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Evaluation of Physical Activity Intensities and Energy Expenditure in Overweight and Obese Adults

Ludivine Paris[1], Martine Duclos[1,2], Romain Guidoux[1], Nicolas Lamaudière[3] and Sylvie Rousset[1]*

[1]Human Nutrition Unit UMR 1019, France

[2]University Hospital Clermont Ferrand, Med Sport & Fonct Explorat Services, France

[3]Medical Centre Clermont Sud, France

***Corresponding author:** *Sylvie Rousset, INRA, Human Nutrition Unit UMR 1019, CRNH d'Auvergne, 63009 Clermont-Ferrand, France, Tel: 33-473624679, Fax: 33-47362475, Email: rousset@clermont.inra.fr*

Abstract

Purpose: This study aims to compare total energy expenditure (TEE) estimations made by Actiheart® and Armband®, as well as by MET with TEE measured by indirect calorimetry in an overweight population.

Methods: Thirteen volunteers were equipped with Actiheart® and Armband® devices and wore a Fitmate® facemask during a controlled scenario of daily-living activities to evaluate TEE. TEE errors were calculated as the ratio of the differences between Actiheart®, Armband®, MET estimations, and the Fitmate® measurements. Time spent in sedentary, light-, moderate- and vigorous-intensity activities was estimated and compared according to the devices.

Results: The three mean absolute values of TEE errors were significantly different from zero and different between themselves. The absolute values of errors were different between Armband® and Actiheart® but not between Armband® and MET values or between Actiheart® and MET values. Armband® was the most accurate device for estimating TEE during the activity schedule in this overweight population sample. The distributions of differences varied less around the means, suggesting a smaller inter-individual variability in TEE estimated using Armband® than Actiheart® and MET values. For the time spent in each category of activity, Actiheart® and Fitmate® provided results that were significantly different from the recorded scenario, with differences ranging from 5 to18%. In contrast, there was no significant difference between the time estimated by Armband and the scenario.

Conclusions: Our results showed that Armband® was more effective than Actiheart® at the individual level for estimating TEE and daily light-intensity activitiesin overweight or obese people.

Keywords

Daily-living activities, Body mass index, Energy metabolism, Physical activity level

Introduction

Western lifestyle characterized by lack of physical activity and diet rich in fat and refined sugars is associated with various non communicable chronic health diseases. The prevalence of obesity worldwide is steadily increasing. In 2014, 39% of adults worldwide were overweight and 13% were obese [1]. Physical inactivity, sedentary behaviors and an excessively rich diet are responsible for chronic imbalance between energy intake and expenditure favoring the development of obesity and its co-morbidities. Sedentary behaviors are defined as "any waking behavior characterized by an energy expenditure lower than 1.5 METs" and they are associated with the development of several chronic diseases and of the premature mortality in adults [2].

Sedentary time, light-, and moderate- to vigorous-intensity activities represent about 57%, 39% and 4% of the awake period in the general population [3]. However, among the sedentary behaviors, sitting time was 1 to 2.7 hours/day longer in obese than in normal-weight population samples according to both studies [4]. Obese people self-reported more time spent watching television or using computers for leisure compared to normal-weight and overweight groups [5].

Recent intervention studies suggest that replacing sitting with standing may result in rapid and positive change in health markers [6]. Light-intensity activities such as standing or slow walking as well could play an essential role in fighting obesity.

Self-monitoring is a key point in long-term behavior change, especially in physical activity. Thus a simple, valid and non-invasive tools are necessary to assess activity intensities and durations in order to be aware of physical sedentary behavior. Knowledge of the total and rest energy expenditure allows assessing the physical activity level. Therefore validity of energy expenditure estimations made by the devices is a crucial issue. It has to be investigated and established in accordance with a reference method. Indirect calorimetry (IC) is the gold standard and consists in measuring gas exchange: the volume of oxygen (VO_2) consumed and carbon dioxide (VCO_2) produced. On the basis of these variables, it is possible to deduce TEE using Weir's equation [7]. Some portable devices such as Fitmate® (Fitmate Pro, Cosmed Inc., Italy) only measure VO_2. The TEE is estimated from VO_2 and the respiratory quotient (RQ), which is the ratio of VCO_2 to

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VO_2 [8]. Fitmate® was validated in a population with a BMI ranging from 18.3 to 32.5 kg.m^{-2} that performed activities such as walking on a treadmill at different speeds and slopes [9]. However, IC techniques are very expensive and require specific equipment and qualified staff. Therefore, TEE is sometimes evaluated on the basis of Metabolic Equivalent Task values (MET) associated with each activity [10]. The MET value represents the ratio of the physical activity energy expenditure to the resting energy expenditure. Classically, activities are organized into five activity categories: sedentary (≤1.5 METs); light [1.6-2.9 METs]; moderate [3-5.9 METs]; vigorous [6-8.9 METs]; and high-intensity [≥ 9 METs] [11].

One MET is equal to approximately 1 kcal.kg^{-1}.h^{-1} or 3.5 ml.kg^{-1}.min^{-1} in a single 40-year-old man with a body mass of 70 kg [12]. Several authors recently reported that the standard MET value of 3.5 ml.kg^{-1}.min^{-1} was significantly higher than those measured in healthy men (3.21 ml.kg^{-1}.min^{-1}) [12] and in overweight to obese men and women (2.62 ml.kg^{-1}.min^{-1} and 2.47 ml.kg^{-1}.min^{-1}, respectively) [13]. It has been recommended that a correction factor be used to adjust MET levels on the basis of an estimate of RMR that accounts for age, height, weight and gender [10]. These MET values therefore make it possible to estimate the activity energy cost and to classify activities according to their intensity. However, this method of TEE estimation using MET values is burdensome because it requires the detailed recording of the successive activities.

As a result, portable tools that are more economical than IC and easier to use than activity recording have been developed, especially for routine measurements. These devices use accelerometry and heart rate (Actiheart®), body temperature, impedancemetry and heat flux (Armband®), or only accelerometry (RT3®, Actigraph®). The reliability and the validity of Actiheart® were studied in controlled conditions (CC), including periods of rest, walking and running, with normal-weight and overweight people (BMI: 20-30 kg.m^{-2}) [14]. Measurements of movements and heart rate were accurate and reliable, allowing Actiheart® to potentially estimate TEE. It was also validated in the general population when simultaneous measurements were made by indirect calorimetry and Actiheart® during physical activity on a treadmill [11]. No significant difference was noted between the two measurements, except for the step at 9.6 km.h^{-1} where Actiheart® underestimated TEE. Armband® was frequently used in controlled (CC) and free-living conditions (FLC). REE and TEE evaluated by Armband were validated for the general population using IC [15]. However, it seems that the accuracy of Armband® varied according to the intensity of the activity. In a heterogeneous population, Armband® overestimated the TEE of light- and moderate-intensity activities, and underestimated TEE for vigorous-intensity activities [16]. Recently, TEE estimated in CC by Actiheart® and Armband® vs. TEE measured by IC were compared in a normal-weight adult population [17]. This study showed that Armband® was more effective for evaluating the TEE of light- and moderate-intensity activities and that Actiheart® was more accurate for evaluating the TEE of vigorous-intensity activities performed in CC.

Most device validation studies had been performed either on normal-weight (18.5-25 kg.m^{-2}) [15] or general (18.5-40 kg.m^{-2}) population samples [18] and few studies specifically involved overweight people [19]. Thus, the aim of our work was to study the validity of TEE estimated in overweight and obese participants by Actiheart® and Armband® devices, and on the basis of MET values during a controlled activity scenario vs. the indirect calorimetry measurements taken by Fitmate®.

Method

Participants

For this study, 13 adults aged between 18 and 60 years old with a BMI ranging from 28 to 42 kg.m^{-2} were recruited through the sports medicine department of the G. Montpied University Hospital (Clermont-Ferrand, France) and advertisements in a local newspaper. First, a medical visit allowed us to verify the selection criteria, i.e., age, BMI, lack of cardiovascular or locomotion diseases and no recent major surgery. During this visit, the volunteers were weighed and their height, neck, hip and waist circumferences were measured by the physician. They also signed an informed consent form and passed a resting electrocardiogram validated by a cardiologist. A maximal exercise test was then performed under the supervision of a cardiologist. All the participants performed a progressive cycling test on an electromagnetically braked cycle ergometer (Ergoline, Bitz, Germany) until volitional exhaustion to determine the maximal values of ventilation (VEmax), oxygen uptake (VO_2max), carbon dioxide output and respiratory exchange ratio (RERmax) by direct method (Oxycon Pro, JAEGER, Germany). VO_2 and VCO_2 were measured breath-by-breath through a mask connected to O_2 and CO analysers (Oxycon Pro-Delta, Jaeger, Hoechberg, Germany). Calibration of gases analysers was performed with commercial gases of known concentration. Ventilatory parameters were averaged every 30 s. Electrocardiogram and heart rate (HR) were measured continuously using 10 precordial electrodes. The first stage of the test lasted 3 min, and the initial power output was 35 W. Power output was then increased by 35 W every 2 min 30 s. Pedaling rate was maintained at 60 revolutions per minute. Criteria for the achievement of VO_2 max were subjective exhaustion the participants' maximal HR (HRmax) was closed to their age-predicted maximum HR (i.e., 220-age ± 10 beats.min-1) and/or Respiratory Exchange ratio (RER, VCO_2/VO_2) above 1.02 and/or a plateau of VO_2. During this exercise, the heart rate and gas exchange were monitored in order to establish the relationship between total energy expenditure and heart rate necessary for individual calibration on the Actiheart® device.

The protocol was approved by the French Committee for the Protection of Human Participantsand was registered under the reference IDRCB 2013-A01140-45 in the ANSM system and 02348554 in Clinical Trials.

Study design

The volunteers performed each of the nine activities several times for a period of 2-20 minutes according to a defined scenario: sitting, slow, normal and brisk walking, climbing and descending stairs (four floors), standing, slow running and taking public transport (tramway). A researcher followed each volunteer in order to observe the beginning and the end of each activity and to record the real duration of each activity using the smartphone application, "Activity Diary", downloadable from https://play.google.com/store/apps/details?id=fr.inra.activitydiary. Process time was estimated at 106 minutes, but it could best opened at any time if the volunteer requested.

Time spent in the four activity categories: We classified activities into four categories. The first category ranged from 0.9 to 2 METs and included sedentary behaviors such as sitting, standing and transportation. The second category, represented by slow walking, corresponded to light-intensity activities and ranged from 2 to 3 METs. The third category included moderate-intensity activities corresponding to 3-5 METs, such as normal walking, descending stairs and brisk walking. The last category, which included vigorous-intensity activities, was higher than 5 METs with running and climbing stairs. The general MET values were defined for normal-weight adults but depend on individual characteristics. This is why some authors [20] recommended personalizing MET values by taking the REE estimated by the Mifflin-St. Jeor equations, which are adapted to overweight men and women and obese people, into account [21].

$$Men\ REE_{Mifflin} = 10*W + 6.25*H - 5*A + 5$$

$$Women\ REE_{Mifflin} = 10*W + 6.25*H - 5*A - 161$$

$REE_{Mifflin}$ is the Resting Energy Expenditure predicted by the Mifflin-St. Jeor equations (kcal.d^{-1}), where W is the Weight (kg), H the Height (m) and A the Age (years).

To personalize MET values, it is necessary to estimate the individual O_2 volume consumed during rest that defines1 MET. This

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value is deduced from the conversion of REE expressed in $kcal.d^{-1}$ into $ml.kg^{-1}.min^{-1}$:

$$REE_{Mifflin}(ml.kg^{-1}.min^{-1}) = \frac{REE_{Mifflin}(kcal.d^{-1}) \times 1000}{1440*5*W}$$

Then:

$$METp(i) = METg(i) * \frac{3.5}{REE_{Mifflin}(ml.kg^{-1}.min^{-1})}$$

METp is the personalized MET; METg is the general MET; 3.5 corresponds to the general oxygen consumption at rest ($ml.kg^{-1}.min^{-1}$); $REE_{Mifflin}$ is the Resting Energy Expenditure predicted by the Mifflin-St. Jeor equations ($ml.kg^{-1}.min^{-1}$).

On the basis of the activity scenario, i.e., durations of activities and their MET values, we calculated $TEE_{scenario}$.

On the basis of TEE given minute-by-minute by Armband®, Actiheart® and Fitmate®, MET values were calculated and time spent in each category was estimated considering the following equations:

$$Equation\ 1)\ TEE = REE + PAEE + Th$$

$$Equation\ 2)\ Th = 0.10 * TEE$$

$$Equation\ 3)\ MET = \frac{PAEE + REE}{REE}$$

$$Equation\ 4)\ MET = \frac{TEE \times 0.9}{REE}$$

where TEE (Total Energy Expenditure), REE (Resting Energy Expenditure), PAEE (Physical Energy Expenditure)and Th (thermogenesis) are expressed in $kcal.min^{-1}$.

Description of the two devices used in the protocol: The description of both devices Pro-3 Armband® (version 6.1, BodyMedia, Pittsburgh, PA, USA) and Actiheart® device (CamNtech, Cambridge, UK), and the calculation of MET values from TEE were shown in [17].

TEE measurements made by Fitmate®: The Fitmate® device (Cosmed, Rome, Italy) was used as a reference for TEE measurement. We used facemasks with a turbine flowmeter (28 mm diameter) adapted to the ventilation measurement during exercise. This device also includes a galvanic fuel cell oxygen sensor for analyzing the fraction of oxygen expired and for subsequently estimating the VO_2. The facemask was connected to the central unit, which was placed in a backpack during the activities for practical reasons. A chest belt connected to the central unit was responsible for monitoring the heart rate in real-time. This real-time monitoring makes it possible, in conjunction with VO_2 measures, to estimate changes in the respiratory quotient during exercise. $TEE_{Fitmate}$ was then calculated using an Excel macro provided by Delta Medical, which takes Weir's equation and the variation of RQ into account. A recent study reported that the average RQ at rest was higher for overweight and obese people (0.87) than for normal-weight people (0.85) [22].

Statistical analysis

The anthropometric and individual characteristics (age, weight, height, BMI, circumferences) recorded in men and women were compared using t-tests. The TEE values given by the devices (Actiheart® and Armband®) and estimated by the scenario were compared to those of Fitmate®. Taking Fitmate® as a reference, we calculated the error as follows:

$$\varepsilon_{Device}(\%) = \frac{TEE_{Device} - TEE_{Fitmate}}{TEE_{Fitmate}} \times 100$$

where TEE_{Device} is the Total Energy Expenditure estimated by Actiheart® or Armband® or from MET values, and $TEE_{Fitmate}$ is the Total Energy Expenditure estimated by Fitmate®.

For each activity category, the error of TEE estimation (%) was expressed either in relative or in absolute values. T-tests and paired t-tests were performed on relative and absolute values of error to determine if the errors were different or not from zero and to compare error levels between them.

The time spent in each activity category was already expressed as the percentage of the total recording time. We therefore calculated the gap between the results from the devices and the duration determined from the scenario, which is the reference for the time.

$$\Delta(\%) = t_{device}^{category}(\%) - t_{scenario}^{category}(\%)$$

where $t_{device}^{category}$ iis the % of time spent in category x given by the device (Actiheart®, Armband® or Fitmate®), $t_{scenario}^{category}$ is the % of time spent in category x measured with the scenario.

All t-tests were performed using SAS 9 software. The percentages of time estimated in an activity category (sitting/standing, light-, moderate- or vigorous-intensity) by Actiheart®, Armband® and Fitmate® were compared to those recorded by the scenario by performing paired t-tests.

Statistical significance was set at $p < 0.05$. Agreement between portable monitoring devices, TEE estimations and reference measurements was evaluated by Bland-Altman plots [23]. The bias was estimated by the mean difference (M) and the standard deviation (s). Statistically, 95% of the difference lies between M ± 2s (agreement limits).

Results

Participant characterization

All participants were overweight or obese ($28.5 < BMI < 41.6$ $kg.m^{-2}$) and middle-aged (Table 1). There was no difference in age ($p = 0.77$), weight ($p = 0.31$), height ($p = 0.13$), BMI ($p = 0.70$), waist circumference ($p = 0.17$) and hip circumference ($p = 0.22$) between male and female volunteers. However, neck circumference was significantly higher in men than in women ($p = 0.02$). The waist-to-hip ratio was not significantly different between men and women, but it seems that this ratio was higher in men ($p = 0.06$).

Table 1: Characteristics of volunteers (Mean ± SD).

	Men (n = 6)	Women (n = 7)
Age (y)	47.2 ± 9.5	45.4 ± 10.1
Height (m)	1.73 ± 0.10	1.64 ± 0.08
Weight (kg)	98.5 ± 13.6	90.7 ± 11.1
BMI ($kg.m^{-2}$)	33.0 ± 3.0	33.9 ± 4.2
Neck circumference (cm)	44.0 ± 3.1	39.6 ± 2.3
Hip circumference (cm)	111.3 ± 4.7	117.3 ± 9.4
Waist circumference (cm)	108.3 ± 10.7	99.9 ± 8.7
Waist-to-hip ratio	0.97 ± 0.08	0.85 ± 0.11

Table 2: General and personalized MET values (METg and METp) according to the activity category.

Volunteer	Sex	METg		
		2	3	5
		METp		
1	F	2.93	4.39	7.32
2	F	2.88	4.32	7.20
3	F	3.22	4.83	8.04
4	F	2.79	4.19	6.98
5	F	2.84	4.27	7.11
6	F	2.54	3.81	6.35
7	F	2.88	4.31	7.19
8	M	2.73	4.10	6.83
9	M	2.50	3.75	6.24
10	M	2.48	3.71	6.19
11	M	2.43	3.64	6.07
12	M	2.60	3.90	6.50
13	M	2.60	3.69	6.15

Activity scenario: duration and MET values

The expected time for the whole set of activities was 106 minutes and the actual mean time was 99 ± 18 minutes. The varying durations were due to external factors such as climate (rain or snow), a tramway strike and the volunteers' reactions such as fatigue.

Each physical activity of the scenario was associated with general MET values, followed by personalized ones, as shown in Table 2. The personalized values of METs were higher than the general MET values because the volunteers were overweight. This means that the intensity of activities is stronger for an overweight than for a normal-weight participant.

Comparison between TEE estimated by both devices, the scenario and TEE Fitmate®

The TEE values measured by Fitmate® were the references for calculating errors. The mean relative value of error for estimating TEE was not significantly different from zero in the case of Actiheart® and MET values: -7.0% ± 15.9% and 3.4% ± 13.0% (p > 0.05), but significantly different from zero for Armband®, indicating an underestimation of -7.7% ± 8.4% (p = 0.008). Errors in absolute value were all significantly different from zero, 9.3% ± 6.9%, 16.3% ± 6.6% and 12.6% ± 4.7 for Armband®, Actiheart® and the scenario, respectively. However, the mean difference between Actiheart® and Armband® errors in absolute value was significantly different from zero (- 6.7%, p = 0.004). Thus, the error expressed in absolute value was higher for Actiheart® (15.9% ± 6.8%) compared to Armband® (8.4%± 6.6%). The two other mean differences in error (between Armband® or Actiheart® and the scenario) were not significant (p = 0.21).

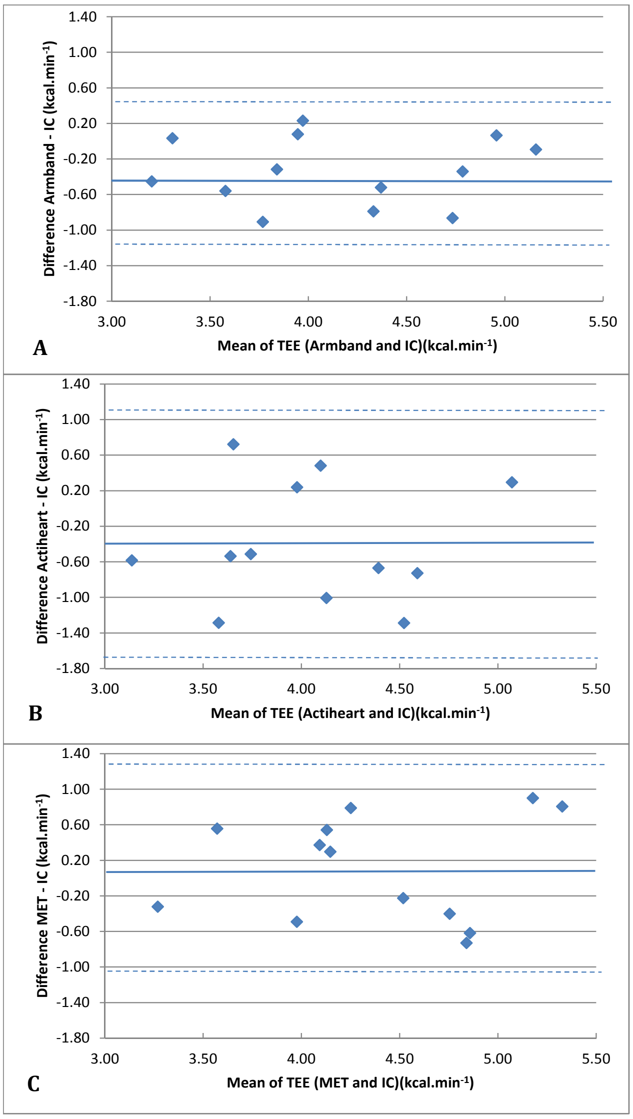

Figure 1: Bland and Altman plots (M ± 2s) of the agreement level between Fitmate® and (**A**) Armband®; (**B**) Actiheart® and (**C**) MET values.

Table 3: Time spent (%) in each intensity category determined by the three devices and the scenario (Mean ± SD).

Activity intensity	Armband	Actiheart	Fitmate	Scenario
Sitting/standing	57 ± 4	50 ± 10	54 ± 5	59 ± 5
Light	6 ± 4	22 ± 10	12 ± 5	4 ± 0
Moderate	33 ± 5	25 ± 10	26 ± 4	34 ± 5
Vigorous	4 ± 6	3 ± 5	7 ± 5	3 ± 0

The mean bias M was also calculated as the relative mean difference between TEE calculated from indirect calorimetry (Fitmate®) and the estimated TEE (Actiheart®, Armband® and MET values) using Bland and Altman's method. The bias was small for the three estimations: -0.34 kcal.min^{-1} for Armband®, -0.33 kcal.min^{-1} for Actiheart® and 0.11 kcal.min^{-1} for the activity scenario compared to the mean TEE (4.2 kcal.min^{-1}) (Figure 1A, B and C). However, the "standard deviation × 2" of the difference was lower for Armband® (2s =0.77 kcal.min^{-1}, Figure 1A) compared to Actiheart® (2s = 1.42 kcal.min^{-1}, Figure 1B) or the activity scenario (2s = 1.19 kcal.min^{-1}, Figure 1C). All differences between the portable devices and Fitmate® were within the limits of agreement (M ± 2s). However, the upper and lower limits of agreement were closer for Armband® ([-1.15 - 0.43 kcal.min^{-1}]) (Figure 1A) compared to Actiheart® ([-1.75 - 1.09 kcal.min^{-1}]) or MET values ([-1.08 - 1.3 kcal.min^{-1}]).

Comparison between activity duration estimations and the scenario

The percentages of time spent in sedentary sitting and standing, light-, moderate- and vigorous-intensity activities are shown in Table 3. Sitting and standing activities took up most of the time: 57%, 50%, 54% and 59%, according to Armband®, Actiheart®, Fitmate® and the scenario recordings, respectively. The paired t-tests showed significant underestimations of -8.7% (p = 0.006) and -4.4% (p = 0.002) between the scenario and Actiheart® or Fitmate® for sitting/standing activities, respectively. A similar result was observed for moderate-intensity activities (-9.7%, p = 0.008 and -8.6%, p < 0.0001 for Actiheart® and Fitmate®, respectively). Conversely, there was an overestimation of light-intensity activity duration by Actiheart® and Fitmate® compared to the scenario (p < 0.0001). Otherwise, there were few vigorous-intensity activities: less than 7% of the time and only one significant overestimation (4.5%, p = 0.006) by Fitmate® compared to the scenario.

No difference was observed between Armband® and the scenario, regardless of the activity intensity (sitting/standing: p = 0.15; light: p = 0.10; moderate: p = 0.28; and vigorous:p = 0.16), or between Actiheart® and the scenario for the estimation of vigorous-intensity activity (p = 0.89).

Discussion

In the present study, the performances of two portable devices (Actiheart® and Armband®) and the personalized MET values for TEE estimation were compared with the results given by a reference method of indirect calorimetry (Fitmate®) in a population sample of overweight and obese volunteers. Knowledge of TEE is essential in order to estimate the time spent in active behaviors (duration and intensity), to propose a diet adapted to the physical activity level. Moreover, research devoted to the study of total and physical activity energy expenditure depends on valid devices. Actiheart® and Armband® were validated on normal-weight populations [11,16]. It was then necessary to specifically test and validate them ona sample of overweight and obese populations in controlled conditions.

Firstly, we compared the TEE estimated by the devices, calculated from the MET values associated with the activities in the scenarios and measured with the Fitmate® device. Our findings showed that the absolute values of errors were smaller for the SenseWear Pro3

Armband® (9%) than for Actiheart® (16%) and MET values (12%). Moreover, the limits of the agreements were closer for Armband® than for the other two methods. Few studies have focused on the validity of both of these devices in overweight and obese adults. As regards energy expenditure estimated by Armband® Pro 2 version 4.0 during exercise sessions performed for five minutes by twenty obese adults, an overestimation of TEE by 20, 30 and 31 % during bicycling, stair stepping and walking was observed [19]. The Bland-Altman plots did not show agreement between Armband Pro 2 and indirect calorimetry measured in obese volunteers. In our study Armband Pro 3 version 6.1 were used. Small biases and good agreement between the recent version of Armband and IC were observed. Furthermore the TEE was evaluated over a longer time span in the present study than in Papazoglou et al.'s work. The device bias may increase with brief time span by reason of edge effects. To our knowledge, Actiheart® was never specifically validated in an overweight or obese adult population. To improve the accuracy of this heart rate monitor, the individual or group "heart rate-TEE" relationship has to be established and implemented in the TEE prediction model [14,24]. The best results were obtained with the individual calibration that was used in our study. Nevertheless, Actiheart® provided less accurate TEE estimation than Armband®. The personalization of the MET values associated with the activity scenario allowed us to obtain a third evaluation of TEE. The magnitude of error in absolute value was intermediate between those of Actiheart® and Armband®, without being significantly different. Thus, if the activity durations are precisely known, the TEE estimation on the basis of the activity scenario and the personalized MET values is accurate. However, the TEE evaluation from MET values requires accurate activity recordings that would be very demanding and tedious in free-living conditions without technological support.

Recent studies have pointed out that sedentary time is the most detrimental to health [25] We therefore then compared the time of immobile activities (sitting and standing), light (slow walking), moderate (normal and brisk walking) and vigorous (running and stair climbing) evaluated by Actiheart® and Armband®, calculated from Fitmate® and recorded by an engineer with the smartphone application "Activity Diary". The scenario provided the real time spent in each category since every change of activity was precisely recorded. The results are similar for Actiheart® and Fitmate®, which significantly underestimated the percentage of time for sitting/standing and moderate-intensity activities, and overestimated light-intensity activities included in the scenario. Both devices, Actiheart® and Fitmate®, made it possible to estimate these times on the basis of TEE and, therefore, from variables such as heart rate. Following an activity, there is a recovery phase where the heart rate/TEE will gradually decrease to return to its resting value. This phase can be the cause of the underestimation of sitting/standing activities and the overestimation of light-intensity activities for these two devices. There is no difference between Armband® and the scenario. This best accuracy is probably due to the fact that the measures made by the Armband are based not only on accelerometry, but also on body temperature, impedancemetry and heat flux. The accuracy of the Armband® device in terms of sedentary time and the opportunity to obtain minute-by-minute results makes it a sensor that is particularly well adapted to the overall assessment of sedentary behavior. Results obtained with Actiheart® and Fitmate® depended on heart rate and recovery. Heart rate is also known to be influenced by factors other than physical activity, such as stress. For these reasons, these last two devices underestimated immobility and were therefore less well suited than Armband® for estimating this activity category.

As in other studies, a small sample size of volunteers was studied because the volunteerswere physically homogeneous and the protocol was performed in controlled conditions ([14,15] and [26]). The volunteers of the present study were all able bodied, without gait disorder and sedentary. On the metabolic basis, they were similar too. Their TEE values recorded during the first sitting activity in the scenario were correlated neither with age nor with BMI (results not shown). Their activities during the scenario were standardized and controlled. Furthermore the small sample size of the present study was sufficient to show significant differences between the devices. In a further additional study, it would be interesting to test both these sensors in larger number of volunteers in free-living conditions where activities are brief, spontaneous and heterogeneous since these activities are assumed to have beneficial effects on health. However, since both of these sensors only provide minute-by-minute results, they cannot identify very short light-intensity activities (less than one minute) such as small displacements involved in daily tasks. The design of a device capable of integrating novel functionalities that are able to capture frequency and duration of brief light-intensity activities is therefore needed.

Health problems related to obesity and sedentary behavior are on the rise. The sensor SenseWear Pro-3 Armband® provided accurate results with a difference of less than 2% of time spent in each of the four intensity category compared to the scenario. It estimated TEE with less than a 10 % error compared to IC. Actiheart® was well adapted to estimate normal weight people TEE. The knowledge of assessment validity of total energy expenditure and sedentary behaviors by the research devices are therefore a major issue in the overweight population.

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