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Activity counts from accelerometers do not add value to energy expenditure predictions in sedentary overweight individuals during weight loss interventions

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Abstract

Background: Knowing the total energy expenditure (TEE) of overweight adults is important for prescribing weight loss interventions. However, objective measurements of TEE may not always be readily available and can be expensive. This study aimed to investigate the validity of RT3 accelerometers in predicting the TEE of sedentary overweight adults, and to identify any sensitivity to anthropometric changes. Methods: The analysis used data from a 12-week weight loss study. At baseline and 12-week, TEE was predicted using RT3 accelerometers during whole room calorimeter stays. Bias between 2 methods was compared at and between the baseline and 12-week measurement points. Multiple regression analyses of TEE data were conducted. Results: Predicted and measured values for TEE were not different at baseline ($P = .677$) but were significantly different after weight loss ($P = .007$). However, the mean bias between methods was small ($/d$) and was not significantly different between 2 time-points. RT3 activity counts explained an additional 2% of the variation in TEE at 12-week but not at baseline. Conclusion: RT3 accelerometers are not sensitive to body composition changes and do not explain variation in TEE of overweight and obese individuals in a sedentary environment. Keywords: energy expenditure, calorimetry, accelerometry

Keywords

weight, individuals, loss, overweight, sedentary, predictions, expenditure, energy, value, interventions, add, not, do, accelerometers, counts, activity, during

Disciplines

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Activity Counts From Accelerometers Do Not Add Value to Energy Expenditure Predictions in Sedentary Overweight Individuals During Weight Loss Interventions

Sze Yen Tan, Marijka Batterham, and Linda Tapsell

Background: Knowing the total energy expenditure (TEE) of overweight adults is important for prescribing weight loss interventions. However, objective measurements of TEE may not always be readily available and can be expensive. This study aimed to investigate the validity of RT3 accelerometers in predicting the TEE of sedentary overweight adults, and to identify any sensitivity to anthropometric changes. **Methods:** The analysis used data from a 12-week weight loss study. At baseline and 12-week, TEE was predicted using RT3 accelerometers during whole room calorimeter stays. Bias between 2 methods was compared at and between the baseline and 12-week measurement points. Multiple regression analyses of TEE data were conducted. **Results:** Predicted and measured values for TEE were not different at baseline ($P = .677$) but were significantly different after weight loss ($P = .007$). However, the mean bias between methods was small (<100 kcal/d) and was not significantly different between 2 time-points. RT3 activity counts explained an additional 2% of the variation in TEE at 12-week but not at baseline. **Conclusion:** RT3 accelerometers are not sensitive to body composition changes and do not explain variation in TEE of overweight and obese individuals in a sedentary environment.

Keywords: energy expenditure, calorimetry, accelerometry

Being able to estimate daily energy expenditure of overweight and obese individuals is important as it serves as the basis for dietary modification to promote weight loss. When objective measurement of energy expenditure is not available, field methods such as predictive equations,¹ motion sensors,² heart rate monitors,³ and activity questionnaires⁴ are used to estimate free-living activity patterns. Among these methods, heart rate monitors may produce an error of up to 30%^{5,6} while a triaxial accelerometer, together with age, body mass, and gender, has been shown to be a relatively better predictor of energy expenditure.⁷ The RT3 triaxial accelerometer predicts energy expenditure by incorporating daily activities measured in 3 dimensions. The measured activities are then translated into energy expenditure, which is based on built-in regression analyses in the device based on age, sex, height, and weight.⁸ Reports on the validation of this device are limited.

One validation study found significant correlations between RT3 counts and oxygen consumption during walking and running on a treadmill in 19 boys and 15 men.⁹ However, this was performed over a short period of time and it is unclear if the correlation between RT3 counts and oxygen consumption (Douglas Bag method) can be translated into correlations between energy

expenditure as measured by these 2 methods. Here, the absence of measured carbon dioxide production using the Douglas Bag made the calculation of energy expenditure during the study period impossible.

A more recent study investigated the relative validity of the RT3 in predicting activity-related energy expenditure in both a free-living and laboratory environment¹⁰ compared with another accelerometer Actigraph (Actigraph, LLC, USA). Laboratory energy expenditure was measured using an AEI Moxus Metabolic Cart. It has been demonstrated that the Actigraph overestimated sedentary and underestimated other activities.¹¹ Therefore, the appropriateness of using this device as a reference is questionable. In addition, both these studies compared activity-related energy expenditure of healthy subjects. It is unclear if RT3 accelerometers are suitable for measuring total daily energy expenditure (TEE) of overweight and obese individuals who tend to have a more sedentary lifestyle.

Total energy expenditure is largely dependent on body composition.¹² Individuals may have a different body composition after weight loss compared with matched controls whom were never obese.¹³ These differences may not be accounted for in the predictive equation in the RT3 accelerometers, as this incorporate only body weight. This study therefore aimed to examine if RT3 accelerometers provide a valid method for predicting TEE in overweight and obese individuals, before and after weight loss.

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Methods

Experiment Protocol

The study analyzed data obtained from a 12-week weight loss dietary intervention trial. Data were obtained on 48 subjects at baseline and 31 subjects at 12-week who wore the RT3 accelerometer (RT3, version 1.2, Stayhealthy Inc., Monrovia, CA, USA) while spending 23.5 hours in the whole room calorimeter (WRC). The study protocol was approved by the University of Wollongong Human Research Ethics Committee (No. HE06/332) and written consent was obtained from every participant before commencement of study. Participants entered the WRC at 0800 hours in the morning after a 10-hour overnight fast. Participants were allowed to adapt to the WRC environment for 30 minutes before being asked to rest in a supine position for 30 minutes where resting energy expenditure was measured. Breakfast, lunch, and dinner were provided at approximately 0900, 1300, and 1800 hours, respectively, and supper at 2100 hours. Participants were also asked to perform 2 stepping exercise (5 minutes each) on a wooden block following a 40-beats-per-minute metronome in the WRC. These activities were estimated to replicate about 85% of their usual free-living energy expenditure.¹⁴

Measurements

Anthropometry. Height, body weight (Tanita scales TBF622), and body composition (DEXA) were measured during the baseline and 12-week visits of the trial.

Whole Room Calorimeter. The WRC comprises of 2 identical air-tight chambers with a floor area of 2.1 m × 3.0 m and a total volume of 15 m³ each. The details of the facility have been previously reported elsewhere.¹⁵ Oxygen consumption and carbon dioxide production were measured through these ventilated chambers, on 10-minute intervals, over the study period of 23.5 hours. Gaseous exchanges were calculated based on in and out-flow of the chambers as previously described by Schofield and colleagues.¹⁶ Total daily energy expenditure was then calculated using the Weir equation,¹⁷ which incorporates gaseous exchanges.

RT3 Accelerometer. The RT3 accelerometer has dimensions of 68 × 48 × 18 mm, weighs 65.2 grams, and is battery powered. The RT3 measures acceleration in 3 orthogonal dimensions (X—vertical, Y—anterioposterior, Z—mediolateral) periodically which is then converted to activity counts as well as energy expenditure based on the counts. This device has 4 operation modes that samples either activity counts or vector magnitude at 1-s or 60-s epoch intervals. Before study, participant code, age, sex, weight, and height were programmed into it using a computer. During the study, the RT3 was initialized and worn to the right side of the anterior torso of participants at the level of waist throughout the stay in a whole room calorimeter. In this study the mode that

collected activity counts and energy expenditure at 60-s epoch intervals was used. This interval was chosen as activity in a WRC is limited due to floor space, so variation is expected to be low when compared with epoch intervals of 1-s data collection.

Data Analysis

Total energy expenditure (TEE) between the 2 methods was compared, with WRC providing the reference method. Bias between the 2 methods was calculated and presented in absolute values as well as a percentage of the WRC energy expenditure value. A Bland-Altman analysis was performed to present the bias between methods at baseline and 12-week of the trial. Correlations between energy expenditure, anthropometric measurements, and total counts (the sum of X, Y, and Z plane activity counts) were examined and bias was tested using a paired-sample *t* test. Linear multiple regression analysis was used to determine the predictors of total energy expenditure. All statistical analyses were performed using statistical analysis software SPSS (version 15.0, SPSS Inc., Chicago, IL, USA).

Results

Among the participants recruited in the original trial, 48/61 at baseline and 31/35 at 12-week completed both WRC and RT3 measurements. Twenty-seven participants completed measurements at both time points. The average age of participants was 44.6 ± 8.6 years. Participants remained overweight after the 12-week intervention period even after significant weight loss (Table 1).

At baseline, significant correlations were found between WRC TEE (kcal/d) and body weight ($R = .797$, $P < .001$), and fat-free mass ($R = .876$, $P < .001$). The same was found for 12-week: body weight ($R = .763$, $P < .001$), and fat-free mass ($R = .890$, $P < .001$). Values for fat mass and activity counts were not significantly correlated with TEE values at both time points.

Significant correlations were found between the measured (WRC) and predicted (RT3) TEE (kcal/d) at both time points (Baseline: $R = .856$, $P < .001$; 12-week: $R = .869$, $P < .001$). TEE values changed significantly ($P < .001$) after the weight loss period (Table 1). TEE values between methods were not significantly different at baseline ($N = 48$, $P = .677$) but were significantly lower for the RT3 at 12-weeks after weight loss ($N = 31$, $P = .007$). Nevertheless, the bias between the 2 methods did not change significantly before and after weight loss ($N = 27$, $P = .244$). The extent of the bias was below 100 kcal/d (Figure 1). The trend for changes in bias was minimal.

Two models were used to predict TEE before and after weight loss (Table 2). The first (Model 1) used standard characteristics (age, weight, and height), and the second (Model 2) included body composition (age, fat mass, and fat-free mass). At baseline, the activity counts from the RT3 did not contribute to the explained variation in measured TEE in both models. Body composition

Table 1 Anthropometric and Metabolic Measurements of Participants at the Baseline and 12-Week of Weight-Loss Trial

	Baseline (N = 48)	12-week (N = 31)	P
Anthropometry			
Weight, kg	91.5 ± 12.9	86.9 ± 13.5	<0.001*
BMI, kgm ⁻²	32.3 ± 3.2	30.6 ± 3.3	<0.001*
Fat mass, kg (% weight)	32.0 ± 6.0 (36.2 ± 6.5)	28.7 ± 6.5 (33.9 ± 7.3)	<0.001*
Fat-free mass, kg (% weight)	57.4 ± 12.1 (63.8 ± 6.5)	56.9 ± 12.9 (66.1 ± 7.3)	<0.001*
WRC TEE, kcal/d	2110 ± 379	1962 ± 345†	0.001*
RT3 TEE, kcal/d	2098 ± 352	1871 ± 322†	<0.001*
RT3 activity counts	92690 ± 28959	74716 ± 20962	<0.001*
Bias between methods			
kcal/d	-12 ± 197	67 ± 176	0.224
As % WRC TEE	-0.004 ± 8.972	3.823 ± 8.663	

Abbreviations: BMI, body mass index; REE, resting energy expenditure; TEE, total daily energy expenditure; WRC, whole room calorimeter.

* Significant changes after 12 weeks, paired sample *t* test, *P* < .05.

† Significantly different between WRC and RT3, paired sample *t* test, *P* = .007.

appeared to be a better predictor of TEE rather than basic characteristics such as weight and height, where *R*² increased by 11.4% to 0.784 when fat-free mass was used. Model 2 was also observed to better predict TEE at 12-week (Table 3). Contrary to the finding at baseline, activity counts were significant predictors of TEE at 12-week. However, activity counts increased the *R*² value by only 2.0%, resulting in a total *R*² of 0.824.

Discussion

This study aimed to examine if RT3 accelerometers provide valid values for predicting the TEE of sedentary overweight and obese individuals. Before weight loss (baseline), values for the predicted TEE (RT3) were not significantly different (from those of the measured TEE (WRC) and the magnitude and percentage of mean bias between methods was small (<100 kcal/d). Bland-Altman analyses confirmed this observation and showed that the variances between the 2 methods were equal.

However, activity measurements by the RT3 accelerometers did not add value to the assessment of TEE in our weight loss study. Activity counts were not significantly correlated to the measured TEE and they were not a significant predictor of TEE regression models at baseline. Instead, only body weight and body composition were shown to be important in explaining variations in the measured TEE. This implies that prediction equations which incorporate body weight¹⁸ or body composition¹² may be sufficient and provide quick and inexpensive ways to estimate the energy expenditure of sedentary overweight adults.

This observation was different to those reported by Plasqui and colleagues,¹⁹ where activity counts explained an additional 19% of the variation in the measured TEE

and 33% of activity energy expenditure. The different outcomes could be explained through the differences in study populations recruited in both studies. We recruited overweight and obese individuals, who were sedentary and TEE was likely to be contributed mainly by resting energy expenditure that depends on body fat-free mass,²⁰ whereas healthy subjects participated in the study by Plasqui. Another study of older men (who spent most time on sedentary activities²¹), also reported poor correlations between accelerometer output and measured energy expenditure in a free-living environment.²²

The second aim of this study was to investigate if RT3 accelerometers were sensitive to weight and body composition changes in the prediction of TEE. The disproportionate loss of fat mass and fat-free mass during weight loss observed in our study was consistent with the scientific literature.²³ As a result, study participants substantially changed body composition after weight loss (Table 1). Body composition has been shown to be an important determinant of energy expenditure¹² and the fact that there was a significant difference between the measured and predicted TEE suggests that the RT3 was not sensitive to body composition changes. The measured TEE (WRC) was significantly higher. This was reflected in the higher percentage of fat-free mass after weight loss (Table 1), which may not have been picked up in the RT3 accelerometers predictions. This is because it utilizes a built-in regression model to predict energy expenditure that only addresses body weight.

From the regression models of TEE, activity counts, on top of age and fat-free mass, became a significant predictor of TEE at 12-week. In our study, this explained an additional 2% of variance in the measured TEE. This suggests that obese individuals may have increased their spontaneous physical activity since the experimental protocol during both WRC stays remained unchanged.

A

B

Figure 1 — Bland-Altman plots showing bias between WRC and RT3 methods to measure energy expenditure at baseline (A) and 12-week (B) of intervention. Solid lines—means; horizontal dotted lines—95% confidence interval of the observations; dashed-lines—trends of bias changes with mean energy expenditure (EE).

Table 2 Multiple Linear Regression Analysis With TEE as the Dependent Variable at Baseline

Model 1 (basic characteristics)				
Independent	Coefficients	SE	P	Partial correlation
Constant	-1298.252	716.595	0.077	
Age	-5.898	3.786	0.127	-0.388*
Weight, kg	16.672	3.526	0.000	0.797*
Height, m	12.285	5.099	0.020	0.722*
Activity counts	0.001	0.01	0.420	0.07
Model		SEE = 212.30853		R = .844, adj. R ² = .686
Constant	-1203.211	680.59	0.083	
Age	-5.887	3.428	0.092	-0.388*
Weight, kg	15.054	3.214	0.000	0.797*
Height, m	13.122	4.821	0.009	0.722*
Model		SEE = 207.43622		R = .837, adj. R ² = .683
Constant	-1617.615	648.668	0.016	
Weight, kg	16.201	3.205	0.000	0.797*
Height, m	13.387	4.912	0.009	0.722*
Model		SEE = 211.44156		R = .826, adj. R ² = .670
Model 2 (body composition)				
Independent	Coefficients	SE	P	Partial correlation
Constant	743.726	306.715	0.020	
Age	-6.367	3.235	0.056	-0.388*
Fat mass, kg	2.457	4.524	0.590	-0.048
Fat-free mass, kg	26.438	2.319	0.000	0.876*
Activity counts	0.001	0.001	0.525	0.07
Model		SEE = 181.30161		R = .889, adj. R ² = .771
Constant	853.894	256.095	0.002	
Age	-6.593	2.848	0.025	-0.388*
Fat mass, kg	2.015	3.774	0.596	-0.048
Fat-free mass, kg	25.983	2.213	0.000	0.876*
Model		SEE = 172.53759		R = .891, adj. R ² = .781
Constant	941.312	195.522	0.000	
Age	-6.862	2.783	0.017	-0.388*
Fat-free mass, kg	25.792	2.077	0.000	0.876*
Model		SEE = 171.29974		R = .890, adj. R ² = .784

* Statistically significant. $P < .05$.

Table 3 Multiple Linear Regression Analysis With TEE as the Dependent Variable at 12-Week

Model 1 (basic characteristics)				
Independent	Coefficients	SE	P	Partial correlation
Constant	-641.48	852.279	0.458	
Age	-9.707	4.834	0.055	-0.425*
Weight, kg	11.912	4.107	0.007	0.763*
Height, m	11.4	5.885	0.064	0.718*
Activity counts	0.001	0.002	0.483	0.112
Model		SEE = 205.06819		$R = .833$, adj. $R^2 = .647$
Constant	-534.481	820.989	0.520	
Age	-9.814	4.438	0.035	-0.425*
Weight, kg	12.306	4.005	0.005	0.763*
Height, m	11.195	5.721	0.060	0.718*
Model		SEE = 200.99620		$R = .832$, adj. $R^2 = .658$
Constant	911.281	375.123	0.022	
Age	-10.84	4.616	0.026	-0.425*
Weight, kg	17.892	2.943	0.000	0.763*
Model		SEE = 210.57369		$R = .806$, adj. $R^2 = .625$
Model 2 (body composition)				
Independent	Coefficients	SE	P	Partial correlation
Constant	1003.06	261.769	0.001	
Age	-8.024	3.407	0.026	-0.425*
Fat mass, kg	-4.476	4.242	0.301	-0.215
Fat-free mass, kg	21.799	2.177	0.000	0.890*
Activity counts	0.003	1	0.034	0.112
Model		SEE = 144.50538		$R = .921$, adj. $R^2 = .825$
Constant	882.453	235.987	0.001	
Age	-8.146	3.412	0.024	-0.425*
Fat-free mass, kg	22.174	2.152	0.000	0.890*
Activity counts	0.003	0.001	0.050	0.112
Model		SEE = 144.80825		$R = .917$, adj. $R^2 = .824$
Constant	1010.457	240.186	0.000	
Age	-6.898	3.544	0.062	-0.425*
Fat-free mass, kg	22.355	2.27	0.000	0.890*
Model		SEE = 152.84392		$R = .904$, adj. $R^2 = .804$

* Statistically significant, $P < .05$.

Conclusion

RT3 accelerometer generated activity counts do not explain the variation in TEE among sedentary overweight and obese individuals before weight loss and they are not sensitive to changes in body composition following weight loss.

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References

- Vinken AG, Bathalon GP, Sawaya AL, Dallal GE, Tucker KL, Roberts SB. Equations for predicting the energy requirements of healthy adults aged 18–81 y. *Am J Clin Nutr*. 1999;69(5):920–926.
- Bassett DR, Ainsworth BE, Swartz AM, Strath SJ, O'Brien WL, King GA. Validity of four motion sensors in measuring moderate intensity physical activity. *Med Sci Sports Exerc*. 2000;32:S471–S480.
- Freedson PS, Miller J. Objective monitoring of physical activity using motion sensors and heart rate. *Res Q Exerc Sport*. 2000;71(2):21–29.
- Ainslie PN, Reilly T, Westerterp KR. Estimating human energy expenditure: a review of techniques with particular reference to doubly labeled water. *Sports Med*. 2003;33(9):683–698.
- Livingstone MBE. Heart-rate monitoring: the answer for assessing energy expenditure and physical activity in population studies? *Br J Nutr*. 1997;78:869–871.
- Christensen CC, Frey HM, Foenstelie E, Aadland E, Refsum HE. A critical evaluation of energy expenditure estimates based on individual O₂ consumption/heart rate curves and average daily heart rate. *Am J Clin Nutr*. 1983;37(3):468–472.
- Washburn RA, Cook TC, LaPorte RE. The objective assessment of physical activity in an occupationally active group. *J Sports Med Phys Fitness*. 1989;29:279–284.
- Powell SM, Rowlands AV. Intermonitor variability of the RT3 accelerometer during typical physical activities. *Med Sci Sports Exerc*. 2004;36(2):324–330.
- Rowlands AV, Thomas PWM, Eston RG, Topping R. Validation of the RT3 triaxial accelerometer for the assessment of physical activity. *Med Sci Sports Exerc*. 2004;36(3):518–524.
- Barreira TV, Kang M, Caputo JL, Farley RS, Bettle JM, Renfrow MS. Validation of the RT3 monitor to estimate energy expenditure. *Am Coll Sports Med*. 2007;39(5, Suppl):S181.
- Crouter SE, Churilla JR, Bassett DR, Jr. Estimating energy expenditure using accelerometers. *Eur J Appl Physiol*. 2006;98(6):601–612.
- Cunningham JJ. Body composition as a determinant of energy expenditure: a synthetic review and a proposed general prediction equation. *Am J Clin Nutr*. 1991;54:963–969.
- Weinsier RL, Nelson KM, Hensrud DD, Darnell BE, Hunter GR, Schutz Y. Metabolic predictors of obesity. Contribution of resting energy expenditure, thermic effect of food, and fuel utilization to four-year weight gain of post-obese women. *J Clin Invest*. 1995;95:980–985.
- de Jonge L, Nguyen T, Smith SR, Zachwieja JJ, Roy HJ, Bray GA. Prediction of energy expenditure in a whole body indirect calorimeter at both low and high levels of physical activity. *Int J Obes*. 2001;25(7):929–934.
- Batterham MJ, Cavanagh R, Jenkins AB, Tapsell LC, Plasqui G, Clifton PM. High-protein meals may benefit fat oxidation and energy expenditure in individuals with higher body fat. *Nutr Diet*. 2008;65(4):246–252.
- Schoffelen PFM, Westerterp KR, Saris WHM, Hoor FT. A dual-respiration chamber system with automated calibration. *J Appl Physiol*. 1997;83(6):2064–2072.
- Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. *Nutrition*. 1990;6(3):213–221.
- Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr Clin Nutr*. 1985;39(Suppl 1):5–41.
- Plasqui G, Joosen AMCP, Kester AD, Goris AHC, Westerterp KR. Measuring free-living energy expenditure and physical activity with triaxial accelerometry. *Obes Res*. 2005;13(8):1363–1369.
- Wang Z, Heshka S, Gallagher D, Boozer CN, Kotler DP, Heymsfield SB. Resting energy expenditure-fat-free mass relationship: new insights provided by body composition modeling. *Am J Physiol*. 2000;279:E539–E545.
- Meijer EP, Goris AH, Wouters L, Westerterp KR. Physical inactivity as a determinant of the physical activity level in the elderly. *Int J Obes Relat Metab Disord*. 2001;25(7):935–939.
- Rafamantanantsoa HH, Ebine N, Yoshioka M, et al. Validation of three alternative methods to measure total energy expenditure against the doubly labeled water method for older Japanese men. *J Nutr Sci Vitaminol (Tokyo)*. 2002;48(6):517–523.
- Piatti PM, Monti LD, Magni F, et al. Hypocaloric high-protein diet improves glucose oxidation and spares lean body mass: comparison to hypocaloric high-carbohydrate diet. *Metabolism*. 1994;43(12):1481–1487.