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Original

Comparison of the ActiGraph acceloremeter and Bouchard diary to estimate energy expenditure in Spanish adolescents

D. Martínez-Gómez[1,2], M.ª A. Puertollano[1], J. Wärnberg[1,3], M. A. Calabro[4], G. J. Welk[4], M. Sjöström[3], O. L. Veiga[2] and A. Marcos[1]

[1]Immunonutrition Research Group. Department of Metabolism and Nutrition. Instituto del Frío-ICTAN. Consejo Superior de Investigaciones Científicas. Madrid. Spain. [2]Department of Physical Education. Sport and Human Movement. Facultad de Formación del Profesorado y Educación. Universidad Autónoma de Madrid. Madrid. Spain. [3]Unit for Preventive Nutrition. Department of Biosciences and Nutrition. Karolinska Institutet. Huddinge. Sweden. [4]Department of Health and Human Performance. Iowa State University. Ames. IA. USA.

Abstract

Introduction: **The aim of this study was to evaluate the agreement between the ActiGraph accelerometer and the Bouchard diary to estimate energy expenditure (EE) in a Spanish adolescent population.**

Methods: **Sixty-one Spanish adolescents, aged 12-16 years, were recruited for this study. The Bouchard diary and the ActiGraph were administered for 3 consecutive days. EE estimated by the Bouchard diary was calculated using 2 different MET category values (BD-Bouchard and BD-Bratteby). EE estimated by the ActiGraph was calculated using 3 predictive equations (AC-Trost, AC-Freedson, and AC-Ekelund). Participants with complete 24 h data were also analyzed to control the possible loss of accuracy. Agreement was examined by Pearson and concordance correlations, paired *t*-test, and Bland-Altman method.**

Results: **Thirty-seven adolescents were included in the analyses with complete 72 h. Relationships between EE calculated by the Bouchard diary and the ActiGraph were high (ranged: r = 0.61-0.78). Concordance correlations were moderate (r_c = 0.60) by BD-Bratteby and AC-Trost, and low using BD-Bratteby and AC-Ekelund (r_c = 0.15). EE estimated by BD–Bratteby and AC–Trost also showed no significant differences (*P* > 0.05) and absolutely agree 0.0 ± 5.0 MJ/d (95% confidence interval: ± 0.90 MJ/d), but with wide limits of agreement (± 9.80 MJ/d). Relationships were higher and differences were smaller in the 72 h sample than in the 24 h sample.**

Conclusions: **The Bouchard diary and the ActiGraph showed high relationships, moderate concordance, and large differences to estimate EE in Spanish adolescents. Advantages, disadvantages, and agreements between both instruments must be taking into consideration for health-related research.**

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Correspondence: Ascensión Marcos.
Immunonutrition Research Group.
Department of Metabolism and Nutrition. Instituto del Frío.
Consejo Superior de Investigaciones Científicas.
C/ José Antonio Novais, 10.
28040 Madrid, Spain.
E-mail: amarcos@if.csic.es

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COMPARACIÓN DEL ACELERÓMETRO ACTIGRAPH Y EL DIARIO DE BOUCHARD PARA ESTIMAR EL GASTO ENERGÉTICO EN ADOLESCENTES ESPAÑOLES

Resumen

Introducción: **el objetivo de este estudio ha sido evaluar el grado de acuerdo entre el acelerómetro ActiGraph y el diario de Bouchard para estimar el gasto energético (GE) en una población de adolescentes españoles.**

Métodos: **61 adolescentes españoles con edades comprendidas entre 12-16 años participaron en este estudio. El diario de Bouchard se completó durante 3 días consecutivos y se utilizó el ActiGraph durante ese tiempo. El GE obtenido del diario de Bouchard se calculó usando dos categorías de equivalentes metabólicos (DB-Bouchard y DB-Bratteby). El GE del ActiGraph se calculó mediante 3 ecuaciones de estimación (AC-Trost, AC-Freedson y AC-Ekelund). También se analizó a los adolescentes con datos completos de 24 h para controlar la posible pérdida de precisión. El acuerdo entre métodos se analizó mediante las correlaciones de Pearson y Concordancia, un t-test y el método de Bland-Altman.**

Resultados: **De 37 adolescentes se obtuvieron datos completos en 72 h. Las correlaciones entre el GE calculado por el diario de Bouchard y el ActiGraph fueron altas (rango: r = 0,61-0,78). Las correlaciones de Concordancia fueron moderadas (rc = 0,60) utilizando DB-Bratteby y AC-Trost, y bajas utilizando DB-Bratteby y AC-Ekelund (rc = 0,15). El GE estimado por DB-Bratteby y AC-Trost tampoco mostró diferencias significativas (p > 0,05) y acuerdo completo 0,0 ± 5,0 MJ/día (intervalo de confianza al 95%: ± 0,90 MJ/día), aunque los límites de acuerdo fueron muy amplios (± 9,80 MJ/día). Las relaciones fueron mayores y las diferencias menores en la muestra que completó 72 h que en la muestra que completó 24 h.**

Conclusiones: **El diario de Bouchard y el ActiGraph mostraron correlaciones altas, una concordancia moderada y amplias diferencias a la hora de estimar el GE en los adolescentes españoles. Se deben tener en cuenta las ventajas, desventajas y el acuerdo entre ambos instrumentos en las investigaciones relacionadas con la salud.**

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Palabras clave: *Actividad física. Registro de actividad. Concordancia. Relación. Juventud.*

Introduction

Obesity prevalence in adolescence increased during recent years in developed countries.[1] For example, according to the International Obesity Task Force (IOTF), there will be approximately 400.000 new obese children each year in Europe,[2] bringing immeasurable future health consequences. In addition, obesity in children and adolescents has been associated with chronic disabilities as diabetes type II,[3] hypertension,[4] cardiovascular diseases,[5] metabolic syndrome[6] and low-grade inflammatory status.[7] Moreover, psychological disorders such as depression, anxiety and body dissatisfaction are also associated with obesity during adolescence.[8,9]

Thermodynamic laws suggest that obesity is developed by a positive energy balance between energy intake and energy expenditure (EE). Thus, it is important to correctly assess EE to understand the nature of the obesity epidemic in adolescent population. The scientific literature reports several methods that facilitate the assessment of EE in humans in free-living conditions.[10,11] The doubly labelled water (DLW) method is the criterion standard to assess EE in free-living conditions, but the technique is relatively costly and therefore reduces the possibility to use it in large groups or epidemiological samples.[11] A variety of other subjective and objective methods have been developed to assess EE but each has inherent limitations. Subjective methods such as diaries and recall instruments are easy to use but have clear limitations for use with youth.[12] Despite the limitations, number of studies has used activity diaries effectively with these age groups[13,14] and there is renewed interest in the value of these instruments for providing valuable contextual information.[15] Accelerometers have been increasingly used to provide objective information about physical activity in youth.[16,17] They are well tolerated by research participants and have been validated in children and adolescents.[18] Hence, accelerometers and activity diaries are feasible and valid methods to estimate EE in youth.

The most commonly used accelerometer and activity diary are the ActiGraph[19] monitor and the Bouchard diary.[20] To our knowledge, agreement between both instruments to assess EE in adolescents has not been previously reported. Therefore, the aim of this study was to evaluate the agreement between the ActiGraph accelerometer and the Bouchard diary to estimate EE in a Spanish adolescent population.

Methods

Participants

For this study, sixty-one healthy Spanish adolescents (27 girls), aged 12 to 16 years, were recruited from a high public school in Madrid (Spain). Before participating in this study, adolescents and parents were informed of the nature of the study, and both gave signed informed consent. The Ethics Committee of Puerta de Hierro Hospital (Madrid, Spain) approved the procedures of this study.

Energy expenditure by the Bouchard activity diary

The activity diary used in this study was the Bouchard diary consisting of 96 15-min blocks per day (24 h) during 3 consecutive days (72 h).[20] Participants were asked to record the main activity in each 15-min block and rate the activity on a scale of intensity levels (1 to 9, 1 being the lowest and 9 the highest intensity). Each numeric activity code refers to a specific energy cost and is then converted to a metabolic ratio of expended energy (MET). Total diary EE was calculated as the amount of time spent in each period multiplied by the correspondent MET and by the estimated basal metabolic ratio (BMR). BMR was calculated using the prediction formulas[21] by sex, age, weight and height. The Bouchard diary was originally validated in children and adults using the sum of skinfold thicknesses and percentage of body fat as proxy measures of EE.[20] Subsequent studies have compared the accuracy of the Bouchard diary to estimate EE in adolescents against DLW[22] and heart rate monitoring.[23] The three validation studies used different MET values for each category in their measurements. Thus, the MET values used in the studies by Bouchard et al.[20] and Ekelund et al.[23] are similar. However, the MET values used by Bratteby et al.[22] are higher in categories 7 to 9 than in the other two studies. Therefore, in this study the MET values proposed by Bouchard et al.[20] and Bratteby et al.[22] were used to assess EE with the Bouchard diary, defined as BD-Bouchard and BD-Bratteby, respectively. Moreover, the sample that completed 24 h of the Bouchard diary was included in the analysis to control the possible loss of accuracy if it is administered over 3 consecutive days in adolescents (e.g. motivation, weekend day, interpretation of the intensity levels).

Energy expenditure by the ActiGraph accelerometer

The ActiGraph GT1M (ActiGraph™, LLC, Pensacola, FL, USA) monitor was used to estimate EE in this study. The ActiGraph GT1M is a small and lightweight uniaxial accelerometer (3.8 cm x 3.7 cm x 1.8 cm, 27 g) designed to detect vertical accelerations ranges in magnitude from 0.05–2.00 G with a frequency response of 0.25-2.50 Hz. The ActiGraph (previously known as MTI and CSA) has been validated widely in laboratory settings and free-living conditions with children and adolescents.[18] Three relevant ActiGraph EE equations validated in youth were used to assess EE in the current study, described in Trost et al.[24] (AC-Trost), Freedson et al.[25] (AC-Freedson), and Ekelund et al.[26] (AC-Ekelund). The used EE predictive

equations were the following (weight [kg], age [years], gender [boys = 0; girls = 1]):

AC-Trost: kcal/min = -2.23 + (0.0008 × counts per minute) + (0.08 × weight).

AC-Freedson: METs = 2.757 + (0.0015 × counts per minute) - (0.08957 × age) - (0.000038 × counts per minute× age).

AC-Ekelund: kcal/d = (-380.9 × gender) + (1.177 × counts per minute) + (21.1 × weight) + 706.

Epochs of 60s were used in the study to store the filtered acceleration signal. Bouts of 10 min of consecutives zeros, defined as non-wearing time, were identified to assess one day of valid data. Participants with at least 10 hours each day of stored data were used in the final analysis. The outcome variable obtained by the ActiGraph and used in each predictive EE equation was counts per minute (cpm). Data were processed by the EXCEL ActiGraph™ macro version 3.5.1.

Procedures

A group of 10 participants was assessed each week. One day before data collection (Wednesday) all participants were given one-hour instructions on how to complete the self-report registration of the diary, and how to wear the ActiGraph. Participants then kept the Bouchard diary for consecutive 72 h (Thursday, Friday and Saturday) and concurrently wore the ActiGraph. Adolescents wore the ActiGraph on an elastic belt at the lower back and were instructed not to use it during shower, water sports and sleep hours. Both instruments were returned the next week, on Tuesday. Weight and height were obtained by standardized procedures. Body mass index (BMI) was calculated as weigh/height squared (kg/m^2). Total data collection lasted for eight weeks since March until April 2007.

Data analysis

EE outcomes in 24 h and 72 h samples were transformed in a single unit of measurement. Thus, EE assessed by the Bouchard diary with BD-Bouchard and BD-Bratteby was calculated in Mili-Joules per day (MJ/d). EE assessments by the ActiGraph (AC-Trost, AC-Freedson, AC-Ekelund) were also converted to the same unit (MJ/d). The 72 h sample EE by each instrument was calculated as the mean of the 3 consecutive days. EE assessed by the Bouchard diary in the 72 h sample was not normally distributed and was transformed (ln) before analyses. Four statistical approaches were used to establish the grade of agreement between both instruments to estimate EE. Statistical methods used were as follows:

1) Pearson product-moment correlation (r) and partial correlation adjust by sex were used to observe the relationships between the Bouchard diary and the ActiGraph in the two samples.

2) Concordance correlation coefficient (r_c) was calculated to evaluate the amount of EE estimated with both instruments fall on the perfect line of agreement (45º line). This correlation is used to evaluate the agreement between paired readings.[27] The formula used was:

$$r_c = r \times [(v + 1/v + u^2)/2]^{-1}$$

where

r = Pearson product-moment correlation.

v = Mean ActiGraph /Mean Bouchard diary.

u = (Standard deviation ActiGraph – Standard deviation Bouchard diary)/(Mean ActiGraph × Mean Bouchard diary)$^{-2}$.

3) Total differences and percent differences were calculated in 24 h and 72 h samples. Paired student's t-test was used to measure significant differences between EE.

4) The degree of agreement, bias and limits of agreement using both instruments to assess EE were plotted by the Bland & Altman[28] method.

All the analyses were performed using the Statistical Package for Social Sciences (SPSS, v. 14.0 for Windows, SPSS Inc, Chicago) and the level of significance was set at the 0.05 level.

Results

Five participants did not return the activity diary on time and one student had invalid ActiGraph output with only zeros recorded during the study. The rest of excluded participants did not comply with the Bouchard diary and/or ActiGraph in the same day. Thus, fifty adolescents (31 boys and 19 girls) obtained concurrent valid data of the Bouchard diary and the ActiGraph in the first 24 h of this study, forty-four completed the 48 h procedures (28 boys and 16 girls), and finally a sample of thirty-seven complied with the 72 h (23 boys and 14 girls). Physical characteristics of the 24 h and 72 h samples used and the corresponding calculated EE by both instruments are shown in table I. EE estimated by all the instruments showed that girls consumed less absolute energy than boys.

First statistical approach: Pearson correlations and partial correlations

Correlations and partial correlations adjusted by sex are shown in table II. Relationships between EE calculated by the diary and the ActiGraph were slightly higher in the 72 h sample (ranged: r = 0.61-0.78) than in the 24 h sample (ranged: r = 0.54-0.73). The highest associations between the diary and ActiGraph estimations of EE were found using BD-Bouchard and AC-Ekelund in both samples. On the other hand, the lowest correlations were found

Table I
Physical characteristics and energy expenditure (EE) estimated by the Bouchard diary and the ActiGraph

	24 h sample (n = 50)		*72 h sample (n = 37)*	
	Boys (n = 31)	*Girls (n = 19)*	*Boys (n = 23)*	*Girls (n = 14)*
Physical characteristics				
Age (years)	14.7 ± 1.5	15.0 ± 1.5	14.7 ± 1.4	15.1 ± 1.2
Height (m)	1.7 ± 0.1	1.6 ± 0.1*	1.7 ± 0.1	1.6 ± 0.1
Weight (kg)	61.5 ± 14.0	53.9 ± 7.7*	61.3 ± 13.9	54.0 ± 8.2
Body mass index (kg/m^2)	21.9 ± 3.6	20.6 ± 2.5	22.0 ± 3.3	20.8 ± 2.6
Activity Diary				
EE by Bouchard et al.[20] (MJ/d)†	13.6 ± 3.5	11.1 ± 2.2**	14.5 ± 2.9	11.6 ± 2.3**
EE by Bratteby et al.[22] (MJ/d)†	16.2 ± 5.6	12.5 ± 3.4*	17.9 ± 4.9	13.6 ± 4.1**
Accelerometer				
Counts per min per day (cpm)	323.3 ± 150.0	254.6 ± 100.6*	360.0 ± 98.6	275.4 ± 99.3*
EE by Trost et al[24] (MJ/d)	17.7 ± 6.7	13.7 ± 3.8*	17.8 ± 6.8	13.9 ± 3.8*
EE by Freedson et al.[25] (MJ/d)	11.2 ± 2.5	9.4 ± 1.6**	10.1 ± 1.4	7.5 ± 0.7*
EE by Ekelund et al.[26] (MJ/d)	9.9 ± 1.4	7.3 ± 0.8***	11.4 ± 2.6	9.4 ± 1.7***

Values are mean ± SD.
† Values in the 72 h sample were transformed (Ln) before analyses, but non-transformed values are presented in the table.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, denotes statistical significance between genders within the same sample.

between BD-Bratteby and AC-Trost in both samples. No considerable changes were found in partial correlations adjusted by sex with regard to Pearson correlations.

Second statistical approach: concordance correlation coefficient

Concordance correlation coefficients are shown in table II. EE estimated by BD-Bratteby and AC-Trost estimations found acceptable concordance coefficients for 24 h and 72 h samples (r_c = 0.52 and 0.60 respectively). The remaining concordance correlations were weaker. BD-Bratteby with AC-Ekelund obtained the lowest concordance with r_c = 0.19 for the 24 h sample and r_c = 0.15 for the 72 h. EE estimated by AC-Trost compared to the BD-Bratteby and BD-Bouchard were the only comparisons that obtained better concordance correlations coefficients in the 72 h sample than in the 24 h.

Third statistical approach: total and percent differences

Values of total and percentage differences are displayed in table III. In the 24 h sample, significant dif-

Table II
Relationships and concordances coefficients between energy expenditure (MJ/d) estimated by the Bouchard diary and the ActiGraph

		24 h sample (n = 50)			*72 h sample† (n = 37)*		
Activity diary§	*Accelerometer¶*	*Pearson correlation*	*Partial correlation‡*	*Concordance correlation coefficient*	*Pearson correlation*	*Partial correlation‡*	*Concordance correlation coefficient*
Bouchard et al.[20]	Trost et al.[24]	0.65*	0.61*	0.43	0.72*	0.68*	0.48
	Freedson et al.[25]	0.71*	0.66*	0.52	0.76*	0.71*	0.50
	Ekelund et al.[26]	0.73*	0.72*	0.30	0.78*	0.71*	0.27
Bratteby et al.[22]	Trost et al.[24]	0.54*	0.49*	0.52	0.61*	0.55*	0.60
	Freedson et al.[25]	0.63*	0.57*	0.30	0.68*	0.60*	0.27
	Ekelund et al.[26]	0.66*	0.64*	0.19	0.69*	0.60*	0.15

† Values were transformed (Ln) before analyses. ‡ Adjusted by sex. § MET values proposed to estimate energy expenditure (EE) in children and adolescents using the Bouchard diary. ¶ Regression equations developed using ActiGraph to convert accelerometer data in EE for children and adolescents. *$P < 0.001$ denotes statistical significance.

Table III
Total and percent energy expenditure (EE) differences estimated by the Bouchard diary and the ActiGraph

		24 h sample (n = 50)			72 h sample† (n = 37)		
Activity diary§	*Accelerometer*¶	*Difference (MJ/d)*	*Range*‡ *(%)*	*Difference*# *(%)*	*Difference (MJ/d)*	*Range*‡ *(%)*	*Difference*# *(%)*
Bouchard et al.[20]	Trost et al.[24]	3.5 ± 4.6	-26.5/127.7	27.7 ± 35.0*	2.0 ± 4.5	-35.0/76.7	20.7 ± 29.4*
	Freedson et al.[25]	-2.2 ± 2.3	-39.5/52.4	-14.8 ± 17.6*	-2.7 ± 2.0	-43.5/5.4	-19.6 ± 12.4*
	Ekelund et al.[26]	-3.7 ± 2.3	-53.5/12.9	-27.2 ± 14.0*	-4.3 ± 2.0	-56.2/-10.6	-31.1 ± 9.1*
Bratteby et al.[22]	Trost et al.[24]	1.4 ± 5.4	-40.3/137.4	9.2 ± 39.0	0.0 ± 5.0	-50.3/56.4	2.8 ± 30.1
	Freedson et al.[25]	-4.3 ± 4.1	-66.7/17.7	-23.8 ± 22.7*	-5.6 ± 3.8	-55.8/5.7	-31.6 ± 15.3*
	Ekelund et al.[26]	-5.8 ± 4.3	-66.7/58.9	-34.9 ± 18.3*	-7.2 ± 4.0	-67.4/-16.3	-41.4 ± 12.2*

Values are mean ± SD.
† Values in the 72 h sample were transformed (Ln) before analyses, but non-transformed values are presented in the table. ‡ Minimum / Maximum ranges. § MET values proposed to estimate EE in children and adolescents using the Bouchard diary. ¶ Regression equations developed using ActiGraph to convert accelerometer data in EE for children and adolescents. # (EE by accelerometer – EE by activity diary) / EE by activity diary × 100. * $P < 0.001$ denotes statistical significance.

ferences were present in all comparisons except in EE estimated by BD-Bratteby and AC-Trost. Despite wide ranges (-40.3 to 137.4%), total mean difference was 9.2 ± 39.0%. Similarly, in the 72 h sample, EE estimated by BD-Bratteby and AC-Trost showed no significant differences with lower ranges (-50.33% to 56.3%) and with a mean difference of 2.8 ± 30.1%. EE assessed by other ActiGraph EE equations and using BD-Bouchard and BD-Bratteby estimations showed significant differences ($P < 0.001$) in the 24 h and 72 h samples. Differences in EE estimated by both instruments in the 72 h sample were higher than the 24 h sample except in the AC-Trost with both BD-Bouchard and BD-Bratteby measurements.

Fourth statistical approach: Bland-Altman plots

The most reasonable absolute agreements between instruments to assess EE are plotted in figure 1. Differences between EE estimations by AD-Bouchard and AC-Trost obtained reasonable agreement in the 24 h sample 1.4 ± 5.4 MJ/d and absolutely agree in the 72 h sample 0.0 ± 5.0 MJ/d (95% confidence interval for the bias was 0.64 to 2.16 MJ/d for the 24 h sample and –0.90 to 0.90 MJ/d for the 72 h). Limits of agreement (mean ± 2SD) were -9.18 to 1.98 MJ/d and ± 9.80 MJ/d correspondingly. Other absolute differences between instruments showed worse agreements (plots not displayed). Hence, EE assessed by the Bouchard diary overestimate EE in adolescents compared with EE estimated by the ActiGraph, except when EE was assessed by BD-Bouchard and AC-Trost.

There were also no systematic bias between the differences in EE assessed by BD-Bouchard and AC-Trost in both samples ($P = 0.227$ and $P = 0.128$ for the 24 h and 72 h samples respectively). Strong positive and negative systematic biases were found in most of the comparisons with the two samples, but not between BD–Bouchard and AC-Freedson in the 72 h sample (r = -0.26, $P = 0.115$).

Discussion

The ActiGraph and the Bouchard diary are instruments commonly used in health-related research and have shown reasonable validity to assess EE and physical activity in adolescents. Therefore, the aim of this study was to evaluate the agreement between the ActiGraph and the Bouchard diary to estimate EE in Spanish adolescents.

To evaluate the agreement in our study between both instruments, four statistical methods were used. Our findings showed that the Bouchard diary and the ActiGraph were highly correlated (r ~ 0.70) and moderate concordance to estimate EE in adolescents. The concordance correlation coefficient analyses yielded some interesting results. The highest relationships between instruments in this study presented lowest concordance correlation coefficients, and vice versa. These results demonstrate that even if high relationships exist between methods they may fail to detect any departure from the 45º line of agreement.[27,29] For example, in the figure 2 is showed two examples of our study. Figure 2a shows a lower Pearson correlation than figure 2b, but in figure 2b the correlation is located more far from the perfect line of 45º than figure 2a.

Evaluation of absolute agreement between instruments revealed large and significant differences with the Bouchard diary overestimated EE in most of the comparisons against the ActiGraph. EE estimated by the Trost et al.[24] predictive equation for the ActiGraph and by the Bouchard diary using MET values proposed by Bratteby et al.[22] showed reasonable agreement in 24 h sample and excellent agreement in the 72 h sample. However, limits of agreement between instruments were too wide to consider them interchangeable.

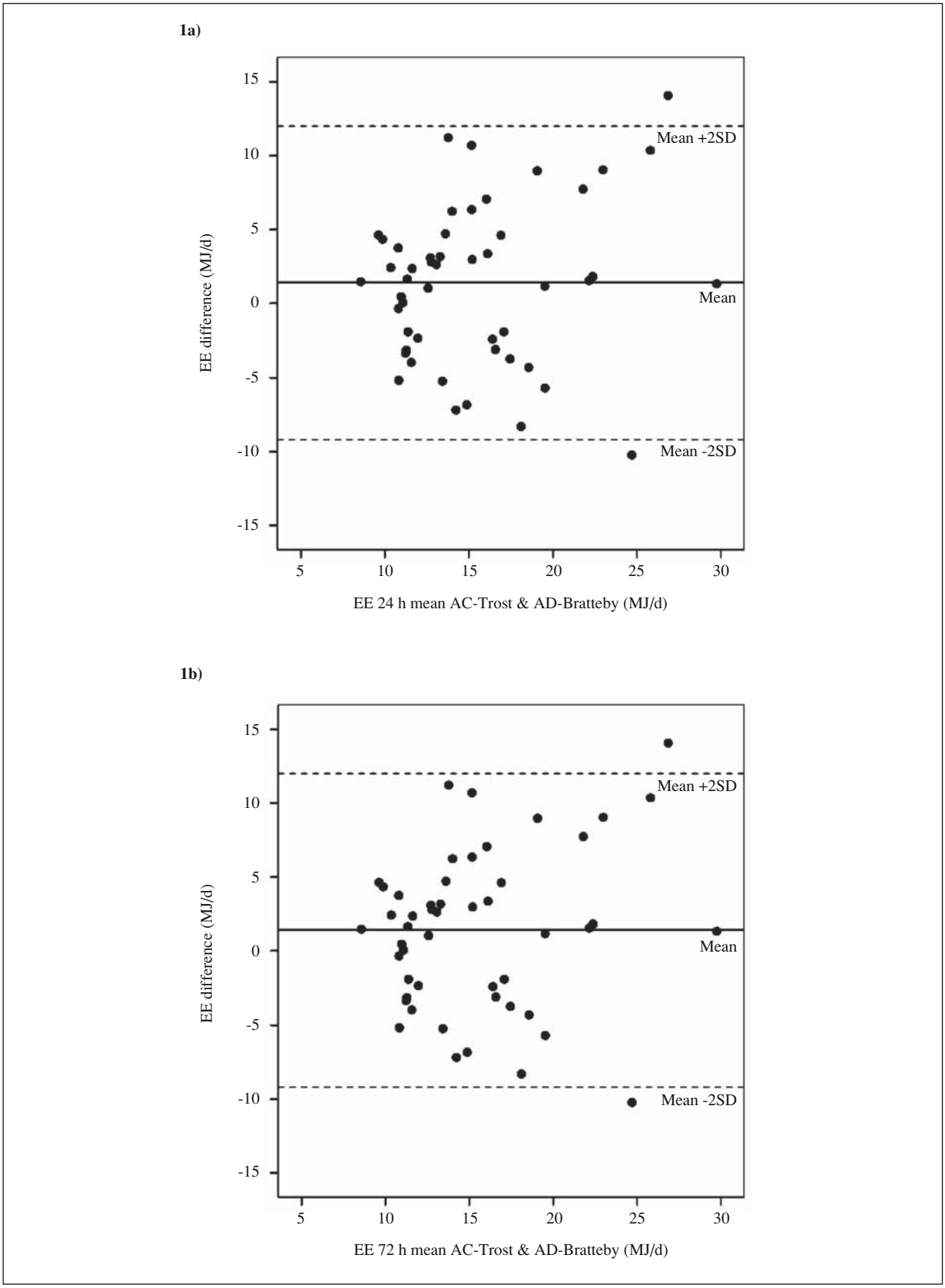

Fig. 1.—Bland-Altman plots for energy expenditure (EE) assessed by the Bouchard diary (BD) and the ActiGraph (AC) in 24 h sample (1a) and 72 h sample (1b) using Bratteby et al.[22] MET values for the activity diary and the Trost et al.[24] equation for the accelerometer. Mean error scores (solid horizontal lines) and limits of agreement (dashed horizontal lines) are shown in each plot.

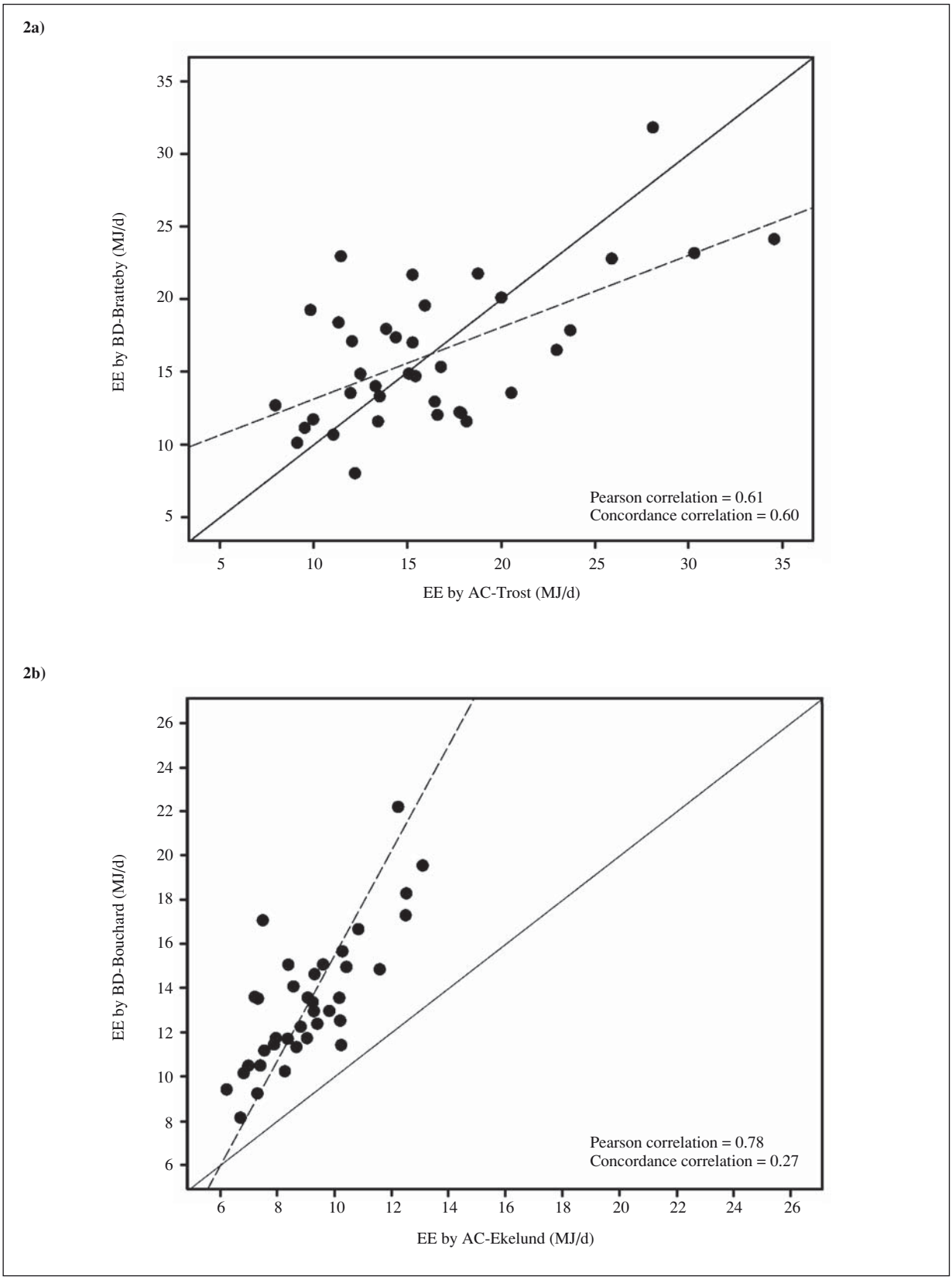

Fig. 2.—Relationships between energy expenditure (EE) assessed by the Bouchard diary (BD) and the ActiGraph (AC) in 72 h sample using Bratteby et al.[22] MET values for the activity diary and the Trost et al.[24] equation for the accelerometer (2a), and Bouchard et al.[24] MET values for the activity diary and the Trost et al.[24] equation for the accelerometer (2b). Solid lines are the perfect line of agreement (45º line) and dashed lines are Pearson correlation.

Table IV
Advantages and disadvantages in the use of activity diaries and acceloremeters in youth[†]

	Advantages	*Disadvantages*
Activity Diary	• Accurate indicator of PA with motivation and cooperation of subjects. • Low-cost. • Easy to administer to large groups. • Non-invasive technique. • Feedback.	• Outcomes must be used with caution in youth. • High-burden in subject. • Time necessary for reliability. • Excessive use of recall. • Non-criteria about what PA cost use. • Necessary cross-survey validation. • Reactivity.
Accelerometer	• Accurate indicator of PA. • Low-burden in the subject. • Non-invasive technique. • Feedback. • Less reactivity (influence behaviour).	• Moderate cost. • Difficult to assess large samples. • Water activities and static activities. • Non-criteria about what equations or cut-off points use. • Worn al least 10-14 hours per day. • Charge and download.

PA: physical activity.
[†]Adapted from references[10,11,33,38].

Ekelund et al.[23] found analogous results to estimate EE by the Bouchard diary and by heart rate monitoring, but limits of agreement were lower (-3.54 to 2.74 MJ/d) than in our study.

In a similar study that assessed the EE in 70 adults, Wickel et al.[30] compared the EE assessed by the triaxial Tritrac-R3D against the Bouchard diary during a 24 h period. The authors found a strong lineal relationship between both instruments to assess EE (r = 0.86), but unfortunately concordance coefficient was not reported. Therefore, comparing the relationship between both studies might not be appropriate because the high correlation found in Wickel's study might have had poorer concordance than in our study. Likewise, large significant differences (~2.7 MJ/d) and systematic bias were found between EE estimated by both instruments used in the Wickel's study.[30]

We previously questioned the use of the Bouchard diary in Spanish adolescents over a 72 h period,[31] essentially because the administration during the third day and/or the weekend day showed low concurrent validity. Thus, there was no significant differences for days 1 and 2 ($P > 0.05$) in time spent in moderate to vigorous physical activity between the Bouchard diary and the ActiGraph, but yes for day 3 and the 3-d mean (141.08 ± 127.20 *vs* 79.70 ± 43.64, $P = 0.012$ minutes in day 3 and 120.68 ± 77.08 *vs* 88.62 ± 36.17, $P = 0.027$ minutes in 3-day mean by the Bouchard and ActiGraph instruments respectively). In the present study, relationships were higher and differences were smaller in the 72 h sample than in the 24 h sample. Furthermore, difference dispersion percentages were lower in all measurements also in the 72 h sample. These results suggest that 3 consecutive days is a valid time interval to assess EE in adolescents by the Bouchard diary compared against an objective instrument as the ActiGraph.

Bratteby et al.[22] used the Bouchard diary in 50 adolescents for 7 days and did not observe significant differences against DLW to assess EE. Even though the Bratteby's study has not been replicated, the Bouchard diary is usually administrated during 72 h (at least 2 week days and 1 weekend day) to assess EE.[20] On the other hand, only EE estimated by the Bouchard diary using MET values proposed by Bratteby et al.[22] and the Trost et al.[24] equation by the ActiGraph found reasonable agreement between instruments. Even so, our study does not clarify which MET categories are more adequate for estimate EE in adolescents by the Bouchard diary.

To date, it has not yet been clarified which method is most accurate to assess EE. The accelerometer is considered an objective technique whereas the activity diary is occasionally included as subjective technique[32] and others as objective.[33] However, it is important to highlight that the almost perfect results published by Bratteby et al.[22] in adolescents have not been found with accelerometers. Nevertheless, the ActiGraph have shown to be correlated reasonably with DLW[34]. Recently, Trost et al.[35] evaluated 2 of the equations used in our study to estimate EE by the ActiGraph against indirect calorimetry in children. The results in this study suggested that both prediction equations do not accurately predict EE but they are useful to estimate participation in moderate and vigorous physical activity.

Despite the common use of the Bouchard diary and the ActiGraph, advantages and disadvantages of both instruments (table IV), as well as the levels of agreement between them should be initially considered by health-related researchers in their studies.

Two main limitations warrant further discussion. Firstly, of the initial sample-size of sixty-one adolescents, only thirty-seven completed correctly the 72 h

procedure and fifty adolescents the 24 h procedure. We could assume that the participants who completed the 72 h protocol were more diligent to register their activities in the Bouchard diary, and to use the activity monitor at all indicated hours of the day. This may explain the differences found between the 24 h data and the 72 h data. Secondly, the Bouchard diary assesses EE during 24 hours but the ActiGraph should be removed in water sports, shower and sleep hours, perhaps introducing some additional error to the comparisons. Moreover, the criterion to consider a valid day was 10 hours with valid data. This criterion is recommended in the analysis of the ActiGraph data.[36] However, we compared EE by both methods using their habitual protocols in concordance with previous studies.[37,38]

In conclusion, the Bouchard Activity diary and the ActiGraph accelerometer showed a high relationship and a moderate concordance to estimate EE in adolescents. However, absolute agreement between instruments showed large differences and systematic bias to estimate EE. Advantages and disadvantages of the Bouchard diary and the ActiGraph, and agreements between them must be taking into consideration when designing future health-related research studies.

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