Physical Activity Compliance: Differences between Overweight/Obese and Normal-Weight Adults

Jaimie N. Davis, Valerie A. Hodges, and M. Beth Gillham

Abstract

DAVIS, JAIMIE N., VALERIE A. HODGES, AND M. BETH GILLHAM. Physical activity compliance: differences between overweight/obese and normal-weight adults. *Obesity.* 2006;14:2259–2265.

Objectives: Comparisons of physical activity measured by accelerometers in overweight/obese adults and their normal-weight counterparts are limited. Compliance with the 2002 Institute of Medicine (IOM) exercise recommendations for 60 minutes of moderate-intensity exercise daily has not been reported. The purpose of this study was to compare physical activity, as measured by accelerometers, in overweight/obese adults vs. normal-weight controls and to assess compliance with recommendations for physical activity by the IOM in 2002 and by the Centers for Disease Control and Prevention and American College of Sports Medicine in 1995 for 30 minutes of moderate-intensity activity, preferably all days of the week.

Research Methods and Procedures: Sixty-two overweight/obese subjects, BMI ≥ 25, included 31 adults, 12 men and 19 women, 25 to 69 years old, and their normal-weight controls, BMI 18.5 to 24.9, matched for gender, age, and height. Body composition was assessed using DXA. Physical activity was measured with Actigraph accelerometers (MTI, Fort Walton Beach, FL) worn by each participant for 7 consecutive days.

Results: Accelerometry data indicated that overweight/obese adults recorded ~60 counts per minute less per day and spent 21 minutes less engaged in moderate or greater intensity activity than their normal-weight counterparts. Although 71% to 94% of those studied met 1995 recommendations, only 13% of overweight/obese subjects and 26% of normal-weight participants met 2002 exercise recommendations.

Discussion: These results suggest that daily minutes spent in moderate-intensity activity or greater are associated with weight status and that the 2002 IOM recommendations may be difficult to meet even for normal-weight individuals.

Key words: accelerometers, exercise recommendations, overweight, controls, adults

Introduction

The role of physical activity in total energy expenditure is difficult to measure objectively in free-living subjects. Two available methods are doubly labeled water (DLW)[1] and accelerometry. Validation studies comparing DLW with direct and indirect calorimetry and with dietary balance studies in which caloric intake was determined have found DLW to be accurate within 97% to 99% over 1- to 3-week intervals (1–3). However, expense ($400 to $600 per subject) and the complex administration procedure make this method unrealistic for most settings (4). In addition, DLW only measures energy expenditure and does not provide qualitative data on physical activity, such as minutes spent in different intensity levels. The development of the accelerometer provides investigators a more practical and relatively inexpensive objective measure for assessing physical activity under free-living conditions. Some accelerometers on the market have validated, published, age-specific cutoff points, which can distinguish the amount of time individuals spend at different intensity levels, i.e., sedentary,

Received for review October 31, 2005.
Accepted in final form August 1, 2006.
The costs of publication of this article were defrayed, in part, by the payment of page charges. This article must, therefore, be hereby marked "advertisement" in accordance with 18 U.S.C. Section 1734 solely to indicate this fact.
Department of Human Ecology, University of Texas, Austin, Texas.
Address correspondence to Jaimie N. Davis, 2250 Alcazar Street, CSC-200, Los Angeles, CA 90033.
E-mail: jaimieda@usc.edu

[1] Nonstandard abbreviations: DLW, doubly labeled water; CDC, Centers for Disease Control and Prevention; ACSM, American College of Sports Medicine; IOM, Institute of Medicine; cpm, count(s) per minute; GLM, general linear model; FFM, fat free mass; MVPA, moderate to vigorous physical activity.

moderate, hard, and very hard (5). Studies have shown that these cut-off ranges are highly accurate in assessing moderate-intensity activity under free-living conditions (6,7). The data also allow assessment of whether individuals are meeting recommended physical activity objectives for moderate-intensity exercise.

In 1995, the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) established physical activity recommendations for health benefits of at least 30 minutes of moderate-intensity activity, preferably all days of the week (8). National data collected from 1990 to 1998 by the CDC revealed a 25% compliance rate among American adults; 29% of those surveyed reported no leisure time regular physical activity (9). In 2002, the Food and Nutrition Board of the National Institute of Medicine (IOM) increased recommendations for physical activity to at least 60 minutes of moderate intensity every day of the week because of the benefits of activity in weight management (10). To date, there are few reports on compliance with the 2002 recommendations and none comparing the difference between compliance for overweight/obese vs. normal-weight adults. However, because few adults met the less stringent 1995 physical activity recommendations, it is unlikely that many are meeting the new standard. Therefore, the present study was designed to compare time spent in activity of moderate intensity or greater by these two groups and to compare the percentage of individuals from each group meeting the 1995 and 2002 recommendations for physical activity.

Research Methods and Procedures

Subjects

Subjects were recruited by posting flyers at local gyms, hospitals, sporting activities, and health centers and by sending out a campus-wide e-mail to University faculty and staff. More than 90% of the participants were recruited through the campus-wide e-mail to faculty and staff. Subjects were 62 adults, 25 to 69 years old, 31 of whom were overweight or obese with a BMI $\geq$ 25 (27 to 41) kg/m^2 and 31 normal-weight subjects with a BMI of 18.5 to 24.9 matched for gender, height ($\pm$1 inch), and age ($\pm$1 year). Subjects received no financial compensation; instead, they participated with the sole incentive of receiving their test results, and all participants completed the study. Subjects were provided the study protocol, approved by University Internal Review Board, before signing a consent form.

Anthropometrics, Body Composition, and Health History

Most data collection, other than accelerometry, took place in a laboratory on the university campus during a single 2-hour appointment. After subjects completed consent forms, height and weight were measured using a physician scale (Detecto, Webb City, MO) and stadiometer (Seca, Columbus, OH), with participants wearing light clothing and shoes removed. Subjects completed a short demographic and health history questionnaire that included questions about occupation and past medical history. None of the subjects were or had been involved in any weight loss or physical activity program 1 year before participation in this study. As for occupation, most participants reported being teachers, students, or administration workers. Body composition was measured by licensed medical radiological technologists using the Prodigy Pro DXA (Encore 2002 software; GE Medical Systems LUNAR, Madison, WI).

Physical Activity

Accelerometers were employed to measure physical activity. Participants wore the ActiGraph (MTI, Fort Walton Beach, FL) for 24 hours a day for 7 consecutive days. Numerous validation studies have shown that the Computer Science and Applications ActiGraph provides accurate and reliable data for assessing physical activity (5,6,11–14). Subjects were instructed to wear the ActiGraph in the same location on their waist every day. A protective pouch and an elastic belt and clip, both worn at the waist, were provided to each subject to aid in proper placement of the ActiGraph and to accommodate subject preference and comfort. Subjects were asked to complete a written log of any times and/or activities when the ActiGraph was not worn, e.g., swimming and water skiing. Physical activity, i.e., counts and intensity minutes, from these additional activities was calculated using the compendium of physical activities (15).

Accelerometer data were recorded and stored on a minute-by-minute basis and later downloaded to a computer using a reader interface unit. Activity data were processed and analyzed with the use of a Microsoft ActiSoft program (ActiSoft version 3.2) (5) and expressed as count(s) per minute (cpm) per day. Previous studies have employed regression equations, using physical activity counts and indirect calorimetry data, to determine the metabolic cost, i.e., metabolic equivalent, corresponding to activity count data (5). Based on the metabolic equivalent system, the counts were converted into minutes spent in different intensity levels, i.e., light, moderate, hard, and very hard.

Statistics

Data were analyzed using the SPSS/PC statistical program (version 11.0 for Mac OS X; SPSS, Inc., Chicago, IL). Subjects were categorized by weight status (normal weight, overweight, and obese). Unadjusted general linear models (GLMs) were used to examine differences in physical activity among overweight and obese adults. Differences between weight groups (overweight/obese vs. normal-weight adults) and gender groups on physical characteristics, accelerometer counts, and minutes spent in various intensity levels were analyzed with two (female, male) $\times$ two (overweight/obese, normal weight) GLMs, with fat free mass

Table 1. Descriptive statistics for matched pairs of overweight/obese and normal-weight adults

	Overweight/obese group			Normal-weight group		
	Total (n = 31)	Men (n = 12)	Women (n = 19)	Total (n = 31)	Men (n = 12)	Women (n = 19)
Age (years)	44.0 ± 11.9	42.5 ± 9.1	44.9 ± 13.5	43.6 ± 12.0	41.8 ± 8.7	44.8 ± 13.7
Height (cm)	169.1 ± 9.1	178.3 ± 6.4†	163.2 ± 4.4†	171.0 ± 9.0	180.5 ± 5.4†	165.0 ± 4.3†
Weight (kg)	94.7 ± 14.3*	105.3 ± 9.4†	87.9 ± 12.7†	66.5 ± 11.3*	78.5 ± 7.7†	58.8 ± 4.1†
BMI (kg/m^2)	33.0 ± 3.3*	33.1 ± 1.7	32.9 ± 4.1	22.5 ± 1.5*	23.9 ± 1.2	21.6 ± 0.9
Fat mass (kg)	39.7 ± 8.9*	36.6 ± 7.7	41.7 ± 9.2	15.6 ± 3.8*	16.5 ± 4.3	15.2 ± 3.6
Fat mass (%)	42.8 ± 7.8*	35.0 ± 5.0	47.8 ± 4.5	24.1 ± 5.4*	21.1 ± 4.5	26.0 ± 5.2

Group and gender comparisons by general linear model; covariate was fat free mass (for fat mass-dependent variables). Overweight/obese group was defined as BMI ≥ 25 (27) and normal-weight group defined as BMI of 18.5 to 24.9.
* $p < 0.001$ for main effect of weight group.
† $p < 0.001$ for interaction of gender × weight group effect.

(FFM) entered as a covariate (as appropriate). GLMs with repeated measures were employed to assess day-to-day differences in minutes spent in various intensity levels throughout the week, with and without controlling for FFM. Repeated analyses were followed with Bonferroni-adjusted paired comparisons. All data that were not normally distributed were log transformed. All assumptions for GLMs were fulfilled. χ^2 Tests were employed to assess categorical accelerometer data, i.e., the number of subjects meeting 1995 CDC/ACSM and 2002 IOM physical activity recommendations, in relation to each group. Accepted statistical significance was $p < 0.05$.

Results

Unadjusted GLM revealed no differences in physical activity variables between overweight (BMI, 25.0 to 29.9 kg/m^2; n = 6) and obese (BMI ≥ 30 kg/m^2; n = 25) subjects; thus, their data were pooled for further analysis. Overweight/obese and normal-weight subjects were matched for gender, age, and height. Mean differences of ~0.4 ± 0.9 years and 2.0 ± 0.9 cm were observed in age and height, respectively, between the overweight/obese and normal-weight groups. On average, the group carrying excess weight was 28 kg heavier than their normal-weight controls. Age, height, weight, BMI, and body composition of the participants are presented in Table 1. As expected, overweight/obese subjects had significantly higher weight, BMI, and fat mass (kilograms and percentage) than their normal-weight counterparts. A significant gender-by-weight group interaction was observed for weight and height only ($p < 0.001$).

Participants wore an accelerometer for an average of 7.0 ± 0.6 days for 24 hours a day and removed it only for showering and water activities. Subjects in both groups rested or slept an average of 9 hours a night and were awake for ~15 hours a day. One subject wore the accelerometer for only 5 days, and four subjects wore the accelerometer for 6 days. All other subjects wore them for the full week. Weekly and daily averages were adjusted for the number of days that each participant actually wore the accelerometer. When individual days were compared, only data from participants who wore the accelerometer on those days were included. For example, three subjects did not wear the accelerometer on Friday, so their data were excluded when assessing the Friday data sets, but their data were included for Saturday through Thursday.

Large group differences were observed in cpm per day and minutes spent in various intensities as recorded by the accelerometers between overweight/obese and normal-weight subjects. These data are presented in Table 2. Overweight/obese subjects registered significantly fewer mean 7-day, 5-day weekday, and 2-day weekend counts when compared with their normal-weight counterparts, with and without controlling for FFM. Normal-weight subjects spent significantly more time, 21 minutes per day on the average, engaged in moderate-intensity or greater activities when compared with overweight/obese subjects. Overweight/obese participants spent significantly less time in combined moderate to vigorous physical activity (MVPA) than their normal-weight controls on weekdays, i.e., data summed from Monday through Friday, 135 ± 198 vs. 251 ± 155 minutes ($p < 0.05$) and during the weekend, i.e., data summed from Saturday and Sunday, 64 ± 65 vs. 95 ± 61 minutes ($p < 0.02$). There was a significant gender-by-weight group interaction for weekend MVPA. Overweight/obese women spent 24 less minutes in engaged in MVPA than their normal-weight female counterparts on weekends, whereas no difference in MVPA on the weekends was

Table 2. Total counts and minutes spent in different intensity level activities as measured with accelerometers by matched pairs of overweight/obese and normal-weight adults

	Overweight/obese group			Normal-weight group		
Physical activity parameters	**Total ($n = 31$)**	**Men ($n = 12$)**	**Women ($n = 19$)**	**Total ($n = 31$)**	**Men ($n = 12$)**	**Women ($n = 19$)**
Counts for 7 days (cpm)*	227 ± 153‡	283 ± 211	192 ± 91	285 ± 111‡	297 ± 155	277 ± 74
Light activity for 7 days (min/d)*	1372 ± 62	1374 ± 67	1370 ± 61	1361 ± 85	1358 ± 71	1364 ± 94
Moderate activity or greater for 7 days (min/d)*	31 ± 21‡	42 ± 18	25 ± 20	52 ± 28‡	58 ± 36	47 ± 21
Weekday counts (cpm)*	237 ± 195†	306 ± 288	193 ± 88	295 ± 115†	310 ± 134	285 ± 105
Weekday moderate activity or greater (min/d)*	27 ± 22	32 ± 23	24 ± 20	50 ± 31	53 ± 35	48 ± 29
Weekend counts (cpm)*	216 ± 113†	232 ± 120	205 ± 111	293 ± 161†	285 ± 219	298 ± 116
Weekend moderate activity or greater (min/d)*	32 ± 33†	45 ± 40	24 ± 25§	48 ± 31†	47 ± 40	48 ± 25§

Data represent mean ± standard deviation.
* Statistical comparisons on non-normally distributed variables were performed using log-transformed data, but data are shown as non-transformed values for ease of interpretation. Mean comparisons with two (female, male) × two (overweight/obese, normal-weight) general linear model with fat free mass entered as a covariate. Overweight/obese group was defined as BMI ≥ 25 (27) and normal-weight group defined as BMI of 18.5 to 24.9.
† $p < 0.05$ for main effects of weight group.
‡ $p < 0.01$ for main effects of weight group.
§ $p < 0.001$ for interaction of gender × weight group effect.

observed between men and their weight groups. No other significant gender-by-weight group interactions for any of the other physical activity measures were observed.

Because there were no gender-by-weight group interaction effects for total counts and total MVPA, genders were combined for repeated measure analyses. There was no significant weight group by time interaction for day-to-day analyses of accelerometer counts or minutes spent in MVPA, indicating that the pattern of change in these variables was similar in the weight groups. However, there was an overall weight group effect for accelerometer counts and minutes spent in MVPA, indicating that these physical activity measures were significantly different between weight categories. Mean minutes spent in MVPA per day are summarized in Figure 1. Similar findings were seen in accelerometer counts (data not shown). Normal-weight subjects had higher accelerometer counts and spent significantly more time engaged in MVPA throughout the week when compared with overweight/obese subjects ($p < 0.05$), with and without controlling for FFM. Bonferroni-adjusted paired comparisons determined that normal-weight subjects had higher accelerometer counts and spent more minutes in MVPA for days Monday through Thursday when compared

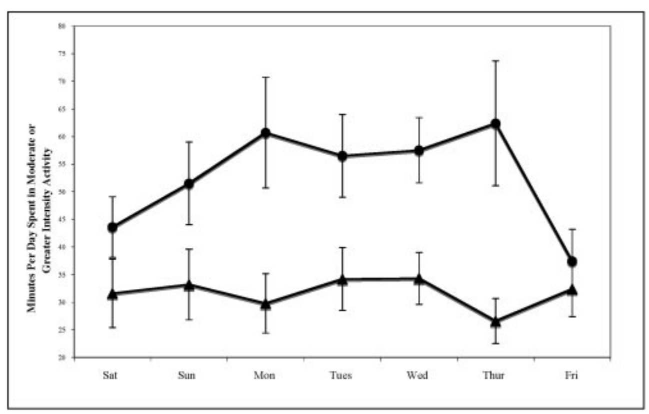

Figure 1: Minutes spent in moderate or greater intensity activity by overweight/obese (▲) and normal-weight (●) subjects as measured by accelerometry. Repeated measures analysis of covariance found that there was a significant weight group overall effect for minutes spent in MVPA ($p < 0.05$). Bonferroni-adjusted paired comparisons indicated significant differences in means for minutes spent in MVPA between groups for days Monday through Thursday ($p < 0.05$). Statistical comparisons on non-normally distributed variables were performed using log-transformed data, but data are shown as non-transformed values for ease of interpretation.

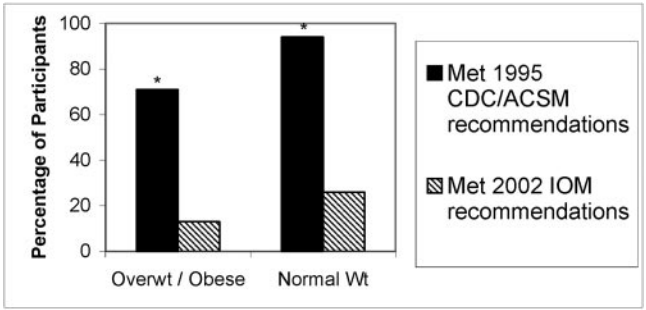

Figure 2: Percentage of overweight/obese and normal-weight subjects, as measured by accelerometry, who met the 1995 CDC/ACSM recommendations (≥30 minutes/d of moderate intensity or greater all days of the week) and the 2002 IOM recommendations (≥60 minutes/d for 7 days). χ^2 Tests showed that all overweight/obese subjects were significantly less likely to meet the 1995 CDC/ACSM recommendations for exercise compared with their normal-weight controls (* $p < 0.05$; ** $p < 0.001$).

with overweight/obese subjects; however, counts and time in MVPA did not differ on Friday, Saturday, or Sunday, where values for the two groups tended to converge.

The percentage of subjects meeting 1995 CDC/ACSM physical activity recommendations for 30 minutes of moderate-intensity or greater activity five or more times a week, or ≥150 minutes a week, and the percentage of subjects meeting 2002 IOM physical activity recommendations for over 60 minutes a day of moderate-intensity activity or greater, or ≥420 minutes a week, based on accelerometer data are summarized in Figure 2. χ^2 Tests showed that normal-weight subjects were significantly more likely to meet 1995 recommendations when compared with overweight/obese subjects, 94% vs. 71% ($p < 0.05$). Percentages of overweight/obese and normal-weight subjects meeting the 2002 physical activity recommendations did not differ. Only 13% of overweight/obese participants and 26% of normal-weight participants met the more stringent recommendations made by the IOM in 2002.

Discussion

In the past, investigators relied on subjective instruments, such as physical activity recall, records, and questionnaires, to evaluate physical activity. Although reported measures are relatively inexpensive and easy to administer, subjects often over-report activity. Research has found that obese individuals overestimate physical activity by 30% to 50% (16,17), whereas normal-weight adults over-report by 8% to 30% (18). Accelerometers provide investigators with an inexpensive and reliable objective measure of physical activity and allow direct comparisons between groups of subjects.

Accelerometer data indicated that overweight/obese subjects in the present study were significantly less active than their matched counterparts. These differences occurred in recorded accelerometer cpm throughout the week and time spent in MVPA for the entire week and most individual days. Based on accelerometer cpm, overweight and obese individuals were less active on weekends and weekdays when compared with their normal-weight match. These results were similar to studies conducted by Cooper et al. (19) and Rutter et al. (20), who reported that obese adults accumulated fewer activity counts than normal-weight adults. In contrast, Meijer et al. (21) and Tyron et al. (22) found no difference in activity counts between obese and normal-weight individuals. However, Meijer and Tyron employed different types and models of accelerometers from those used in our laboratory, and none of the other studies employed overweight/obese and normal-weight subjects matched for gender, age, and height.

Accelerometry allows for comparison of minutes spent in different intensities in an obese/overweight and normal-weight population; however, few studies have examined this phenomenon using overweight/obese subjects matched for gender, age, and height with those of normal weight. In the present study, overweight and obese participants spent significantly less time in MVPA for the entire week, and during weekdays and weekends than their normal-weight counterparts, and weekend differences were observed for women but not men. Cooper et al. (19), who studied 72 normal-weight and 12 obese adults, found that obese adults spent significantly less time in activity of at least moderate intensity than non-obese adults on weekends; however, in their study, this difference was absent among their subjects on weekdays. Ekelund et al. (23) employed both accelerometers and DLW methods and found that obese adolescents spent significantly less accumulated time in moderate-intensity physical activity when compared with normal-weight subjects matched for height and age. Levine et al. (24), using inclinometers, an instrument that measures angles and elevation, and accelerometers found that lean individuals stand for 2 hours longer per day than obese individuals. These results suggest that activities associated with the routines of daily life (called non-exercise activity thermogenesis) are also affected by obesity status. All of these results indicate that if an overweight/obese individual spent more time in MVPA and adopted the non-exercise activity thermogenesis-enhanced behavior, they could considerably increase their daily energy expenditure, which would, in the absence of increased food intake, result in substantial weight loss.

To our knowledge, only one other study has used accelerometers to assess how many adults met 1995 CDC recommendations for exercise. Cooper et al. (19), who also used the Actigraph, found that only 80% of non-obese participants and 60% of the obese accumulated at least 30 minutes of moderate-intensity activity on 5 or more days of the week. Among subjects in the present study, over 70% of the overweight/obese subjects and over 90% of our normal-weight subjects met 1995 CDC/ACSM recommendations, but only 13% of overweight/obese and 26% normal-weight subjects met 2002 IOM recommendations for 420 minutes or more of moderate-intensity exercise over the week. Previous well-known studies have shown that long-term weight loss is improved as exercise participation nears the current recommendation by the IOM (25,26).

It is likely that more of our participants than the subjects studied by Cooper et al. (19) met the 1995 recommendations because they volunteered for a study evaluating exercise and energy expenditure and probably were more active than the general population. Thus, among the general population, it is likely that larger percentages of both overweight/obese and normal-weight adults do not meet either 1995 or 2002 national recommendations for exercise. Possibly a more modest recommendation would encourage more adults to exercise to meet their goals for weight management.

The major limitation of our study is that it is cross-sectional in nature and does not allow definitive conclusions regarding the cause-and-effect relationship between physical activity measures and adiposity. Another limitation is the relatively small sample size. However, the limitations of the small sample size is somewhat offset by the objective measures of physical activity (accelerometers) and the matched participant design. Another limitation is that accelerometers have some margin of error when measuring physical activity in free-living populations. The waist-mounted accelerometers may not capture all of a person's motion, especially arm movement, e.g., cooking, golf, deskwork, and weight training (6,11). In addition, the model of accelerometers used in the current study could not be used for swimming or other water activities. However, our participants were asked to keep a log of all swimming and water activities and to record any activities performed that required excessive arm movement. Fortunately, very few of our participants ($n = 5$) were swimmers, two in the overweight group and three in the normal-weight group, and their logs allowed us to account for the additional minutes spent in MVPA.

The present study found that obese and overweight adults were less physically active, on the basis of recorded accelerometer counts throughout the week and on the amount of time spent engaged in moderate-intensity activity or greater, than their normal-weight counterparts matched for age, gender, and height; and over two-thirds of both overweight/obese and normal-weight subjects met 1995 CDC/ACSM national exercise recommendations, whereas about one-fourth or less of either group met 2002 IOM exercise recommendations. These results suggest the amount of time spent in moderate-intensity activity or greater is associated with weight status. Weight loss/maintenance interventions should encourage individuals to increase MVPA; however, as indicated by our population, which was probably more active than most, the 2002 IOM may be too ambitious for the average adult. Practitioners, specifically registered dietitians and health educators, as well as other health care workers, should consider using objective instruments like the accelerometer to help their clients and patients monitor their physical activity levels and realign these levels with current recommendations.

Acknowledgments

We are grateful to the subjects for cheerful participation in the study without compensation other than individual results. In addition, we thank the Department of Kinesiology and Health Education (University of Texas, Austin), particularly Philip R. Stanforth, for support of data collection activities, especially the measurement of body composition with DXA. We appreciate the support of the Graduate Program in Nutritional Sciences for procurement of the accelerometers and for the financial support of J.N.D. and V.A.H. with teaching assistantships. We appreciate the contributions of Kendra Burke, honors student in Nutrition and Dietetics, who assisted with data collection and entry. Jack H. Wilmore kindly reviewed the early stages of the manuscript. No conflicts of interest are declared.

References

1. **Schoeller DA, Hnilicka JM.** Reliability of the doubly labeled water method for the measurement of total daily energy expenditure in free-living subjects. *J Nutr*. 1996;126:348–54S.
2. **Westerterp KR, Brouns F, Saris W, Hoor F.** Comparison of doubly labeled water with respirometry at low- and high-activity levels. *J Appl Physiol*. 1988;65:53–6.
3. **Coward WA, Prentice AM, Murgatroyd PR, et al.** In: van Es AJH, ed. *Human Energy Metabolism: Physical Activity and Energy Expenditure Measurements in Epidemiological Research Based upon Direct and Indirect Calorimetry*. Wageningen, The Netherlands: Stichting Nederlands Instituut voor de Voeding; 1984.
4. **Montoye HJ, Kemper CG, Saris W, Washburn RA.** *Measuring Physical Activity and Energy Expenditure*. Champaign, IL: Human Kinetics; 1996.
5. **Freedson PS, Melanson E, Sirard J.** Calibration of the Computer Science and Application, Inc. accelerometer. *Med Sci Sports Exerc*. 1998;30:777–81.
6. **Hendelman D, Miller K, Debold BE, Freedson PS.** Assessment of moderate intensity physical activity in the field. *Med Sci Sports Exerc*. 2000;32:S442–9.
7. **Nichols JF, Morgan CG, Chabot LE, Sallis JF, Calfas KJ.** Assessment of physical activity with the Computer Science and Applications, Inc., accelerometer: laboratory versus field validation. *Res Q Exerc Sport*. 2000;71:36–43.
8. **Pate RR, Pratt M, Blair SN, et al.** Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 1995;273:402–7.
9. **CDC.** Physical activity trends: United States, 1990–1998. *Morb Mort Week Rep*. 2001;50:166–9.

10. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients).* Washington, DC: National Academies Press; 2002.
11. **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 Exer*. 2000;32:S471–80.
12. **Patterson SM, Krantz DS, Montgomery LC, Deuster PA, Hedges SM, Nebel LE.** Automated physical activity monitoring: validation and comparison with physiological and self-report measures. *Psychophysiology*. 1993;30:296–305.
13. **Melanson EL, Freedson PS.** Validity of the Computer Science and Applications, Inc. (CSA) activity monitor. *Med Sci Sports Exerc*. 1994;27:934–40.
14. **Welk GJ, Blair SN, Wood K, Jones S, Thompson J.** A comparative evaluation of three accelerometry-based physical activity monitors. *Med Sci Sports Exerc*. 2000;32:S489–97.
15. **Ainsworth BE, Haskell WL, Whitt MC, et al.** Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32:S498–516.
16. **Lightman SW, Pirsarska K, Berman ER, et al.** Discrepancy between self-reported and actual caloric intake and exercise in obese subjects. *New Engl J Med*. 1992;327:1893–8.
17. **Jakicic JM, Polley BA, Wing RR.** Accuracy of self-reported exercise and the relationship with weight loss in overweight women. *Med Sci Sports Exerc*. 1998;30:634–8.
18. **Conway JM, Seale JL, Jacobes DR, Irwin ML, Ainsworth BE.** Comparison of energy expenditure estimates from doubly labeled water, a physical activity questionnaire, and physical activity records. *Am J Clin Nutr*. 2002;75:519–25.
19. **Cooper AR, Page A, Fox KR, Misson J.** Physical activity patterns in normal, overweight and obese individuals using minute-by-minute accelerometry. *Eur J Clin Nutr*. 2000;54:887–94.
20. **Rutter S.** Comparison of energy expenditure in normal-weight and overweight women using the Caltrac personal activity computer. *Int J Eat Dis*. 1994;15:37–42.
21. **Meijer GA, Westerterp KR, Hulsel A, Hoor F.** Physical activity and energy expenditure in lean and obese adult human subjects. *Eur J Appl Physiol*. 1992;65:525–8.
22. **Tyron WW.** Activity as a function of body weight. *Am J Clin Nutr*. 1987;46:451–5.
23. **Ekelund U, Aman J, Yngve A, Renman C, Westerterp KR, Sjöström M.** Physical activity but not energy expenditure is reduced in obese adolescents: a case-control study. *Am J Clin Nutr*. 2002;76:935–41.
24. **Levine JA, Lanningham-Foster LM, McCrady SK, et al.** Interindividual variation in posture allocation: possible role in human obesity. *Science*. 2005;307:584–6.
25. **Schoeller DA, Shay K, Kushner RF.** How much physical activity is needed to minimize weight gain in previously obese women? *Am J Clin Nutr*. 1997;66:551–6.
26. **Jakicic JM, Winters C, Lang W, Wing RR.** Effects of intermittent exercise and use of home exercise equipment on adherence, weight loss, and fitness in overweight women: a randomized trial. *JAMA*. 1999;282:1554–60.
27. **National Heart, Lung, and Blood Institute.** *Clinical Guidelines on the Identification, Evaluation and Treatment of Overweight and Obesity in Adults: The Evidence Report*. Rockville, MD: National Heart, Lung and Blood Institute; 1998.