本研究で得られた初年度の研究成果の要約は以下の通りである。

1) 身体活動量，食物摂取量の実態

1日あたりの歩行数の中央値は，男性が7,447歩，女性が7,488歩であった。3METs以上の身体活動量は，男女ともに4エクササイズ(EX)であった。摂取カロリーは，男性が1,839kcal（たんぱく質: 13.2%, 脂質: 26.6%, 炭水化物: 60.0%），女性が1,443kcal（たんぱく質: 13.6%, 脂質: 30.0%, 炭水化物: 56.1%）であった。一人暮らしの学生は実家暮らしの学生と比較して，全ての栄養素において栄養摂取量が有意に少なかった。

2) うつ症状の実態

うつ症状の自己評価尺度であるCES-Dの得点が16点以上である有症状の割合は男子27.7%（391名），女子25%（156名）であった。CES-Dの得点は男子12.29±8.24（N=1412），女子11.83±7.42（N=623）で男女に差はなかった。主観的健康感やキャンパス生活の満足感が高く，主観的ストレスが低いほど，うつ症状の自己評価尺度であるCES-D得点の低いことが示唆された。また，生活習慣項目では，規則正しい生活を送り，主観的な睡眠の充足度が高いほどCES-D得点が低いことが示された。朝食の摂取頻度や平日の睡眠時間，住居形態，課外活動の有無については，男女で異なる結果となった。女子は毎日朝食を摂取し，適度な睡眠時間をとっている者，男子は自宅に住み，課外活動をしている者がCES-D得点の低いことが報告された。

3) ストレス対処能力（首尾一貫感覚：SOC）の実態

初年度のストレス対処能力（首尾一貫感覚：SOC）および主観的健康感，主観的ストレス，生活習慣との関連性について検討した。その結果，主観的健康感やキャンパス生活の満足感が高く，主観的ストレスが低い者ほど，SOC得点の高いことが示唆された。また，生活習慣項目では，規則正しい生活をしており，主観的な睡眠の充足度が高いほどSOC得点の高いことが報告された。

4) QOLの実態

主観的健康感が高く，主観的ストレスが低いほど，WHO/QOL26の得点が高いことが示唆された。また，生活習慣項目では，規則正しい生活を送り，主観的な睡眠の充足度が高いほどQOL得点が高いことが示された。勉強時間が1時間以上で，運動習慣のあるものがQOLが高い傾向にあることも認められた。通学に関しては，通学時間という客観的な指標ではQOL得点に差はみられなかったが，主観的な通学の疲労感が高いほどQOL得点が高かった。QOLについて，ライフスタイルや学業，運動，通学など環境要因と主観的・心理的指標と関連していることが示唆された。

3. 今後の課題と展望

大学時代は，概ね学部の時期が青年期後期に相当し，その後には社会人として社会に適応していく前成年期が続く。現在は大学院進学率も上がっているので前青年期にも社会にでない人が増えている。青年期は精神的な危機を迎える時期の一つであると見なされてきたが，一方で多くの人々は青年期を特に問題なく過ごすともいわれている。なお思春期（青年期前期）の心性を残す人々があるが，社会への巣立ちが近づいた青年期後期に至って多くの人々は大きく精神的な成長を遂げていく。しかし近年，我が国では社会性の低い若者が増えていると憂う見方が強まっている。

大学生（学部生）に精神的な問題が生じる時期として，入学直後と研究室への配属の時期，そして卒業前の半年を上げることが出来るであろう。今回の調査研究では，入学後の前期期間中に，必須科目である「健康・スポーツ科学演習」の授業を通じて全学生の精神状態や生活などについて調査した。これによって，大学生の初期の精神状態や生活状態について或る程度の詳しさをもった情報を直接把握することができた。この結果から，大学生活の初期の適応の良し悪しについて状態を推定することができる。

今後は，この学年の学生達について在学中に追跡調査を行うことで大学生活のその後の変化について調べ，入学初期の状態のその後の精神状態の変化や学生生活への影響を明らかにして。大学入学後の指導や介入の必要性などについて知見を得ることができるだろう。

まず1年後に同様の調査を行って，大学生活の初期の状態とその短期的な変化の関係，また初期の修学への影響を明らかにして，大学入学後早期の指導や介入の必要性などについて知見を得ることができるだろう。

追跡調査としては，そのほか従来4月の定期健康診断時に行っているアンケートによる健康調査のデータを使うことが出来る。定期健康診断の際に，身体計測や診察の前にアンケートによる健康調査をおこなって学生の精神状態や生活習慣について調べている。今回の調査をもとにして，大学在学中の学生の変化につい

て知見を得ることが可能となるであろう。特に今回の調査では運動量を直接測定しており，このデータを用いて日常的な身体活動の効果（これには健康科学センターで従来調査して指導加入してきた肥満など生活習慣病の萌芽との関係も含まれる），また学生時代の自由な生活のなかでの身体活動習慣の進展や衰弱への影響について知見が得られると期待される。

今回の調査の主要な部分は，自覚についての調査である。メンタルヘルスの悪化した場合の難しい問題として，本人の自覚と客観的な精神的な状況が一致しない点にある。しかし，病的ではない人々で知的能力が低くない人であれば，集団としてそれほどの乖離は見られないと考えられる。

また，その後の修学状況，休学や退学，あるいは卒業の遅延との関係を調べることで，入学後の状況がその後の修学に与える重篤な影響の有無を調べることができるであろう。

大学の学生の全員について調査を行う機会は少ない。大学では個別的な活動が原則であり，入学後に全調査を行うことは難しい。今回は，「健康・スポーツ科学演習」という健康と密接な関係を有する授業で，健康に関する意識を身につけるための授業の一貫として調査を行うので，全員に調査を行うことが出来た。

今回の調査の結果を踏まえて，健康や精神状態に不安やそのほかの心配される問題がある場合には，専門のカウンセラー，医師など連携して学生の健康支援を行う予定にしている。今後は，こうした支援を合理的で納得のいくものにするための客観的な証拠としての研究成果を得たいと思う。

九州大学の学生のメンタルヘルス支援はこれまで系統的ではなかった。メンタルヘルスの悪化が危惧されるが，全学的な一次予防の充実なしには対策が構築できない状況にある。今後，修学支援とコミットした形で全学的な学生支援システムが構築される予定であるが，今回の調査で行った入学直後からの学生の状態の適切な評価をもとに個々の学生への支援を目指すことになるであろうと期待する。

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Original Article

Relationship Between the Change in Daily Step Count and Brachial-Ankle Wave Velocity During a Pedometer-Based Physical Activity Program for Older Adults

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Abstract

Objective: To study the relationship between the change in the number of steps taken and brachial-ankle pulse wave velocity (baPWV) during a long-term pedometer-based physical activity program in healthy older adults.
Methods: Sixty older adults participated in this 17-week program. Each subject was provided with a pedometer and was given a goal to walk a set number of steps/day. After five subjects were excluded because of insufficient step data, data from 55 subjects (19 men and 36 women; age range: 65–79 years, mean age: 71.3±3.7 years; mean body mass index [BMI]: 24.1±8.8 kg/m^2) were analyzed. Subjects were checked before and after the study. Each subject was informed of his or her vascular age, calculated from baPWV, at the start of the study.
Results: Subjects were divided into four groups based on the results of baPWV. The group in which baPWV improved above a selected cut-off value (1,700 cm/s) revealed the largest increase in steps/day among groups. This increase (4837.7±1868.7 steps) was larger than in groups in which baPWV remained low (1406.7±2402.1 steps, p=0.036) and high (1678.2±2871.4 steps, p=0.059). In any group, age or initial steps/day did not influence the change in steps. Subjects classified as having an older vascular age than the actual age on the basis of initial baPWV walked further.
Conclusion: An increase in steps/day might improve baPWV. Although walking is a low intensity physical activity, it can have an anti-atherosclerosis effect.

KEY WORDS: walking, atherosclerosis, arterial stiffness, baPWV, aging

Introduction

Pulse wave velocity has been used as an indicator of atherosclerosis and arterial stiffness [1].Recent studies have focused on the use of brachial-ankle pulse wave velocity (baPWV) as a clinical tool for screening atherosclerosis [2]; this variable was recognized in 2009 as a tool for the measurement of arterial stiffness in guidelines for the diagnosis of hypertension by the Japanese Society of Hypertension (JSH2009) [3].Habitual Physical activity has been reported to effectively prevent atherosclerosis [4] even when begun at an older age [5,6]. This emphasizes the importance of appropriate physical activity programs for older people. Such physical activity programs should be effective, safe and easy, and walking is one activity suitable for older people [7]. A quantitative increase of physical activity has been reported to prevent atherosclerosis [8]. Accordingly, an increase in the number of steps taken may improve baPWV. However, most previous studies assessed the effectiveness of physical activity programs on baPWV either using resistance training [9] or exercise at special facilities [10-14]. Such exercise programs are difficult for older people to complete at home without supervision. We are not aware of any investigation the relationship between the number of steps taken and baPWV among older adults.

In the present study, we established a long-term pedometer-based physical activity program for healthy older adults and analyzed the relationships between change in steps/day and change in baPWV. We hypothesized that the change in steps/day would lead to an improvement in baPWV.

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Methods

1. Subjects

A total of 60 healthy older adults (65 years old or older), living in the central district of S City, Hokkaido participated in this study. Subjects were recruited either from the city news of S City or bulletin boards in the city center (the Central Health Center or the M Community Development Center). During analysis, four subjects were excluded because of insufficient step data during the study period and one subject missed the final checkup for personal reasons and was excluded from the study. Therefore, data from a total of 55 subjects (19 men and 36 women; age range: 65–79 years, mean age: 71.3±3.7 years; mean body mass index [BMI]: 24.1±8.8 kg/m^2) were included in the analyses. All subjects provided written informed consent. The present study was approved by the Ethics Committee of the Graduate School of Education at Hokkaido University.

2. Pedometer-based physical activity program

The procedures of the physical activity program are described elsewhere [15]. Briefly, the program consisted of pedometers and newsletters. Each subject was provided a pedometer (Walking Style HJ-720IT, Omron Healthcare Co. Ltd., Ukyo-ku, Kyoto) and instructed to walk everyday during the study. Each subject was given a goal to walk a set number of steps/day. At least once a month, subjects were instructed to bring their pedometers to the assigned center. Step data were entered by health nurses or staff into a personal computer using BI-Link Professional Edition 2.0 software (Omron Healthcare Co. Ltd., Ukyo-ku, Kyoto). Newsletters were delivered to each subject's house every four weeks. Newsletters for each subject showed the average steps/day achieved for the current month as well as the goal number of steps/day for the upcoming months, determined based on the individual's average steps/day in the current month using the following criteria. Step goals for each month were decided as follows: increase of 1,000 steps/day for subjects below 5,000 [16], increase to 7,500 steps/day for 5,000-7,500 [17], increase to 10,000 steps/day for 7,500-10,000 [17], and maintenance steps/day over 10,000 [16]. In step data analysis, the average steps/day for the first week (Week 0) of the study were treated as baseline data for "start of the study". Only data obtained during a wearing period of >12 hours per day was included in analysis. This excluded low steps/day data if a subject forgot to wear his or her pedometer.

3. Measurements of anthropometrics, blood pressure and baPWV

Each subject was given a medical checkup before and after the study, after an overnight fast. Anthropometrics, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured before the program was started; baPWV was measured separately on a different day during 0900-1500 h at rest using an automatic oscillometric device (form PWV/ABI; Omron Colin Co. Ltd., Bunkyo-ku, Tokyo). The validity and reproducibility of baPWV measurements have been described elsewhere [18].

4. Estimation of vascular age from baPWV

The instrument used in the study is calibrated so that vascular age can be calculated from baPWV [19]. At the beginning of the study, each subject was informed of his or her vascular age via mail. When a subject's calculated baPWV was within the range average to average + ½ standard deviation (SD) of the standard baPWV [19] for their actual age, their vascular age was set as equal to their actual age. If baPWV differed by more than average + ½ SD from the standard, his or her vascular age was calculated from the value average +½ SD. The subjects were divided into two groups to analyze the effect of differences between estimated vascular age and actual age; subjects were allocated to a vascular age-older group if vascular age was estimated as ≥2 years older than actual age; otherwise, the subject was enrolled into the vascular age-younger group.

5. Statistical analysis

All data were expressed as mean±SD, and $p<0.05$ was considered statistically significant. Statistical tests were performed using SPSS for Windows Ver. 15.0 (SPSS Inc., Chicago, IL, USA). Differences within groups were estimated by paired t-test or Wilcoxon's signed rank test. The differences between groups were estimated using one-way ANOVA, ANCOVA and the x^2-test. Dunnett's test was used to compare weekly average steps/day (Week 1-16) with baseline steps/day (Week 0). To estimate the effect of increasing steps/day during the study, Δsteps/day was calculated using the following formula [20]:

Δsteps/day = ∑{(steps/day at Week X) – (steps/day at Week 0)} *(X=1-16)

To evaluate change in baPWV, we set a cut-off baPWV = 1,700 cm/s. Although there is no clear cut-off value of baPWV that defines organ disorders [21], this value is a predictor of several health disorders such as all mortality [22], type 2 diabetes mellitus [23], cerebral ischemic small vessel disease [24] and acute coronary syndrome [25]. Each subject was categorized as either 'high' or 'low' according to his or her starting baPWV above or below the cut-off value.

At the end of the study, subjects were divided into four groups: the high-high (HH) group remained above the cut-off value baPWV throughout the study; the low-low (LL) group remained below the cut-off value; and the low-high (LH) and high-low (HL) groups showed a change in baPWV across the cut-off value.

Results

Characteristics of the subjects

Fifty-five subjects completed the study. At the start of the study (baseline), actual age, SBP, DBP and baPWV of the HH group was higher than other groups ($p<0.05$) The average steps/day in the first week (Week 0) and the sex ratio was similar in all groups (*Table 1*).

Change in steps/day (Δsteps/day)

The change in number of steps/day (Δsteps/day) in each group is shown in *Fig. 1*. The HL group (4837.7±1868.7 steps) changed more than the LL group (1406.7±2402.1 steps, p=0.036) and tended to be larger than HH group (1678.2±2871.4 steps, p=0.059). The difference between groups in Δsteps/day was unchanged after age and steps/day at baseline were adjusted using ANCOVA. This indicates that neither age nor steps/day at baseline affected Δsteps/day among groups.

Table 1 Characteristics of the subjects at baseline

	LL (n=22)	LH (n=4)	HL (n=6)	HH (n=23)	*p* -value	post-hoc
Male sex (No.)	5	3	3	8		
Weight (kg)	56.2 ± 7.0	61.1 ± 11.5	60.1 ± 9.4	60.8 ± 9.6	0.323	
BMI (kg/m²)	23.2 ± 2.1	24.1 ± 2.9	23.7 ± 1.8	24.7 ± 2.5	0.203	
Waist circumference (cm)	86,0 ± 6.3	82.8 ± 10.0	88.9 ± 2.5	90.4 ± 7.9	0.097	
Hip circumference (cm)	95.9 ± 5.2	96.1 ± 2.6	97.6 ± 4.2	98.4 ± 4.7	0.371	
SBP (mmHg)	132.7 ± 14.2	135.8 ± 14.6	141.7 ± 18.0	154.6 ± 19.0	0.001	LL<HH
DBP (mmHg)	76.3 ± 7.4	76.2 ± 3.4	79.2 ± 8.6	82.9 ± 12.1	0.019	LL<HH
baPWV (cm/s)	1,520.9 ± 121.9	1,666.8 ± 14.3	1,793.8 ± 94.0	2,068.7 ± 284.7	0.000	LL<HL<HH
Steps/day at week 0 (step)	10,114.2 ± 3,062.9	9,509.2 ± 3,882.3	8,506.1 ± 2,303.6	8,801.0 ± 3,940.4	0.573	

Values are Means ± SD.

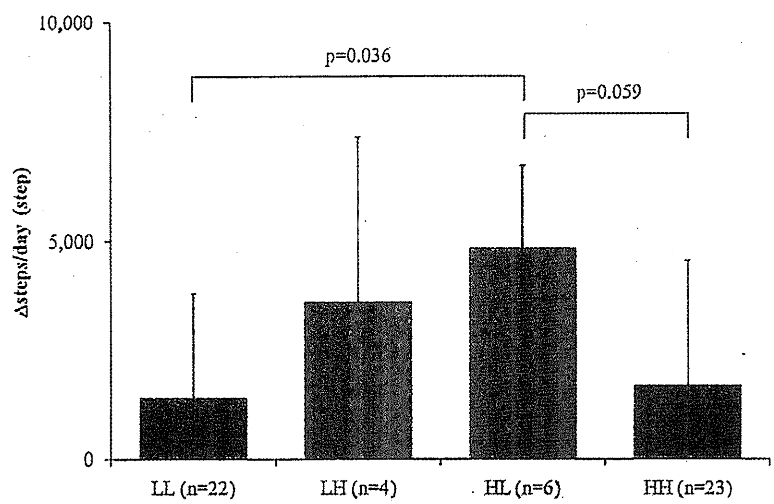

Fig. 1. Comparison of the change in steps/day among four groups based on the cut-off value of baPWV
Error bars show SD.

Change in anthropometrics and resting blood pressure

The changes in weight, waist circumference, hip circumference, SBP and DBP are shown in *Table 2*. Weight, waist circumference and hip circumference decreased in all groups except the LH group ($p<0.05$, *Table 2*).

Change in baPWV

The baPWV of the two groups above or below the baseline cut-off value are compared in *Fig. 2*. The change in baPWV tended to be larger in the LH group than the LL group ($p=0.083$) but there was no significant difference in change in baPWV between the HH and HL groups.

Difference in steps/day between vascular age-older and age-younger groups.

The average steps/day in the age-older group increased every week except week 1 and 2 ($p<0.05$, *Fig. 3a*); in the vascular age-younger group, the average steps/day only increased in week 5–9 and 13–14 ($p<0.05$, *Fig. 3b*).

Discussion

The present study examined whether change in baPWV was related to the number and change in number of steps/day. We found the HL group (indicating baPWV changed from high level at the start of the study to low level at the end of the study) exhibited greatest increase in steps/day. This implies that subjects with a higher initial baPWV who increased steps/day tended to decrease baPWV by the end of the program.

It is important to note that this program consisted of daily walking and all subjects were older adults. As far as we know, the effect of walking alone and quantitative investigation of physical activity on baPWV have not been previously reported. Most previous studies [10-14] measured the effect of supervised physical activity sessions using exercise facilities. For older people, visiting exercise facilities appears more difficult than walking. Given that walking is easily included in everyday routine, the results in the present study are clinically meaningful.

BaPWV is strongly influenced by SBP [26]. However, when the baPWV was adjusted for baseline SBP the change of baPWV in the HL group was greater than that in the LH group. As Δsteps/day in HL group was the largest of the four groups, the result suggests the improvement in baPWV was related to the increase in steps.

Table 2 The change in anthropometrics, blood pressure and baPWV in each group

	LL (n=22)	*p* -value	LH (n=4)	*p* -value	HL (n=6)	*p* -value	HH (n=23)	*p* -value
Weight (kg)	−1.6 ± 2.1	0.002 **	−0.6 ± 2.1	0.583 **	−2.3 ± 1.8	0.026 *	−1.8 ± 1.6	0.000 ***
BMI (kg/m²)	−0.7 ± 0.9	0.002 **	−0.3 ± 0.8	0.553 **	−0.9 ± 0.6	0.023 *	−0.7 ± 0.6	0.000 ***
Waist circumference (cm)	−2.4 ± 3.6	0.005 **	−2.2 ± 2.1	0.126 **	−3.4 ± 4.0	0.090	−1.7 ± 3.9	0.043 *
Hip circumference (cm)	−3.6 ± 5.1	0.003 **	−0.5 ± 5.3	0.854 **	−5.3 ± 3.5	0.014 *	−3.0 ± 3.5	0.001 **
SBP (mmHg)	−11.4 ± 13.3	0.001 ***	8.8 ± 17.6	0.394 ***	−11.7 ± 13.6	0.090	−2.7 ± 16.8	0.450
DBP (mmHg)	−4.4 ± 7.6	0.014 *	8.0 ± 6.9	0.104 *	−6.0 ± 4.1	0.016 *	−2.9 ± 12.0	0.258
baPWV (cm/s)	−46.2 ± 87.6	0.022 *	157.5 ± 103.6	0.056 *	−134.0 ± 70.1	0.005 **	−69.5 ± 211.9	0.130

Values are Means ± SD. * p <0.05, ** p <0.01, *** p <0.001 vs. baseline.

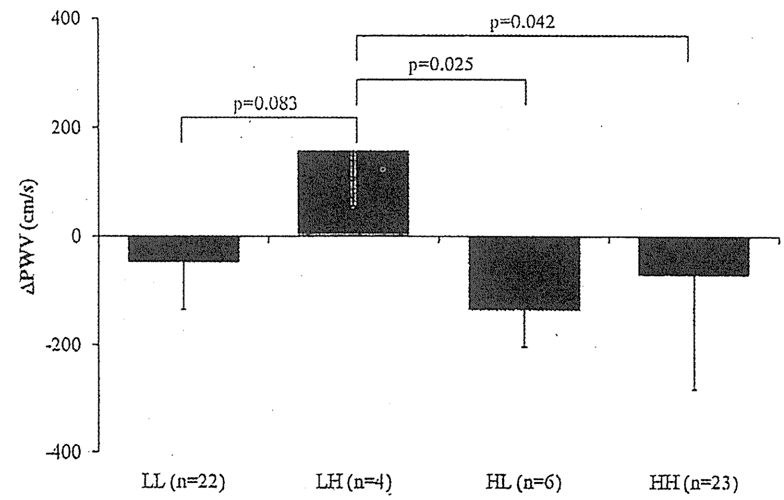

Fig. 2. Comparison of the change in baPWV among four groups based on the cut-off value of baPWV
Error bars show SD.

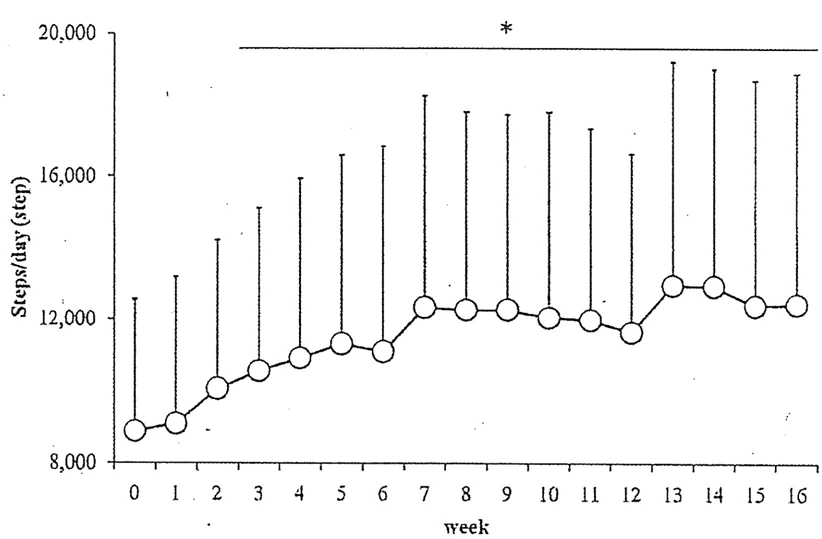

Fig. 3a. The average steps/day of vascular age-older group during the study
* p<0.05 compared with week 0. Error bars show SD.

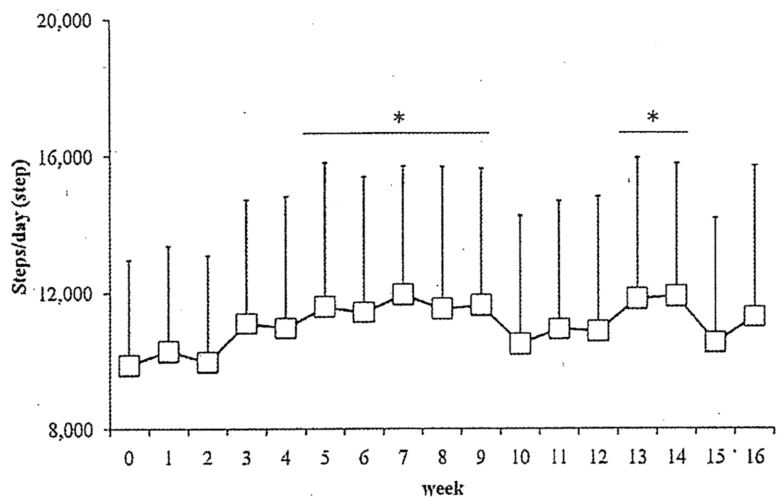

Fig. 3b. The average steps/day of vascular age-younger group during the study
*$p<0.05$ compared with week 0. Error bars show SD.

There is a dramatic, exponential [27] increase in baPWV with increasing age [28,29]. In the present study, the average baPWV of the subjects at baseline (men, 1,820.1±321.5 cm/s; women, 1,774.7±323.7 cm/s) was slightly higher than previously reported [28]. Previous studies found PWV increased 7.5–11.8 cm/s per year [29] and the decrease of 46.0 cm/s found in the present study (data not shown) is equivalent to an Anti-Aging effect of approximately 4–6 years. This demonstrates the potential of programs that encourage older people to increase daily steps to prevent atherosclerosis.

However, the physical activity level of the subjects at baseline may also affect the results. Subjects in the present study were highly active; the average steps/day at baseline was 9,389.1±3,412.1, markedly higher than that reported in other studies of men and women in their 60s (7,961 for men and 6,666 steps for women) [30]. Further study needs to explore the effects of physical activity in more sedentary people.

Further, the steps/day of subjects in the two groups based on vascular age assessed by baPWV differed. The vascular age-older group (indicating vascular age > actual age at start of the study) exhibited greatest increase in steps/day, although there was no difference between the two groups at the start of the study (*Fig. 3a,b*). That is, subjects whose vascular age was diagnosed >2 years older than actual age, walked more during the study. This result suggests that informing subjects of their vascular age encouraged the age-older group to increase physical activity. Previous studies have also suggested that telling subjects their cardiovascular age [31] or lung age [32] yielded better results than traditional therapies. Similarly, it was reported that interventions that used a pedometer and provided a goal induced an increase in steps/day [33]. Taken together, showing older people simple indexes such as "goal steps/day" or "vascular age" may be an effective tool for increasing physical activity among the elderly.

The limitation of the present study was that we could not show any relationship between baPWV and other indicators except steps/day. This may be a result of small sample size or individual differences. However, previous studies reported that higher baPWV is related to slower walking speed among older people [34] and an increase of 100 cm/s baPWV increases sarcopenia risk among older people by 1.14 times [35]. Higher PWV may affect other physical measures other than atherosclerosis. These facts imply the decrease of PWV in this study may improve health and physical functions of older people.

Conclusions

The present study examined the effects of a 17-week pedometer-based physical activity program for healthy older adults and the relationship between change in steps/day and change in baPWV. The findings are:

1. Even low intensity physical activity such as walking may decreased baPWV.
2. A group, in whom baPWV was above 1,700 cm/s at baseline and decreased baPWV during the study, showed the largest increase in steps/day during the study
3. A group, in whom vascular age at baseline was diagnosed older than his/her actual ages, increased steps/day during the study.

These findings suggest that high individual baPWV may be decreased by increasing number of steps/day although no dose-response relationship was found between number of steps/day and baPWV. Providing simple indicators such as vascular age and target number of steps can encourage older people to increase physical activity.

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Original Article

Use of Doubly Labeled Water to Validate a Physical Activity Questionnaire Developed for the Japanese Population

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ABSTRACT

Background: No study has attempted to use the doubly labeled water (DLW) method to validate a physical activity questionnaire administered to a Japanese population. The development and refinement of such questionnaires require that physical activity components related to physical activity level be examined.

Methods: Among 226 Japanese men and women 20 to 83 years of age, total energy expenditure (TEE) was assessed using the Japan Arteriosclerosis Longitudinal Study Physical Activity Questionnaire (JALSPAQ), and the results were compared with TEE measured by the DLW method as a gold standard. Resting metabolic rate (RMR) was measured using the Douglas Bag method.

Results: The median TEE by DLW and physical activity level (PAL: TEE/RMR) were 11.21 MJ/day and 1.88, respectively, for men, and 8.42 MJ/day and 1.83 for women. JALSPAQ slightly underestimated TEE: the differences in mean and standard error were −1.15 ± 1.92 MJ/day. JALSPAQ and DLW TEE values were moderately correlated (Spearman correlation = 0.742, $P < 0.001$; intraclass correlation coefficient = 0.648, $P < 0.001$), and the 95% limit of agreement was −4.99 to 2.69 MJ. Underestimation of TEE by JALSPAQ was greater in active subjects than in less active subjects. Moderate and vigorous physical activity and physical activity during work (ie, occupational tasks and housework) were strongly related to physical activity level. However, the physical activity components that differentiated sedentary from moderately active subjects were not clear.

Conclusions: Physical activity level values on JALSPAQ and DLW were weakly correlated. In addition, estimation of TEE in active subjects should be improved, and the use of a questionnaire to differentiate activity in sedentary and moderately active subjects must be reassessed.

Key words: physical activity questionnaire; doubly labeled water; physical activity; energy expenditure

INTRODUCTION

Accurate assessment of physical activity level is fundamental in epidemiological studies that examine the effect of physical activity on disease prevention and health promotion. Although there are several methods for estimating physical activity level, questionnaires are the most common assessment tool in such studies. Many types of physical activity questionnaires are used in epidemiological studies, but a validation study of such questionnaires suggested that the reliability and validity of measurements of habitual physical activity are quite low.[1–3] In addition, Neilson et al suggested that the ability of physical activity questionnaires to predict total energy expenditure (TEE) is limited. Westerterp et al suggested that questionnaires are satisfactory as an instrument for ranking physical activity level, but not as tools for assessing absolute TEE.[4] We previously examined the International Physical Activity Questionnaire (IPAQ) and reported that it was difficult to distinguish sedentary from moderately active individuals in the Japanese population.[5] Although the IPAQ was developed for international use, we maintain that questionnaires designed to suit each country or culture would increase the validity of assessments of physical activity level. The Japan Arteriosclerosis Longitudinal Study Physical Activity Questionnaire (JALSPAQ) was developed to assess physical activity in the Japan Arteriosclerosis Longitudinal Study.[6,7] This questionnaire was developed using data from physical activity records for the Japanese

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population and included detailed questions on occupational work, housework, and leisure-time physical activity.

The doubly labeled water (DLW) method is an excellent method for measuring TEE in free-living subjects over a period of 1 to 2 weeks[8] and is often used as a gold standard to validate field methods of assessing physical activity levels. However, to our knowledge, only our previous study[5] has used it to examine the validity of a questionnaire used for the Japanese population.

The primary objective of this study was to use the DLW method as the gold standard to validate a physical activity questionnaire developed for the Japanese population. To aid in the development of a valid physical activity questionnaire for Japanese, the secondary objective was to identify the physical activity component that had the greatest impact on physical activity level (PAL).

METHODS

Subjects

The study participants were 226 Japanese men and women age 20 to 83 years (mean ± standard deviation, 50.4 ± 17.1 years) who volunteered at community health care centers and workplaces or enrolled via the internet homepage of our institute. The inclusion criteria of the present study were as follows: absence of any condition affecting energy or water metabolism (eg, thyroid or kidney disease), not pregnant or breast-feeding, residence in home prefecture 2 weeks before and during the study, not on weight-loss or treatment diet, and not consuming more than 40 grams of alcohol per day. The occupations of the participants were homemaker ($n = 59$), office worker ($n = 57$), shipbuilder ($n = 17$), shop assistant ($n = 14$), no regular work ($n = 14$), nurse ($n = 13$), teacher ($n = 11$), salesperson ($n = 11$), factory worker ($n = 6$), clinical examination technician ($n = 5$), physiotherapist ($n = 4$), and other ($n = 12$, cleaner, gardener, dietitian, priest, sports instructor, carpenter, etc.). We were unable to randomly select subjects according to physical activity level. Over the entire assessment period, the participants were carefully instructed to maintain their normal daily activities and eating patterns and to make no conscious effort to lose or gain weight.

Study protocol

This study was approved by the Ethics Committee of the National Institute of Health and Nutrition in Japan. All subjects gave their informed consent in writing before the investigation was begun. TEE was estimated over 1 or 2 weeks, depending on the 2 half-lives of the isotopes used in the DLW method. Body mass and height were measured in the fasting state before administering the dose of DLW and on the last day of the study. On the first day of the study period, baseline urine was collected, and measurements of resting metabolic rate (RMR) and DLW dosing were obtained. The physical activity questionnaire and dietary assessment were completed between the 10th and 12th day of the study period and were checked by the researchers on the last day.

Measurement of resting metabolic rate

Subjects were instructed to refrain from moderate to vigorous physical activity for 24 hours, to fast at least 12 hours, and to get sufficient sleep before the measurements. They were instructed to arrive at the laboratory between 8AM and 9AM. After arrival, they rested quietly in the supine position for 30 minutes before the measurements. Using a mask connected to a Douglas bag, expired gas was collected twice for 10 minutes, with a 1-minute interval between collections. During all RMR measurements, the room temperature was maintained at approximately 24°C. Subjects were lying down and fully awake during the measurements. They were also free from emotional stress and were familiar with the apparatus used. The volume of expired air was measured with a certified gas meter (DC-5, Shinagawa, Tokyo, Japan), the accuracy and precision of which were maintained within 1% of the coefficient of variation (CV). Concentrations of oxygen and carbon dioxide were measured with a mass spectrometer (ARCO-1000, Arco Systems, Chiba, Japan). The precision of expired gas measurement was 0.02% for oxygen and 0.06% for carbon dioxide. RMR was calculated using Weir's equation.[9]

DLW energy measurement

After providing a baseline urine sample, a single dose of approximately 0.06 g/kg body weight of $^{2}H_2O$ (99.8 atom%, Cambridge Isotope Laboratories, MA, USA) and 1.4 g/kg body weight of $H_2{}^{18}O$ (10.0 atom%, Taiyo Nippon Sanso, Tokyo, Japan) was given orally to each subject. Then subjects were asked to collect urine samples at 8 predetermined times during the study period, at the same time of day. Except for the baseline collection, all urine samples were collected by the participant, and the time of sampling was recorded. All samples were stored by freezing at −30°C in airtight parafilm-wrapped containers and then analyzed in our laboratory.

Gas samples for the isotope ratio mass spectrometer (IRMS) were prepared by equilibration of the urine sample with a gas. CO_2 was used to equilibrate ^{18}O, and H_2 was used for ^{2}H. Pt catalyst was used for equilibration of ^{2}H. The gas sample of the CO_2 and H_2 was analyzed by IRMS (DELTA Plus; Thermo Electron Corporation, Bremen, Germany). Each sample and the corresponding reference were analyzed in duplicate. The average standard deviations for the analyses were 0.5‰ for ^{2}H and 0.03‰ for ^{18}O. TEE was expressed as mean TEE per day over the study period.

Calculations of isotopic abundance and TEE

The ^{2}H and ^{18}O zero-time intercepts and elimination rates (k_H and k_O) were calculated using a least-squares linear regression on the natural logarithm of isotope concentration as a function of the elapsed time from dose administration. Zero-time intercepts were used to determine the isotope pool sizes. Total body water (TBW) was calculated from the mean value of the isotope pool size of ^{2}H divided by 1.041 and that of ^{18}O divided by 1.007. The mean ko/kd of the present study was 1.28 ± 0.06 (range, 1.15–1.56). All ko/kd values were maintained within the recommended range (1.1 to 1.7) for quality control of the analysis, as recommended by the International Atomic Energy Agency.[10] rCO_2 was calculated as follows: $rCO_2 = 0.4554 \times TBW \times (1.007ko - 1.041k_H)$. Calculation of TEE (kcal/day) was performed using a modified Weir's formula based on the CO_2 production rate (rCO_2) and food quotient (FQ).[9] FQ was calculated from the dietary survey during the study period. The calculation assumed that under conditions of perfect nutrient balance, the FQ must equal the respiratory quotient (RQ).[11–13] The average FQ of each occupational group was used for each group (FQ = 0.85–0.95). However, FQ values stratified by occupational group, sex, and age were not significantly different. Physical activity level (PAL) was calculated as TEE/RMR.

Physical activity questionnaire

The physical activity questionnaire developed for the Japan Arteriosclerosis Longitudinal Study (JALSPAQ) was used in this study.[6,7] This questionnaire comprises 14 questions on occupation, locomotion, housework, sleep time, and leisure-time physical activities. In this questionnaire, occupational work was assessed as duration of sitting, standing, walking, and heavy work. Heavy work was defined as lifting more than 10 kg or manual labor of similar intensity. Leisure-time physical activity was assessed by type, duration, and frequency. Questionnaire data were converted to the intensity of each physical activity expressed in metabolic equivalents (METs), according to the Compendium by Ainsworth et al, and summarized as METs·h/day and energy expenditure.[14] In the present study, we used TEE per day, METs·h/day, and PAL as indices of physical activity level from JALSPAQ. Duration of light (<3 METs), moderate (3–5.9 METs), and vigorous (≥6 METs) physical activities was calculated for all physical activities (including occupational activity, housework, and leisure-time physical activity), as well as for leisure-time physical activity only. Working time, including occupational and housework time, was divided into the duration of sitting (<2 METs), standing (2 to <3 METs), walking (3 to <6 METs), and heavy work (≥6 METs), including housework. We calculated the durations of occupational activity and housework together because their frequencies and durations were quite complicated.

Dietary assessment

Dietary habits were assessed by using a brief self-administered diet history questionnaire (BDHQ)—a 4-page structured questionnaire that requested information on the consumption frequencies for a total of 56 food and beverage items, with specified serving sizes described in terms of the servings commonly consumed in the general Japanese population.[15] Energy and macronutrient intakes were calculated using a computer algorithm for the BDHQ, which was based on the Standard Tables of Food Composition in Japan. FQ was calculated by using the equation of Black et al.[11]

Statistical analysis

Statistical analyses were performed using SPSS for Windows (version 16.0J; SPSS Inc., IL, USA). Physical characteristics are classified using the sex and age groups outlined in the Dietary Reference Intake (DRI) of Japan. The estimated energy expenditure data were generally not normally distributed; therefore, medians and interquartile ranges are used to describe these results. Sex and age-group differences were compared using 2-way analysis of covariance. The Bonferroni procedure was used as the post-hoc test. The relation between TEE as estimated by DLW and JALSPAQ was expressed as Spearman correlations, intraclass correlation coefficient (ICC), and 95% limits of agreement (95% LOA: mean difference ± 2 × SD of the mean difference). Bland-Altman plots were also created to evaluate the differences between the 2 methods. To examine the type of physical activities that affected physical activity level, we used 1-way analysis of covariance, Pearson's correlation coefficients, and partial correlation coefficients adjusted for sex and age group.

RESULTS

The physical characteristics of the subjects are shown in Table 1. Body weight did not change significantly during the study period ($P = 0.313$). Among all subjects, 2.8% of men and 6.8% of women were classified as lean (body mass index [BMI] <18.5 kg/m^2), and 31.5% of men and 17.8% of women were classified as obese (BMI >25 kg/m^2) according to the criteria for Japanese.[16] The average TBW was 37.3 ± 7.1 kg in men and 25.9 ± 2.8 kg in women. When 73.2% was defined as the proportion of water in fat-free mass, the percent of fat mass was 24.3 ± 6.1% in men and 33.4 ± 7.0% in women.[17] Three men aged 30 to 49 years had a body weight higher than 100 kg; however, they were fit and their percent of fat mass was less than 25%. In addition, in the assessment of TEE by DLW and JALSPAQ, they did not significantly differ from other subjects.

The medians plus interquartiles for RMR, TEE, and PAL by DLW, TEE by questionnaire, and the differences between the 2 methods are shown by sex and age group in Table 2. The respective medians of TEE and PAL were 11.21 MJ/day and 1.88 for men and 8.42 MJ/day and 1.83 for women. PAL significantly differed by age group, but not by sex. PAL in subjects older than 70 years was significantly higher than in those aged 30 to 49 years ($P = 0.016$) and 50 to 69 years

Table 1. Characteristics of study subjects

Age group, years	n	Age (years)	Height (cm)	Body weight pre (kg)	Body weight post (kg)	Body weight change (kg)	BMI (kg/m²)	TBW (kg)
Male								
20–29	18	25.0 ± 2.5	171.5 ± 6.0	62.1 ± 7.9	62.3 ± 8.0	0.2 ± 0.7	21.1 ± 2.0	36.4 ± 3.7
30–49	42	36.7 ± 5.3	173.8 ± 6.6	74.8 ± 16.7	74.9 ± 16.6	0.0 ± 1.1	24.6 ± 4.7	41.8 ± 8.3
50–69	31	60.2 ± 6.5	163.8 ± 6.6	63.9 ± 8.1	64.0 ± 8.3	0.1 ± 0.9	23.8 ± 2.4	34.5 ± 4.1
≥70	17	75.1 ± 4.0	162.1 ± 5.0	60.7 ± 8.1	60.8 ± 8.2	0.2 ± 0.9	23.1 ± 2.7	32.0 ± 4.2
Female								
20–29	8	25.3 ± 2.4	157.0 ± 3.9	51.3 ± 2.5	51.2 ± 2.5	−0.1 ± 0.8	20.9 ± 1.6	25.5 ± 1.5
30–49	42	38.7 ± 4.4	158.0 ± 5.4	53.7 ± 8.3	53.7 ± 8.3	0.0 ± 0.7	21.5 ± 3.2	26.9 ± 3.1
50–69	49	62.0 ± 5.1	154.0 ± 4.6	54.6 ± 7.8	54.7 ± 7.9	0.1 ± 0.7	23.0 ± 3.2	25.8 ± 2.7
≥70	19	73.4 ± 3.9	148.0 ± 4.4	50.2 ± 6.1	50.1 ± 6.1	0.1 ± 0.6	22.9 ± 2.8	24.1 ± 2.0

All values are mean ± SD, unless otherwise indicated.
BMI: body mass index; TBW: total body water measured by doubly labeled water method.

Table 2. Resting metabolic rate (RMR) and total energy expenditure (TEE) measured by doubly labeled water (DLW) method and questionnaire

Age group, years		RMR (MJ/day)	TEE by DLW (MJ/day)	PAL	TEE by JALSPAQ (MJ/day)	Difference between DLW and JALSPAQ (MJ/day)	(%)
Male							
	20–29	6.27 (0.92)	12.00 (0.19)	1.89 (0.35)	9.60 (2.12)	−1.69 (2.89)	−15.7 (23.0)
	30–49	6.72 (1.53)	12.88 (4.64)	1.87 (0.45)	11.14 (2.85)	−1.18 (3.30)	−9.5 (20.3)
	50–69	5.50 (1.30)	10.81 (2.11)	2.08 (0.55)	9.18 (1.61)	−2.02 (1.99)	−18.1 (17.5)
	≥70	5.76 (1.41)	11.76 (3.59)	2.11 (0.52)	8.03 (1.65)	−0.97 (2.34)	−12.2 (21.0)
Female							
	20–29	4.73 (0.27)	8.10 (1.18)	1.86 (0.22)	7.43 (1.01)	−1.09 (1.85)	−13.2 (22.3)
	30–49	4.83 (0.82)	8.82 (1.80)	1.84 (0.32)	7.33 (1.75)	−1.26 (1.73)	−14.9 (19.1)
	50–69	4.58 (0.95)	8.53 (1.42)	1.86 (0.37)	8.12 (1.28)	−0.43 (1.76)	−5.3 (20.4)
	≥70	4.62 (0.99)	8.56 (0.86)	1.86 (0.41)	7.08 (1.33)	−0.36 (1.68)	−5.2 (23.3)
P value	Sex	<0.001	<0.001	0.067	<0.001	0.003	0.071
	Age group	<0.001	<0.001	<0.001	<0.001	0.335	0.370
	Sex by age	0.010	0.004	0.481	<0.001	0.591	0.188

All values are median (interquartile), unless otherwise indicated.
PAL: physical activity level (TEE/RMR); JALSPAQ: Japan Arteriosclerosis Longitudinal Study Physical Activity Questionnaire.

($P < 0.001$). JALSPAQ slightly underestimated TEE, with differences in mean and standard error of the mean of −1.15 ± 1.92 MJ/day and −0.020 ± 0.030 MJ/kg/day. TEE values by JALSPAQ and DLW were moderately correlated (Spearman correlation = 0.742, $P < 0.001$; ICC = 0.648, $P < 0.001$). The 95% LOA was −4.99 to 2.69 MJ. The absolute difference between TEE values by DLW and JALSPAQ was significantly greater in men than in women, but the percent difference was not significantly different. The Spearman correlation coefficient and ICC for PAL were 0.423 ($P < 0.001$) and 0.332 ($P < 0.001$), respectively, and the 95% LOA for PAL was −0.86 to 0.46. Use of Bland-Altman plots to compare TEE and PAL by DLW and JALSPAQ suggested that TEE tended to be underestimated in subjects with higher TEE (Spearman correlation, −0.201; $P = 0.002$); however, most values were within the 2 SD of the difference in TEE as determined by the 2 methods (Figure). PAL was not underestimated even in subjects with higher PALs (Spearman correlation, −0.011; $P = 0.866$); however, individual differences were widely distributed.

Using PAL determined using TEE measured by DLW, the subjects were divided into 3 groups according to Dietary Reference Intake (Table 3).[18] The proportions of active (PAL >1.9), moderately active (PAL 1.6 to <1.9), and sedentary (PAL <1.6) individuals were 45.4%, 43.5%, and 11.1% in men, respectively, and 40.7%, 41.5%, and 17.8% in women. TEE by JALSPAQ in the sedentary group was significantly lower than in moderately active and active adults. Total METs assessed by JALSPAQ was lower in sedentary and moderately active individuals than in active individuals. The differences between the 2 methods in the TEE of sedentary and moderately active adults were significantly smaller than in active adults. The total duration of each intensity of physical activity, including occupational and housework activity and leisure-time physical activity, was compared among physical activity levels. The duration of moderate and vigorous

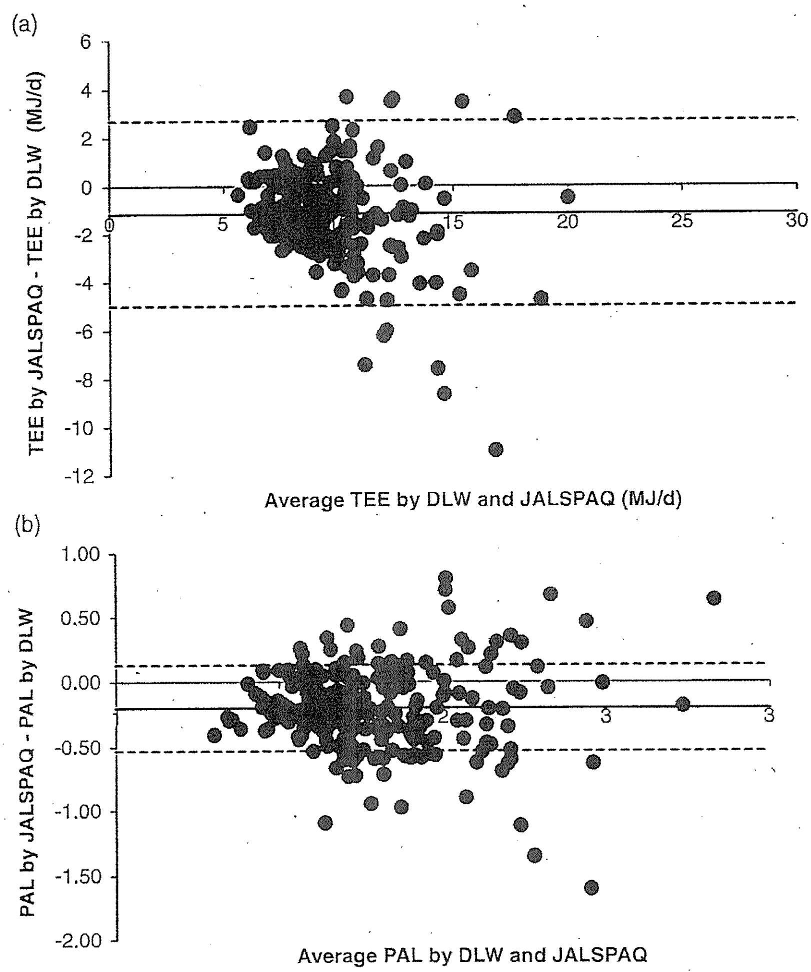

Figure. Bland-Altman plots of total energy expenditure (TEE) and physical activity level (PAL). (a) Comparison of mean TEE estimated by the doubly labeled water (DLW) method and the Japan Arteriosclerosis Longitudinal Study Physical Activity Questionnaire (JALSPAQ), and the difference in TEE as estimated by the 2 methods. (b) Comparison of mean PAL by DLW and JALSPAQ, and the difference in PAL as estimated by the 2 methods. Solid lines indicate the mean difference, and the broken lines indicate 2 SD limits.

physical activity in sedentary and moderately active adults was significantly shorter than in active adults. When we compared only leisure-time physical activity, there was no difference in duration of physical activity. Regarding physical activity during work, duration of walking was significantly shorter in sedentary individuals than in moderately active and active individuals. In addition, walking duration was significantly shorter in moderately active adults than in active adults. The proportion of heavy work differed significantly among groups; greater activity was associated with heavier work.

Regarding the types of physical activity that were correlated with PAL, correlation coefficients and partial correlation coefficients adjusted for sex and age group are shown in Table 4. Duration of total, moderate, and vigorous physical activity were weakly correlated with PAL. However, duration of leisure-time physical activity was not correlated with PAL. During working time, duration of standing, walking, and heavy work were weakly correlated with PAL.

DISCUSSION

This study used the DLW method as a gold standard to examine the validity of a physical activity questionnaire designed for the Japanese population in a large number of subjects with widely varying physical activity levels. With the DLW method as the gold standard, JALSPAQ estimated TEE relatively well, but underestimation was more frequent at higher physical activity levels.

The body height and weight of the present subjects were similar to the standard values for the Japanese population.[18] RMR was also similar to the standard RMR values for the Japanese population presented in Dietary Reference Intake.[18] Thus, we conclude that the present subjects had the general physical characteristics of the Japanese general population. However, the physical activity level of the present subjects was higher than that noted in our previous studies: 42.9% of the present subjects were classified as active, using the definition in the Dietary Reference Intake.[18] We recruited

Table 3. Total energy expenditure (TEE) and duration of each activity among groups by physical activity level

	Physical activity level			P
	I Sedentary	II Moderately active	III Active	
TEE by DLW (MJ/day)	8.11 (1.39)[a,b]	9.18 (2.29)[b]	10.76 (4.25)	<0.001
TEE by questionnaire (MJ/day)	7.78 (1.21)[b,c]	8.45 (2.87)	8.90 (3.06)	0.006
Total METs (METs·h/day)	33.5 (4.1)[b]	34.4 (4.8)[b]	35.8 (6.4)	<0.001
Difference in TEE between DLW and PAQ (MJ/day)	−0.07 (0.50)[b]	−0.80 (1.62)[b]	−2.02 (2.23)	<0.001
Difference in TEE between DLW and PAQ (%)	−0.9 (15.3)[b]	−8.4 (17.6)[b]	−19.1 (19.0)	<0.001
Total duration of physical activity (h/day)				
Light (<3 METs)	3.41 (3.58)	4.14 (3.50)	4.16 (3.72)	0.155
Moderate (3–5.9 METs)	1.65 (1.81)[b]	2.06 (2.07)[b]	2.53 (3.89)	<0.001
Vigorous (≥6 METs)	0.00 (0.09)[b]	0.00 (0.20)[a]	0.0 (0.54)	0.007
Duration of leisure-time physical activity (h/day)				
Light (<3 METs)	0.00 (0.26)	0.00 (0.07)	0.00 (0.09)	0.766
Moderate (3–5.9 METs)	0.01 (0.17)	0.02 (0.23)	0.03 (0.27)	0.965
Vigorous (≥6 METs)	0.00 (0.08)	0.00 (0.02)	0.00 (0.00)	0.556
Duration of work (h/day)				
Sitting	0.00 (2.86)	1.55 (4.61)	0.00 (4.29)	0.129
Standing	1.75 (2.20)	1.42 (2.14)	2.00 (2.85)	0.176
Walking	0.25 (0.86)[b,c]	0.54 (1.90)[b]	1.00 (3.07)	<0.001
Proportion of subjects participating in heavy work (%)	6.1	24	36.1	0.003

TEE: total energy expenditure; DLW: doubly labeled water; MET: metabolic equivalent; PAQ: physical activity questionnaire.
All values are median (interquartile), unless otherwise indicated.
[a]$P < 0.05$ as compared with physical activity level III.
[b]$P < 0.01$ as compared with physical activity level III.
[c]$P < 0.01$ as compared with physical activity level II.

Table 4. Correlation coefficients for physical activity level (as measured by doubly labeled water method) and duration of physical activities

	Correlation coefficient	P value	Partial correlation coefficient	P value
Total duration of physical activity (h/day)				
Light (<3 METs)	0.034	0.608	0.022	0.746
Moderate (3–5.9 METs)	0.257	<0.001	0.225	0.001
Vigorous (≥6 METs)	0.354	0.481	0.330	<0.001
Duration of leisure-time physical activity (h/day)				
Light (<3 METs)	−0.018	0.790	0.008	0.910
Moderate (3–5.9 METs)	0.002	0.978	0.000	0.996
Vigorous (≥6 METs)	−0.048	0.474	−0.072	0.286
Duration of work (h/day)				
Sitting	−0.064	0.337	−0.133	0.047
Standing	0.165	0.013	0.256	<0.001
Walking	0.271	<0.001	0.239	<0.001
Heavy	0.376	<0.001	0.354	<0.001

MET: metabolic equivalent; TEE: total energy expenditure.
Partial correlation coefficients are adjusted for sex and age group.

subjects at worksites requiring vigorous physical activity (ie, shipbuilding and hospitals). This may explain the higher physical activity level of the subjects.

Neilson et al reviewed a validation study of a physical activity questionnaire and suggested that, at the group level, the mean difference in TEE ranged from −800 to 1589 kcal/day (−3.35 to 6.65 MJ/day) and that the Spearman correlation coefficient for TEE ranged from 0.15 to 0.51.[2] As compared with these results, JALSPAQ showed a smaller negative mean difference of −1.15 MJ/day and a higher correlation (Spearman correlation, 0.742; $P < 0.001$). A comparison of individual-level agreement indicates that the width of the 95% LOA in our study (7.68 MJ/day) was smaller than that in most other questionnaires described in the review of Neilson and colleagues (1133 to 17 948 kcal/day; 4.74 to 75.09 MJ/day).[2] The relatively good agreement in this study partly resulted from the greater number of subjects ($n = 226$ in the present study vs $n = 13$ to $n = 65$ in previous studies) and the wide variation in TEE. Standard deviation was 2.77 MJ in the present study and 0.35 to 3.51 MJ in previous studies. A study by Racette showed the lowest 95% LOA (−2.42 to 0.16 MJ/day).[19] However, that study was part of an investigation of a 17-week outpatient weight loss treatment, so the subjects were thought to be highly motivated and to have answered the questionnaire carefully. One reason why TEE is assumed to have greater accuracy than the existing questionnaire is that it is believed to have more detailed questions regarding occupational activity, housework, and leisure-time physical activity.

JALSPAQ tended to greatly underestimate TEE in more active subjects, possibly because the algorithm for the calculation of TEE for JALSPAQ only includes duration of time spent sitting, standing, and walking. These activities were scored on a scale from 1.5 to 4.0 METs. Even when there was a question regarding carrying heavy objects or engaging in activity of similar intensity, such activity was not used to calculate TEE. Thus, underestimation would be greater in subjects who expended considerable energy at work. In the present study, 16 subjects were engaged in shipbuilding, and the differences between TEE by DLW and JALSPAQ ranged from −10.98 to 0.34 MJ/day; TEE was overestimated by JALSPAQ in only 2 subjects.

Although TEE estimated by JALSPAQ showed a relatively good correlation with TEE by DLW, RMR accounted for a large part of TEE. To lessen the contribution of RMR, PAL was compared between the two methods. The results for PAL were poor, and individual differences were widely distributed. Therefore, JALSPAQ must either be improved or another new questionnaire should be developed to assess individual PAL.

We also attempted to identify a physical activity that characterized physical activity level. Our results showed that total time spent in moderate physical activity was significantly greater in the active group. In addition, moderate and vigorous physical activity had a weak but significant correlation with PAL. Thus, moderate physical activity is an important component of physical activity level, as Westerterp has suggested.[20] However, the duration of moderate physical activity did not differ in the sedentary and moderate groups. Wareham et al used a very brief questionnaire that only included physical activity during work and recreational activities and found that physical activity ratio (daytime energy expenditure/resting metabolic rate), which was estimated using a heart rate monitor, did not differ between inactive and moderately inactive groups, even though VO_{2max} was different between these groups.[21] Another method of classifying physical activity in sedentary subjects should thus be considered.

The present results also suggest that intensity and duration of physical activity during work (including occupational activity and housework) strongly affect PAL, whereas leisure-time physical activity does not. Both work and leisure-time physical activity play fundamental roles in total physical activity, which explains why previous brief physical activity questionnaires assessed only physical activity during work and leisure time.[21,22] In the present study, because the mean duration of all leisure-time physical activity was 22 ± 21 minutes per day, the effect of leisure-time physical activity on TEE might be very small.

The most significant limitation of this study was that subjects were not selected randomly: they joined the study as volunteers. Hence, as compared with the general population, they might have remembered their physical activities better and completed the questionnaire more carefully. In addition, the variation in their physical activity level might differ from that of the general Japanese population. However, we were unable not determine the nature or extent of error that resulted from these subject characteristics. A second limitation is that the study periods for DLW and JALSPAQ were not identical. The DLW method determined the average TEE over 1 or 2 weeks. In contrast, JALSPAQ assessed typical physical activity over 1 month. This discrepancy could affect the validation of JALSPAQ. Finally, the relatively small proportion of sedentary subjects made it difficult to characterize the sedentary population. Although we tried to collect subjects with a broad range of physical activities, we could not collect comparable numbers of sedentary and active subjects.

In conclusion, PAL by JALSPAQ weakly correlated with PAL by DLW, although TEE by JALSPAQ was better correlated with TEE by DLW than with TEE assessed by the questionnaires used in previous studies. TEE underestimation was greater in active subjects than in sedentary and moderately active subjects. In addition, in this population, total moderate physical activity and physical activity during work were related to physical activity level, whereas leisure-time physical activity was not. To improve the physical activity questionnaire, an algorithm for heavy work should be added. In addition, to better differentiate sedentary subjects form moderate subjects, additional questionnaire items should be added or the algorithm should be reevaluated.

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【特別論文】

身体活動のトロント憲章日本語版：世界規模での行動の呼びかけ

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【要約】第3回国際身体活動公衆衛生会議（2010年5月，トロント市）において「身体活動のトロント憲章：世界規模での行動の呼びかけ」が採択された。本憲章は会議を主催した国際身体活動健康学会（International Society of Physical Activity and Health）の協議会の1つであるGlobal Advocacy Council for Physical Activityが中心となって作成したものである。学会終了後，本会議への出席者が中心となって日本語版への翻訳を行った。本稿では日本語版を資料として添付するとともに，憲章作成の背景，翻訳の経緯，憲章の内容等を解説した。

本憲章は，身体活動推進に携わる研究者，専門家，政策決定にかかわる者の合意として世界規模で身体活動推進の優先順位を高めるための行動を呼びかけ（call for action），関連する団体や個人に支援ツール（advocacy tool）を提供するものである。憲章の中心となる部分は，身体活動がもたらす効果の概要，「9つの指針」と「行動の枠組み」であり，身体活動推進の根拠と対策のあり方が示されている。

本憲章は政策立案に際してのチェックリスト，政策決定者の説得，現在行われている事業のチェックや課題の抽出，研究課題の抽出，論文作成時の引用文献などとして有用であり，広く活用されることが期待される。

Key words：トロント憲章，身体活動，運動，支援活動，健康増進

1．緒　言

2010年5月5日から8日にかけてカナダのトロント市で第3回国際身体活動公衆衛生会議（International Congress of Physical Activity and Public Health; ICPAPH）が開催され，「The Toronto Charter for Physical Activity: A Global Call for Action（身体活動のトロント憲章：世界規模での行動の呼びかけ）」が採択された[1]。本憲章は，身体活動推進に携わる研究者，専門家，政策決定にかかわる者の合意として世界規模で身体活動推進の優先順位を高めるように訴えるもので（行動の呼びかけ：call for action），これを支援するツール（支援ツール：advocacy tool）でもある。学会終了後，この憲章を多くの人に広めるという趣旨に従い，本会議への出席者が中心となって日本語翻訳版を作成した。2011年1月7日時点において，フランス語，スペイン語，ドイツ語等を含む9カ国語で公開されている。本稿では，憲章作成の背景，翻訳の手順，および憲章の内容について概説する。また，原本である英語版と対照する形で日本語版を資料として添付する（資料1）。

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2．憲章作成の背景

本憲章は会議を主催した国際身体活動健康学

会（International Society of Physical Activity and Health; ISPAH）の協議会の 1 つである Global Advocacy Council for Physical Activity（GAPA）が中心となって作成されたものである。憲章作成の発案は 2008 年に開催された第 2 回 ICPAPH（オランダ・アムステルダム）にさかのぼる。以後，2 年間にわたり草稿の作成，コメントの募集とそれに基づいた修正作業が繰り返されてきた。最終版の確定までに，55 カ国，460 人の研究者・専門家・政策決定者より，1,697 のコメントが寄せられたことが本会議において報告されている。これまでにも，非感染性疾患（noncommunicable diseases）への対策の指針が WHO によって示されているが [2,3]，これらは生活習慣全般にわたるものであった。本憲章は，これらの先行する文書を踏まえて，身体活動推進のための具体的な指針を示すものである。本憲章を採択したトロント会議には世界各国の主要な身体活動研究者・専門家・政策決定者 1,200 名以上が参加しており，現時点における身体活動の専門家によるコンセンサスとも考えることができる。

3．翻訳の手順

翻訳は GAPA が提示する翻訳プロトコルに従って実施した。はじめに 2 人の翻訳者が別々に翻訳を行い，その後，翻訳チームのコアメンバーによって 2 つの翻訳が 1 つの翻訳案に統合された。翻訳案の作成にあたり，適宜，原本作成者と連絡を取り，内容の確認を行った。その後，翻訳グループ内での意見交換を行い，さらに公衆衛生関係のメーリングリスト，第 13 回運動疫学研究会学術集会における発表で広く意見を求めて翻訳を改訂し最終版を確定した。翻訳プロトコルにおいて，本憲章が「身体活動」を扱ったものであり，「運動」のみを扱ったものではないことが強調されている。したがって，挿入する写真は，運動と生活活動の両方が含まれるように配慮した。

4．　憲章の内容

本憲章では，はじめに，身体活動の推進が①健康，②社会の持続的発展，③経済発展に対して恩恵をもたらすことが述べられている。①では心血管疾患，がん，小児肥満，メンタルヘルス，高齢者の自立などと身体活動の関連が取り上げられている。②ではアクティブな移動手段（歩行，自転車，公共交通の利用）によって自家用車の利用が抑制され，温室効果ガスの排出削減・環境負荷の低減を通して社会の持続的発展に資することが示されている。また，③では身体活動推進による医療コストの抑制，健康によって得られる生産性の向上が経済的発展につながることが示されている。②③が①と同じ分量で取り上げられていることは近年の学際的な身体活動研究の動向を反映していると同時に，健康以外の利益を強調することにより，この憲章の社会へのより広い浸透を意図していることがうかがえる。

それに続く，身体活動推進のための「9 つの指針」と「行動の枠組み」は本憲章の中心となる部分である。以下，それぞれについて解説する。

4-1.　9 つの指針：Guiding principles

身体活動推進のための 9 つの指針が示されている。英文では「Guiding principles for a population based approach to physical activity」となっている。ここで，population based approach をどのように訳すべきかが翻訳者間および翻訳者と原本作成者の間で議論となった。ここでは，ハイリスクアプローチの手法を用いることも含めて，「全ての人々の身体活動推進を図る」という意味で考えてもよいことを原本作成者に確認し，「全ての人々を対象とした身体活動推進の指針」と訳出した。

以下，9 つの指針それぞれについて解説する。なお，解説は，9 つの指針に沿って現在，実施されている政策や事業を点検する，という視点で行った。また，解説の内容は本稿の著者の解釈によるものであることを付記する。

1) 全人口および特定の集団（女性，高齢者，子ども，障がい者，勤労者など），特に身体活動を行うことに大きな障壁を有する人々に対して，科学的根拠に基づいた戦略を用いる

行われている事業が全ての住民に届いているのかを考える必要がある。アプローチできていない集団（例えば，健康に関心のない住民）はないだろうか？　全住民を対象とした対策を実施するとともに，特定の集団，例えば，女性，高齢者，子ども，障がい者，勤労者などに対して，どのようにアプローチできているかを考えるべきである。これらの特定の集団には，それぞれ異なったアプローチが有効かもしれない。また，政策・事業が科学的根拠に基づいていることが重要である。

2) 社会的不平等，健康の不平等，身体活動機会の不均等を減少させるような平等の戦略を用いる

実施している対策が身体活動機会の不平等，健康の不平等を是正する効果をもっていることを確認する必要がある。近年，ポピュレーションアプローチが健康格差を拡大する可能性が指摘されている。すなわち，健康に関するメッセージを受け取る力が弱い集団，将来リスクをもつ可能性が高い集団（例えば，社会経済的状況が不良な集団）に対するアプローチについて十分に考慮されるべきである。

3) 身体不活動の環境的，社会的，個人的な規定要因の改善に取り組む

対策を実施するにあたり，身体活動に影響を与える環境要因，社会的要因，個人要因を理解し，これらに働きかける効果的な戦略を用いるべきである。環境要因としては，運動場所・施設などを含む身体活動の機会の有無，近年研究が盛んに行われている都市の構造（walkability）などがある。社会的要因としては，指導者や運動プログラム，スポーツクラブの存在，地域のソーシャル・キャピタルなどがある。個人的要因としては，性別，年齢等の人口統計学的要因や，現在の健康状態，社会経済的状況，さらに性格，自己効力感，運動の楽しみといった心理的な要因などが含まれる。

4) 効果を最大にするために，持続可能な対策を，国や地域の各レベルで複数部門の連携を通じて実施する

身体活動推進対策は，単発的ではなく，継続的に，継続可能な方法で実施する必要がある。その際，多くの関連する部門（保健，労働，教育・スポーツ，都市計画，都市交通，NGO，民間，研究機関など）が協力することにより効果的な対策が行える。他部門との連携は十分に取られているだろうか？　また，国と地方自治体の各レベルでの対策が連携し，効果的に実施されていることが望まれる。

5) 研究，実践，政策，評価，調査のための能力を高め（キャパシティ・ビルディング），トレーニングを支援する

身体活動の推進においては研究，実践，政策立案，評価，調査などの能力が必要であり，これらの技能をもつ人材を育成するための支援を行う必要がある。

6) 子ども，家族，成人，高齢者のニーズに対応した，生涯を通じたアプローチを行う

子ども，家族，成人，高齢者の身体活動推進には異なる対策が必要となることが多い。それぞれのグループのニーズに対応した施策が求められる。

7) 身体活動に関する政治的取り組みを強化し，資源を増大するように，政策決定者や社会一般に対して政策提言・支援活動（アドボカシー）を行う

政策決定者や地域社会に対して，身体活動推進のための取り組みを強化するように働きかける。あるいは身体活動のための機会（運動施設，公園，運動プログラム，歩きやすい街路，公共交通など）を充実させるように働きかける必要がある。

8) 文化的差異に配慮し，多様な地域の現状，背景，資源に応じた戦略を採用する

画一的な対策ではなく，地域の特徴に応じた対策が必要である。気候，歴史，風土，文化，都市化の程度，地域に特有の生活習慣，行事などに応じた対策を構築する必要がある。

9) 身体活動を行うという選択が容易にできるようにすることで，個人が健康な選択をすることを促進する

最終的に身体活動を行うのは個人だが，身体不活動の問題を個人の責任のみに帰するのではなく，住民（国民）にとって，身体活動を行うことがより容易な選択となるような環境を作ることが重要である。不活動よりも活動的であることを選ぶような環境，社会になっているかを考える必要がある。

4-2.　行動の枠組み：A framework for action

行動の枠組みとして。4 つの行動（対策）領域が示されている。これは上記の 9 つの指針に沿ってどのような行動が取られるべきかを示したもので，各項目（4 つの行動）に対して具体的な対策例が示されている。9 つの指針と同様に，実施されている事業や活動を点検する，という視点で解説を行う。

1) 国家政策，行動計画の策定と実行

国家政策と行動計画は示されているか？　日本においては健康日本 21 等がこれにあたるものと考えられる。これらの国家レベルでの政策，行動計画が適切に策定，実行されるための具体的視点，方法が例示されている。

2) 身体活動を支援する施策の導入

身体活動に影響する「施策の枠組み」と「規制」

の重要性およびその例が述べられている。例えば，都市計画の政策や指針において身体活動をサポートする（歩行，自転車，公共交通利用を促進する）方針を明示すること，運動施設利用に関する税制上の優遇措置，職場の身体活動環境に関する政策・規制，などが可能性のある施策として示されている。

3）身体活動に重点を置いたサービスと財源の新たな方向づけ

身体活動の推進を成功させるためには，教育，交通計画，都市計画，労働環境，スポーツ，健康などの分野において現在実施されている施策・サービスやその財源を身体活動推進の視点から見直すことが重要であることを示している（例えば，教育において非競争的スポーツを重視したり，交通において歩行や自転車の利用に重点をシフトするなど）。政策の優先順位を変えることによりさまざまな利益が社会にもたらされる可能性が述べられている。

4）対策のためのパートナーシップの構築

上記の項目とも関連しているが，身体活動推進は健康部門のみで行えることではなく，持続的，かつ効果的な取り組みのためには，他の多くの部門との協働（パートナーシップ）が重要である。そのためには「共通の価値観」「共通のプログラム（事業など）」を見いだし，役割と責任を明確化することが重要であることが指摘されている。

5．行動の呼びかけ

本憲章の最後には，「行動の呼びかけ（A call for action）」として，憲章の内容を支持する者に期待される4つの行動が示されている。①憲章への支持を表明すること，②憲章を同僚に配布すること，③政策決定者に憲章の内容を伝えること，④さまざまな部門とネットワークを構築して協力すること，である。①については，本憲章のサイト http://www.globalpa.org.uk/charter/register.php から支持の表明が可能である。支持を表明すると本憲章のサイトに名前が表示される。2011年1月7日時点で10名の日本人が本憲章への支持を表明している。（http://www.globalpa.org.uk/charter/supporters.php）簡単な手続きであり，本稿を読んで同意できる方には是非登録をお願いしたい。

6．まとめ

本憲章は身体活動に携わる世界中の専門家の意見を取り入れて作られたものであり，身体活動の推進に関する研究成果を広め，政策に反映していくことが今後重要なテーマであるという認識を反映したものである。また，この憲章は政策立案に際してのチェックリスト，政策決定者の説得，現在行われている事業のチェックと課題の抽出，研究課題の抽出，論文作成時の引用などさまざまな目的で活用可能である。広く活用されることが本憲章の目的であり，便利な文書として幅広く活用されることを期待している。

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