HHS Public Access

Author manuscript

Eur J Clin Nutr. Author manuscript; available in PMC 2016 January 01.

Published in final edited form as:

Eur J Clin Nutr. 2015 July ; 69(7): 850–855. doi:10.1038/ejcn.2014.241.

Objective and subjective measurement of energy expenditure in older adults: A doubly-labeled water study

Miguel Andres Calabro[1], **Youngwon Kim**[1], **Warren D. Franke**[1], **Jeanne M. Stewart**[2], and **Gregory J. Welk**[1]

[1]Department of Kinesiology, Iowa State University

[2]Department of Food Science & Human Nutrition, Nutrition & Wellness Research Center, Iowa State University

Abstract

Background/Objectives—Objective and subjective measurement instruments have been used to estimate energy expenditure as alternatives to the doubly labeled water (DLW) methodology, but their relative validity for older adults remains uncertain. The purpose of this study was to validate an objective monitor (Sense Wear Mini Armband) and a self-report instrument (7-Day Physical Activity Recall) relative to the doubly-labeled water (DLW) under free-living conditions in older adults.

Subjects/Methods—Twenty-nine older adults (60–78 yrs) each wore the Mini for 14 consecutive days, and completed two 7D-PARs after each week. For each measurement method, activity energy expenditure (AEE) was calculated as total energy expenditure (TEE) – measured resting metabolic rate –diet induced thermogenesis (10% of TEE). TEE and AEE from the Mini and 7D-PAR were each compared to values from the DLW.

Results—Equivalence testing indicated that estimates of TEE from the Mini and the 7D-PAR were statistically equivalent to those measured with DLW; however, differences were evident for estimates of AEE. The Mini had smaller mean absolute percent error for TEE (8.0%) and AEE (28.4%) than the 7D-PAR (13.8% and 84.5%, respectively) and less systematic bias in the estimates.

Conclusions—The Mini and 7D-PAR provided reasonably valid estimates of TEE but large errors in estimating AEE. The Mini and 7D-PAR have the potential to accurately estimate TEE for older adults.

Keywords

physical activity; energy expenditure; doubly-labeled water

Corresponding Author/Requests for reprints: Name: Youngwon Kim, Mailing Address: Department of Kinesiology, Iowa State University, 235 Forker Building, Ames, IA, 50011, myungshingo@gmail.com, Telephone: 1 - 515 - 294 – 3583 Fax: 1 - 515 - 294 – 8740.

Conflict of Interest: The authors have no conflict to declare.

INTRODUCTION

Regular physical activity (PA) in older adults is known to be associated with decreased mortality[1, 2] as well as reduced prevalence of metabolic risk factors,[3] diabetes mellitus[4] and cognitive impairment.[5] However, the proportion of U.S. older adults adhering to the *Physical Activity Guidelines for Americans* (i.e. 30 min of PA on most days of a week)[6] is less than 3%, which is the lowest among all age groups of U.S. populations. A substantial reduction in PA levels from early/mid adulthood to late adulthood[7, 8] is a critical factor that leads to a reduction in energy requirements for older adults[9]; another critical factor is a decrease in resting metabolic rate (RMR) owing to aging-related loss of fat free mass.[10–12] Furthermore, older adults are exposed to an increased risk of developing impairments of energy regulating systems.[13] Therefore, accurate assessment of PA and energy expenditure (EE) is desirable for this population.

The doubly-labeled water (DLW) method is the acknowledged “gold standard” method for measuring true levels of EE under free-living conditions.[14–17] However, it is impractical and expensive to employ the DLW method in clinical studies and applications. As proxies for the DLW method, subjective (i.e. self-report) and objective (i.e. accelerometer-based monitor, multi-sensor monitor) assessment tools have been proposed and validated. Previous studies identified somewhat mixed findings about the validity of both self-report[18–20] and objective[21, 22] methods relative to the DLW technique in older adults. Consensus recommendations now advocate for the use of a combination of subjective and objective measurement tools to better understand both the quantity and context of behavior.[23, 24] This is an especially important consideration for older adults since objective and subjective measures may yield distinct activity patterns in this population. Therefore, the purpose of this study was to examine the relative validity of two promising measures (one objective and the other subjective) compared to criterion data from the DLW method.

SUBJECTS and METHODS

Participants

Twenty-nine healthy older adult ages 60–80 yrs was recruited to participate in the study. Participants were screened using a medical history form followed by oral review to ensure that they could safely and effectively complete the study. Exclusion criteria included health condition that may have prevented the participant from being active, the use of supplemental oxygen or medical devices, and overt cognitive impairment. Additionally, individuals taking diuretics or thyroid medication were excluded from the study to avoid a confounding effect with the DLW method. This study was approved by the Institutional Review Board of Iowa State University, and participants signed the informed consent form before participation.

Data collection procedures

Participants reported to the lab following a 10-hour fast and provided a baseline urine sample upon arriving. Height was measured to the nearest 0.1 cm with a wall-mounted stadiometer. Body mass was measured with an electronic scale to the nearest 0.1 kg. Body mass index was calculated as weight(kg)/height^2(m^2).

The Mini was initialized using the participant's personal information and adjusted to fit snugly on the triceps of the participant's right arm following manufacturer recommendations. After fitting the Mini, a DLW dose was administered to the participant. The dose was determined based on body weight in accordance with a standardized protocol.[25] Each participant received a 1.5 ml/kg body weight dose of the whole mixture of heavy water (mixture of 10% atom-enriched H2 18O and 99% atom-enriched 2H2O) (Cambridge Isotopes, Cambridge, MA). Four urine samples were collected at 1.5, 3.0, 4.5 and 6.0 hours following DLW ingestion. Liquid consumption was monitored during these 6 hours.

The participants were instructed to continue their normal life while wearing the Mini for 24 hours a day, except while doing water-related activities (showering, swimming). Participants were instructed to record non-wearing periods. On days 7 and 14 of the protocol, participants reported to the lab in a fasted state and provided additional urine samples at two time points (90-minutes apart). On both visits to the lab, the participants completed a 7D-PAR guided by the researchers. RMR was measured on both days using an indirect calorimetry system (Physiodyne Instruments, Quogue, NY) following the manufacturer's recommendations. Participants were supine and resting quietly by avoiding speaking and minimizing their movement for 25 minutes. Only the data from the last 15 minutes were used. The averaged RMR value between the two RMR measures was then extrapolated for 24-h RMR.

Instruments

Doubly Labeled Water—The DLW method is a non-invasive technique that, via ingestion of isotopic tracers (deuterium and Oxygen-18) gradually eliminated from the body, enables estimation of carbon dioxide production and subsequent estimation of oxygen consumption (using a standardized Respiratory Quotient).[16] Activity EE (AEE) can be estimated by subtracting the RMR and diet-induced thermogenesis (~10%), from daily EE.[26]

The collected urine samples from Days 0, 7 and 14 were divided into duplicate samples (12 ml each), labeled and frozen. Samples were sent to the Pennington Biomedical Research Center (Baton Rouge, LA) for processing on a gas isotope ratio mass spectrometer. The ^2H and ^{18}O isotope elimination rates (k_D and k_O) were calculated using linear regression following a log transformation and total body water (N) was determined at time zero using the regression line of the $H_2{}^{18}O$ isotope. The rate of CO_2 production rCO_2 (moles/d) was calculated using standard equations.[27] TEE was then calculated using the following equation: $\mathrm{TEE}\ (\mathrm{kcal/d}) = 22.4\ \mathrm{rCO_2}\ (3.9/\mathrm{respiratory\ quotient} + 1.10)$. This formula assumes a respiratory quotient of 0.86 which is typical for a healthy, rather low fat diet. Both TEE and AEE values were expressed per day to facilitate interpretation. Additional information about the DLW protocol and processing are published elsewhere.[25]

Sense Wear Mini Armband—The Mini is a light (45.4 g), small (55×62×13 mm) and triaxial accelerometer-based activity monitor, coupled with several heat-related sensors (heat flux, body temperature and galvanic skin response). The Mini has a rechargeable battery for

7 days of use, and a memory for 14 consecutive days. Data from the Mini were processed using a proprietary software package (v.7.0 with algorithm v.2.2).

During visits to the laboratory on days 7 and 14 of the protocol, data from the Mini were downloaded. Using the activity log provided by the participants, EE values for the non-wearing periods were estimated using MET values based on the Compendium of Physical Activities by Ainsworth et al.[28] After all data gaps were filled, daily TEE was calculated by summing the amount of EE expended by the participant over the monitoring period (14 days).

7-day Physical Activity Recall—The 7D-PAR instrument has been one of the most widely used physical activity instruments in the field. It provides data across a 7-day period in order to capture typical activity behavior but this advantage may be offset by the lack of precision in the data for the individual days.[29]

TEE was calculated as the average hours per day in each activity category multiplied by a previously assigned MET value (sleep=1.0, light=1.5, moderate=4.0, hard=6.0, and very hard=10), body weight (kg) and 24 hrs. The values from the two independent 7D-PAR reports were summed together to capture the same 14-day period assessed with the DLW method.

AEE estimates for all the three methods (i.e. DLW, Mini, and 7D-PAR) were obtained by subtracting thermic effect of foods (10% of TEE) and measured RMR from the TEE (AEE= [(TEEx0.9)−RMR]).

Statistical analyses

Data were checked for normality and constant variance assumptions. Descriptive statistics were computed to describe the characteristics of the participants and their activity profiles.

Equivalence testing was used to evaluate group-level agreement of Mini and 7D-PAR relative to DLW.[30, 31] This approach is different from a regular hypothesis testing of a difference in that it reverses the traditional null hypothesis to specify that two methods are not the same. Therefore, equivalence testing is more suitable for validation studies to examine whether one method equates with the other since it provides a direct test of equivalence (i.e. rejecting the null hypothesis). In order for the null hypothesis to be rejected (i.e., two methods are not equivalent) in a 95% equivalence test, 90% confidence intervals (CI) of Mini or 7D-PAR must be completely included within a pre-specified zone of equivalence (±10% of the mean of the DLW in this study). This corresponds to rejecting two one-sided tests: a lower end of 95% CI greater than a lower boundary (i.e., −10%) of the equivalence zone and an upper end of 95% CI smaller than an upper boundary (i.e., +10%) of the equivalence zone. Tukey-Kramer adjustment was applied to account for multiple methods (i.e., Mini, 7D-PAR, and DLW) for each participant.

Traditional indicators of agreement were also computed to facilitate comparisons with other studies. Mean absolute percent errors (MAPE) were computed as the average of the absolute value of the residuals divided by the actual DLW value, multiplied by 100. Pearson correlations were computed to evaluate the associations between the various estimates of TEE and AEE. Bland-Altman graphical procedures along with 95% limits of agreement (LoA)[32] were used to examine agreement across the range of TEE and AEE values between the alternative methods (Mini, 7D-PAR) and DLW. The averages of the two methods were regressed to the differences on the Bland-Altman plots in order to quantify any patterns of systematic bias. The equivalence testing was performed using SAS Version 9.3 (SAS Institute Inc., Cary, NC, USA), and all other statistical analyses were performed using STATA/SE Version 12 (StataCorp LP, College Station, TX, USA).

RESULTS

Twenty nine participants (12 males, 17 females) completed the study. Participants wore the monitors for 97.9% (±3.8%) of the time during the 14 days of monitoring. Descriptive statistics for the participants study cohort are provided in Table 1.

In performing the equivalence testing, the original TEE values violated the assumptions of the normal distribution and equal variance. Therefore, we logarithmically transformed the data, which led to the satisfaction of both the normality (i.e. through a p-value of 0.10 from the Shapiro-Wilk's test and visual inspection on the histogram) and equal variance (through a p-value of 0.06 from the Breusch-Pagan/Cook-Weisberg test) assumptions. As shown in Figure 1, results from 95% equivalence testing indicated that TEE from the Mini (90% CI; log of 7.74 and 7.9) and 7D-PAR (90% CI; log of 7.8 and 8.0) were equivalent to TEE values measured with DLW (equivalence zone; log of 7.0 and 8.6). A subsequent analyses by gender also indicated that TEE values from both the Mini and 7D-PAR were equivalent to those from the DLW. In estimating AEE vales, however, neither the Mini (90% CI; 699.0 and 910.5 kcal/d) nor the 7D-PAR (90% CI; 889.1 and 1130.7 kcal/d) was equivalent to the DLW (equivalence zone; 741.8 and 906.6 kcal/d). A similar pattern of results was identified for males and females with neither the Mini or the 7D-PAR yielding AEE values equivalent to the DLW values (see Figure 1).

Compared to the DLW, the Mini underestimated TEE (difference ranges from −33.0 to −12.1 kcal/d) while the 7D-PAR overestimated TEE (difference ranges from 96.7 to 276.2 kcal/d). The MAPEs of the Mini (range from 6.2 to 7.1%) and 7D-PAR (range from 8.8 to 14.9%)were small in estimating TEE values and this was consistent for both men and women (See Table 2). The MAPEs were considerably higher for estimating AEE but they were much smaller for the Mini (range from 19.1 to 34.9%) than the 7D-PAR (range from 36.8 to 118.1%). The smaller MAPE values for the Mini were consistent for all demographic comparisons. Correlations with the DLW estimates were also consistently higher for the Mini (range from 0.59 to 0.88) than for the 7D-PAR (range from 0.38 to 0.73).

Bland-Altman plots along with 95% LoA revealed no specific pattern of systematic bias for the Mini in estimating TEE (panel (a); r=0.02, p-value=0.851) and AEE (panel (c); r=0.02, p-value=0.861) (See Figure 2 and Table 3). However, evidence of systematic bias was identified for the 7D-PAR for TEE (panel (b); r=0.26, p-value=0.001) and AEE (panel (d); r=0.22, p-value=0.068). In both cases, there was larger EE over-estimation for higher TEE or AEE values. Relatively larger LoAs were observed for the 7D-PAR in comparison with the Mini for both TEE and AEE (See Table 3 and Figure 2).

DISCUSSION

Overall, relative to the DLW method, both the Mini and 7D-PAR showed equivalence and small MAPEs in estimating TEE values, but demonstrated non-equivalence and considerable MAPEs for AEE.

To date, only a single study[21] has been carried out that compared both accelerometer-based and self-reported measures of EE to the DLW technique in older adults. Colbert and colleagues[21] used DLW in 56 older adults to compare AEE from several activity monitors as well as three different self-report instruments. The resulting findings were similar to those from the present study.[21] For example, they[21] also observed large MAPEs for AEE for the objective measurements (range: 22.5–26.8%) but even larger MAPEs for the self-report instruments (range: 30.4–32.8%). In addition, the associations between the monitors and the DLW method were moderate (range: r=0.48–0.60), but low associations for the self-report instruments (range: r=0.07–0.28).[21] However, the study by Colbert et al.[21] did not examine agreement for TEE or investigate overall group-level agreement among different methods. However, the present study directly evaluated both TEE and AEE and employed a robust and innovative methodology for group-level agreement (i.e. equivalence testing).

The results for the validity of the Mini monitor relative to DLW were consistent with values recently reported in a study by Mackey et al.[22] who used the DLW method to validate the previous model of the Mini (i.e. Sense Wear Pro Armband) in a sample of 19 older adults. They[22] reported non-significant mean differences in TEE between the Armband and DLW, and high intra-correlation coefficients (r>0.90). For AEE, however, the Armband yielded significant mean differences and moderate intra-correlation coefficients (r=0.65 to r=0.72). Overall, objective multi-sensor monitoring tools appear to provide accurate estimates of TEE, but inaccurate estimates of AEE. However, it is important to note that RMR alone can account for approximately 60%~80% of TEE,[33] and participants' demographic characteristics are the major components of determining TEE estimates (from the Mini) and RMR measures. Hence, it is not surprising for the Mini to show relatively low errors for TEE comparisons, and high errors for AEE comparisons. Nonetheless, multi-sensor data from the Mini appeared to have reduced the AEE prediction errors as compare to the 7D-PAR in these relatively active older subjects, although it is not transparent how the multiple sensor data were modeled due to the proprietary nature of the software algorithm.

The supportive evidence for the validity of the 7D-PAR relative to the DLW is also noteworthy. For TEE, we found the 7D-PAR to have good agreement with the DLW at both the group-level and individual-level. This was consistent with the two previous studies[18, 19] that demonstrated the validity of the 7D-PAR relative to the DLW for TEE in older adults. To be specific, these previous studies[18, 19] both reported mean percent differences of approximately 10%, which were not significantly different. While these studies[18, 19] both demonstrated relatively high validity for estimating TEE, our study and others[20] demonstrate the lower accuracy for AEE. It is also important to note that we found in this study a larger MAPE and lower correlations with DLW for the 7D-PAR method, compared to the Mini. Bland-Altman plots for TEE showed a similar systematic bias than the Mini, with larger 95% LoA. Nearly identical patterns of findings were also identified for younger adults in previous studies using the DLW method to validate varying types of questionnaires.[18, 29, 34, 35] In general, the 7D-PAR appears to clearly provide less precision than the objective monitor but the ability to capture context of PA may still provide some advantages.

On average, the 7D-PAR overestimated TEE and AEE for our sample of older adults. A related comparison between self-report instruments and the DLW method[36] showed similar overestimations in AEE and minutes of PA. Researchers suggested a possible influence of social desirability and social approval explaining the “over reporting” by the participants. However, there are a number of alternative explanations for the overestimation in EE with the 7D-PAR. One source of error is with the use of standard metabolic equivalents (i.e., MET=3.5 mL O_2.kg^{-1}. $min.^{-1}$) in the calculations of EE since these do not account for individual variability in RMR and may be high.[37] Another possible explanation could be the inability of the 7D-PAR to discriminate sitting time (~1–1.2 METs) from light activity (1.5 METs). This may seem like a small difference but it would add considerable error due to the large amount of sitting time in a day.[38] A final explanation is due to a systematic perception of PA being more vigorous than it really wa The strengths of the study include the use of the DLW method as a criterion measure to validate both widely used objective and subjective monitoring tools. Another strength is the inclusion of measured RMR obtained via indirect calorimetry in estimating AEE for all the three methods compared, which led to reducing inherent errors in the AEE comparisons. A noteworthy aspect of the study is the high level of compliance noted for wear time (average of 97.9% wear time). This may have contributed to the more favorable findings than reported in a similar study[21] with older adults (average of 58.3%).

Key limitations include the small sample size and the use of a convenience sample, thereby, precluding the generalization of the results to the general population. Additional work is warranted to advance research on physical activity assessment techniques in older adults but the findings support the use of the Mini and the 7D-PAR in this population.

In conclusion, the results indicate that the Mini and 7D-PAR both provide reasonably valid estimates for TEE, but not for AEE, in relation to the DLW technique in older adults under free-living environments. The objective monitor would provide more robust estimates but the subjective measures may identify discrepancies or provide valuable contextual information of energy expended under free-living conditions.

Acknowledgments

Source of funding: National Institute of Health grant (HL091024-04)

The authors gratefully acknowledge the enthusiastic support of the volunteers who participated in this study. The authors have no personal relationships with the National Institutes of Health that financially supported this study. This work was supported by a National Institute of Health grant (HL091024-04).

References

1. Sherman SE, Dagostino RB, Cobb JL, Kannel WB. Does Exercise Reduce Mortality-Rates in the Elderly - Experience from the Framingham Heart-Study. Am Heart J. 1994; 128(5):965–972.10.1016/0002-8703(94)90596-7 [PubMed: 7942491]
2. Shahar DR, Yu B, Houston DK, Kritchevsky SB, Lee JS, Rubin SM, et al. Dietary factors in relation to daily activity energy expenditure and mortality among older adults. Journal of Nutrition Health & Aging. 2009; 13(5):414–420.10.1007/s12603-009-0077-y
3. Wijsman CA, Westendorp RGJ, Verhagen EALM, Catt M, Slagboom E, de Craen AJM, et al. Effects of a Web-Based Intervention on Physical Activity and Metabolism in Older Adults: Randomized Controlled Trial. J Med Internet Res. 2013; 15(11):e233. UNSP. 10.2196/jmir.2843 [PubMed: 24195965]
4. Zhao G, Ford ES, Li C, Balluz LS. Physical activity in U.S. older adults with diabetes mellitus: prevalence and correlates of meeting physical activity recommendations. J Am Geriatr Soc. 2011; 59(1):132–137.10.1111/j.1532-5415.2010.03236.x [PubMed: 21226683]
5. Middleton LE, Manini TM, Simonsick EM, Harris TB, Barnes DE, Tylavsky F, et al. Activity Energy Expenditure and Incident Cognitive Impairment in Older Adults. Arch Intern Med. 2011; 171(14):1251–1257.10.1001/archinternmed.2011.277 [PubMed: 21771893]
6. United States. Dept. of Health and Human Services. 2008 physical activity guidelines for Americans: be active, healthy, and happy!. U.S. Dept. of Health and Human Services; Washington, DC: 2008.
7. Black AE, Coward WA, Cole TJ, Prentice AM. Human energy expenditure in affluent societies: An analysis of 574 doubly-labelled water measurements. Eur J Clin Nutr. 1996; 50(2):72–92. [PubMed: 8641250]
8. Johannsen DL, DeLany JP, Frisard MI, Welsch MA, Rowley CK, Fang X, et al. Physical activity in aging: comparison among young, aged, and nonagenarian individuals. J Appl Physiol (1985). 2008; 105(2):495–501.10.1152/japplphysiol.90450.2008 [PubMed: 18556430]
9. Blumenthal HT. Normal Human Aging - the Baltimore Longitudinal-Study of Aging - Shock, Nw, Greulich, Re, Andres, R, Arrenberg, D, Costa, Pt, Lakatta, Eg, Tobin, Jd. Journals of Gerontology. 1985; 40(6):767–767.
10. Manini TM, Everhart JE, Anton SD, Schoeller DA, Cummings SR, Mackey DC, et al. Activity energy expenditure and change in body composition in late life. Am J Clin Nutr. 2009; 90(5): 1336–1342.10.3945/ajcn.2009.27659 [PubMed: 19740971]
11. Speakman JR, Westerterp KR. Associations between energy demands, physical activity, and body composition in adult humans between 18 and 96 y of age. Am J Clin Nutr. 2010; 92(4):826–834.10.3945/ajcn.2009.28540 [PubMed: 20810973]
12. Newman AB, Lee JS, Visser M, Goodpaster BH, Kritchevsky SB, Tylavsky FA, et al. Weight change and the conservation of lean mass in old age: the Health, Aging and Body Composition Study. Am J Clin Nutr. 2005; 82(4):872–878. quiz 915-876. [PubMed: 16210719]
13. Morley JE. Anorexia of aging: physiologic and pathologic. Am J Clin Nutr. 1997; 66(4):760–773. [PubMed: 9322549]
14. Montoye, HJ.; Kemper, HC.; Saris, WHM.; Washburn, RA. Measuring Physical Activity and Energy Expenditure. Human Kinetics; Champaign, IL: 1996.
15. Starling, RD. Use of doubly labeled water and indirect calorimetry to assess physical activity. In: Welk, GJ., editor. Physical Activity Assessments for Health-Related Research. Human Kinetics; Champaign, IL: 2002. p. 197-209.
16. Westerterp KR, Brouns F, Saris WHM, Tenhoor F. Comparison of Doubly Labeled Water with Respirometry at Low-Activity and High-Activity Levels. J Appl Physiol. 1988; 65(1):53–56. [PubMed: 3136137]
17. Schoeller DA. Recent advances from application of doubly labeled water to measurement of human energy expenditure. J Nutr. 1999; 129(10):1765–1768. [PubMed: 10498745]
18. Bonnefoy M, Normand S, Pachiaudi C, Lacour JR, Laville M, Kostka T. Simultaneous validation of ten physical activity questionnaires in older men: A doubly labeled water study. J Am Geriatr Soc. 2001; 49(1):28–35.10.1046/j.1532-5415.2001.49006.x [PubMed: 11207839]

19. Seale JL, Klein G, Friedmann J, Jensen GL, Mitchell DC, Smiciklas-Wright H. Energy expenditure measured by doubly labeled water, activity recall, and diet records in the rural elderly. Nutrition. 2002; 18(7–8):568–573. [PubMed: 12093431]
20. Schuit AJ, Schouten EG, Westerterp KR, Saris WHM. Validity of the physical activity scale for the elderly (PASE): According to energy expenditure assessed by the doubly labeled water method. J Clin Epidemiol. 1997; 50(5):541–546.10.1016/S0895-4356(97)00010-3 [PubMed: 9180646]
21. Colbert LH, Matthews CE, Havighurst TC, Kim K, Schoeller DA. Comparative Validity of Physical Activity Measures in Older Adults. Med Sci Sport Exer. 2011; 43(5):867–876.10.1249/Mss.0b013e3181fc7162
22. Mackey DC, Manini TM, Schoeller DA, Koster A, Glynn NW, Goodpaster BH, et al. Validation of an armband to measure daily energy expenditure in older adults. J Gerontol A Biol Sci Med Sci. 2011; 66(10):1108–1113. e-pub ahead of print 2011/07/08. [pii]. 10.1093/gerona/glr101glr101 [PubMed: 21734231]
23. Bowles HR. Measurement of active and sedentary behaviors: closing the gaps in self-report methods. Journal of physical activity & health. 2012; 9 (Suppl 1):S1–4. e-pub ahead of print 2012/02/01. [PubMed: 22287442]
24. Troiano RP, Pettee Gabriel KK, Welk GJ, Owen N, Sternfeld B. Reported physical activity and sedentary behavior: why do you ask? Journal of physical activity & health. 2012; 9 (Suppl 1):S68–75. e-pub ahead of print 2012/02/01. [PubMed: 22287450]
25. Johannsen DL, Calabro MA, Stewart J, Franke W, Rood JC, Welk GJ. Accuracy of armband monitors for measuring daily energy expenditure in healthy adults. Med Sci Sports Exerc. 2010; 42(11):2134–2140.10.1249/MSS.0b013e3181e0b3ff [PubMed: 20386334]
26. Levine JA. Nonexercise activity thermogenesis (NEAT): environment and biology. Am J Physiol-Endoc M. 2005; 288(1):E285–E285.10.1152/ajpendo.00479.2004
27. Racette SB, Schoeller DA, Luke AH, Shay K, Hnilicka J, Kushner RF. Relative Dilution Spaces of H-2-Labeled and O-18-Labeled Water in Humans. Am J Physiol-Endoc M. 1994; 267(4):E585–E590.
28. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of Physical Activities: an update of activity codes and MET intensities. Med Sci Sport Exer. 2000; 32(9):S498–S516.10.1097/00005768-200009001-00009
29. Washburn RA, Jacobsen DJ, Sonko BJ, Hill JO, Donnelly JE. The validity of the Stanford seven-day physical activity recall in young adults. Med Sci Sport Exer. 2003; 35(8):1374–1380.10.1249/01.Mss.0000079081.08476.Ea
30. Dixon PM, Pechmann JHK. A statistical test to show negligible trend. Ecology. 2005; 86(7):1751–1756.10.1890/04-1343
31. Wellek, S. Testing statistical hypotheses of equivalence. Chapman & Hall/CRC; Boca Raton, Fla: 2003.
32. Bland JM, Altman DG. Statistical Methods for Assessing Agreement between Two Methods of Clinical Measurement. Lancet. 1986; 1(8476):307–310. [PubMed: 2868172]
33. Goran MI. Energy metabolism and obesity. Med Clin North Am. 2000; 84(2):347–362. [PubMed: 10793646]
34. Besson H, Brage S, Jakes RW, Ekelund U, Wareham NJ. Estimating physical activity energy expenditure, sedentary time, and physical activity intensity by self-report in adults. Am J Clin Nutr. 2010; 91(1):106–114.10.3945/ajcn.2009.28432 [PubMed: 19889820]
35. Mahabir S, Baer DJ, Giffen C, Clevidence BA, Campbell WS, Taylor PR, et al. Comparison of energy expenditure estimates from 4 physical activity questionnaires with doubly labeled water estimates in postmenopausal women. Am J Clin Nutr. 2006; 84(1):230–236. [PubMed: 16825700]
36. Adams SA, Matthews CE, Ebbeling CB, Moore CG, Cunningham JE, Fulton J, et al. The effect of social desirability and social approval on self-reports of physical activity. Am J Epidemiol. 2005; 161(4):389–398.10.1093/Aje/Kwi054 [PubMed: 15692083]
37. Byrne NM, Hills AP, Hunter GR, Weinsier RL, Schutz Y. Metabolic equivalent: one size does not fit all. J Appl Physiol. 2005; 99(3):1112–1119.10.1152/japplphysiol.00023.2004 [PubMed: 15831804]

38. Welk GJ, Thompson RW, Gaper DI. Temporal validation of scoring algorithms for the 7-day physical activity recall. Meas Phy Edu Exer Sci. 2001; 5(3):123–138.

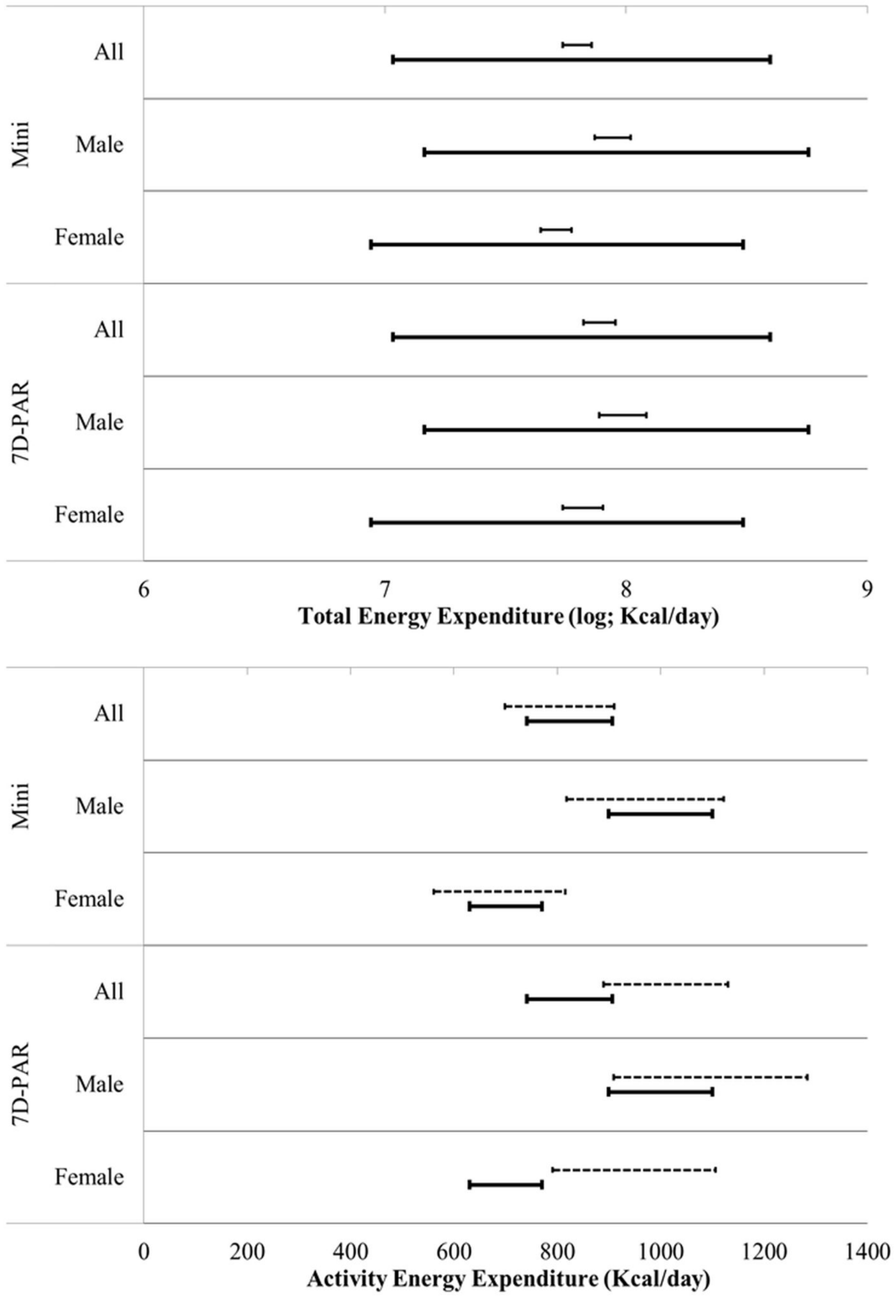

Figure 1.

Results from 95% equivalence testing for total energy expenditure (top; log scale) and activity energy expenditure (bottom) for the Sense Wear Mini Armband (Mini) and 7-Day Physical Activity Recall (7D-PAR) compared to Doubly-Labeled Water (DLW). across all, male, and female. The thicker solid line is the equivalence zone for DLW while the other line is that for either the Mini or PAR. A single thinner solid line indicates that the two measures are equivalent while a single dotted line indicates that they are not.

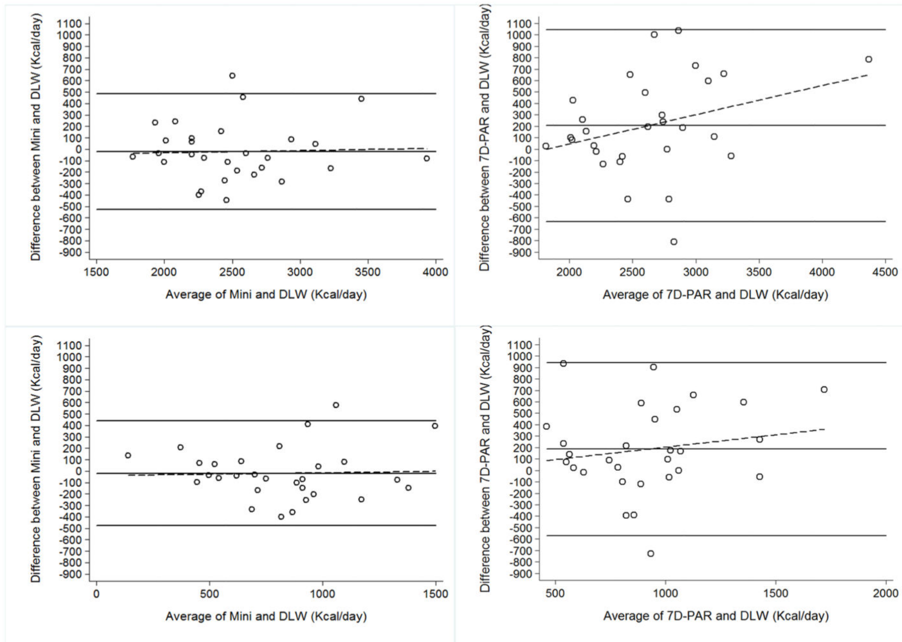

Figure 2.

Bland Altman plots for total energy expenditure and activity energy expenditure (kcal/day): Mini vs. DLW for TEE (top-left panel), (b) 7D-PAR vs. DLW for TEE (top-right panel), (c) Mini vs. DLW for AEE (bottom-left panel) and (d) 7D-PAR vs. DLW for AEE (bottom-right panel). Note: Mini-Sense Wear Mini Armband; DLW-Doubly labeled water; TEE-total energy expenditure; AEE–active energy expenditure

Table 1

Descriptive statistics for the sample population.

	All (n=29)		Men (n=12)		Women (n=17)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	68.8	6.3	68.9	6.4	68.8	6.4
Height (cm)	169.0	7.9	174.4	7.7	165.2	5.5
Weight (kg)	75.6	17.9	81.9	21.0	71.2	14.4
Body Mass Index (kg/m^2)	26.3	4.9	26.7	5.3	26.0	4.7
RMR (kcal·day^{-1})	1446.7	275.2	1609.9	239.0	1331.5	243.3
TEF (kcal·day^{-1})	252.3	49.7	90.0	49.1	225.8	29.3
PAL (TEE/RMR)						
DLW	1.76	0.27	1.80	0.19	1.73	0.31
Mini	1.75	0.27	1.78	0.25	1.72	0.29
7D-PAR	1.89	0.28	1.86	0.26	1.92	0.30
PAI (RMR/Weight)						
DLW	11.1	4.2	12.5	3.7	10.2	4.4
Mini	10.9	4.6	12.1	4.9	10.1	4.3
7D-PAR	13.1	3.1	13.1	3.5	13.2	2.9

Note: RMR – resting metabolic rate; SD – Standard Deviation; TEF – thermic effect of food; PAL – Physical Activity Level; TEE – Total Energy Expenditure; PAI – Physical Activity Index; DLW – Doubly-Labeled Water; Mini – Sense Wear Mini Armband; 7D-PAR – 7-Day Physical Activity Recall

Table 2

Comparison of the Sense Wear Mini Armband (Mini) and 7-day Physical Activity Recall (7D-PAR) with the doubly-labeled water (DLW) method in assessment of total energy expenditure (TEE) and activity energy expenditure (AEE) (kcal/day).

		Mini (Kcal/day)		7D-PAR (Kcal/day)		DLW (Kcal/day)		Mini vs. DLW					7D-PAR vs. DLW				
								ME[a] (Kcal/day)		MAPE[b] (%)		r[c]	ME (Kcal/day)		MAPE (%)		r
		M	SD	M	SD	M	SD	M	SD	M	SD		M	SD	M	SD	
TEE	All (n=29)	*2501.7*	*506.3*	*2729.6*	*621.2*	*2523.2*	*497.4*	*−21.5*	*253.9*	*8.0*	*6.7*	*.87**	*206.4*	*424.9*	*13.8*	*12.6*	*.73**
	Men (n=12)	*2866.5*	*550.6*	*3007.0*	*705.5*	*2899.6*	*490.7*	*−33.0*	*266.1*	*7.3*	*6.2*	*.88**	*107.4*	*490.6*	*13.6*	*8.8*	*.72**
	Women (n=17)	*2244.1*	*264.4*	*2533.7*	*484.4*	*2257.5*	*293.4*	*−13.4*	*252.9*	*8.4*	*7.1*	*.59**	*276.2*	*371.5*	*13.9*	*14.9*	*.64**
AEE	All (n=29)	*804.8*	*334.8*	*1009.9*	*382.5*	*824.2*	*327.5*	*−19.4*	*228.5*	*28.4*	*37.8*	*.76**	*185.7*	*382.4*	*84.5*	*242.1*	*.43**
	Men (n=12)	*970.0*	*361.6*	*1096.4*	*461.6*	*999.7*	*285.6*	*−29.7*	*239.5*	*19.1*	*16.2*	*.75**	*96.7*	*441.5*	*36.8*	*23.0*	*.38*
	Women (n=17)	*688.2*	*267.1*	*948.9*	*316.2*	*700.3*	*303.6*	*−12.1*	*227.6*	*34.9*	*47.0*	*.69**	*248.6*	*334.4*	*118.1*	*315.1*	*.42*

Mini-Sense Wear Mini Armband; 7D-PAR–7-Day Physical Activity Recall; DLW-Doubly labeled water; TEE-total energy expenditure; AEE–activity energy expenditure; ME–mean error; MAPE–mean absolute percent error; SD–standard deviation; r–Correlation coefficient. An asterisk (*) indicates a significant association at an alpha level of .05.

[a] Difference in TEE between the Mini (and 7D-PAR) and DLW;

[b] Absolute difference in TEE between the Mini (and 7D-PAR) and DLW divided by TEE, then multiplied by 100;

[c] Correlation coefficients

Table 3

Statistics obtained from regression analyses in relation to Bland-Altman plots.

	Mini vs. DLW						7D-PAR vs. DLW					
	Mean	95% LoA		Fitted Line			Mean	95% LoA		Fitted Line		
	Bias	L	U	β_0	β_1	p	Bias	L	U	β_0	β_1	p
TEE (kcal/day)												
All (n=29)	−21.5	−529.3	486.3	−69.4	0.02	0.851	206.4	−632.4	1045.1	−463.6	0.26	0.001
Male (n=12)	−33.0	−565.2	499.1	−386.4	0.12	0.468	107.4	−841.9	1056.8	−1119.9	0.42	0.001
Female (n=17)	−13.4	−519.3	492.4	281.0	−0.13	0.622	276.2	−450.0	1002.4	−1137.3	0.59	<0.001
AEE (kcal/day)												
All (n=29)	−19.4	−476.4	437.6	−39.7	0.02	0.861	185.7	−569.1	940.6	−12.7	0.22	0.068
Male (n=12)	−29.7	−508.7	449.2	−293.4	0.27	0.281	96.7	−757.7	951.1	−602.1	0.67	0.001
Female (n=17)	−12.1	−467.3	443.2	93.1	−0.15	0.503	248.6	−405.0	902.1	201.4	0.06	0.718

LoA–limits of agreement; Mini-Sense Wear Mini Armband; DLW-Doubly labeled water; TEE-total energy expenditure; AEE–active energy expenditure; β_0-intercept; β_1–slope; L–lower limit; U–Upper limit