the same total acceleration, compared with walking and running [19,21]. The increased EE during household activities is due to arm movements, lifting and carrying objects, climbing hills and stairs, and changing directions in the horizontal plane [21]. Therefore, different prediction equations are needed for accurate estimation of household and locomotive activities.

The acceleration signal was passed through a high-pass filter to remove the gravitational acceleration component in order to examine the actual relation of acceleration to physical activity [22]. In the present study, total acceleration was calculated from both the filtered and the unfiltered signals. If the acceleration signal is derived from locomotive activity which consists of only dynamic movement, the TAU/TAF ratio is mostly found to be 1.0. In contrast, if the acceleration signal is derived from household activity which consists of dynamic movement and gravitational acceleration, the TAU/TAF ratio is found to be larger than 1.0. The change in the gravitational acceleration component indicates a change in the inclination of the acceleration sensor. Because the acceleration sensor is attached to the waist of the subject, TAU/TAF reflects dynamic changes in body posture. The waist is not in the upper body, but the inclination of the upper body accompanies that of the waist in most instances. Therefore the gravitational acceleration signal at the waist reflects postural changes of the upper body to some degree. The cut-off value for classification was set at 1.16 in the present study, as a slight postural change at the waist seems sufficient to capture the postural changes of the upper body. Previous studies have reported a classification method for physical activity using the gravitational component of the triaxial accelerometer [23,24]. However, most such classification methods only discriminate static postures such as sitting and standing.

The TAU/TAF ratio was around 1.0 during locomotive activities regardless of the speed and was above 1.0 during household activities. This result suggests that there is a characteristic dynamic change in posture, such as inclining the upper part of the body forward, during household activities. While mainly the lower limbs move during locomotive activities such as walking and jogging, movement of the arms while lifting and pushing accompany household activities. Therefore, some researchers have attempted to classify and quantify the different types of physical activities using both trunk acceleration and wrist acceleration [25–27]. However, using multiple sensors can have disadvantages such as increased monetary cost and reduced convenience. If classification can be done with a single acceleration sensor, those disadvantages can be avoided. It has been reported that wrist-worn accelerometer signals can explain only a small part of the variance in EE [25,26]. In addition, it has been reported that the EEs of upper limb movements in activities such as deskwork were not different from the resting level, whereas self-care tasks accompanied by trunk movements approximately doubled the resting level [25]. Therefore, measurements of changes in posture are more important for discrimination of household activity intensity than measurements of upper arm movements.

The percentage of correct discrimination between locomotive and household activities by the VAF/HAF ratio was over 63.6% in the present study. Midorikawa et al. [16] reported that the sensitivity and specificity for discriminating between housework and walking using the VAF/HAF ratio was over 90%. This discrepancy may be due to differences between the protocols. Although 12 activities were chosen in the present study, only four types of activity (sitting, standing, housework, and walking) were performed in the study of Midorikawa et al. [16]. Moving a small load, which is a dynamic activity, complicated by lifting and walking, had the lowest discrimination accuracy of the 12 activities and slow walking had the lowest discrimination accuracy among the locomotive activities. The VAF/HAF ratio reflects the main direction of movement and may be associated with differences in movement between the upper body and the lower body. In the above two activities (moving a small load and slow walking), movement of both the upper and lower body occur to some degree and there may be large inter-individual differences. Therefore, the VAF/HAF ratio may tend to misclassify dynamic household activities and light locomotive activities.

Crouter et al. [19] attempted to distinguish walking and running from all other activities by calculating the coefficient of variation from Actigraph data. Because locomotive activities yielded a consistent minute-to-minute count, the coefficient of variation during locomotive activities was lower than that of other activities. They used six 10-s epochs of data to calculate the coefficient of variation for each minute. Therefore, it is necessary to keep a constant speed for at least 1 min for an accurate discrimination of walking with their method. Although it is possible to maintain an even pace in experimental conditions using a treadmill, speed is more variable in free-living walking because of pauses for traffic lights or walking on curved roads. Therefore, it is preferable that the discrimination be done over shorter time periods. In contrast, we could discriminate with 10-s epochs of data using TAU/TAF. Further research is required to determine the effectiveness of our approach for measurements of daily life EE.

In addition, it is possible that TAU/TAF may increase even during locomotive activities due to soft tissue movement or loosening of the belt that attaches the device to the waist. Since our study included only five subjects whose BMI was more than 30, we do not know the degree to which soft tissue may influence the results. It would be necessary to confirm whether our new algorithm can be adjusted for subjects with abdominal obesity.

In conclusion, we have shown that it is possible to classify locomotive and household activities using a single waist-mounted triaxial accelerometer. By analyzing raw acceleration data, changes in gravitational acceleration could be evaluated. The TAU/TAF ratio during household activities was larger than that during locomotive activities.

Acknowledgments

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Conflicts of interest

I declare that I have no conflict of interest.

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エネルギー

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Key word　推定エネルギー必要量，身体活動レベル，基礎代謝量，付加量

はじめに

2009年5月下旬に日本人の食事摂取基準(2010年版)が発表された．2010年版でのエネルギーの考え方は，日本人の食事摂取基準(2005年版)に準拠している．しかし，その後の研究成果の蓄積により，多くの部分が改定されている．本誌の読者の方がたも，その改定がどのようなエビデンスや理由からなされたかを知ったうえで活用していただきたい．

推定エネルギー必要量

2010年版の食事摂取基準では，個人と集団の両方についての確率論的考え方を明確に取り入れた．すなわち，推定エネルギー必要量について，個人の場合は「当該年齢，性別，身長，体重，および健康な状態を損なわない身体活動量を有する人において，エネルギー出納（成人の場合，エネルギー摂取量ーエネルギー消費量）がゼロ（0）となる確率が最も高くなると推定される，習慣的なエネルギー摂取量の1日当たりの平均値」と定義される（図1）．当該個人のエネルギー摂取量が推

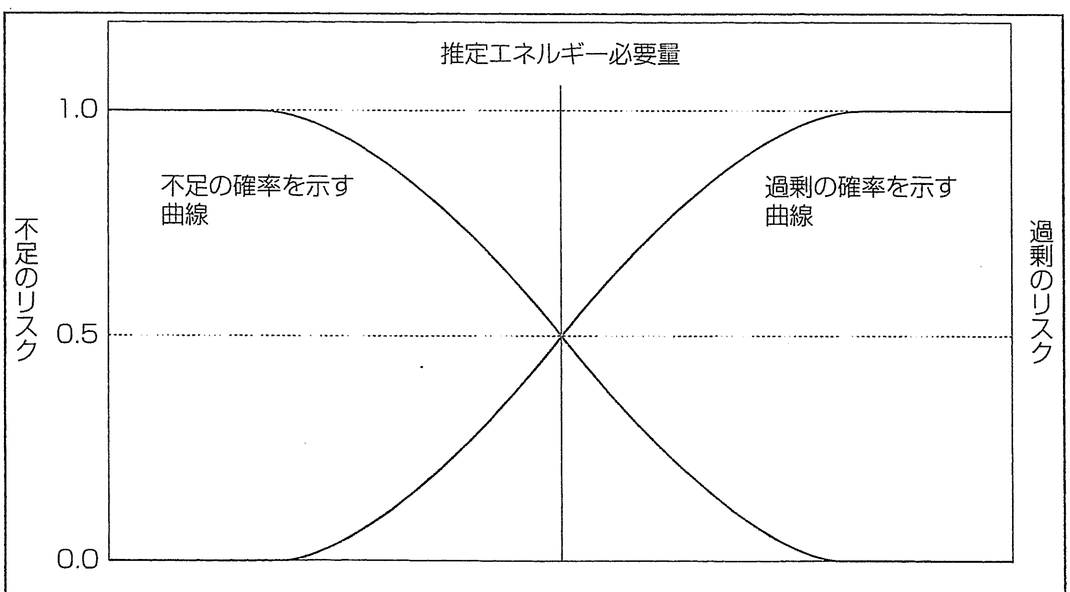

図1　推定エネルギー必要量を理解するための概念図
縦軸は個人の場合は不足または過剰が生じる確率を，集団の場合は不足または過剰の者の割合を示す．

表1　エネルギーの食事摂取基準：推定エネルギー必要量(kcal/日)[1)]

性別	男性			女性		
身体活動レベル	I	II	III	I	II	III
0～5(月)	—	550	—	—	500	—
6～8(月)	—	650	—	—	600	—
9～11(月)	—	700	—	—	650	—
1～2(歳)	—	1,000	—	—	900	—
3～5(歳)	—	1,300	—	—	1,250	—
6～7(歳)	1,350	1,550	1,700	1,250	1,450	1,650
8～9(歳)	1,600	1,800	2,050	1,500	1,700	1,900
10～11(歳)	1,950	2,250	2,500	1,750	2,000	2,250
12～14(歳)	2,200	2,500	2,750	2,000	2,250	2,550
15～17(歳)	2,450	2,750	3,100	2,000	2,250	2,500
18～29(歳)	2,250	2,650	3,000	1,700	1,950	2,250
30～49(歳)	2,300	2,650	3,050	1,750	2,000	2,300
50～69(歳)	2,100	2,450	2,800	1,650	1,950	2,200
70以上(歳)[2)]	1,850	2,200	2,500	1,450	1,700	2,000
妊婦(付加量)初期				+50	+50	+50
中期				+250	+250	+250
末期				+450	+450	+450
授乳婦(付加量)				+350	+350	+350

[1] 成人では，推定エネルギー必要量＝基礎代謝量(kcal/日)×身体活動レベルとして算定した．18～69歳では，身体活動レベルはそれぞれ I＝1.50，II＝1.75，III＝2.00としたが，70歳以上では，それぞれ I＝1.45，II＝1.70，III＝1.95とした．

[2] 主として，70～75歳ならびに自由な生活を営んでいる対象者に基づく報告から算定した．

定エネルギー必要量の場合，その個人のエネルギー摂取量が真のエネルギー必要量より不足する確率が50％，過剰になる確率が50％となる．

集団の場合は「当該集団全体におけるエネルギー出納（成人の場合，エネルギー摂取量−エネルギー消費量）がゼロ（0）となる確率が最も高くなると推定される，習慣的な1日当たりのエネルギー摂取量」と定義される．当該集団のエネルギー摂取量が，推定エネルギー必要量である場合，その集団のエネルギー摂取量が真のエネルギー必要量より不足する割合（人数）が50％，過剰になる割合が50％となる．

実際に，3食を給食などで提供する場合，半分の対象者は不足であり，半分の対象者には過剰であるという“考え方”である．学校給食においてエネルギー不足である人が，それぞれ不足にならないように多めに食べない限り，残食がでる（過剰と感じて食べない）のは当然であるという考え方である．このように明確に規定することにより，推定エネル

表2　年齢階級別にみた身体活動レベルの群分け(男女共通)

身体活動レベル	レベルI(低い)	レベルII(ふつう)	レベルIII(高い)
1～2(歳)	—	1.35	—
3～5(歳)	—	1.45	—
6～7(歳)	1.35	1.55	1.75
8～9(歳)	1.40	1.60	1.80
10～11(歳)	1.45	1.65	1.85
12～14(歳)	1.45	1.65	1.85
15～17(歳)	1.55	1.75	1.95
18～29(歳)	1.50	1.75	2.00
30～49(歳)	1.50	1.75	2.00
50～69(歳)	1.50	1.75	2.00
70以上(歳)	1.45	1.70	1.95

ギー必要量の理解が進むと考えられる。

推定エネルギー必要量について，今回も二重標識水法により測定された総エネルギー消費量から求めた[1]．食事調査から出されたものではない．これは食事調査において過小申告の問題があり[2]，食事調査では少なくともエネルギー摂取量を正確に把握できないからである．とくに，病者ではその傾向が強く，注意すべきである．成人の身体活動レベル(ふつう)の推定エネルギー必要量（表1）が，国民健康・栄養調査で報告されているエネルギー摂取量よりも多いように見えるのは，前述したように食事調査特有の過小評価によるものと考えられる．国民の真のエネルギー消費量（エネルギー必要量）は，各身体活動レベルの推定エネルギー必要量により近い．

身体活動レベル

今回の改定で，推定エネルギー必要量に直接的な影響を与える身体活動レベルで，児童（6歳から11歳）については従来の2区分から3区分となった（表2）．これは，従来，学校体育や放課後の遊びにより十分な身体活動量が確保されているので，わが国において，身体活動が“低い”と判定されるものは存在しないという仮定のもとに“ふつう”と“高い”の2区分であった．

しかし，海外の研究成果により，このような年齢の児童についても成人と同じ程度の身体活動レベルのばらつきがあることが報告されており，さらにわが国の児童においても，ゲーム機の普及などで戸外の身体活動が減っているという現状を鑑み，今回はじめて，この年代の児童において“低い”という身体活動レベルを設定した．近いうちに，食事摂取基準（2010年版）を基に，文部科学省において小学生の給食の基準が定められるということである．

高齢者については，身体活動レベルが高くなった．これは，2005年版策定後に発表された二重標識水法を用いた大規模研究を含め，いくつかの“健康で自立した”70歳代および80歳代についての報告[3]より，それらの身体活動レベルの平均値が1.69であったため，身体活動レベルの代表値（ふつう）を1.70とした．2005年版では身体活動レベル「ふつう」が1.50であったことより，それに比例してこの年代の推定エネルギー必要量が高くなった．

表3　基礎代謝量

性別	男性			女性		
年齢	基礎代謝基準値 (kcal/kg体重/日)	基準体重 (kg)	基礎代謝量 (kcal/日)	基礎代謝基準値 (kcal/kg体重/日)	基準体重 (kg)	基礎代謝量 (kcal/日)
1～2(歳)	61.0	11.7	710	59.7	11.0	660
3～5(歳)	54.8	16.2	890	52.2	16.2	850
6～7(歳)	44.3	22.0	980	41.9	22.0	920
8～9(歳)	40.8	27.5	1,120	38.3	27.2	1,040
10～11(歳)	37.4	35.5	1,330	34.8	34.5	1,200
12～14(歳)	31.0	48.0	1,490	29.6	46.0	1,360
15～17(歳)	27.0	58.4	1,580	25.3	50.6	1,280
18～29(歳)	24.0	63.0	1,510	22.1	50.6	1,120
30～49(歳)	22.3	68.5	1,530	21.7	53.0	1,150
50～69(歳)	21.5	65.0	1,400	20.7	53.6	1,110
70以上(歳)	21.5	59.7	1,280	20.7	49.0	1,010

70歳以上の推定エネルギー必要量は，健康な生活を営んでいる自立した高齢者から得られた値である．老人保健施設入所などの生活状況によっては，身体活動量に大きな個人差が存在すること，また体重についても高齢者では個人差がとくに大きいことを考慮し，対象者の状況(身体活動量，体重，体重の変化)を調査・把握して，エネルギー給与量を決めるようにするべきである．

基礎代謝量

推定エネルギー必要量は，身体活動レベルに基礎代謝量（kcal/日）を乗じて算出される．さらに，基礎代謝量は基礎代謝量基準(kcal/kg/日）に基準体重をかけたものである．今回の改定では最近の報告を基に，18歳から29歳の女性の基礎代謝基準値を低めに改定した（23.6 kcal/kg/日→22.1 kcal/kg/日）（**表3**）．一方，基準体重はやや増加したが，結果として，この年代の基礎代謝は1,180 kcal/日から1,120 kcal/日とやや低くなった．

乳児

乳児については，2005年版では母乳栄養児と人工乳栄養児を並列に示したが，2010年版では，母乳栄養児のみの推定エネルギー必要量を示し，人工栄養児の推定エネルギー必要量は，参考として本文中にのみ示した．これは，他の栄養素と同様に，エネルギーについても“目安量”という考え方を採用したことを明確にしたためである．

妊婦と授乳婦の付加量

妊婦において，推定エネルギー必要量を“妊婦の推定エネルギー必要量（kcal/日）＝妊娠前の推定エネルギー必要量（kcal/日）＋妊婦のエネルギー付加量(kcal/日)”と明確に示した．これは，妊娠中に体重が大幅に増加し基礎代謝量が増加するが，身体活動量が低下して身体活動で消費するエネルギー量が低下する結果，妊娠前の体重当たりのエネルギー消費量と妊娠時の体重当たりエネルギー消費量に差がないとする報告によるものである．し

たがって，妊婦の付加量は，妊婦の体重増加量に比例して計算された．

今回の妊婦の最終体重増加量が11 kg (2005年版では12 kg) とされたため，妊婦の付加量は低い値になった．たとえば20歳代の女性の妊娠後期における推定エネルギー必要量は，2005年版では2,550 kcalであったが，2010年版では2,400 kcalとなった．しかしこれは，妊娠中のエネルギー摂取量が以前と比べて低くてもよいということを意味するものではない．

授乳婦についても，2010年版では“授乳婦の推定エネルギー必要量（kcal/日）＝妊娠前の推定エネルギー必要量（kcal/日）＋授乳婦のエネルギー付加量(kcal/日)”とし，授乳婦の推定エネルギー必要量の基準を妊娠前の値とすることを明確にした．

活用に当たって

エネルギーの活用に当たっては，推定エネルギー必要量に推定誤差があることを知ることが大切である．アメリカの食事摂取基準によると，推定エネルギー必要量の基礎となる成人の総エネルギー消費量の推定の標準誤差がおよそ300 kcal/日弱である．この変動が生物学的な変動と実験上の変動（二重標識水法の測定誤差など）に分けられ，それらが等しいと仮定すると，生物学的な変動は，標準偏差相当でおよそ±200 kcal/日 (≒$300\div\sqrt{2}$) と考えられる．

たとえば，推定エネルギー必要量（＝総エネルギー消費量）を算出した結果が2,500 kcal/日であった場合，真のエネルギー必要量がおよそ2,300 kcal/日～2,700 kcal/日の間である確率が約68％，およそ2,100 kcal/日～2,900 kcal/日の間である確率が約95％であると考えられる．言い換えれば，推定エネルギー必要量が2,500 kcalであっても，ほぼ3人に1人の真のエネルギー必要量が2,300 kcal未満あるいは2,700 kcalより多いということである．

今回，はじめて“活用の理論”が示された．まず，“エネルギーのバランスを適切に保つことは栄養管理の基本である”として，食事計画立案においてエネルギーがもっとも優先順位が高いことを明記している．

また，評価に当たって，食事摂取基準2005年版では，エネルギーの過不足の評価をBMIのみで行うこととなっていたが，2010年版では体重の変化も評価に用いることが示された．たとえばBMIが24であっても，最近，体重が増加している個人について体重増加を食事改善のための評価に用いる．

また，食事改善の計画については，“数カ月間（少なくとも1年以内）に2回以上の体重測定を行い，体重変化を指標として用いる”という文言が入った．

おわりに

2010年版では，“特有の食事指導，食事療法，食事制限が適用されたり，推奨されている疾患を有する場合，または，ある疾患の予防を目的として特有の食事指導，食事療法，食事制限が適用されたり，推奨されている場合，その疾患の治療ガイドライン等の栄養管理指針を優先して用いるとともに，食事摂取基準を補助的な資料として参照することが勧められる．”という記述があり，エネルギーも他の栄養素と同じように臨床においても，一義的には各臨床科の治療ガイドラインを用いる

が，減量とか増量とかいうような各疾病の治療として減量等を行っていない場合，積極的に食事摂取基準を参考に病院食の提供を行うことを推奨している．

しかし，各臨床科における食事指導の指針には食事摂取基準の基本的な考え方との差もある．たとえば，BMI 22 を“標準体重”としてエネルギー必要量の推定に利用しようとするある臨床科の考え方は，食事摂取基準の考え方，即ち“エネルギーの過不足の評価には，BMI または体重変化を用いる．日本肥満学会の定義にしたがって，BMI の正常範囲を 18.5 以上 25.0 未満とし，測定された BMI が 18.5 未満であれば「不足」，25.0 以上であれば「過剰」と判断するのが適当であろう”として，BMI が 18.5〜25.0 をエネルギーの過不足の正常範囲としているものとは異なる．また，さらに摂取すべきエネルギー量を“理想 BMI”から計算される“理想”体重（kg）に“ある係数（kcal/kg）”をかけて，摂取すべきエネルギー量とする，という方法は，食事摂取基準とはかけ離れたものである．このようにして算出された“摂取すべきエネルギー量”は，エネルギーの食事摂取基準で示された推定エネルギー必要量よりもかなり低くなる．

今後，食事摂取基準と各臨床科の給食などにおける食事指導法の摺り合わせが必要と考えられる．

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Association of physical activity and neighborhood environment among Japanese adults

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ABSTRACT

Objective. Although environmental attributes related to physical activity is an emerging research topic, most studies have been reported from Western countries. This study aimed to examine the relationship between perceived environment and physical activity among Japanese adults.

Methods. The sample included 492 adults aged 20 to 74 years (61%: male) living in Tokyo and Himeji in Japan. Primary measures were the short version of International Physical Activity Questionnaire and its Environmental Module. Data were collected between October and December 2003. Odds ratio (OR) of meeting physical activity recommendations was examined in relation to neighborhood environmental characteristics, adjusted for age, sex, employment status and education.

Results. Three perceived environmental attributes were significantly related to walking 150 min/week or more: high residential density (OR=1.82), good access to shops (OR=1.65) and presence of sidewalks (OR=1.65). Two environmental attributes, access to shops (OR=2.32) and the presence of bike lanes (OR=1.57), were related to high levels of moderate to vigorous physical activity (950 MET*min/week or more).

Conclusion. Associations of physical activity with four environmental attributes emerged in this Japanese sample. These results support the generalizability of findings on physical activity environments across Western countries and Japan.

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Introduction

Regular physical activity reduces the risk of mortality, incidence of cardiovascular diseases, diabetes and some kinds of cancers (U.S. Department of Health and Human Services, 1996). However, large proportions of the population in Japan and in many countries in the world are insufficiently physically active (Haskell et al., 2007; Sjöström et al., 2006). According to pedometer measurements in the Japan National Health and Nutrition Survey 2005, only 21.3% of Japanese walk more than 10,000 steps a day (Ministry of Health, Labour and Welfare of Japan, 2008). Physical activity promotion is one of the priorities of public health, but to establish effective intervention strategies, evidence of physical activity correlates is needed. To date, many studies have focused on individual demographics and psychological correlates. More recent research has revealed that certain neighborhood environmental characteristics, such as residential density, access to destinations, walking facilities, aesthetics, and safety also are consistently associated with physical activity (Saelens and Handy, 2008; Gebel et al., 2007; Trost et al., 2002; Sallis and Owen, 2002; Hill et al., 2003; Humpel et al., 2002; Owen et al., 2004). Manipulations of environmental variables are expected to have a long-term and substantial impact on the population, which could complement the usually short-term effects of individually-targeted interventions.

Although an increasing number of studies examining the association between physical activity and environment have been reported, most studies were conducted in Western countries, especially in the United States and Australia (Humpel et al., 2002; De Bourdeaudhuij et al., 2003; Saelens et al., 2003; Owen et al., 2004; Wendel-Vos et al., 2007). On the other hand, few studies on physical activity and neighborhood environments could be located in English language journals from Asian countries including Japan (Takano et al., 2002). Limited variability of environmental attributes where the studies were conducted is one of the limitations of this research area. Thus, one of the directions of this research area is to conduct studies in a greater variety of cultures and geographic settings and to examine if evidences from US and Australia could be generalized to other countries.

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Japan is the most economically developed Asian country, but it has a population density that is more than ten times greater than that of the US. Because both the culture and physical environment are very different from the US and Australia, while the level of economic development is roughly comparable, Japan is an interesting country in which to test the generalizability of built environment–physical activity associations. The physical activity environment in Japan appears to be different from the US and Australia on several dimensions. For instance, in contrast to Australia, the low proportion of commuters who drive their cars to work, only 32% in the Tokyo metropolitan area and 36% in the Osaka metropolitan area (Ministry of Land, Infrastructure, Transport and Tourism, 2008), compared with 80.1% in Australia (Australian Bureau of Statistics. 2006), may be due to environmental differences, such as the extent of walkable environment and the development of public transportation network, between the two countries. The difference of overweight prevalence ($BMI \geq 25$ kg/m^2) between Japan; 27.6% in males, 21.4% in females (Ministry of Health, Labour and Welfare of Japan, 2008) and the US; 70.8% in males, 61.8% in females (Ogden et al., 2006) may be partially explained by the differences in environment and physical activity.

In the present study, we examined the association between the perceived neighborhood environment and physical activity among Japanese adults using the International Physical Activity Questionnaire and its Environmental Module.

Methods

Participants and data collection

Four hundred and ninety-two Japanese adults aged 20 to 74 years (61%: male) were recruited. Study collaborators at eight worksites, including four universities and four private companies, approached employees at the worksites or their acquaintances as potential research volunteers. Seven of eight worksites were located in and around the Tokyo metropolitan area, while one was in Himeji city, located in western Japan, which has a population of about 536,000. If the person was interested in joining the survey, the collaborator delivered a study consent form and a set of self-administered questionnaires for data collection. To examine the test–retest reliability, 93 of the 492 participants were asked to answer the same questionnaire after a 7-day interval. Written informed consent was obtained from all participants. Data were collected between October 2003 and December 2003.

Environmental measure and its translation

The International Physical Activity Questionnaire Environment Module (IPAQ-E) was used to measure perceived neighborhood environmental attributes related to physical activity. This questionnaire was originally developed as an optional component of the International Prevalence Study of Physical Activity (Craig et al., 2003). Most questions were taken or adapted from previous measures developed in the United States (Addy et al., 2004; Saelens et al., 2003). The IPAQ-E consists of 17 questions; 7 core items, 4 recommended items, and 6 optional items. In this study, we used 11 items, including core and recommended items (Table 1). These questions refer to a neighborhood environment where the person could walk within 10 to 15 min from their residences. Nine of 11 items, excluding residential density and household motor vehicles, involve statements which explain neighborhood features believed to be related to physical activity, followed by four response options: strongly disagree, somewhat disagree, somewhat agree and strongly agree. The residential density item asks about the main types of houses in neighborhoods (e.g., detached single-family residences, condos, apartments), with higher scores indicating higher densities. The question about motor vehicles concerns the number of motor vehicles in the participant's household. The Swedish version of IPAQ-E has shown good test–retest reliability (Alexander et al., 2006).

In this study, the Japanese version of the IPAQ-E was used. The original English version was directly translated into Japanese. The

Table 1
Items of international physical activity questionnaire environmental module in original English version

Scale composition	Items	Response categories
Residential density	What is the main type of housing in your neighborhood?	Detached single-family residences/townhouses, row houses, apartments, or condos of 2–3 storeys/mix of single-family residences and townhouses, row houses, apartments or condos/apartments or condos of 4–12 storeys/apartments or condos of more than 12 storeys
Access to shops	Many shops, stores, markets or other places to buy things I need are within easy walking distance of my home. Would you say that you...	
Access to public transport	It is within a 10–15 minute walk to a transit stop (such as bus, train, trolley, tram) from my home. Would you say that you...	
Presence of sidewalks	There are sidewalks on most of the streets in my neighborhood. Would you say that you...	
Presence of bike lanes	There are facilities to bicycle in or near my neighborhood, such as special lanes, separate paths or trails, shared use paths for cycles and pedestrians. Would you say that you...	
Access to recreational facilities	My neighborhood has several free or low-cost recreation facilities, such as parks, walking trails, bike paths, recreation centers, playgrounds, public swimming pools, etc. Would you say that you...	Strongly disagree/somewhat disagree/somewhat agree/strongly agree
Crime safety	The crime rate in my neighborhood makes it unsafe to go on walks at night. Would you say that you...	
Traffic safety	There is so much traffic on the streets that it makes it difficult or unpleasant to walk in my neighborhood. Would you say that you...	
Social environment	I see many people being physically active in my neighborhood. Physically active means doing things like walking, jogging, cycling, or playing sports and active games. Would you say you...	
Aesthetics	There are many interesting things to look at while walking in my neighborhood. Would you say that you...	
Household motor vehicles	How many motor vehicles in working order (e.g., cars, trucks, motorcycles) are there at your household?	Number of household motor vehicles

translation was conducted according to the standardized translation manual of IPAQ (IPAQ website, 2008). At first we made sure of the concept of each question via discussion with the IPAQ Reliability and Validity Committee. Then the questionnaire was translated into Japanese by two independent physical activity researchers. These translations were reviewed by a group of bilingual individuals to develop the first draft. After the pilot test of the first draft, the wording was revised. Then a bilingual person who was not a researcher and who had no conflicts of interest in this research back-translated it into English. Finally, the translation was checked up by the IPAQ Reliability and Validity Committee. Then, the Japanese version of IPAQ-E was adopted. Table 1 indicates the contents of IPAQ-E according to the wording of the original English version. The Japanese version of IPAQ-E is available from website (Japanese version of IPAQ-E website, 2008).

Physical activity measure

To assess physical activity, the self-administered, short form of IPAQ was used (Craig et al., 2003; Murase et al., 2002). Participants were asked about the frequency and duration of vigorous activity, moderate activity and walking for all purposes such as transportation, work, recreation and household chores. To avoid overlap, moderate activity did not include walking.

In this study, two variables, walking time (min/week) and total moderate to vigorous physical activity (MVPA) energy expenditure (MET*min/week) were used as dependent variables. MET means Metabolic Equivalent and is a unit of intensity of activity. One MET is equivalent to the intensity of resting while sitting. Walking time was calculated using frequency and duration of walking. MVPA was calculated according to the IPAQ scoring manual (IPAQ website, 2008). MET values used in the calculation were 8 METs for vigorous activity, 4 METs for moderate activity and 3.3 METs for walking.

The reliability and validity of this questionnaire in 12 countries, including Japan, has been reported. Test–retest reliability for total physical activity of the Japanese IPAQ was adequate (Spearman's rho = 0.76). Criterion validity for total physical activity assessed against the accelerometer was comparable to other survey measures (Spearman's rho = 0.32) (Craig et al., 2003).

Statistical analyses

The reproducibility of the Japanese IPAQ-E was evaluated by test–retest with a 7-day interval, calculating the Spearman rank-correlation coefficient and Kappa statistic for each question.

To examine the relationship between the neighborhood environment as the independent variable and physical activity, i.e. walking time and MVPA, as the dependent variable, odds ratios of meeting walking and physical activity criteria were examined using logistic regression models. For the analysis, environmental variables were converted into dichotomous variables. For residential density, the choice of 'detached single-family residences' formed a category indicating low residential density, while others were included in another category indicating high residential density. As to the number of household motor vehicles, responses were categorized as 'none' and as 'one or more'. Regarding other questions, responses were classified into two categories of agree (strongly agree and somewhat agree) and disagree (somewhat disagree and strongly disagree). For walking, participants were classified as active if they walked 150 min or more, consistent with current physical activity guidelines (Haskell et al., 2007). MVPA was divided into two levels at the median of all participants: >950 MET*min/week or more, and <950 MET*min/week. To calculate odds ratios, the references were environmental characteristics expected to be associated with lower levels of physical activity, meaning that an odds ratio of more than 1.00 indicates an expected positive association. All odds ratios were adjusted for reported age, sex, employment status and educational level.

Significance was considered to be at a level of $P<0.05$. Analyses were conducted by SPSS ver15.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Table 2 presents the demographic characteristics of participants. The sample included 62% of male. Age was widely distributed from 20 to 74 years, and the mean age (SD) was 42 (12) years. The locations of participants were mainly urban settings. In this population, 43% of participants walked more than 150 min/week. The characteristics of 93 participants for test–retest reliability were similar to the overall sample.

Spearman correlation coefficients and Kappa statistics for test–retest reliability of the questionnaire are shown in Table 3. Spearman correlation coefficients were from 0.79 for the presence of bike lanes to 0.99 for residential density. Kappa statistics were also good and ranged from 0.63 for the presence of bike lanes to 0.97 for residential density.

Logistic regression analyses revealed that three of eleven environmental attributes were significantly associated with walking (Table 4). Participants were more likely to walk 150 min/week or more when they perceived high residential density (OR, 95% CI: 1.82, 1.16–2.84), good access to shops (OR, 95% CI: 1.65, 1.05–2.58) and presence of sidewalks (OR, 95% CI: 1.65, 1.13–2.42). The number of household motor vehicles indicated borderline association with walking. Participants who did not have motor vehicles in their household were more likely to satisfy the criterion of 150 min of walking per week (OR, 95% CI: 1.54, 0.99–2.41). All of these associations were in the expected direction. Regarding the association of meeting the MVPA criterion with environmental attributes, people who perceived good access to shops (OR, 95% CI: 2.32, 1.47–3.66) and presence of bike lanes (OR, 95% CI: 1.57, 1.04–2.36) reported more physical activity. Three additional environmental attributes, the presence of sidewalks, aesthetics and

Table 2
Characteristics of participants (Tokyo and Himeji, Japan, 2003)

	Overall sample n (%)	Test–retest reliability sample[a] n (%)
Sex		
Male	303 (61.6)	58 (62.4)
Female	189 (38.4)	35 (37.6)
Age (years)		
20–39	253 (51.4)	49 (52.7)
40–59	181 (36.8)	30 (32.3)
60–	58 (11.8)	14 (15.1)
Education (years)		
–12	125 (25.7)	19 (20.7)
13–	361 (74.3)	73 (79.3)
Employment status (h/week)		
≥40	336 (68.6)	62 (68.1)
<40	154 (31.4)	29 (31.9)
Location (population of city)		
100,000–	227 (55.6)	51 (64.6)
30,000–99,999	99 (24.3)	18 (22.8)
–29,999	74 (18.1)	2 (2.5)
Unknown	8 (2.0)	8 (10.1)
BMI (kg/m^2)		
–24.9	400 (81.5)	72 (78.3)
25.0–29.9	80 (16.3)	18 (19.6)
30.0–	11 (2.2)	2 (2.2)
Walking (min/week)		
150–	211 (42.9)	38 (40.9)
–149	281 (57.1)	55 (59.1)
MVPA[b] (MET*min/week)		
950–	245 (49.8)	45 (48.4)
–949	247 (50.2)	48 (51.6)

[a] Participants in the test–retest reliability sample are included in the overall sample.
[b] MVPA: moderate to vigorous physical activity.

Table 3
The reproducibilities of each item of the Japanese IPAQ Environmental Module estimated by test–retest with a seven day interval (Tokyo and Himeji, Japan, 2003)

	Spearman's correlation coefficients	P values	Kappa statistics	P values
Residential density	0.99	<0.001	0.97	<0.001
Access to shops	0.90	<0.001	0.85	<0.001
Access to public transport	0.83	<0.001	0.79	<0.001
Presence of sidewalks	0.85	<0.001	0.67	<0.001
Presence of bike lanes	0.79	<0.001	0.63	<0.001
Access to recreational facilities	0.82	<0.001	0.75	<0.001
Crime safety	0.86	<0.001	0.71	<0.001
Traffic safety	0.82	<0.001	0.69	<0.001
Social environment	0.88	<0.001	0.78	<0.001
Aesthetics	0.90	<0.001	0.83	<0.001
Household motor vehicles	0.96	<0.001	0.91	<0.001

household motor vehicles, also showed borderline associations with MVPA.

Discussion

The results of this study demonstrated that 4 of 11 environmental variables: residential density, access to shops, presence of sidewalks and presence of bike lanes, were significantly associated with walking or MVPA among Japanese adults. Adults who reported living in neighborhoods with high residential density, good access to shops, presence of sidewalks, and presence of bike lanes had higher physical activity levels. In addition, borderline significant associations between physical activity and 2 additional environmental variables: aesthetics and household motor vehicles were observed. The environmental measures used in the present study have been developed and used mainly in Western countries, such as the United States and Australia (Humpel et al., 2002; Saelens et al., 2003; Owen et al., 2004, Mota et al., 2005). To date, few studies have been reported from Asian countries, where neighborhood environmental characteristics and physical activity patterns of people are different from Western countries (Takano et al., 2002). Present results indicate that the same kinds of neighborhood attributes related to physical activity in Western countries are also related to physical activity among Japanese. In other words, these results support the generalizability of previous findings in Western countries to different environments and cultures like Japan.

On the other hand, five environmental variables: access to public transport, access to recreational facilities, crime safety, traffic safety and social environment were not significantly related to physical activity among Japanese adults. There are some possible reasons for these results. As for access to public transport, 85% of participants in this study reported good access. This clustering of responses may cause weak statistical power and the result of no significant relationship. Access to recreation facilities has been related repeatedly to leisure time physical activity (Humpel et al., 2002; Gebel et al., 2007). However, in this study, we used the short version of IPAQ which did not assess specific purposes of physical activity, leading to a limited test of the hypothesis regarding recreation facilities. Environmental attributes regarding crime safety and traffic safety were not related to physical activity. These issues may be more relevant in specific populations such as women, children, and older adults. Results, especially for crime safety, have been inconsistent in the previous

Table 4
Odds ratios for environmental variables and likelihood of subjects meeting walking and physical activity criteria (Tokyo and Himeji, Japan, 2003)

	n (%)	Walking>=150 min/week			MVPA[a]>=950 MET*min/week		
		Odds ratios	95% CI[b]	P values	Odds ratios	95% CI	P values
Residential density							
High	111 (23.6)	1.82	(1.16, 2.84)	0.009	1.07	(0.69, 1.68)	0.753
Low	360 (76.4)	1.00			1.00		
Access to shops							
Good	373 (76.7)	1.65	(1.05, 2.58)	0.029	2.32	(1.47, 3.66)	<0.001
Poor	113 (23.3)	1.00			1.00		
Access to public transport							
Good	420 (86.4)	1.43	(0.82, 2.48)	0.205	1.50	(0.87, 2.59)	0.148
Poor	66 (13.6)	1.00			1.00		
Presence of sidewalks							
Yes	288 (59.6)	1.65	(1.13, 2.42)	0.010	1.39	(0.95, 2.04)	0.087
No	195 (40.4)	1.00			1.00		
Presence of bike lanes							
Yes	140 (29.0)	0.93	(0.62, 1.40)	0.739	1.57	(1.04, 2.36)	0.032
No	343 (71.0)	1.00			1.00		
Access to recreational facilities							
Good	283 (58.4)	1.14	(0.79, 1.66)	0.484	1.09	(0.75, 1.58)	0.663
Poor	202 (41.6)	1.00			1.00		
Crime safety							
Safe	321 (66.6)	1.30	(0.87, 1.94)	0.200	1.37	(0.92, 2.04)	0.126
Not safe	161 (33.4)	1.00			1.00		
Traffic safety							
Safe	309 (63.8)	0.80	(0.55, 1.17)	0.258	1.01	(0.69, 1.48)	0.963
Not safe	175 (36.2)	1.00			1.00		
Social environment							
Good	318 (65.6)	1.05	(0.72, 1.55)	0.795	1.35	(0.92, 1.99)	0.128
Poor	167 (34.4)	1.00			1.00		
Aesthetics							
Good	216 (44.5)	1.04	(0.71, 1.50)	0.855	1.38	(0.95, 2.02)	0.090
Poor	269 (55.5)	1.00			1.00		
Household motor vehicles							
None	107 (22.0)	1.54	(0.99, 2.41)	0.055	1.47	(0.93, 2.32)	0.097
One or more	379 (78.0)	1.00			1.00		

Note. All odds ratios were calculated, adjusted for age, sex, employment status and educational attainment. The references were the categories which were hypothesized to be associated with lower levels of physical activity.
[a] MVPA: moderate to vigorous physical activity.
[b] CI: confidence interval.

studies (Humpel et al., 2002). Due to the relatively small sample size of this study, stratified analyses of these demographic characteristics were not conducted in this study. Further studies are needed to examine associations of specific environments with specific physical activities among specific populations.

IPAQ (Craig et al., 2003) and IPAQ-E, internationally-standardized measurement tools, were used in this study. Translation into Japanese was strictly conducted according to the standardized manual of IPAQ. Test–retest reliability of the Japanese IPAQ-E was supported in this study. The ICCs of items in the Swedish version were from 0.47 to 0.98 (Alexander et al., 2006). The Japanese version of IPAQ-E also demonstrated good reliability in this study.

There are several limitations in this study. Due to the cross-sectional design, we were unable to address the direction of the causality. Secondly, the sample was relatively small and consisted of volunteers as participants and therefore not a representative of the general population in Japan. This study supports the generalizability of findings from previous studies in Western countries to Japan. However, there might be limited generalizability of findings among the Japanese population. Thirdly, we used the short form of IPAQ which did not differentiate domain-specific physical activity, such as leisure time and transportation activities. Thus, we were not able to examine activity-specific associations with environmental attributes that were expected (Owen et al., 2004). Fourth, residential preference which is controlled as covariate in recent studies was not assessed in this study. However, this study, conducted in Japan where people live in different environmental characteristics and have different physical activity patterns from Western countries, is important for better understanding environmental attributes related to physical activity. Studies of specific physical activity–environment relationships in specific populations living in a variety of environments are needed to clarify the role of environmental effects in shaping physical activity.

Conclusion

Four environmental variables, residential density, access to shops, presence of sidewalks and presence of bike lanes, were significantly associated with walking or moderate to vigorous physical activity among Japanese adults. These results support the generalizability of findings from previous studies conducted in Western countries to Japan and suggest that targeting these environmental characteristics could be an effective strategy for promoting physical activity.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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Original Article

Sociodemographic Variation in the Perception of Barriers to Exercise Among Japanese Adults

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ABSTRACT

Background: The perception of barriers to exercise is an important correlate of exercise participation. However, only a limited number of studies—mostly from Western countries—have attempted to describe the perceptions of barriers to exercise in specific population groups. This study examined the associations between sociodemographic attributes and perceived barriers to exercise in Japanese adults.

Methods: A population-based cross sectional study of 865 participants (age: 20–69 years old, men: 46.5%) was conducted in 4 cities in Japan. Nine sociodemographic attributes (sex, age, location of residence, educational attainment, marital status, employment status, presence of dependents in the household, self-rated health, body mass index), along with exercise frequency and perception of barriers to exercise (discomfort, lack of motivation, lack of time, lack of social support, poor environment) were assessed by self-administered questionnaire.

Results: The most strongly perceived barrier was lack of time. Five of 9 sociodemographic attributes were significantly related to certain types of perceived barriers. Participants who more strongly perceived barriers were younger, more highly educated, more likely to be employed, and had relatively poor self-rated health and a high BMI. The specific types of barriers that were strongly perceived varied with the sociodemographic attributes of the participants.

Conclusions: The results show that the perception of barriers to exercise varies among specific population groups, which indicates the importance of targeting exercise promotion strategies to specific populations.

Key words: exercise; physical activity; perceived barrier; sociodemographic correlates

INTRODUCTION

Although regular physical activity reduces the risks of morbidity and mortality of diseases such as cardiovascular disease, diabetes, and cancer,[1] a large proportion of the adult population is not sufficiently physically active to gain these health benefits. In Japan, only 31% of men and 28% of women engage in 30 minutes or more of exercise 2 or more times per week.[2] A similarly low prevalence of exercisers has been noted in many countries in the world. For example, in the United States less than half the adult population meets the physical activity recommendation to participate in at least 30 minutes of moderately intense physical activity on most days of the week.[3,4] Physical activity promotion remains one of the priorities of public health.

The World Health Organization Guide for Population-based Approaches to Increase Levels of Physical Activity encourages national action plans, including large-scale interventions to reach the whole population.[5] This guide also emphasizes that, "Some interventions may be tailored to specific population groups, such as adults, children, older persons, employees, people with disabilities, women, men, cultural groups, and people at risk to develop non-communicable diseases." To accomplish this, determinants of physical activity among specific population groups must be understood.

Exercise is an important domain of physical activity. Therefore, understanding exercise determinants is a key area of physical activity promotion. Perceptions of barriers to exercise can be important determinants of exercise participation.[6–8] Janz et al[9] indicated that, "Perceived barriers will be strong predictors of behavior change." According to the health belief model, a person will have a negative attitude toward exercise as a means to promote health

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when there are more perceived barriers than benefits.[10] Strategies that consider barriers should be incorporated into interventions to promote exercise.[11] Thus, the understanding of perceived barriers among specific population groups is important for promoting exercise.

Studies have examined the perception of barriers in convenience samples[12] and among specific populations, such as students and overweight persons.[8,13–16] However, there have been only a limited number of population-based studies, which were conducted in Europe,[17] Brazil,[18] and Australia.[19] These studies demonstrated that perception of barriers varied according to the sociodemographic attributes of the populations. In addition, the relationships differed by country. Therefore, conducting research in a number of countries should prove useful in better understanding exercise behavior. There are few published studies on sociodemographic variation in perceived barriers to exercise among Japanese.[15,20] The present study therefore examined the perception of barriers to exercise in specific population groups among Japanese adults.

METHODS

Participants and data collection

In this cross-sectional study, data were collected from February 2007 through January 2008. A total of 4000 residents, aged 20 to 69 years, who lived in 4 Japanese cities (Koganei, Tsukuba, Shizuoka, Kagoshima) were randomly selected from the registry of residential addresses of each city, and stratified by sex (male/female), age (20–29 years, 30–39 years, 40–49 years, 50–59 years, 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, in a specific age category, and living in a specific city were obtained. Four divergent Japanese cities were chosen in order to account for lifestyle variations. Koganei is a suburban city of Tokyo; Tsukuba is a university town located 50 km northeast of Tokyo; and Shizuoka and Kagoshima are middle-sized cities located in central and west Japan, respectively.

Because of the large number of questions and the use of an accelerometer for other purposes of this project, the survey was divided into 2 parts. Both parts of the survey were conducted by mail. Questionnaires were sent to and collected from participants via post. Participants who agreed to participate in the second survey were sent the materials approximately 7 days after receiving their response to the first survey. Participants were asked to sign the questionnaire before answering. The first survey was a self-administered questionnaire that included questions on sociodemographic status and exercise habits. The second survey consisted of a 7-day accelerometer survey and a second self-administered questionnaire with additional items, which included the scale of perceived barriers to exercise. To obtain a better response rate, participation letters that described the contents of the study were sent to all 4000 subjects 2 weeks before the first survey. During the survey, a call center was set up for subjects who had enquiries regarding the survey. For nonrespondents, requests to join the survey were mailed twice. If the survey was incomplete, we asked the participant to redo the survey. As a result, among the 4000 residents asked to participate, 1508 (37.7%) responded to the first survey; 865 (57.4%) of these 1508 participated in the second survey, which resulted in a final response rate of 21.6%. The response rates for the 4 cities were 20.7% (Tsukuba, 207/1000), 24.8% (Koganei, 248/1000), 22.2% (Shizuoka, 222/1000), and 18.8% (Kagoshima, 188/1000), respectively. In this study, we used data on sociodemographic status and exercise habits from the first survey and data on perceived barriers to exercise from the second survey.

All participants signed an informed consent document before answering the questionnaire. This study received prior approval from the Tokyo Medical University Ethics Committee.

Measures

Perceived barriers to exercise

The Perceived Barriers to Exercise Scale[20] was the dependent variable. All items of this scale and Cronbach's alpha coefficients in this study sample are shown in Table 1. The scale consists of 5 subscales: (1) "discomfort," which comprises 7 items, including "causes sore muscles" and "get

Table 1. Scale for perceived barriers to exercise

Factors	Items	Alpha*
Discomfort		0.85
	Causes sore muscles	
	Look silly	
	Too uncoordinated	
	Too boring	
	Get hot and sweaty	
	Too fatigued by exercise	
	Uncomfortable	
Lack of motivation		0.70
	Too lazy	
	Lack of motivation	
Lack of time		0.85
	Too busy	
	Not enough time	
	Too much work to do	
	Interferes with work	
	Too tired	
Lack of social support		0.73
	Family does not encourage	
	Friends do not exercise	
	Interferes with social life	
	No one to exercise with	
Poor environment		0.60
	Bad weather	
	Lack of facilities	

*Cronbach's coefficient alpha.

hot and sweaty" (Cronbach's alpha, 0.85), (2) "lack of motivation," which comprises "too lazy" and "lack of motivation" (0.70), (3) "lack of time," which comprises 5 items, including "too busy" and "not enough time" (0.85), (4) "lack of social support," which comprises 4 items, including "family does not encourage" and "friends do not exercise" (0.73), and (5) "poor environment," which comprises "bad weather" and "lack of facilities" (0.60). Participants provided ratings on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) to the statement: "When I do not exercise, the important barrier is ..." followed by 20 barrier items. The mean values of the number of selected choices were calculated as scores of factors (range, 1 to 5). A higher score meant a stronger perception of the barrier. The factor structure, reliability, and criterion-related validity of the scale, as compared with the stage of change in exercise behavior, were confirmed in a previous study.[20]

Sociodemographic attributes and exercise habits

Sex, age, location of residence, educational attainment, employment status, marital status, presence of dependents (living with a child or a person in need of care), self-rated health, body mass index (BMI), and exercise habits were assessed by self-administered questionnaire. In this study, a child was defined as a junior high school student or younger. 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 of, "In general, would you say that your health is ...?". BMI was calculated based on self-reported weight and height. Regular exercise frequency (days/month) in a typical month was queried if the participant engaged in exercise for at least 60 minutes per month.

Statistical analysis

The Mann–Whitney U test and Kruskal–Wallis test were used to examine differences in perceptions of barriers to exercise by sociodemographic attributes. Responses to sociodemographic attributes and exercise habits were categorized as: sex (men/women), age (20–39 years/40–59 years/60–69 years old), location of residence (Tsukuba/Koganei/Shizuoka/Kagoshima), educational attainment (<13 years/≥13 years), employment status (employed/not employed), marital status (married/not married), presence of dependents (living with a child or a person in need of care/without dependent), self-rated health (good: excellent, very good, or good/fair or poor: fair or poor), BMI (<25.0/≥25.0), and exercise habits (<3 days/week/≥3 days/week). To examine the independent relationships between each sociodemographic variable and perceived barriers to exercise, multiple logistic regression analyses were conducted. For these analyses, all 9 sociodemographic variables were included in the model. Scores for perceived barriers were converted into dichotomous variables at the median. Locations of residences were included in the model as dummy variables. The odds of higher perceived barriers for the 9 sociodemographic attributes (sex, age, location of residence, educational attainment, employment status, marital status, presence of dependents, self-rated health, and BMI) were calculated. A P value of less than 0.05 was considered to indicate statistical significance. All statistical analyses were performed with SPSS 12.0J for Windows, SPSS Inc., Chicago, USA.

RESULTS

Participant characteristics

Table 2 shows the characteristics of the participants. In the overall sample, 46.5% of the participants were men. The mean age (SD: standard deviation) was 47.9 (13.9) years old. Average BMI was 23.5 (3.0) in men and 21.5 (3.1) in women. The percentage of regular exercisers (≥3 days/week) was 19.4% in men and 22.3% in women. The characteristics of participants living in each city are also shown in Table 2. The prevalence of exercisers and 3 sociodemographic variables—educational attainment, employment status, and living status—significantly differed by city.

Associations between perceived barriers and sociodemographic attributes

Among the overall sample, the medians (25th percentile to 75th percentile) of barrier scores were lack of time 3.0 (2.3–3.8), lack of motivation 2.9 (2.1–3.7), poor environment 2.2 (1.4–3.0), discomfort 1.8 (1.3–2.4), and lack of social support 1.6 (1.1–2.3) (Table 3). Perceptions of barriers to exercise differed significantly for 8 of 9 sociodemographic attributes and by exercise habit. Only location of residence was not related to perceived barriers. Men perceived significantly stronger barriers to exercise, as did participants who were younger, more highly educated, not married, employed, living with a child or person in need of care, overweight, nonexercisers, and had poorer self-rated health. Subscales of perceived barriers related to these variables differed by sociodemographic attributes. For example, subscales related to age were lack of motivation and lack of time, while those related to BMI were discomfort, lack of social support, and poor environment.

Table 4 shows the odds ratios of participants who perceived higher barriers. According to the results, 5 of 9 variables—age, education, employment status, self-rated health, and BMI—were independently related to the perception of barriers. Sex, location of residence, marital status, and presence of dependents were not associated with barrier perception. Younger participants perceived lack of motivation and lack of time more strongly than did older participants. Middle-aged participants perceived poor environment as a less of a barrier than did those who were older (60–69 years old). As for employment status, employed participants strongly perceived lack of time. Poorer self-rated health was significantly related to strong perceptions of

Table 2. Descriptive characteristics (numbers and percentages) of subjects and subsamples

	Overall *n* = 865	Men *n* = 403	Women *n* = 462	*P* value*	Tsukuba *n* = 207	Koganei *n* = 248	Shizuoka *n* = 222	Kagoshima *n* = 188	*P* value†
	n (%)	*n* (%)	*n* (%)		*n* (%)	*n* (%)	*n* (%)	*n* (%)	
Age, years									
20–29	135 (15.6)	52 (12.9)	83 (18.0)		37 (17.9)	36 (14.5)	31 (14.0)	31 (16.5)	
30–39	140 (16.2)	53 (13.2)	87 (18.8)		36 (17.4)	40 (16.1)	33 (14.9)	31 (16.5)	
40–49	185 (21.4)	85 (21.1)	100 (21.6)		48 (23.2)	50 (20.2)	53 (23.9)	34 (18.1)	
50–59	188 (21.7)	104 (25.8)	84 (18.2)		43 (20.8)	51 (20.6)	51 (23.0)	43 (22.9)	
60–69	217 (25.1)	109 (27.0)	108 (23.4)		43 (20.8)	71 (28.6)	54 (24.3)	49 (26.1)	
Mean ± SD	47.9 ± 13.9	49.3 ± 13.5	46.6 ± 14.3	0.001	45.5 ± 13.7	48.7 ± 14.1	48.3 ± 13.9	47.3 ± 14.3	0.090
Education, years									
<13	332 (38.6)	148 (37.1)	184 (39.8)	0.440	74 (35.9)	62 (25.2)	101 (45.5)	95 (50.8)	<0.001
≥13	529 (61.4)	251 (62.9)	278 (60.2)		132 (64.1)	184 (74.8)	121 (54.5)	92 (49.2)	
Marital status									
Married	650 (75.5)	321 (79.9)	329 (71.7)	0.005	153 (74.6)	183 (74.1)	179 (81.0)	135 (71.8)	0.148
Not married	211 (24.5)	81 (20.1)	130 (28.3)		52 (25.4)	64 (25.9)	42 (19.0)	53 (28.2)	
Employment status									
Employed	644 (74.5)	345 (85.6)	299 (64.9)	<0.001	169 (81.6)	179 (72.5)	172 (77.5)	124 (66.0)	0.002
Not employed	220 (25.5)	58 (14.4)	162 (35.1)		38 (18.4)	68 (27.5)	50 (22.5)	64 (34.0)	
Living with a child or person in need of care									
Yes	313 (36.2)	136 (33.8)	177 (38.3)	0.178	87 (42.0)	75 (30.4)	94 (42.3)	57 (30.3)	0.004
No	551 (63.8)	266 (66.2)	285 (61.7)		120 (58.0)	172 (69.6)	128 (57.7)	131 (69.7)	
Self-rated health									
Fair or poor	407 (47.2)	205 (50.9)	202 (43.9)	0.047	98 (47.8)	117 (47.2)	111 (50.0)	81 (43.1)	0.571
Good	456 (52.8)	198 (49.1)	258 (56.1)		107 (52.2)	131 (52.8)	111 (50.0)	107 (56.9)	
BMI, kg/m^2									
<25	689 (79.9)	288 (71.6)	401 (87.2)		161 (77.8)	204 (82.6)	181 (81.5)	143 (76.9)	
≥25	173 (20.1)	114 (28.4)	59 (12.8)		46 (22.2)	43 (17.4)	41 (18.5)	43 (23.1)	
Mean ± SD	22.4 ± 3.2	23.5 ± 3.0	21.5 ± 3.1	<0.001	22.5 ± 3.3	22.3 ± 3.2	22.4 ± 3.2	22.4 ± 3.2	0.926
Exercise, days/week									
<3	684 (79.1)	325 (80.6)	359 (77.7)	0.315	156 (75.4)	202 (81.5)	163 (73.4)	163 (86.7)	0.004
≥3	181 (20.9)	78 (19.4)	103 (22.3)		51 (24.6)	46 (18.5)	59 (26.6)	25 (13.3)	

Abbreviations: BMI, body mass index; SD, standard deviation.
*Comparisons between men and women, using the chi-square test or *t*-test.
†Comparisons between locations of residence, using the chi-square test or ANOVA.
The total numbers of respondents are not always equal, due to missing data.

discomfort, lack of motivation, and lack of social support. Regarding BMI, overweight participants (≥25.0) perceived stronger barriers of discomfort, lack of social support, and poor environment.

DISCUSSION

This study examined specific barriers to exercise perceived by populations of Japanese adults characterized by 9 sociodemographic attributes. The results indicated that 5 of 9 sociodemographic attributes were independently related to perception of barriers. In general, those who perceived higher barriers were younger, more highly educated, employed, had fair or poor self-rated health, and a high BMI. The specific types of perceived barriers varied by sociodemographic characteristics. For example, age was related to lack of motivation, lack of time, and poor environment, but not to other barriers. As for BMI, discomfort, lack of social support, and poor environment were more strongly perceived among overweight participants. Additional associations between population characteristics and specific types of barriers were also revealed in this study. These findings are important to better understand the correlates of exercise habits among specific population groups, and have implications for the development of exercise promotion strategies that are adjusted to the needs of target populations.

Among all participants, lack of time was the barrier for which the median was highest. As compared to 3 studies from other countries using population-based samples, our results are similar to those of the European[17] and Australian[19] studies, but not to those of the Brazilian study.[18] Because these studies used different scales to measure barriers, comparison and interpretation of the results must be undertaken carefully. Depending on the wording of items in each study, work/study, no time, and lack of time were the strongest barriers, respectively, in the European, Australian, and the present study, while in the Brazilian study, lack of money was reported as the strongest barrier. Lack of time was fourth-

Table 3. Comparison of scores for perceived barriers to exercise, by sociodemographic variables and exercise habits

	n*	Discomfort	Lack of motivation	Lack of time	Lack of social support	Poor environment
		Median (25%–75%)†	Median (25%–75%)†	Median (25%–75%)†	Median (25%–75%)†	Median (25%–75%)†
Overall		1.8 (1.3–2.4)	2.9 (2.1–3.7)	3.0 (2.3–3.8)	1.6 (1.1–2.3)	2.2 (1.4–3.0)
Sex						
Male	403	2.0 (1.4–2.5)	2.9 (2.1–3.7)	3.0 (2.3–3.8)	1.8 (1.1–2.4)	2.3 (1.5–3.0)
Female	462	1.7 (1.3–2.4)	3.0 (2.2–3.6)	3.1 (2.3–3.8)	1.6 (1.1–2.2)	2.2 (1.4–3.0)
P value‡		0.028	0.944	0.952	0.102	0.282
Age, years						
20–39	275	1.8 (1.3–2.5)	3.1 (2.3–3.9)	3.3 (2.6–3.9)	1.6 (1.1–2.3)	2.3 (1.4–3.1)
40–59	373	1.9 (1.4–2.5)	3.0 (2.2–3.7)	3.2 (2.5–3.9)	1.6 (1.1–2.3)	2.1 (1.4–2.9)
60–69	217	1.8 (1.3–2.4)	2.6 (1.8–3.3)	2.4 (1.7–3.2)	1.6 (1.1–2.3)	2.4 (1.5–3.0)
P value§		0.320	<0.001	<0.001	0.706	0.155
Location of residence						
Tsukuba	207	1.8 (1.3–2.5)	2.9 (2.1–3.7)	3.0 (2.3–3.9)	1.6 (1.1–2.3)	2.2 (1.4–3.0)
Koganei	248	1.8 (1.4–2.4)	3.0 (2.3–3.8)	3.1 (2.5–3.7)	1.6 (1.1–2.2)	2.3 (1.6–3.0)
Shizuoka	222	1.9 (1.3–2.5)	3.0 (2.2–3.6)	3.0 (2.2–3.9)	1.7 (1.1–2.4)	2.3 (1.5–3.0)
Kagoshima	188	1.8 (1.3–2.3)	2.8 (2.0–3.5)	2.9 (2.1–3.6)	1.7 (1.1–2.3)	2.1 (1.3–2.9)
P value§		0.501	0.203	0.149	0.603	0.215
Education, years						
<13	332	1.8 (1.4–2.5)	2.7 (1.9–3.4)	2.8 (2.1–3.6)	1.7 (1.1–2.3)	2.2 (1.4–3.0)
≥13	529	1.8 (1.3–2.4)	3.1 (2.3–3.8)	3.2 (2.4–3.8)	1.6 (1.1–2.3)	2.2 (1.5–3.0)
P value‡		0.751	<0.001	0.001	0.193	0.979
Marital status						
Married	650	1.9 (1.3–2.4)	2.9 (2.1–3.6)	3.0 (2.3–3.7)	1.6 (1.1–2.2)	2.2 (1.4–3.0)
Not married	211	1.8 (1.3–2.6)	3.0 (2.2–3.8)	3.2 (2.4–4.0)	1.7 (1.1–2.5)	2.3 (1.4–3.1)
P value‡		0.515	0.491	0.020	0.344	0.594
Employment status						
Employed	644	1.8 (1.3–2.5)	3.0 (2.2–3.7)	3.2 (2.5–3.9)	1.6 (1.1–2.3)	2.2 (1.5–3.0)
Not employed	220	1.8 (1.3–2.4)	2.9 (2.0–3.5)	2.5 (1.7–3.2)	1.6 (1.1–2.3)	2.2 (1.4–3.0)
P value‡		0.600	0.317	<0.001	0.832	0.740
Living with a child or person in need of care						
Yes	313	1.7 (1.3–2.5)	2.9 (2.0–3.7)	3.2 (2.4–3.9)	1.6 (1.1–2.3)	2.2 (1.4–3.0)
No	551	1.9 (1.4–2.4)	3.0 (2.2–3.7)	3.0 (2.2–3.6)	1.6 (1.1–2.3)	2.2 (1.5–3.0)
P value‡		0.301	0.473	0.010	0.941	0.944
Self-rated health						
Fair or poor	407	2.1 (1.5–2.6)	3.1 (2.3–3.8)	3.0 (2.3–3.8)	1.8 (1.1–2.4)	2.3 (1.6–3.0)
Good	456	1.7 (1.2–2.3)	2.8 (2.0–3.5)	3.1 (2.3–3.8)	1.5 (1.1–2.2)	2.1 (1.3–3.0)
P value‡		<0.001	<0.001	0.849	0.008	0.037
BMI, kg/m^2						
<25	689	1.8 (1.3–2.4)	2.9 (2.1–3.7)	3.0 (2.3–3.7)	1.5 (1.1–2.3)	2.2 (1.4–2.9)
≥25	173	2.1 (1.4–2.6)	3.1 (2.4–3.7)	3.1 (2.2–3.9)	1.9 (1.2–2.4)	2.5 (1.7–3.3)
P value‡		0.010	0.169	0.732	0.028	0.001
Exercise, days/week						
<3	684	1.9 (1.4–2.5)	3.0 (2.2–3.7)	3.1 (2.4–3.9)	1.7 (1.1–2.3)	2.3 (1.5–3.0)
≥3	181	1.5 (1.1–2.3)	2.7 (1.7–3.4)	2.8 (1.9–3.5)	1.3 (1.0–2.1)	2.2 (1.3–3.0)
P value‡		<0.001	<0.001	0.001	0.001	0.519

Abbreviation: BMI, body mass index.
Higher score means higher perception of a barrier to exercise.
*Total numbers of respondents are not equal, due to missing data.
†Twenty-fifth and 75th percentiles.
‡The Mann–Whitney U test was used to compare the scores of barrier perception between groups.
§The Kruskal–Wallis test was used to compare the scores of barrier perception between groups.

ranked among the 8 barriers in the Brazilian study. Regarding the relationship between sociodemographic characteristics and this barrier, all studies reported that lack of time was perceived more strongly among younger, as compared to older, age groups. However, the relationship between sex and the lack of time barrier is more complicated. In the European study, men strongly perceived this barrier; however, it was perceived more strongly among women in Brazil. By contrast, there were no sex differences in the perception of time constraints in either the present study or the Australian study. This suggests that the associations between specific types of barriers and population characteristics vary according to cultural