Validation of the Actiheart Monitor for the Measurement of Physical Activity

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ABSTRACT

Int J Exerc Sci 2(1) : 60-71, 2009. The Actiheart monitor uniquely allows simultaneous measurement of heart rate and movement counts. The purpose of this study was to establish validity evidence for the Actiheart monitor under laboratory and free-living conditions. A total of 34 college students (17 males and 17 females, age = 21.8 ± 3.6 years) participated in the study. In the laboratory environment, the participants completed three, 5 min bouts of treadmill walking and/or running at speeds of 3.2, 6.4, and 9.6 km/h. Outside the laboratory, participants were asked to perform free-living physical activity for 30 min. For validation, energy expenditure, movement counts, and heart rate measurements from the Actiheart monitor were compared with an AEI Moxus Metabolic Cart, Actigraph accelerometer, Polar heart rate monitor (HRM), and electrocardiogram (ECG), respectively. The Actiheart underestimated energy expenditure only at the highest workload in the laboratory environment compared with the metabolic cart (p = .009). Actiheart heart rate (HR) was similar to the HR measured by ECG at all workloads. Under free-living conditions, the Actiheart energy expenditure was highly correlated (r = .81) with the Actigraph energy expenditure with no significant differences (t(33) =.26; p = .80). Actiheart heart rate was also highly correlated with HR from the Polar HRM (r = .93), however, there was an overestimation of HR by the Actiheart monitor (t(33) = 3.00; p = .005) under free-living conditions. The Actiheart monitor appears to accurately measure physical activity under free-living conditions and at low and moderate intensities in the laboratory environment.

KEY WORDS: Movement counts, accelerometer, energy expenditure, heart rate, validity

INTRODUCTION

Physical activity serves as a primary preventive behavior for several chronic health conditions including coronary heart disease (14, 19), cancer (15), type 2 diabetes (4, 25), stroke (8), metabolic syndrome (18), and osteoporosis (30). Because of the potential health benefits of physical activity, a number of organizations have issued physical activity recommendations. Publications from the American College of Sports Medicine and the American Heart Association (12, 21), recommend specific levels of physical activity.

Numerous field measures have been developed for assessing physical activity as researchers search for accurate, reliable, and easy-to-use tools. Heart rate monitors

(HRM) and motion sensors, including accelerometers, are commonly used field measures (17, 26). Heart rate (HR) is the most convenient physiological parameter for assessing physical activity in the field (16). Accelerometers are based on the principle that motion results in acceleration of the trunk or limbs and that motion combined with acceleration is associated with increased energy expenditure (31).

With improvements in technology, HRMs and accelerometers are now small and portable (i.e., worn around the chest or at the waist) and thus, increasingly used in field research. Heart rate monitors and accelerometers capture free-living physical activity information (i.e., frequency, intensity, and duration of activity) on a minute-by-minute basis for extended time periods (16, 28, 31). However, these devices, when used separately, have disadvantages. Factors such as temperature, humidity, fatigue, and emotional stress can influence HR (9). Problems with lost data from signal interruptions and delayed HR responses are additional challenges (16, 27). Most accelerometers are not designed to be waterproof, and thus cannot monitor water activities. Static physical activity, such as weight lifting, which generates less body movement, but requires energy expenditure, is also problematic to measure when using accelerometers (11, 31).

A combination of physical activity assessments might provide more accurate activity profiles by overcoming individual sources of error (11, 24). Treuth (28) reviewed six studies incorporating combined measures of physical activity and concluded that using a HRM and a motion sensor improved the accuracy of

monitoring physical activity. One such device is the Actiheart which combines a HRM and an accelerometer.

Recent studies have examined the reliability of the Actiheart. Brage et al. (3) looked at the intra- and inter-instrument reliability of the Actiheart during movement and HR simulations and found that the corresponding inter-instrument coefficient of variation value was 5.7 for movement and 0.03% for HR. The median intra-instrument coefficient of variation was 0.5 and 0.03% for movement and HR, respectively. Brage et al. (1) also investigated the intra-instrument reliability during treadmill locomotion and free-living. The authors found a placement effect on HR data quality only for men. Further, regardless of position, there was no difference in movement counts and energy expenditure (EE) calculations during treadmill and free-living activity.

A few studies have examined the Actiheart with positive results. Brage et al. (3) examined the reliability and validity of the Actiheart during electronically and mechanically simulated HR and movement. They also assessed the agreement among the Actiheart, electrocardiogram (ECG), and Polar measurements of HR during both resting and treadmill exercise. The authors concluded that the Actiheart was a reliable and valid tool for the measurement of movement and HR in humans at rest and during walking and running. The authors also recommended the assessment of Actiheart validity during free-living activities. Corder et al. (5) examined the validity of the Actiheart to predict physical activity energy expenditure (PAEE) of children during treadmill walking and

running. The combined HR and movement model provided the most accurate prediction of PAEE. It also had the lowest level of systematic error. Crouter et al. (7) tested the ability of the Actiheart to predict activity energy expenditure (AEE) during 18 different activities which are commonly performed. Each activity was performed separately for a pre-determined time period. The participants wore an Actiheart and simultaneously, AEE was measured with a Cosmed K4b2 portable metabolic system. The Actiheart HR algorithm, activity algorithm, and combined activity and HR algorithm were used to estimate AEE. The Actiheart combined activity and HR algorithm provided similar estimates of AEE as the Cosmed on both a group and individual basis.

While studies have provided accuracy information of the Actiheart monitor in assessing HR and energy expenditure during controlled settings, more research is needed to establish validity evidence of the Actiheart and document the feasibility of using it with adults, especially during free-living conditions. The purpose of this study was to validate the Actiheart monitor at different treadmill speeds in the laboratory and during free-living activity outside of the laboratory. To establish validity evidence, the Actiheart monitor was compared with criterion measures (i.e., metabolic cart, ECG) and other objective measures of assessing physical activity (i.e., Actigraph, Polar HRM).

METHOD

Participants
Participants were recruited from a university in the southeastern United States (*N* = 36). The university Institutional Review Board approved the study. An informed consent form was voluntarily signed by all participants. Data from two participants were not used because of noncompliance or monitor malfunction. Therefore, results are reported on 34 participants, 17 males and 17 females. Participant characteristics can be found in Table 1. Height was recorded to the nearest 1/2 cm using a standard stadiometer and body mass was measured in kilograms to the nearest tenth of a kilogram using a SECA Alpha digital scale (Model 770). Those two measures were used to calculate body mass index. Waist and hip circumferences were measured using a Gulick tape measure. The waist was measured at the narrowest part of the torso (obove the umbilicus and below the xiphoid process), the hip was measured at

Table 1. Participants characteristics.

Group	Age (years)	BMI (kg/m²)	Height (m)	Weight (kg)	% BF	Lean Body Mass (kg)	W/H	Resting HR (bpm)
Male (*n* = 17)	22.4 ± 4.6	25.2 ± 3.3	1.79 ± 0.07	80.9 ± 12.2	9.8 ± 4.8	72.7 ± 9.4	.83 ± .05	61 ± 13
Female (*n* = 17)	21.3 ± 2.3	23.4 ± 3.3	1.65 ± 0.08	63.9 ± 11.5	19.8 ± 5.4	50.8 ± 7.3	.73 ± .04	67 ± 11
Overall (*N* = 34)	21.8 ± 3.6	24.3 ± 3.4	1.72 ± 0.10	72.4 ± 14.5	14.84 ± 7.1	61.7 ± 13.9	.78 ± .07	64 ± 12

BMI= Body mass index; %BF = Percent body fat; W/H = Waist to hip ratio; HR = Heart rate; Results are presented as mean ± standard deviation.

the maximal circumference of the buttocks. These two measures were used to calculate waist/hip ratio. Body fat percentage was calculated using seven site skinfold measurements and the appropriate population specific equations. Skinfolds were measured using a Harpenden skinfold caliper. Lean body mass was calculated by subtracting the fat mass (based on percentage body fat) from the total weight. To ensure the participants were physically ready for the physical fitness testing employed in the study, a medical and health history questionnaire (23) was supplemented with questions drawn from the Behavioral Risk Factor Surveillance System questionnaire. This provided each participant's health and medical history and information regarding smoking habits and level of physical activity. Sixty percent of the participants identified themselves as physically fit when compared with other persons of the same age. Eighty percent of participants reported taking part in physical activity on average 3 or more times per week with walking and weight lifting being the most reported activities performed.

Instruments
Actiheart monitor
The Actiheart (Mini-Mitter Co., USA) is a compact device that records movement counts and HR. Activity energy expenditure can be determined using the information acquired by the device. The Actiheart has a sensitivity of 0.250mV. The ECG signal is sampled at 128Hz and at the end of each epoch, the trimmed mean of the last 16 R-R intervals is calculated by ignoring values outside ± 25% of the initial mean. This signal is converted to beats per minute (bpm) and written to the memory at the end of each epoch. The measurable range of HR in the manufacturer specification is 31-250 bpm. Two ECG electrodes were placed on the participant's upper chest. The medial electrode was placed at the level of the third intercostal space on the sternum and the lateral electrode was placed on the same horizontal level and as lateral as possible on the major pectoral muscle (3). This placement was used because the alternative position offered in the manual, below the apex of the sternum, would not allow for HR measurement by ECG. The Actiheart has an internal memory that is capable of storing 11 days of movement counts and HR in 15 sec epochs. Data were downloaded using a docking station and proprietary software and then exported to a Microsoft Excel file which provides movement counts, activity energy expenditure, and HR. The Actiheart is described in detail elsewhere (3).

Heart rate
Heart rate was recorded using a Quinton Q-stress ECG machine (Cardiac Science Corporation, USA) in the laboratory environment and using a Polar Vantage XL HRM (Polar Electro Oy, Finland) during free-living.

Actigraph accelerometer
The Actigraph accelerometer (ActiGraph, LLC, USA) records movement counts by user pre-established time intervals. In this study, an interval of 15 sec was used to match the Actiheart recording period. The Actigraph can detect vertical acceleration of the hip at magnitudes ranging from 0.05 to 2.00 G and a frequency response from 0.25 to 2.5 Hz. The Actigraph records information on an internal memory card

that can be downloaded using the software provided by the manufacturer. More information about the Actigraph can be found elsewhere (22).

Energy expenditure
The AEI Moxus Metabolic Cart was used to measure caloric expenditure in the laboratory environment by means of open-circuit spirometry''. The environment was controlled, with temperatures ranging from 21 to 24 °C for all tests. Analysis of expired gases was done using Ametek O_2 (S-3A/I) and CO_2 (CD-3A) analyzers (AEI Technologies, USA). The testing equipment was manually calibrated (environmental settings and gas analyzer calibration) at the start of every testing session. This process consisted of allowing the system to warm up and stabilize (1 hour minimum), followed by testing both ambient and calibration gas values (oxygen and carbon dioxide). The analyzers were calibrated to both high and low values. Energy expenditure (kcal/min) was computed by multiplying the oxygen uptake (L/min) by the caloric equivalent based on the respiratory exchange ratio (RER). The oxygen consumption for the 4th and 5th minute of each condition were averaged for use in calculating caloric expenditure.

Procedures
Data collection
Prior to testing, participants voluntarily signed an informed consent form and were acclimated to the treadmill by performing 5 min of activity at each of the testing speeds. The participants were tested on two separate days. On the first day, participants completed the free-living portion and were acclimated to the treadmill. On the second day, they completed the laboratory portion of the study. For validation of the Actiheart in the laboratory environment, participants were monitored by ECG and were asked to lie down and rest for a 10 min period, as instructed in the Actiheart manual, to obtain a resting HR. The lowest HR observed in the 10 min period was recorded as the resting HR. Sleeping heart rate (SHR) was then estimated using the following equation; SHR = 0.83*lying HR, as used by Crouter and colleagues (7). Before the participants started walking, the lowest HR in the previous 5 min was recorded as standing HR. Participants were then asked to either walk or jog on a treadmill for 5 min at each speed wearing the Actiheart on the chest and the Actigraph on the waist: (a) walking at 3.2 km/h, (b) walking at 6.4 km/h, and (c) jogging at 9.6 km/h. Between trials, participants were required to rest until their HR was within 10 bpm of their original standing HR. Heart rate and movement counts were recorded and oxygen consumption was measured. Data from the Actiheart monitor were then compared with the HRs from the ECG, movement counts from the Actigraph accelerometer, and activity energy expenditure computed from oxygen consumption minus resting energy expenditure.

For the free-living validation of the Actiheart, participants were asked to perform free-living physical activity for 30 min. With the exception of water activities, no other limitations or guidance were given. Participants' HR and movement counts were recorded using the Actiheart. These values were compared with HRs from the Polar HRM, movement counts from the Actigraph monitor, and energy

expenditure from the Actigraph monitor minus resting energy expenditure.

Data management

Actiheart data were downloaded to a personal computer using a docking station and Mini-Mitter Software. The SHR was entered into the software for calculation of activity energy expenditure using the equation developed by Brage et al. (2). Data were loaded into Microsoft Excel files. A similar procedure was done with the data from the Actigraph. Movement counts from the Actigraph were used to calculate energy expenditure based on equations developed by Freedson et al. (10). For the Polar HRM, the data were downloaded using a docking station and Polar Electro software and then copied to the Microsoft Excel file. The data from the metabolic cart and ECG were exported to the Microsoft Excel file. For the data in the laboratory-setting, energy expenditure, movement counts, and HR were averaged across the 4th and 5th mins of each workload. For the free-living condition, energy expenditure, movement counts, and HR were averaged across the 30 min session. Due to their small weight, the weight of the devices was ignored for all the calculations.

Data Analysis

Data analysis was performed using SPSS (version 15.0). Descriptive statistics were computed for all variables and data. Data were analyzed separately for the laboratory and free-living conditions. For validation of the Actiheart in the laboratory environment, Pearson's correlation coefficients were analyzed to determine the relationship among the Actiheart monitor and the comparison measures. The Shapiro-Wilk test of normality and Mauchly's sphericity test were conducted prior to the data analysis. Two-factor repeated measures ANOVA were performed to assess absolute differences in energy expenditure and HR between the measurements across changes in workload. Both measures (i.e., the Actiheart monitor vs. the comparison measures) and workload (i.e., 3.2, 6.4, and 9.6 km/h) were considered within-subject factors in the repeated measures ANOVA. In addition, simple effects were analyzed when a significant integration effect was present. The alpha level was set at .05.

For validation of the Actiheart under free-living conditions, Pearson's correlation coefficients were analyzed to determine the relationship between the Actiheart and the Actigraph and Polar HRM, respectively. Paired t-tests were also used to identify the absolute differences in measurements among the Actiheart and the comparison measures.

RESULTS

Energy Expenditure, Movement Counts, and Heart Rate in the laboratory

The results from the laboratory environment can be found in Tables 2 and 3. Pearson's correlation coefficients for energy expenditure between the Actiheart and the metabolic cart were moderate to high. The Shapiro-Wilk test of normality showed no violation of the assumptions. A two-factor (2 measures x 3 workloads) repeated measure ANOVA was performed to assess differences in energy expenditure between the measures. Mauchly's sphericity test indicated that the data violated the assumption of sphericity ($X^2(2)$ = 10.82, p = .004), so the F value was

Table 2. Comparing measurements of physical activity at three workloads in the laboratory environment (*N* = 32).

Speed	Energy Expenditure (kcal/min)								Movement Counts (counts/min)			
	Actiheart	MC	MD	*r*	Actigraph	MC	MD	*r*	Actiheart	Actigraph	MD	*r*
3.2 km/h	2.3 ± 1.0	2.3 ± 0.6	0.01	.79	2.7 ± 1.5	2.4 ± 0.6	0.33	.71	164 ± 60	1130 ± 339	.	.13
6.4 km/h	5.2 ± 1.6	5.4 ± 1.0	-0.17	.72	5.9 ± 2.3	5.4 ± 1.0	0.52	.80	684 ± 124	4,491 ± 997	.	.39
9.6 km/h	10.1 ± 2.7	10.9 ± 2.5	-0.81*	.80	11.1 ± 3.8	11.0 ± 2.5	0.11	.54	2,069 ± 276	10,501 ± 3,258	.	.13

MC = Metabolic cart; MD = Mean difference; *r* = Pearson's correlation coefficient; Results are presented as means ± standard deviation; *$p < .05$

corrected using the Greenhouse-Geisser estimate. A significant measure x workload interaction was shown, $F(1.53,47.60) = 5.80$, $p = .01$. Further testing was done to determine at which workload the difference occurred, and the analysis of simple effect showed that there was a significant difference between the Actiheart and the metabolic cart ($p = .009$) only at 9.6 km/h (see Table 2).

Table 3. Comparing measurements of heart rate at three workloads in the laboratory environment ($N = 32$).

Speed	Heart Rate (bpm)			
	Actiheart	ECG	MD	*r*
3.2 km/h	93.7 ± 15.6	93.6 ± 15.6	0.1	.99
6.4 km/h	125 ± 22.4	123.8 ± 21.1	1.2	.98
9.6 km/h	172.3 ± 23.3	168.3 ± 22.3	4.0	.88

MD = Mean difference; *r* = Pearson's correlation coefficient; Results are presented as means ± standard deviation.

Pearson's correlation coefficients for movement counts between the Actiheart and the Actigraph were low to moderate at 3.2, 6.4, and 9.6 km/h. The absolute difference in movement counts between the Actiheart and Actigraph monitors was not analyzed due to the different scales of measurement for movement counts between the two instruments (i.e., 972.27 ± 827.13 counts/min for the Actiheart movement counts and 5,540.73 ± 4,332.37 counts/min for the Actigraph movement counts).

Pearson's correlation coefficients for HR between the Actiheart and the ECG HR were high at 3.2, 6.4, and 9.6 km/h. The Shapiro-Wilk test of normality showed no violation of the assumptions. A 2 x 3 repeated measure ANOVA was performed to assess differences in HR between the measures. Mauchly's sphericity test showed that the assumption had been violated ($X^2(2) = 35.08$, $p < .001$). Therefore, the *F* value was again corrected using the Greenhouse-Geisser estimate of sphericity. The two-factor repeated measure ANOVA showed that there were no measure x workload interaction effect on HR, $F(1.18,35.26) = 2.64$, $p = 0.11$.

Free-Living Energy Expenditure, Movement Counts, and Heart Rate
Results from the free-living condition appear in Tables 4 and 5. Pearson's correlation coefficient for energy

Table 4. Comparing measurements of physical activity during free-living condition (*N* = 34).

	Energy Expenditure (kcal/min)				Movement Counts (counts/min)			
	Actiheart	Actigraph	*t*-value	*r*	Actiheart	Actigraph	*t*-value	*r*
Free-living	4.30 ± 1.94	4.24 ± 2.24	.26	.81	436 ± 391	3,166 ± 1692	.	.91

r = Pearson's correlation coefficient; Results are presented as mean ± standard deviation.

expenditure of the Actiheart and the Actigraph was high for the average of the 30 min of physical activity. A paired t-test showed no significant difference in energy expenditure between the measures ($p > .05$). Pearson's correlation coefficient for movement counts from the Actiheart and the Actigraph was also high . The absolute difference between the two measures was not analyzed, again due to the different scales of measurement. For HR measured by the Actiheart and the Polar HRM, the correlation coefficient was high. The paired t-test showed that there was a significant difference between the measures, $t(33) = 3.0$, $p = .005$, with the Actiheart overestimating HR.

Table 5. Comparing measurements of heart rate during free-living condition (*N* = 34).

	Heart Rate (bpm)			
	Actiheart	Polar	*t*-value	*r*
Free-living	120.1 ± 18.9	116.6 ± 16.9	3.00*	.93

r = Pearson's correlation coefficient; Results are presented as mean ± standard deviation;*$p < .05$

DISCUSSION

Accurately measuring physical activity is important for researchers to better understand the dose-response relationship between physical activity and health. It is also important for practitioners because they can use the information to develop more effective activity programs for their clients. The Actiheart monitor is a relatively new device that combines an accelerometer and a HRM into a single device. The combination of these measures has been shown to be more accurate in the classification of physical activity than the individual measures (11, 24, 28).

Few researchers have tested the reliability and validity evidence of the energy expenditure estimation of the Actiheart monitor. Recently, Crouter and colleagues (6) investigated the accuracy of the Actiheart monitor but only to pre-determined activities (i.e., raking grass, vacuuming, washing dishes, basketball) for a set period of time. Corder et al. (5) developed equations for the prediction of physical activity energy expenditure of children using different accelerometers. Among the techniques considered, combined HR and movement counts was the most valid for estimating physical activity energy expenditure in children while treadmill walking and running. Compared with movement and HR alone, the combination from the Actiheart also had the lowest level of systematic error.

Brage et al. (3) provided evidence of validity for the Actiheart monitor energy expenditure in the laboratory setting. These authorsdid not examine the validity of the Actiheart for measurement of HR and energy expenditure during free-living conditions without control. In the present study, there was a high positive correlation between the Actiheart monitor and other comparable measures, with the Actiheart underestimating energy expenditure only at one workload (jogging at 9.6km/h). This was a statistically significant difference, but it could be relatively insignificant in practice. A person running at 9.6 km/h for 30 mins would have their energy expenditure underestimated on average by 24.3 kcal. Because it is not common for people to spend large amounts of time at this level of intensity, the margin of error for daily energy expenditure may be low.

Laboratory HR data from the current study are similar to existing research (3). Brage and colleagues had nine participants walk and run on a treadmill at speeds ranging from 3.2 to 12.1 km/h. There were no significant mean differences among any of the methods of HR measurements utilized (i.e., Actiheart, ECG, and Polar S610). However, in the present study, the Actiheart overestimated HR during the free-living condition.

Pearson's correlation coefficients between the Actiheart and the Actigraph movement counts in the laboratory environment were low as opposed to a high positive Pearson's correlation coefficient under free-living conditions. The low correlation coefficients found in the laboratory environment were not surprising. It is well acknowledged that the correlation coefficient is influenced by a restricted (or truncated) range of data (i.e., variability). Because the laboratory data were analyzed within the limited speeds of 3.2, 6.4, and 9.6 km/h and the Actiheart has a constricted measurement scale, the Pearson's correlation coefficients were understandably to be low. When we re-calculated the Pearson's correlation coefficient with all workloads combined, the relationship between the two measures was strong ($r = .88$).

The Actiheart monitor provides information on physical activity intensity classification (i.e., low, moderate, vigorous intensity). The accuracy of the physical activity intensity classifications of the Actiheart were examined by comparing them with those of the Actigraph monitor. The contingency coefficient between the Actiheart monitor and the Actigraph accelerometer was calculated by the sum of proportions of correct classifications (i.e., diagonal) from a 3 x 3 cross tabulation table (i.e., the proportion of correct classifications between the two monitors). For the Actigraph, two cut-off points were derived from the literature: Freedson et al. (10) set the cut-off point between low and moderate activity at 1,952 movement counts and Hendelman et al. (13) set the cut-off point between moderate and vigorous activity at 6,893 movement counts. In this study a total of 1,020 minutes of data were collected. The data from the Actiheart showed that study participants spent 295 min in low, 615 min in moderate, and 110 min in vigorous activities during the free-living condition. The contingency coefficient between the Actigraph and the Actiheart was .747, representing a moderately high accuracy of physical activity intensity classifications. A higher percentage of low and moderate

activities were correctly classified (i.e., low = 70.1% and moderate = 79.8%) compared with vigorous (58.2%) activities. These findings indicate that the accuracy of physical activity intensity classifications of the Actiheart is more acceptable at low and moderate intensities. Considering the emphasis on the public health impact of low to moderate physical activity intensity, the use of the Actiheart monitor is a promising tool in identifying these types of activities.

Although the present study was carefully constructed, a few limitations persisted. The number of participants is relatively small. The Actigraph is a device that has been previously studied and the measurement of energy expenditure has been found to be fairly accurate. However, the Actigraph is not the criterion measure for the assessment of free-living energy expenditure (20). Crouter et al. (6) developed a new two-regression model for the Actigraph, which is based on the counts per minute and variability in counts between 10 sec epochs. The authors found the two-regression model to be more accurate than the Freedson et al. (10) equation for energy expenditure estimation. The new two-regression model equation may have been more appropriate to use in this study. However, because it was desirable to match the recording period of the Actigraph to that of the Actiheart, which is set at 15 sec epoch, the two-regression model was not applicable.

The Actiheart is a device with great potential because it takes into consideration two widely used measurements of physical activity, movement counts and HR. While the device is strongly correlated with energy expenditure determined from open-circuit spirometry, the Actiheart underestimated energy expenditure at the highest workload under laboratory conditions. During free-living, the Actiheart was highly correlated with the Actigraph energy expenditure and Polar HR. The energy expenditure calculations were similar to the Actigraph. However, there was an overestimation of HR by the Actiheart monitor during free-living conditions. Overall, the Actiheart was valid at measuring and categorizing intensities of physical activity. Some adjustments on the estimation formula of the Actiheart monitor are necessary to better reflect the measurements of higher intensity physical activity. Future research should look at different populations and investigate if the Actiheart may be affected by varying levels of adipose/muscle tissue.

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