Validation and Comparison of 3 Accelerometers for Measuring Physical Activity Intensity During Nonlocomotive Activities and Locomotive Movements

Yuki Hikihara, Shigeho Tanaka, Kazunori Ohkawara, Kazuko Ishikawa-Takata, and Izumi Tabata

Background: The current study evaluated the validity of 3 commercially-available accelerometers to assess metabolic equivalent values (METs) during 12 activities. Methods: Thirty-three men and thirty-two women were enrolled in this study. The subjects performed 5 nonlocomotive activities and 7 locomotive movements. The Douglas bag method was used to gather expired air. The subjects also wore 3 hip accelerometers, a Lifecorder uniaxial accelerometer (LC), and 2 triaxial accelerometers (ActivTracer, AT; Actimarker, AM). Results: For nonlocomotive activities, the LC largely underestimated METs for all activities (20.3%–55.6%) except for desk work. The AT overestimated METs for desk work (11.3%) and hanging clothes (11.7%), but underestimated for vacuuming (2.3%). The AM underestimated METs for all nonlocomotive activities (8.0%–19.4%) except for hanging clothes (overestimated by 16.7%). The AT and AM errors were significant, but much smaller than the LC errors (23.2% for desk work and –22.3 to –55.6% for the other activities). For locomotive movements, the 3 accelerometers significantly underestimated METs for all activities except for climbing down stairs. Conclusions: We conclude that there were significant differences for most activities in 3 accelerometers. However, the AT, which uses separate equations for nonlocomotive and locomotive activities, was more accurate for nonlocomotive activities than the LC.

Keywords: algorithm, metabolic equivalents, daily activity

It is well known that physical fitness and activity confer numerous health benefits in the prevention of lifestyle-related diseases. Physical activity energy expenditure (PAEE) can be divided into exercise-related activity thermogenesis and nonexercise activity thermogenesis (NEAT), with the latter consisting mainly of energy expenditure (EE) of low-to-moderate intensity during lifestyle activities. Levine et al suggested that the EE due to NEAT, including nonlocomotive activity, is much larger than EE due to exercise throughout the day and may be an important factor in the prevention of obesity. Therefore, it is important to estimate EE of daily activities, including locomotive movements and nonlocomotive activities such as household tasks and occupational activities. As Westerterp indicates, PAEE of nonlocomotive activities accounts for more than 50% of total PAEE.

Recently, various types of small and lightweight accelerometers have become available for assessing the amount and intensity of physical activity (PA). However, these devices use different algorithms, which depend on the number of axes (uni- or triaxial) and predictive equations for PAEE and intensity. The usefulness of the Kenz Lifecorder EX (LC; SUZUKEN Co., Ltd., Nagoya, Japan), a uniaxial accelerometer widely used in Japan, for assessing PA intensity and PAEE during locomotive movements such as walking and jogging has been reported. However, total energy expenditure (TEE) calculated from the LC data significantly underestimated by 20%–35% the TEE measured by the doubly labeled water method in Japanese men. We speculate that the most important reason for this underestimation is related to the algorithm of the LC accelerometer, which was designed to assess PA intensity during ambulation. The LC device determines PA intensity from the frequency of steps and the degree of vertical acceleration. However, if some PA such as household work does not involve a sufficient number of steps, the LC instrument may not be able to accurately assess PA intensity.

Triaxial accelerometers have also become popular devices for assessing PA intensity. Nevertheless,
Hendelman et al indicated that the regression equation used to predict metabolic equivalent (MET) values based on locomotive movements had a different slope and intercept compared with regression equation based on nonlocomotive activities.12 Thus, when an equation based on locomotive movements is used to predict MET values for nonlocomotive activities and ambulation, there could be large prediction errors. Midorikawa et al tried to resolve 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/m²) 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.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. 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).15 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:

\[
\text{PAR} = 0.0123 \times b + 1.7208 \quad \text{(House work)}
\]
\[
\text{PAR} = 0.0081 \times b + 0.9234 \quad \text{(Walk)}
\]

\[
\text{MET} = \text{PAR} / 1.1
\]

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:

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

\[
\text{MET} = \frac{\text{Kcal (min)}}{\text{RMR (kcal/min)}}
\]

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.

**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:\(^{23}\)

\[
\text{EE (kcal)} = 3.9 \times \text{VO}_2 + 1.1 \times \text{VCO}_2.
\]

**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.

**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. Mitorikawa’s discriminative method was used to discriminate data produced by nonlocomotive activities from that produced by locomotive movements.\(^{15}\) \(P < .05\) 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/m\(^2\)) 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/m\(^2\)).

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.

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.

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.

**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. 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. 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,”...
Comparison of the Accuracy of 3 Accelerometers

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.

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. 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. 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
Table 2  Percent of Differences Between Measured and Predicted METs

<table>
<thead>
<tr>
<th>Activity</th>
<th>Measured METs</th>
<th>Predicted METs</th>
<th>Percent of difference</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean  SD</td>
<td>Lifecorder Mean SD</td>
<td>ActivTracer Mean SD</td>
<td>Actimarker Mean SD</td>
</tr>
<tr>
<td>Desk work</td>
<td>1.1 0.1</td>
<td>1.4 0.0</td>
<td>1.3 0.0</td>
<td>1.0 0.1</td>
</tr>
<tr>
<td>Vacuuming</td>
<td>2.9 0.7</td>
<td>1.6 0.0</td>
<td>2.7 0.4</td>
<td>2.3 0.3</td>
</tr>
<tr>
<td>Hanging clothes</td>
<td>2.3 0.4</td>
<td>1.5 0.0</td>
<td>2.5 0.4</td>
<td>2.6 0.4</td>
</tr>
<tr>
<td>Washing dishes</td>
<td>1.8 0.4</td>
<td>1.4 0.1</td>
<td>1.8 0.3</td>
<td>1.6 0.3</td>
</tr>
<tr>
<td>Moving a small load</td>
<td>4.4 0.7</td>
<td>1.9 0.1</td>
<td>4.2 0.6</td>
<td>3.5 0.3</td>
</tr>
<tr>
<td>Climbing down stairs</td>
<td>3.2 0.5</td>
<td>3.4 0.8</td>
<td>3.0 0.4</td>
<td>3.3 0.4</td>
</tr>
<tr>
<td>Climbing up stairs</td>
<td>7.6 0.8</td>
<td>2.5 0.3</td>
<td>2.8 0.5</td>
<td>2.7 0.3</td>
</tr>
<tr>
<td>Slow walk</td>
<td>3.1 0.4</td>
<td>2.7 0.3</td>
<td>2.8 0.7</td>
<td>2.8 0.3</td>
</tr>
<tr>
<td>Normal walk</td>
<td>3.6 0.5</td>
<td>3.2 0.4</td>
<td>3.3 0.7</td>
<td>3.3 0.3</td>
</tr>
<tr>
<td>Brisk walk</td>
<td>4.6 0.7</td>
<td>4.0 0.5</td>
<td>4.2 0.7</td>
<td>4.0 0.6</td>
</tr>
<tr>
<td>Walk with a baggage</td>
<td>4.2 0.6</td>
<td>3.5 0.5</td>
<td>3.7 0.8</td>
<td>3.6 0.4</td>
</tr>
<tr>
<td>Jogging</td>
<td>9.5 1.1</td>
<td>6.8 1.5</td>
<td>9.0 1.3</td>
<td>8.1 1.8</td>
</tr>
</tbody>
</table>

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

Note. Post hoc test was adapted by Tukey’s HSD test.
algorithm and equation, the LC can detect PA up to 8.3 MET values corresponding to a maximum LC intensity of “9”. 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. 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. 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. 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

### Table 3 Rate of Steps for Each Activity*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Rate of steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desk work</td>
<td>0.0</td>
</tr>
<tr>
<td>Vacuuming</td>
<td>6.8</td>
</tr>
<tr>
<td>Hanging clothes</td>
<td>1.6</td>
</tr>
<tr>
<td>Washing dishes</td>
<td>0.3</td>
</tr>
<tr>
<td>Moving a small load</td>
<td>44.4</td>
</tr>
<tr>
<td>Climbing down stairs</td>
<td>104.1</td>
</tr>
<tr>
<td>Climbing up stairs</td>
<td>90.9</td>
</tr>
<tr>
<td>Slow walk</td>
<td>100.0</td>
</tr>
<tr>
<td>Normal walk</td>
<td>111.1</td>
</tr>
<tr>
<td>Brisk walk</td>
<td>121.0</td>
</tr>
<tr>
<td>Walk with a baggage</td>
<td>115.5</td>
</tr>
<tr>
<td>Jogging</td>
<td>161.0</td>
</tr>
</tbody>
</table>

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

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

11. McClain JJ, Sisson SB, Washington TL, Craig CL, Tudor-Locke C. Comparison of Kenz Lifecorder EX and...
Comparison of the Accuracy of 3 Accelerometers

943


