1-2013

Differences in Demographic, Behavioral, and Biological Variables Between Those With Valid and Invalid Accelerometry Data: Implications for Generalizability

Paul D. Loprinzi
Bellarmine University

Bradley J. Cardinal
Oregon State University

Carlos J. Crespo
Portland State University, ccrespo@pdx.edu

Gary R. Brodowicz
Portland State University

Ross E. Andersen
McGill University

See next page for additional authors

Citation Details

Loprinzi, P. D., Cardnal, B. J., Crespo, C. J., Brodowicz, G. R., Andersen, R. E., & Smith, E. (2013). Differences in Demographic, Behavioral, and Biological Variables Between Those With Valid and Invalid Accelerometry Data: Implications for Generalizability. Journal Of Physical Activity & Health, 10(1), 79-84.

Journal of Physical Activity and Health, 2013, 10, 79-84

JOURNAL OF
Physical Activity & Health
Official Journal of ISPAH
www.JPAH-Journal.com
ORIGINAL RESEARCH

Differences in Demographic, Behavioral, and Biological Variables Between Those With Valid and Invalid Accelerometry Data: Implications for Generalizability

Paul D. Loprinzi, Bradley J. Cardinal, Carlos J, Crespo, Gary R. Brodowicz, Ross E. Andersen, and Ellen Smit

Background: The exclusion of participants with invalid accelerometry data (IAD) may lead to biased results and/or lack of generalizability in large population studies. The purpose of this study was to investigate whether demographic, behavioral, and biological differences occur between those with IAD and valid accelerometry data (VAD) among adults using a representative sample of the civilian noninstitutionalized U.S. population. ***Methods:*** Ambulatory participants from NHANES (2003–2004) who were 20–85 years of age were included in the current study and wore an ActiGraph 7164 accelerometer for 7 days. A "valid person" was defined as those with 4 or more days of at least 10+ hrs of monitoring per day. Among adults (20–85 yrs), 3088 participants provided VAD and 987 provided IAD. Demographic, behavioral, and biological information were obtained from the household interview or from data obtained in a mobile examination center. ***Results:*** Differences were observed in age, BMI, ethnicity, education, smoking status, marital status, use of street drugs, current health status, HDL-cholesterol, C-reactive protein, self-reported vigorous physical activity, and plasma glucose levels between those with VAD and IAD. ***Conclusions:*** Investigators should take into consideration the potential cut-off bias in interpreting results based on data that excludes IAD participants.

Keywords: bias, validity, exclusion, physical activity

Regular participation in physical activity is associated with a myriad of different positive health outcomes in adults.[1] Despite the known benefits of physical activity on health in adults, a high proportion of adults are not physically active at the recommended levels (ie, 150 or 75 minutes a week, respectively, of moderate- or vigorous-intensity physical activity for adults).[2]

With the high rates of adult obesity[3] and its accompanying comorbidities,[4] the promotion of physical activity in adults has become a public health priority. Given the limitations of self-report measures of physical activity (eg, recall bias), accelerometry has recently been used as an objective method of providing population estimates of physical activity, as well as for evaluating the effectiveness of physical activity interventions.[2,5] However, it is important that the methods and instruments used are robust enough to produce valid and reliable estimates of physical activity across different populations.[6] Toward that end, there is an important methodological issue that requires further research attention when working with accelerometers.

Standard accelerometry-based data reduction procedures involve including only participants who provide valid accelerometry data (VAD; ie, at least 4 days with 10 or more hours per day of monitoring).[2,5] However, it is possible that the exclusion of participants who have invalid accelerometry data (IAD) may lead to biased results if those who are excluded are different from those included in the analysis. For example, when examining the relationship between physical activity and C-reactive protein (CRP), if individuals with IAD have significantly higher CRP and lower physical activity levels than those with VAD, then the exclusion of participants with IAD might bias the results toward the null, possibly underestimating the association between physical activity and CRP.

To determine the extent to which excluding participants with IAD introduces bias in the analysis and minimizes generalizability, studies examining biological, behavioral, and demographic variables in adults are needed. To address these gaps in the research literature, the aim of the current study was to investigate whether biological, behavioral, and demographic factors known to be associated with physical activity are different between

Loprinzi is with the Dept of Exercise Science, Bellarmine University, Louisville, KY. Cardinal is with the Program in Exercise and Sport Science, School of Biological and Population Health Sciences, Oregon State University, Corvallis, OR. Crespo, Brodowicz, and Smit are with the School of Community Health, Portland State University, Portland, OR. Smit is also with the Program in Epidemiology, School of Biological and Population Health Sciences, Oregon State University, Corvallis, OR. Andersen is with the Dept of Kinesiology, McGill University, Montreal, Quebec, Canada.

those with IAD and VAD in a nationally representative sample of adults in the U.S.

Methods

Design and Participants

The National Health and Nutrition Examination Survey (NHANES) data are collected annually. The data presented herein are from the NHANES 2003–2004 cycle. Like all preceding NHANES cycles, 2003–2004 used a representative sample of noninstitutionalized U.S. civilians, selected by a complex, multistage probability design across 15 U.S. geographic locations. Initially, after households were identified, an interviewer visited the home to conduct an interview-administered questionnaire. Once the interview was completed, participants were asked to attend a health examination at a local mobile examination center (MEC). The study was approved by the National Center for Health Statistics ethics review board, with informed consent obtained from all participants before data collection. For the current study, the final analytical sample included 3088 participants with VAD and 987 participants with IAD. Participants ranged in age from 20–85 years.

Measurement of Physical Activity

The physical activity monitoring component was first added to the NHANES 2003–2004 cycle. At the MEC, participants ≥ 6 yr who were not limited by impairments of walking or wearing an accelerometer were recruited to wear an ActiGraph 7164 accelerometer (Shalimar, FL). Following their examination, participants were asked to wear the accelerometer during all waking hours, positioned on the right hip on an elasticized fabric belt, over a 7-day period. Participants were instructed to remove the accelerometer while involved in any water-based activities (eg, showering). After the 7-day monitoring period, participants received a $40 remuneration upon returning the accelerometer in a prepaid envelope. Before data collection, the accelerometers were initialized to summarize activity counts in 1-min time intervals (ie, epochs). Accelerometry data were reduced using the SAS macro provided by the National Cancer Institute.[7] Consistent with previous studies,[2] a valid day of activity monitoring was defined as at least 10 or more hours of monitoring. After the 7-day monitoring period, NHANES classified participants as either a "valid person" or "invalid person," with valid individuals having at least 4 days with 10 or more hours per day of monitoring data, and invalid individuals having fewer than 4 days with 10 or more hours per day of monitoring data.

Measurement of Demographic and Behavioral Variables

A variety of demographic and descriptive variables were assessed from data collected using a questionnaire administered during the household interview. Among these were age, gender, ethnicity, education, marital status, self-reported drug use (ie, ever used cocaine or other street drugs), current health status (ie, number of inactive days within the last 30 days due to poor physical or mental health), self-reported physical activity (ie, whether they engaged in at least 10-min of moderate or vigorous physical activity on at least 1 occasion within the last 30-days), and medical history (ie, smoking status). These demographic and behavioral variables were chosen for this study as all have previously been shown to be associated with physical activity. Further details about the demographic and behavioral variables are available elsewhere.[8]

Trained household interviewers administered the questionnaire, with interview data recorded using a Blaise format computer-assisted personal interview (CAPI) system. During examination at the MEC, body mass index (BMI) was calculated from measured weight and height (weight in kilograms divided by the square of height in meters). For individuals 20+ years, overweight was defined as a BMI between 25.0 kg/m^2 and 29.9 and obese was defined as a BMI ≥ 30.0 kg/m^2.

Measurement of Biological Variables

During examination at the MEC, blood samples were obtained from the participants. Fasting plasma glucose, fasting insulin, total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides, and CRP were obtained from blood samples at the MEC. These biological variables were chosen for this study as all have previously been shown to be associated with physical activity.[9,10] Further details about the laboratory procedures and quality control have been previously reported.[11]

Data Analysis

All statistical analyses were performed using procedures from sample survey data using STATA (version 10.0, College Station, TX) to account for the complex survey design used in NHANES. To account for oversampling and nonresponse, all analyses included the use of appropriate sample weights. Means and standard errors were calculated for continuous variables and proportions were calculated for categorical variables. Statistical differences between continuous variables were tested using an adjusted Wald test, a survey-data analog to the parametric *t* test. Statistical differences between categorical variables were tested with design-based likelihood ratio chi-square tests. To account for the multiple comparisons (ie, 21), a Bonferroni adjustment was applied. Statistical significance was established as $P < .0024$ (0.05/21).

Results

Demographic, behavioral, and biological variables among those participants with VAD and IAD are displayed in Table 1 for middle-age adults (20–59 yrs) and older adults (60+ yrs).

Table 1 Weighted Demographic, Behavioral, and Biological Variables [Mean (Standard Error)] Among Younger and Middle-Age Adults (20–59 yr) and Older Adults (60+ yr) With Valid and Invalid Accelerometry Data

	Valid	Invalid		Valid	Invalid	
	20–59 yr	20–59 yr	*P*	60+ yr	60+ yr	*P*
N	1828	763		1260	224	
Demographic variables						
Age (yr)	40.60 (0.44)	35.13 (0.55)	< 0.001	70.61 (0.31)	71.78 (0.51)	0.01
% Male	49.74 (1.4)	45.42 (2.22)	0.20	44.28 (1.46)	44.31 (3.23)	0.99
Height (cm)	169.96 (0.49)	169.60 (0.31)	0.49	166.84 (0.31)	165.69 (0.80)	0.20
Weight (kg)	81.24 (0.63)	83.78 (0.97)	0.05	78.83 (0.47)	79.15 (1.71)	0.86
BMI (kg/m2)	28.04 (0.19)	29.12 (0.32)	0.008	28.21 (0.17)	28.55 (0.48)	0.49
% Overweight or obese[a]	65.30 (1.26)	66.90 (1.57)	0.41	71.93 (2.03)	70.34 (3.34)	0.72
Ethnicity, %			< 0.001			0.04
Non-Hispanic White	72.83 (3.46)	64.04 (4.65)		83.96 (3.40)	77.01 (5.15)	
Non-Hispanic Black	9.92 (1.67)	17.28 (2.80)		7.26 (1.79)	14.95 (3.45)	
Hispanic	8.80 (2.07)	9.73 (2.36)		3.45 (1.81)	3.37 (1.86)	
Other	8.45 (1.16)	8.95 (1.41)		5.33 (0.98)	4.66 (2.09)	
Education, %			< 0.001			0.13
< High school	12.64 (0.97)	22.96 (2.16)		25.76 (3.47)	31.33 (4.85)	
High school	25.23 (1.35)	25.62 (2.35)		28.70 (1.73)	29.47 (5.17)	
> High school	62.14 (1.29)	51.42 (2.10)		45.54 (3.00)	39.20 (4.13)	
Marital status, %			< 0.001			0.14
Married	68.95 (2.50)	48.33 (2.69)		92.37 (1.00)	86.85 (4.00)	
Separated	2.79 (0.54)	2.86 (0.67)		1.30 (0.47)	3.84 (1.98)	
Never married	20.19 (1.96)	35.03 (2.93)		4.25 (0.88)	8.11 (2.96)	
Living with partner	8.06 (0.87)	13.79 (0.79)		2.08 (0.64)	1.20 (0.81)	
Behavioral variables						
Smoking status, %			< 0.001			0.11
Never smoked	53.52 (1.28)	42.97 (2.98)		45.12 (2.02)	40.09 (4.25)	
Former smoker	20.81 (1.99)	17.11 (1.83)		44.26 (2.01)	42.04 (3.48)	
Currently smoke	25.67 (1.26)	39.93 (2.75)		10.62 (1.07)	17.88 (3.34)	
% Used street drugs	20.31(1.44)	25.93 (2.24)	0.02	N/A	N/A	N/A
Inactive days due to poor physical/ mental health within last 30 days	1.38 (0.22)	2.60 (0.41)	0.01	1.47 (0.15)	3.63 (0.66)	0.004
Moderate intensity activities for ≥ 10 min over last 30 days, %	62.78 (1.31)	57.71 (2.81)	0.10	56.43 (1.68)	46.43 (5.85)	0.10
Vigorous intensity activities for ≥ 10 min within last 30 days, %	39.26 (1.77)	33.10 (3.74)	0.10	13.98 (1.51)	6.84 (2.48)	0.03
Biological variables						
Plasma glucose (mmol/L)	5.47 (0.07)	5.41 (0.07)	0.61	5.94 (0.09)	6.96 (0.28)	0.004
Insulin (pmol/L)	60.39 (2.06)	77.06 (9.74)	0.09	66.85 (3.87)	80.11 (11.53)	0.26
Total cholesterol (mmol/L)	5.20 (0.03)	5.16 (0.05)	0.56	5.37 (0.03)	5.43 (0.10)	0.56
HDL cholesterol (mmol/L)	1.41 (0.01)	1.33 (0.02)	0.005	1.45 (0.02)	1.40 (0.03)	0.29
LDL cholesterol (mmol/L)	2.98 (0.03)	3.03 (0.04)	0.34	3.12 (0.04)	3.08 (0.17)	0.83
Triglycerides (mmol/L)	1.64 (0.08)	1.70 (0.12)	0.66	1.75 (0.04)	1.87 (0.12)	0.37
C-reactive protein (mg/dL)	0.40 (0.2)	0.48 (0.03)	0.02	0.41 (0.02)	0.78 (0.11)	0.006

[a] Overweight defined as a BMI between 25.0–29.9 and obese defined as a BMI ≥ 30.0.

Note. N/A, not applicable—not measured in this age group.

Of the demographic variables for adults 20–59 years, those with IAD were more likely to have a higher BMI (borderline significant; $P = .008$) and less likely to be a non-Hispanic White ($P < .001$) and have a high school diploma ($P < .001$) than those with VAD. Additionally, those with IAD were less likely to be married ($P < 0.001$) and were younger ($P < 0.001$) than those with VAD. For adults 60+ years, those with IAD, compared with those with VAD, were older (borderline significant; $P = .01$) and less likely to be non-Hispanic Whites (borderline significant; $P = .04$).

Adults aged 20–59 years with IAD were more likely to smoke ($P < .001$) and use street drugs (borderline significant; $P = .02$), and had a greater number of inactive days within the last 30 days due to poor health (borderline significant; $P = .01$) compared with those with VAD; adults aged 60+ years with IAD had a greater number of inactive days within the last 30 days due to poor health (borderline significant; $P = .004$), and had a lower prevalence of engaging in self-reported vigorous-intensity activities within the last 30 days (borderline significant; $P = .03$) than those with VAD.

With regard to biological variables for adults aged 20–59 years, those with IAD had lower mean HDL-cholesterol (borderline significant; $P = .005$) and higher CRP concentrations (borderline significant; $P = .02$) than those with VAD; and for adults aged 60+ years, those with IAD had higher CRP concentrations (borderline significant; $P = .006$) and fasting plasma glucose levels (borderline significant; $P = .004$) compared with those with VAD.

Discussion

The aim of the current study was to investigate whether demographic, behavioral, and biological factors known to be associated with physical activity are different between those with IAD and VAD among adults using a representative sample of the noninstitutionalized U.S. population. The major finding was that adults with IAD differed from those with VAD in various demographic, behavioral, and biological variables.

Although we were not able to identify any studies examining demographical, behavioral, or biological differences among adults with VAD and IAD, 2 previous studies have examined demographic differences between children with VAD and IAD. Mattocks and colleagues[12] had 7159 children from the UK (mean age: 11.8 yrs) wear an MTI ActiGraph accelerometer over a 7-day period. Of these individuals, 5595 children provided VAD, with 1564 children having IAD. In contrast with the criteria employed in the current study, in the Mattocks et al[12] study data were considered valid if a child had at least 3 days of at least 10 hrs of monitoring per day. These results showed that those with IAD were older (11.8 vs. 11.7 yrs), heavier (44.9 vs. 43.5 kg), and had a higher BMI (19.5 vs. 19.0 kg/m^2). In contrast to these findings, Van Coevering et al,[13] who examined differences among children's compliance in wearing the accelerometer, with noncompliance defined as 1 or more periods of time with episodes of 180 minutes or more of continuous zero-count measures in a single day, showed that overweight American children in grades 6–8 were more likely to be in compliance compared with nonoverweight children (65.6% vs. 34.4%).

The results of the current study suggest that excluding participants with IAD may lead to a biased interpretation of findings. Among adults 60+ years of age, those with IAD were more likely to have higher fasting plasma glucose levels, have higher CRP concentrations, and less likely to self-report participation in vigorous-intensity physical activity. Consequently, excluding adults with invalid accelerometry data may lead to inconsistent findings among studies that examine the role that physical activity plays in preventing chronic diseases. For example, when examining the relationship between physical activity and C-reactive protein (CRP), if individuals with invalid accelerometry data have significantly higher CRP levels and lower physical activity levels than those with valid accelerometry data, then the exclusion of participants with invalid accelerometry data might bias the results toward the null, thus possibly underestimating the association between physical activity and CRP. Among studies that have found a significant association between physical activity and CRP,[14] for example, it is possible that the strength of association is greater than reported, demonstrating further evidence for the health benefits associated with physical activity.

Although excluding participants with IAD may bias results in studies that examine the association between physical activity and various biological variables or investigate the influence of demographics on physical activity, we are not advocating that researchers include all participants with any level of accelerometry data. If summary estimates are computed using accelerometer data on days in which the monitor is worn only part of the day, then such estimates have the potential to be biased. For example, during the time the monitor is not worn, it is likely that the participant is still engaging in some degree of physical activity; thus, computing summary statistics on this day will likely underestimate their true level of total activity for that particular day.[15] To minimize bias by calculating summary statistics on *incomplete* days of accelerometry data, Catellier and colleagues[15] used an alternative analytic approach whereby the *complete* accelerometer data (ie, days with sufficient monitoring data based on an established criteria, such as 10+ hours) were used to predict activity levels for segments of the day (or an entire day) in which the monitor was not worn.

This imputation strategy is analogous to imputing missing item responses on questionnaires, which has been shown to reduce bias.[16] Using data from the Trial for Activity in Adolescent Girls (TAAG), results showed that when missing data were deleted at random, estimates of activity computed from the observed data and those based on a data set in which the missing data were imputed were equally unbiased; however, the imputation estimates were more precise. When the missing data were deleted

in a systematic fashion, the bias in estimated activity was lower using imputation procedures. Both imputation techniques—single imputation through expectation maximization and multiple imputation—performed similarly with no significant differences in bias or precision. These findings suggest that one possible strategy for minimizing bias and increasing generalizability is to implement missing value imputation.

To better understand the extent to which excluding participants with IAD influences genaralizability, additional studies examining differences in demographic and biological variables between those with IAD and VAD, while applying different criteria for a valid person (eg, 1, 2, 3 days of 10+ hrs of monitoring data compared with 4 days of 10+ hrs of monitoring data) are needed. For example, previous studies have shown that the use of 3 days of physical activity measurement provides good reliability (R = .7);[12] therefore, if this lower threshold produces less bias, then it may be sensible to adopt this criteria for the constitution of a valid day. Further, a lower threshold may be more appropriate for younger children as they spend fewer hours awake.[17,18]

To maximize generalizability by limiting IAD and maximizing VAD, compliance with the monitoring protocol is important. Several strategies have been recommended to achieve good compliance to the monitoring protocol.[12,19] These include, but are not limited to, 1) maintaining contact with the participants as frequently as possible (eg, phone calls, e-mail, or text messaging to remind participants to wear the monitor as well as to return it), 2) attempting to make initial contact face-to-face to provide detailed explanation of the protocol, 3) asking participants to complete an activity monitoring log, 4) distributing written materials for participants to display in a conspicuous location that prompts wearing the monitor, and 5) providing incentives contingent upon compliance. To understand why some participants wear the monitor as directed, and others do not, future studies should identify factors (eg, psychological, biological and environmental) that predict monitoring compliance. In particular, qualitative studies employing focus groups may provide rich information on key factors that influence monitoring compliance for accelerometers mounted on the waist. Although smaller-scale studies will likely continue to mount accelerometers on the waist, thereby necessitating the need to understand factors that influence monitoring compliance, future NHANES cycles plan to increase monitoring compliance by using a wrist-mounted accelerometer that can be "locked on" with a bracelet.[20]

In summary, significant differences in demographic, behavioral, and biological variables known to be associated with physical activity were observed between adults with IAD and VAD. This suggests that excluding participants with IAD may limit the extent with which estimates of physical activity are valid and representative. Researchers should exercise caution when interpreting the results of studies that exclude participants with IAD. Future studies are needed to examine the extent to which various imputation procedures can affect differences in demographics, behavioral, and biological variables. Lastly, studies should examine the differences in demographic, behavioral, and biological variables when applying different criteria for a valid person.

References

1. U.S. Department of Health and Human Services. *Physical activity and health: a report of the Surgeon General*. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 1996.
2. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181–188. PubMed
3. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999-2008. *JAMA*. 2010;303(3):235–241. PubMed doi:10.1001/jama.2009.2014
4. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *JAMA*. 1999;282(16):1523–1529. PubMed doi:10.1001/jama.282.16.1523
5. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am J Epidemiol*. 2008;167(7):875–881. PubMed doi:10.1093/aje/kwm390
6. Plasqui G, Westerterp KR. Physical activity assessment with accelerometers: an evaluation against doubly labeled water. *Obesity (Silver Spring)*. 2007;15(10):2371–2379. PubMed doi:10.1038/oby.2007.281
7. Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey (NHANES 2003-2004): National Cancer Institute. Accessed at: http://www.cdc.gov/nchs/nhanes/nhanes2003-2004/exam03_04.htm.
8. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Protocol and Questionnaire. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2010. Available at: http://www.cdc.gov/nchs/nhanes/nhanes2003-2004/nhanes03_04.htm.
9. Lokey EA, Tran ZV. Effects of exercise training on serum lipid and lipoprotein concentrations in women: a meta-analysis. *Int J Sports Med*. 1989;10(6):424–429. PubMed doi:10.1055/s-2007-1024937
10. Plaisance EP, Grandjean PW. Physical activity and high-sensitivity C-reactive protein. *Sports Med*. 2006;36(5):443–458. PubMed doi:10.2165/00007256-200636050-00006
11. Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey (NHANES 2003-2004): Laboratory Manual. Bethesda, MD: National Center for Health Statistics. Accessed at http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/l11_c.pdf.
12. Mattocks C, Ness A, Leary S, et al. Use of accelerometers in a large field-based study of children: protocols, design issues, and effects on precision. *J Phys Act Health*. 2008;5(Suppl 1):S98–S111. PubMed

13. Van Coevering P, Harnack L, Schmitz K, Fulton JE, Galuska DA, Gao S. Feasibility of using accelerometers to measure physical activity in young adolescents. *Med Sci Sports Exerc*. 2005;37(5):867–871. PubMed doi:10.1249/01.MSS.0000162694.66799.FE
14. Loprinzi PD, Cardinal BJ, Crespo CJ, et al. Objectively measured physical activity and C-reactive protein: National Health and Nutrition Examination Survey. *Scan J Med Sci Sports Exerc*; 2011. [epub ahead of print]
15. Catellier DJ, Hannan PJ, Murray DM, et al. Imputation of missing data when measuring physical activity by accelerometry. *Med Sci Sports Exerc*. 2005;37(11, Suppl):S555–S562. PubMed
16. Gmel G. Imputation of missing values in the case of a multiple item instrument measuring alcohol consumption. *Stat Med*. 2001;20:2369–2381. PubMed doi:10.1002/sim.837
17. Cappuccio FP, Taggart FM, Kandala NB, et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep*. 2008;31(5):619–626. PubMed
18. Iglowstein I, Jenni OG, Molinari L, Largo RH. Sleep duration from infancy to adolescence: reference values and generational trends. *Pediatrics*. 2003;111(2):302–307. PubMed doi:10.1542/peds.111.2.302
19. Trost SG, McIver KL, Pate RR. Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc*. 2005;37(11, Suppl):S531–S543. PubMed
20. National Cancer Institute. National Health and Nutrition Examination Survey. Risk Factor Monitoring and Methods. Accessed at http://riskfactor.cancer.gov/studies/nhanes/