this discrepancy by separating nonlocomotive activities from locomotive movements using the ratio of vertical to horizontal acceleration.[13] That approach contributed to a small difference between predicted EE for 10.5 h and EE measured with a metabolic chamber. As observed above, accelerometers are gradually being developed with new specific algorithms. To date, numerous epidemiological studies on physical activity have been performed. Some studies used several different types of accelerometers to assess PA.[15,16] Since each accelerometer has a specific algorithm for estimating PA, it is difficult to compare the results obtained from different accelerometers.[17]

The current study examined the validity of 3 commercially-available accelerometers to predict MET values focusing specifically on nonlocomotive activities in field conditions. The accelerometers included the LC device, a triaxial accelerometer that uses 2 separate regression equations for nonlocomotive and locomotive activities, and a triaxial accelerometer that uses a single regression equation for all activities. We believe that these discussions might help us understand data of various accelerometers accumulated in epidemiology.

Methods

Subjects

All subjects were recruited through public applications and had no physical impairments that could affect household and locomotion activities. All subjects were fully informed of the purpose of the study and written informed consent was obtained from all subjects before the beginning of the study. This study was conducted according to the guidelines of the Declaration of Helsinki, and all procedures involving human subjects were approved by the Ethical Committee of the National Institutes of Health and Nutrition.

Anthropometry

Body weight was measured to the nearest 0.1 kg using a digital balance, and height was measured on a stadiometer to the nearest 0.1 cm. Body mass index (kg/m^2) was calculated as body weight divided by the square of body height.

Instruments

Lifecorder EX (LC).

The LC (size: 72.5 × 41.5 × 27.5 mm; mass: 60 g, including a battery) was worn on the hip with an attached belt. This device was a uniaxial accelerometer with a sampling interval of 32 Hz. The LC output was a PA intensity score that consisted of a scale from 0–9 (level 0: rest; level 0.5: micro activity; level 1–9: movement). The intensity of PA (level 1–9) was determined from the frequency of steps and the magnitude of vertical acceleration that was categorized into 4 parts with 4 thresholds [threshold 1 (TH1): 0.06 g, TH2: manufacturer's fixed values, TH3: manufacturer's fixed values, TH4: 1.96 g]. The LC device registered steps when the vertical acceleration signal exceeded the second threshold or when the gap between the pulses was ≤ 1.5 s.[7,11] An activity eliciting 3 acceleration signals during a 4-s sampling interval was recognized as PA, which caused the grade (level 1–9) to be computed. If this condition was not satisfied and vertical acceleration did not exceed TH2, activities were considered by the LC to be micro activities (level 0.5). The LC intensity data output (level 1–9) were entered into a previously published equation to predict the MET value.[7] The equation was as follows:

$$\text{MET} = 0.043 \times a^2 + 0.379 \times a + 1.361$$

where a is the LC intensity.

ActivTracer (AT).

This device (AC-210; size: 48 × 67 × 16 mm; mass: 57 g; GMS Co., Ltd., Tokyo, Japan) is a triaxial accelerometer for detecting movement in 3 dimensions. It was able to obtain 3-dimensional accelerations every 4 s with a sensitivity of 2 mG and using a band-pass filter of 0.3–100 Hz. We calculated the synthetic accelerations from the following equation:

$$\text{Synthetic acceleration} = (x^2 + y^2 + z^2)^{0.5}$$

where x is anteroposterior acceleration, y is mediolateral acceleration and z is vertical acceleration. The synthetic acceleration was inserted into the formula reported by Midorikawa et al to calculate the physical activity ratio (PAR).[13] The PAR was then divided by 1.1 to convert it to a MET value because resting metabolic rate (RMR) in the sitting position without a meal was 1.1 times the basal metabolic rate (BMR) (RMR: 0.99 ± 0.177 kcal/min; BMR: 0.89 ± 0.19 kcal/min) in the current study. Although Midorikawa et al adapted their formula for sleeping metabolic rate (SMR; ie, average metabolic rate over an 8-h sleeping period),[13] we confirmed that SMR for adults was approximately equal to BMR.[18] The equations of Midorikawa et al were as follows[13]:

$$\text{PAR} = 0.0123 \times b + 1.7208 \text{ (House work)}$$

$$\text{PAR} = 0.0081 \times b + 0.9234 \text{ (Walk)}$$

$$\text{MET} = \text{PAR} / 1.1$$

where b is the synthetic acceleration in mG detected by the AT. Midorikawa et al reported that this device could differentiate the activity level from "housework" to "walk" based on the ratio of vertical to horizontal acceleration (housework < 0.750; walk > 0.751). Therefore, we followed this procedure and predicted MET values from these equations.[13]

Actimarker (AM).

The AM (test model; size: 60 × 35 × 13 mm; mass: 24 g; Matsushita Electric Works, Ltd., Osaka, Japan) was another triaxial accelerometer. It obtained 3-dimensional acceleration every 12 s with a sensitivity of 40 mG at a sampling rate of 20 Hz. We calculated the synthetic acceleration from the following equation:

$$\text{Synthetic acceleration} = (X^2 + Y^2 + Z^2)^{0.5}$$

where X is anteroposterior acceleration, Y is vertical acceleration, and Z is mediolateral acceleration. A predictive equation was obtained from the relationship between 3-dimensional synthetic acceleration and oxygen uptake during sedentary to vigorous PA, including nonlocomotive activities and locomotive movements.[19–21] The following equations were used to convert 3-dimensional synthetic acceleration to EE:

$$\text{Kcal (min)} = c \times d \times \text{BMR (kcal/day)} + \text{RMR (kcal/min)}$$

$$\text{MET} = \text{kcal (min) /RMR (kcal/min)},$$

where c is the coefficient and d is synthetic acceleration. BMR was estimated using predicted body surface area (cm^2). BMR was calculated from body weight (kg), height (cm), sex, and age using a formula for the Japanese population standardized by multiplying by a standard value ($kcal/m^2/h$) corresponding to age (5th edition of Recommended Allowances Dietary Reference Intake in Japan).[22] Moreover, BMR (kcal/day) was multiplied by 1.2, which is the ratio of sitting RMR to BMR in AM and includes diet-induced thermogenesis, and then divided by 1440 min to estimate RMR per minute in the sitting position several hours after a meal.

Procedures

The subjects visited the laboratory early in the morning in a fasted state. After the study protocol was explained, anthropometric measurements were done. Next, they were asked to rest in the supine position for 30 min, and then BMR was measured in the supine position and RMR in the sitting position. The subjects performed 12 physical activities that included nonlocomotive activities such as desk work, vacuuming, hanging clothes, washing dishes, and moving a small load (5 kg), and locomotive activities such as climbing down stairs, climbing up stairs, slow walk (55 m/min), normal walk (70 m/min), brisk walk (100 m/min), walk with 3-kg baggage (70 m/min), and jogging [male (140 m/min), female (120 m/min)]. These activities were chosen as representative activities of daily life and were based on our preliminary 3-day observations in free-living conditions. The preliminary study was performed using the activity records of 93 subjects who lived in the Tokyo metropolitan area. MET values were measured during all activities. All subjects wore the AM on the right waist and the AT on the left waist symmetrically. Furthermore, the LC was placed diagonally forward right of the waist according to the instructions of the manufacturer. These accelerometers were tightly attached with a belt during each activity. According to our unpublished data, such a small difference in the position of placement does not systematically affect the results. Before the experiment started, the accelerometers were synchronized using a wave clock for reference.

Measurement of BMR and RMR

After we verified that the subjects had fasted, each subject was fitted with a facemask and breathed into a Douglas bag twice for 10 min; the bag concentrations of oxygen and carbon dioxide were analyzed by a mass spectrometer (ARCO-1000; Arco System Inc., Kashiwa, Japan). Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) at rest and during activity were measured using the Douglas-bag method. Expired gas volume was measured using a certified dry gas meter (DC-5; Shinagawa Co., Ltd., Tokyo, Japan). EE was calculated from VO_2 and VCO_2 using Weir's equation:[23]

$$\text{EE (kcal)} = 3.9 \times VO_2 + 1.1 \times VCO_2 .$$

Measurement of PA intensity

Measurement of each activity began after a preliminary period that was needed for subjects to reach a steady-state condition. The times needed to collect expired gas, which differed between activities, are shown in Table 1. The method for calculating the EE of each activity was the same as the method used for BMR and RMR. To calculate the MET value, EE during each activity was divided by the measured value of RMR.

\ insert table 1 \

Statistics

Statistical analysis was performed using JMP version 6.0 for Windows (SAS Institute, Tokyo, Japan). All results are shown as mean ± standard deviation (SD). Pearson's correlation coefficient was used to evaluate the relationships between variables. One-way analysis of variance (ANOVA) was used to compare measured and predicted MET values, and Tukey's HSD test was used for post hoc comparisons when the ANOVA was significant. Midorikawa's discriminative method was used to discriminate data produced by nonlocomotive activities from that produced by locomotive movements.[13] $P < .05$ was considered statistically significant.

Results

The participants were 33 men (age: 41.8 ± 14.0 years, height: 169.9 ± 6.2 cm, weight: 67.3 ± 14.1 kg, body mass index (BMI): 23.2 ± 3.9 kg/m2) and 32 women (age: 43.1 ± 12.8 years, height: 158.0 ± 5.2 cm, weight: 55.6 ± 9.6 kg, BMI: 22.2 ± 3.5 kg/m2).

We examined the effects of sex and age on measured MET values using a general linear model before statistical analysis because of the large age range of the subjects. As a result, there was no effect ($R^2 = .003$, $P = 0.23$) of age (F value = 2.35, $P = .13$) or sex (F value = 0.55, $P = .46$) on the measured MET values. Therefore, the relationships between measured and predicted PA intensities were examined without adjustment for age and sex.

The differences between predicted and measured MET values are shown in Figure 1 (nonlocomotive) and Figure 2 (locomotive). Predicted MET values of nonlocomotive activities estimated by the AT and AM moderately agreed with measured MET values, whereas the LC systematically underestimated measured MET values. In contrast to nonlocomotive activities, the 3 accelerometers tended to have similar validity for locomotive movements.

\ insert figure 1 \
\ insert figure 2 \

The percentage difference between predicted and measured MET values is shown in Table 2. In all nonlocomotive activities except desk work, MET values were significantly underestimated by 20.3%–55.6% using the LC data. Using the AT data, MET values were significantly underestimated by 11.0% for moving a small load and by 2.3% for vacuuming, whereas MET values were overestimated by 11.3% for desk work and 11.7% for hanging clothes. Using the AM data, the MET values during all activities except for hanging clothes (overestimated by 16.7%) were significantly underestimated by 8.0%–20.0%. Although MET values during locomotive movements except for climbing down stairs were significantly underestimated by all 3 accelerometers, there were no differences among the 3 devices with the exception that high-intensity PA such as jogging was underestimated more by the LC (25.7%) than by the 2 other devices.

\ insert table 2 \

We described the relationship between LC intensity and MET values in Figure 3. For nonlocomotive activities, the LC intensities were within a narrow range (0.5 to 1.5), in spite of the finding that the MET values during each activity were significantly different.

Table 3 indicates that the rate of walking evaluated by the LC device, which was calculated from dividing the total number of steps during each activity by the length of that activity period, was considerably less during nonlocomotive activities than during locomotive movements.

\ insert figure 3 \
\ insert table 3 \

Discussion

The purpose of this study was to compare the validity of 3 accelerometers equipped with specific algorithms to measure PA intensity during nonlocomotive activities and locomotive movements.

Figure 1 and Figure 2 show the differences between predicted MET values and measured MET values. We found that the LC instrument had difficulty evaluating PA intensity during nonlocomotive activities (Figure 1, Table 2). One of the reasons for this is that the equations for the LC device were specific for walking and running on a treadmill in the laboratory.[7] In addition, although the LC intensity (output data) was determined from the number of steps and vertical acceleration, the steps per minute were considerably less in nonlocomotive activities than in locomotive movements (Table 3). The LC device registered movement when the vertical acceleration signal exceeded the second threshold or when the gap between pulses was $\leq$ 1.5 s.[7,11] Therefore, it is possible that most steps taken during nonlocomotive activities were not detected by the LC device because the acceleration signals were not regular but rather intermittent. For example, during vacuuming, the LC accelerometer could not detect movements because the interval between them was often > 1.5 s (Table 3). We confirmed that nonlocomotive activities such as vacuuming and moving a small load corresponded to LC intensities "0.5–1.5," even when these MET values were comparable to slow walk and normal walk (Figure 3).

In contrast, the differences between measured and predicted MET values obtained using AT and AM data were less than those obtained using LC data, although there were also significant differences between MET values by triaxial accelerometers and measure MET values for several nonlocomotive activities (Table 2). The predictive equations for the AT and AM devices were obtained for both locomotive movements and nonlocomotive activities.[13,21] This might explain why the differences between predicted and measured MET values were better with the AT and AM accelerometers compared with the LC accelerometer. Moreover, the AT equations tended to have better predictive ability than the AM equations because the suggested discrimination method of Midorikawa et al was applied for discriminating between the MET values of nonlocomotive activities and locomotive movements.[13] An advantage of the AT over other devices is that it can evaluate complex motions such as moving a small load, which consist of both types of activity like ambulatory movement, bending forward (unloading) and standing up (catching up load). However, since the AT as well as the other accelerometers could not detect the weight that an individual was carrying, it is not surprising that the MET values predicted by the AT underestimated the actual values by 11.0%.

Meanwhile, we confirmed that the accuracy of 3 accelerometers in locomotive movements was similar (Figure 2, Table 2). However, the underestimation of MET values for jogging was greater with the LC device than with the 2 other devices. Based on the original algorithm and equation, the LC can detect PA up to 8.3 MET values corresponding to a maximum LC intensity of "9".[7] Therefore, it would be difficult to evaluate jogging over 120–140 m/min using the LC, because jogging in this study corresponded to 9.5 MET values.

An important aspect of MET prediction by the 3 accelerometers is the measurement of RMR, and the error in RMR can affect the predicted MET values. The equation for the AT device predicts the physical activity ratio (PAR), which is the energy expenditure divided by the BMR. Therefore, the PAR was divided by 1.1 to convert it to a MET value in this study according to the Dietary Reference Intake in the US.[24] Actually, since the ratio of RMR to BMR in this study was 1.11 (see the Methods section), there was little effect of the RMR on the MET values predicted by the AT device. Furthermore, the LC equation depends on MET values calculated using 3.5 ml/kg/min as the RMR according to a previous report.[7] With the AM device, the estimated RMR was used (see the Methods section). We found that 3.5 ml/kg/min (LC) and the predicted RMR (AM) were about 8% higher than the actual RMR. Considering the difference of RMRs, it may raise the validity of this study by up to approximately 7% positively. However, even if the RMR differences slightly affected the predictive accuracies of the LC and AM accelerometers, we still found that there was a larger error for nonlocomotive activities than for locomotive movements.

An important issue that must be considered is whether the AT accelerometer evaluated in the current study is valid in obese individuals. With respect to this point, we previously reported the effect of body weight on MET values in the same subjects and during the same physical activities as in the current study.[25] Our previous report indicated that when the BW is more than 10 kg above average body weight (60.0 kg), there is about a +5% error for nonlocomotive activities (vacuuming) and +3% to 5% error for locomotive movements. Thus, MET values are associated with body weight to some degree. Therefore, when the results of this study are applied to obese individuals, the effect of body weight on MET values should be considered. However, significant correlations were not obtained between the predictive errors and body weight in this study except for climbing up stairs.

There are 2 limitations in this study. The primary limitation is whether the errors in predictive accuracy in the current study affect TEE in an entire day. To address this issue, it will be necessary to examine the validity using the doubly labeled water method under free-living conditions in a future study. However, Westerterp indicated that in a subject with an average physical activity level of 1.75, PAEE of nonlocomotive activities, which consist of sitting and standing without movement and standing active (ie, washing dishes), accounts for more than 50% of total PAEE.[5] Therefore, it may be possible that the difference in predictive ability among the AT, AM and LC devices in the current study affects the prediction of TEE. Furthermore, Leenders et al indicated that the predictive equations based on the relationship between acceleration and energy expenditure during locomotive movements led to underestimation of TEE by more than 10%, but the predictive equations based on both nonlocomotive activities and locomotive movements did not necessarily lead to TEE underestimation.[26] Considering these viewpoints, to improve the predictive ability for TEE, the predictive equation should be based on both nonlocomotive activities and locomotive movements.

Another limitation is that it is not easy to make generalizations regarding the currently used other accelerometers, because the aim of this study was to examine the validity of 3 commercially-available accelerometers that employ specific algorithms. However, few previous studies have attempted to validate PA intensity from commercially-available accelerometers data for both nonlocomotive activities and locomotive movements obtained under field conditions. Based on our results, we suggest that triaxial accelerometers based on nonlocomotive activities and locomotive movements have better accuracy than uniaxial accelerometer. In particular, triaxial accelerometer with equations that distinguish between nonlocomotive and locomotive movements might be more accurate. Meanwhile, the algorithm of LC could not evaluate nonlocomotive activities, which probably attributes to underestimation of PA in a whole day. We also believe that it gives full recognition to the significance of nonlocomotive activities (or NEAT). In addition, our results may help both researchers and general users understand how to use accelerometers to evaluate PA.

In conclusion, we didn't find a difference in predictive ability of 3 accelerometers for locomotive movements except for jogging. Meanwhile, we found that the MET values obtained during nonlocomotive activities by the LC device consistently underestimated the measured MET values. In contrast, the AT and AM devices more accurately assessed MET values during nonlocomotive activities, although there were still significant deviations from measured MET values. In particular, the reason why the AT device has better predictive ability for nonlocomotive activities is probably due to the use of separate predictive equations for both nonlocomotive activities and locomotive movements.

Acknowledgments

Heartfelt thanks are given to the subjects in this study. We also wish to thank the members of the Health and Exercise Program in the National Institutes of Health and Nutrition. All authors contributed to the interpretation of experimental data, so there is no conflict of interest in this manuscript. This work was supported by the Health and Labour Sciences Research Grants for Comprehensive Research on Cardiovascular and Life-style Related Diseases from the Japanese Ministry of Health, Labour and Welfare (PI: S. Tanaka).

References

1. Carnethon MR, Gidding SS, Nehgme R, Sidney S, Jacobs DR, Jr, Liu K. Cardiorespiratory fitness in young adulthood and the development of cardiovascular disease risk factors. *JAMA*. 2003;290:3092–3100. PubMed doi:10.1001/jama.290.23.3092
2. Metter EJ, Talbot LA, Schrager M, Conwit RA. Arm-cranking muscle power and arm isometric muscle strength are independent predictors of all-cause mortality in men. *J Appl Physiol*. 2004;96:814–821. PubMed doi:10.1152/japplphysiol.00370.2003

3. Levine JA. Non-exercise activity thermogenesis. *Proc Nutr Soc.* 2003;62:667–679. PubMed doi:10.1079/PNS2003281
4. Levine JA, Lanningham-Foster LM, McCrady SK, et al. Interindividual variation in posture allocation: possible role in human obesity. *Science.* 2005;307:584–586. PubMed doi:10.1126/science.1106561
5. Westerterp KR. Assessment of physical activity: a critical appraisal. *Eur J Appl Physiol.* 2009;105:823–828. PubMed doi:10.1007/s00421-009-1000-2
6. Matthew CE. Calibration of accelerometer output for adults. *Med Sci Sports Exerc.* 2005;37:S512–S522. PubMed doi:10.1249/01.mss.0000185659.11982.3d
7. Kumahara H, Schutz Y, Ayabe M, et al. The use of uniaxial accelerometry for the assessment of physical-activity-related energy expenditure: a validation study against whole-body indirect calorimetry. *Br J Nutr.* 2004;91:235–243. PubMed doi:10.1079/BJN20031033
8. Tanaka C, Tanaka S, Kawahara J, Midorikawa T. Uniaxial accelerometer for assessing physical activity in 5- to 6-years old children. *Jpn J Phys Fitness Sports Med.* 2007;56:489–500.
9. Rafamantanantsoa HH, Ebine N, Yoshioka M, et al. Validation of three alternative methods to measure total energy expenditure against the doubly labeled water method for older Japanese men. *J Nutr Sci Vitaminol (Tokyo).* 2002;48:517–523. PubMed doi:10.3177/jnsv.48.517
10. Hikihara Y, Saitoh S, Yoshitake Y. Validity of methods to measure total energy expenditure of baseball players in Japanese high school. (in Japanese) *Jpn J Phys Fitness Sports Med.* 2005;54:363–372.
11. McClain JJ, Sisson SB, Washington TL, Craig CL, Tudor-Locke C. Comparison of Kenz Lifecorder EX and ActiGraph accelerometers in 10-yr-old children. *Med Sci Sports Exerc.* 2007;39:630–638. PubMed doi:10.1249/mss.0b013e3180313056
12. Hendelman D, Miller K, Baggett C, Debold E, Freedson P. Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Med Sci Sports Exerc.* 2000;32:S442–S449. PubMed doi:10.1097/00005768-200009001-00002
13. Midorikawa T, Tanaka S, Kaneko K, et al. Evaluation of low-intensity physical activity by triaxial accelerometry. *Obesity (Silver Spring).* 2007;15:3031–3038. PubMed doi:10.1038/oby.2007.361
14. Tanaka C, Tanaka S, Kawahara J, Midorikawa T. Triaxial accelerometry for assessment of physical activity in young children. *Obesity (Silver Spring).* 2007;15:1233–1241. PubMed doi:10.1038/oby.2007.145
15. Davis JN, Hodges VA, Gillham MB. Physical activity compliance: differences between overweight/obese and normal-weight adults. *Obesity (Silver Spring).* 2006;14:2259–2265. PubMed doi:10.1038/oby.2006.265
16. Young DR, Jerome GJ, Chen C, Laferriere D, Vollmer WM. Patterns of physical activity among overweight and obese adults. *Prev Chronic Dis.* 2009;6:A90. PubMed
17. Guinhouya CB, Hubert H, Soubrier S, Vilhelm C, Lemdani M, Durocher A. Moderate-to-vigorous physical activity among children: discrepancies in accelerometry-based cut-off points. *Obesity (Silver Spring).* 2006;14:774–777. PubMed doi:10.1038/oby.2006.89
18. Ganpule AA, Tanaka S, Ishikawa-Takata K, Tabata I. Interindividual variability in sleeping metabolic rate in Japanese subjects. *Eur J Clin Nutr.* 2007;61:1256–1261. PubMed doi:10.1038/sj.ejcn.1602645
19. Hara T, Matsumura Y, Yamamoto M. The relation between body weight reduction and intensity of daily physical activities assessed with 3-dimenssion accelerometer. *Jpn J Phys Fit Sports Med.* 2006;55:385–391.
20. Matsumura Y, Yamamoto M, Kitado T. High-accuracy physical activity monitor utilizing three-axis accelerometer. *Natl Tech Rep.* 2008;56:60–66.
21. Yamada Y, Yokoyama K, Noriyasu R, et al. Light-intensity activities are important for estimating physical activity energy expenditure using uniaxial and triaxial accelerometers. *Eur J Appl Physiol.* 2008;105:141–152. PubMed doi:10.1007/s00421-008-0883-7
22. Nagamine S, Suzuki S. Anthropometry and body composition of Japanese young men and women. *Hum Biol.* 1964;36:8–15. PubMed
23. Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. *J Physiol.* 1949;109:1–9. PubMed
24. Food and Nutrition Board IoM. *Dietary reference intakes for energy, carbohydrate, fiber, fatty acids, cholesterol, protein, and amino acids.* National Academies Press; 2005:107–264.
25. Taguri E, Tanaka S, Ohkawara K, et al. Validity of physical activity indices for adjusting energy expenditure for body size: do the indices depend on body size? *J Physiol Anthropol.* 2010;29:109–117. PubMed doi:10.2114/jpa2.29.109
26. Leenders NY, Sherman WM, Nagaraja HN. Energy expenditure estimated by accelerometry and doubly labeled water: do they agree? *Med Sci Sports Exerc.* 2006;38:2165–2172. PubMed doi:10.1249/01.mss.0000235883.94357.95

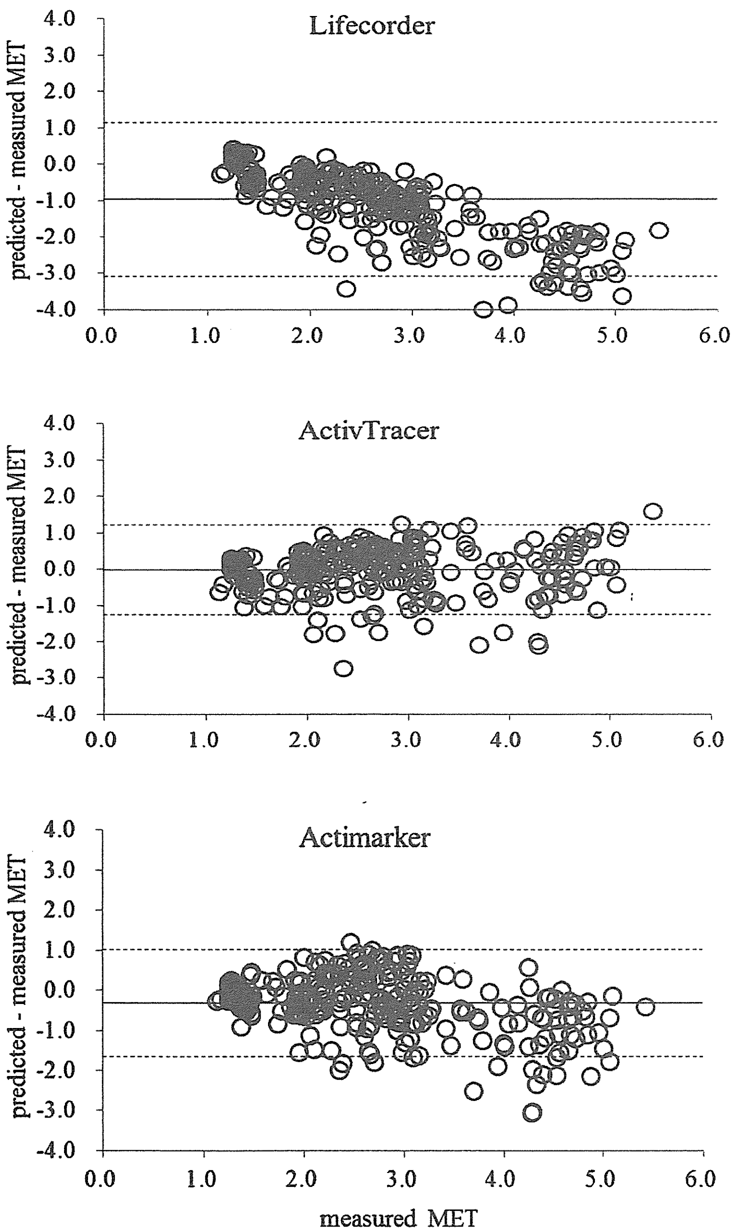

Figure 1 — Mean differences of each accelerometer between predicted and measured METs for nonlocomotive activities using Bland and Altman plots.

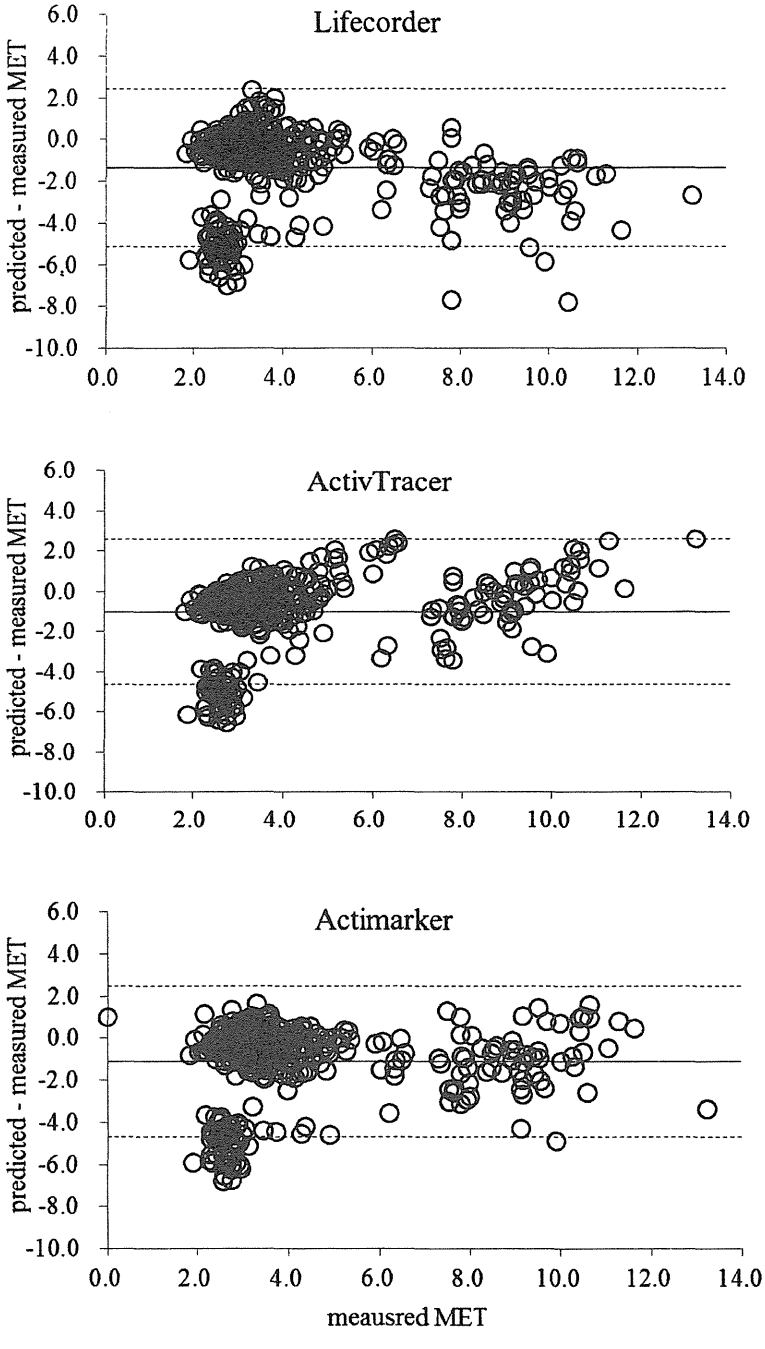

Figure 2 — Mean differences of each accelerometer between predicted and measured METs for locomotive movements using Bland and Altman plots.

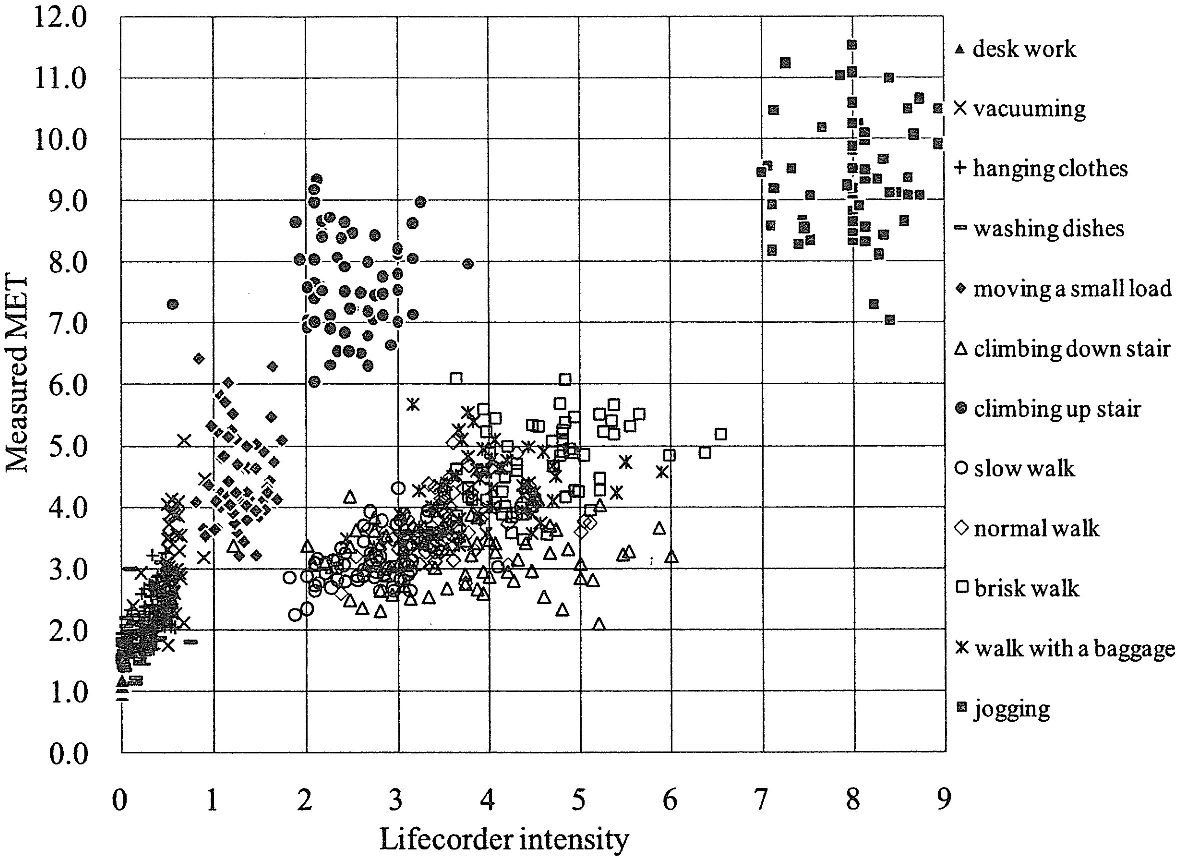

Figure 3 — Relationship between output data from Lifecorder and measured MET values.

Table 1 Duration for Measurement of Physical Activity Intensity

	Content of activity	Steady state (min)	Measurement of expired gas (min)
Desk work	Typewriting using personal computer with sitting in a chair	3.0	7.0
Vacuuming	Vacuuming clean in a room (about 17m2) while moving	3.0	3.0
Hanging clothes	Hanging out washing then and there	3.0	3.0
Washing dishes	Washing dishes with standing position	3.0	3.0
Moving a small load	Moving a small load (5kg) from one place to the other place (between about 3 meters), repeatedly	3.0	2.0
Climbing down stairs	Climbing down stairs according to the leader	2.0	1.0
Climbing up stairs	Climbing up stairs according to the leader	1.0*	0.8
Slow walk	Walk according to pace leader machine (55m/min) on ground	3.0	3.0
Normal walk	Walk according to pace leader machine (70m/min)on ground	3.0	2.0
Brisk walk	Walk according to pace leader machine (100m/min) on ground	3.0	2.0
Walk with a baggage	Walk with a baggage (3kg)according to pace leader machine (70m/min) on ground	3.0	2.0
Jogging	Jogging according to pace leader machine (male: 140m/min, female: 120m/min) on ground	3.0	1.0

Table 2 Percent of Differences Between Measured and Predicted METs

	Measured METs		Predicted METs: Lifecorder		Predicted METs: ActivTracer		Predicted METs: Actimarker		Percent of difference: Lifecorder		Percent of difference: ActivTracer		Percent of difference: Actimarker		Statistics	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*	Post hoc test
Desk work	1.1	0.1	1.4	0.0	1.3	0.0	1.0	0.1	23.2	7.9	11.3	7.9	−8.0	7.6	<0.0001	LC > AT > ME > AM
Vacuuming	2.9	0.7	1.6	0.0	2.7	0.4	2.3	0.3	−44.0	11.1	−2.3	24.9	−20.0	14.1	<0.0001	ME > AT > AM > LC
Hanging clothes	2.3	0.4	1.5	0.0	2.5	0.4	2.6	0.4	−32.6	10.5	11.7	21.8	16.7	20.4	<0.0001	AM,AT > ME > LC
Washing dishes	1.8	0.4	1.4	0.1	1.8	0.3	1.6	0.3	−20.3	13.5	0.2	23.6	−12.0	19.5	<0.0001	ME,AT > AM > LC
Moving a small load	4.4	0.7	1.9	0.1	4.2	0.6	3.5	0.3	−55.6	7.3	−11.0	7.3	−19.4	13.8	<0.0001	ME,AT > AM > LC
Climbing down stairs	3.2	0.5	3.4	0.8	3.0	0.4	3.3	0.4	9.6	30.3	−3.2	20.1	8.6	22.4	0.0003	LC,AM > AT
Climbing up stairs	7.6	0.8	2.5	0.3	2.8	0.5	2.7	0.3	−66.4	5.1	−63.8	8.0	−64.5	5.6	<0.0001	ME > AM,AT,LC
Slow walk	3.1	0.4	2.7	0.3	2.8	0.7	2.8	0.3	−12.7	13.2	−11.3	19.7	−9.0	12.8	<0.0001	ME > AT,AM,LC
Normal walk	3.6	0.5	3.2	0.4	3.3	0.7	3.3	0.3	−10.5	12.8	−7.3	20.4	−8.0	13.1	<0.0001	ME > AT,AM,LC
Brisk walk	4.6	0.7	4.0	0.5	4.2	0.7	4.0	0.6	−12.9	12.6	−9.1	18.3	−11.7	13.8	<0.0001	ME > AT,AM,LC
Walk with a baggage	4.2	0.6	3.5	0.5	3.7	0.8	3.6	0.4	−16.1	12.3	−12.8	20.3	−14.5	12.6	<0.0001	ME > AT,AM,LC
Jogging	9.5	1.1	6.8	1.5	9.0	1.3	8.1	1.8	−25.7	14.6	−4.0	14.8	−10.7	14.6	<0.0001	ME > AT < AM < LC

Abbreviations: ME; measured, LC; Lifecorder, AT; ActivTracer, AM; Actimarker.

Note. Post hoc test was adapted by Tukey's HSD test.

Table 3 Rate of Steps for Each Activity*

	Rate of steps	
	Mean	SD
Desk work	0.0	0.0
Vacuuming	6.8	8.0
Hanging clothes	1.6	2.6
Washing dishes	0.3	1.6
Moving a small load	44.4	9.4
Climbing down stairs	104.1	14.6
Climbing up stairs	90.9	13.9
Slow walk	100.0	6.8
Normal walk	111.1	6.2
Brisk walk	121.0	6.8
Walk with a baggage	115.5	6.0
Jogging	161.0	25.5

* Rate of steps (frequency/minute) was calculated from dividing total steps during each activity by action time (minutes).

厚生労働科学研究費補助金
（長寿科学総合研究事業）

チームによる効果的な栄養ケア・マネジメントの標準化をめざした総合的研究

～大学－施設連携による研究基盤・人材育成システム構築の試み～

平成24年度
総括・分担研究報告書

2013年 3月31日　発行

公立大学法人　青森県立保健大学
吉池　信男

〒030-8505　青森県青森市浜館間瀬58-1
電話：017-765-2000、FAX：017-765-2188