BMJ Open Sport & Exercise Medicine

Impact of walking aids on estimating physical activity using a tri-axial accelerometer in frail older adults

Yuki Nishida [ID], [1,2] Shigeho Tanaka,[1,3] Yoichi Hatamoto,[1] Mana Hatanaka,[1] Kazuko Ishikawa-Takata,[4] Takayuki Abe,[5] Yasuki Higaki,[6] Fuminori Katsukawa[2]

To cite: Nishida Y, Tanaka S, Hatamoto Y, *et al*. Impact of walking aids on estimating physical activity using a tri-axial accelerometer in frail older adults. *BMJ Open Sport & Exercise Medicine* 2021;**7**:e001014. doi:10.1136/bmjsem-2020-001014

Accepted 12 June 2021

[1]National Institute of Health and Nutrition, National Institutes of Biomedical Innovation, Health and Nutrition, Tokyo, Japan
[2]Keio University, Yokohama, Japan
[3]Kagawa Nutrition University, Sakado, Japan
[4]Tokyo University of Agriculture, Tokyo, Japan
[5]Yokohama City University, Yokohama, Japan
[6]Fukuoka University, Fukuoka, Japan

Correspondence to
Professor Shigeho Tanaka; tanaka.shigeho@eiyo.ac.jp

ABSTRACT

Objectives This study aimed to compare the estimation error of physical activity level (PAL) estimated using a tri-axial accelerometer between an independent walking group and an assisted walking group with walking aids.

Methods Subjects were 6 older adults who could walk independently and 10 older adults requiring walking assistance during gait. Total energy expenditure (TEE) was measured using the doubly labelled water (DLW) method over 2 weeks and PAL was calculated as the measured TEE divided by the basal metabolic rate measured using indirect calorimetry (PAL_{DLW}). The participants wore a tri-axial accelerometer (Active style Pro HJA-750C) on the waist simultaneously as the DLW period, and the estimated PAL was derived from it (PAL_{ACC}).

Results The median PAL estimation error in the assisted walking group was −0.30 kcal/day (range: −0.77 to −0.01 kcal/day) and more underestimated than that in the independent walking group (p=0.02). The estimation error of PAL_{ACC} was significantly correlated with PAL_{DLW} (r=−0.80, p<0.01).

Conclusions Using the accelerometer, PAL was underestimated for older adults who used walking aids but not for those who walked independently under free-living conditions.

What are the new findings

- The accelerometer underestimated physical activity levels (PALs) in older adults who use walking aids under free-living conditions.
- There was a possibility that the energy cost was higher in the assisted group than that in the independent walking group if the former group relied too much on their walking aids.
- Future studies should develop an algorithm for estimating the PAL specific to elderly adults using walking aids.

INTRODUCTION

Although frailty is a high-risk factor for falls, hospitalisation, institutionalisation and mortality in older adults,[1] it can be reversed using early interventions, such as increasing physical activities.[2] Accelerometers are one of the methods for evaluating the physical activity level (PAL) and are widely used in many studies under free-living conditions. However, it is uncertain in older adults who use walking aids such as cane and wheel walker whether PAL can be accurately estimated using the accelerometer under free-living conditions. Park *et al* examined the validity of an accelerometer for estimating metabolic equivalents (METs) during gait compared with the Douglas bag technique under experimental conditions and concluded that the METs were more underestimated in participants using walking aids than in controls.[3] From the above, we hypothesise that the PAL estimated using accelerometers under free-living conditions is underestimated in older adults using walking aids.

This study calculated PAL by total energy expenditure (TEE) measured using the doubly labelled water (DLW) method and basal metabolic rate (BMR) using indirect calorimetry as the gold standard in frail older adults and then, compared the estimation error of PAL using a tri-axial accelerometer between independent and assisted walking groups with walking aids.

METHODS

Subjects

Twenty-four older adults were recruited for this cross-sectional observational study. The inclusion criteria were participants aged 65 years or above, and attending an orthopaedic clinic or an elderly day care facility in metropolitan Tokyo. Participants were excluded if they had infections, serious disease or dementia; used medications that could affect energy or water metabolism; or were at risk of aspiration. Six participants withdrew their consent before measurement, and two were excluded as they had dementia or were using thyroid medications. Therefore, 16 participants were analysed in this study.

Study design

Body weight (kg) and height (cm) were measured using an electronic scale at each facility, and body mass index (BMI) was calculated as the body weight divided by the height squared (kg/m^2).

The TEE was measured using the multiple-point DLW method in each facility over a 14-day period (TEE_{DLW}). Baseline urine samples were collected within a few days before drinking the DLW. All participants collected their urine samples seven times, in air-tight containers after the dose day of DLW, where day 1, day 2, day 13 and day 14 were mandatory. An oral dose of 0.06 g/kg body weight ^2H_2O (99.8 atom%, Cambridge Isotope Laboratories, Massachusetts, USA) and 1.4 g/kg body weight $H_2{}^{18}O$ (10.0 atom%, Taiyo Nippon Sanso, Tokyo, Japan) was administered according to the body weight. The total body water was calculated as the mean of the dilution space estimated by ^2H and ^{18}O after correction for isotope exchange by 1.041 and 1.007, respectively.[4] Carbon dioxide production was estimated from the difference between the elimination rates of ^2H and ^{18}O and was used to calculate TEE. The food quotient was derived from the dietary assessment data (g/day) of the Brief-Type Self-Administered Diet History Questionnaire[5] and calculated using the Black *et al*'s equation.[6] The average value of all subjects (0.870) was used to estimate TEE. During the DLW period, the BMR was measured in the fasting state. The gas exchange of measurement was initiated by indirect calorimetry using a ventilated hood (Quark RMR, COSMED, Rome, Italy) after the subject had rested comfortably for 30 min lying down, and consistent data longer than 5 min were used in the analyses. The BMR was calculated according to the Weir equation,[7] and the PAL was calculated as the TEE_{DLW} divided by the measured BMR (PAL_{DLW}).

During the DLW period, the participants wore a triaxial accelerometer (Active style Pro HJA-750C, Omron Healthcare, Kyoto) on the waist, and the estimated activity energy expenditure (AEE) was obtained. This AEE was estimated based on the predicted BMR by Ganpule *et al*'s equation[8] and thus, PAL by the accelerometer (PAL_{ACC}) was calculated as follows: PAL_{ACC}=(predicted BMR+AEE)×10/9)/predicted BMR).[9] The coefficient '10/9' was used to consider diet-induced thermogenesis. Estimated TEE using the accelerometer (TEE_{ACC}) was calculated by multiplying measured BMR by PAL_{ACC}.

We used the Kihon Checklist Questionnaire,[10] whose higher scores represented frail conditions.

Statistical analysis

Median (minimum and maximum) was calculated for continuous variables, and proportion was calculated for binary variables. Mann-Whitney U test was used to compare the distributions of the continuous variables between the two groups or measured and predicted values. The association between variables was estimated using the Spearman's rank correlation coefficient. Significance levels for all tests were two-tailed, 0.05. Statistical analyses were performed using SPSS for Windows (V.26.0J).

RESULTS

Participants characteristics

In total, 16 participants were included in the analysis. The demographic factors and baseline characteristics of the participants are summarised in table 1. Six participants were able to walk independently, while 10 participants needed the cane and/or wheel walker to walk outdoors. Male participants tended to be younger than female participants (median age: 83 years vs 90 years, p=0.15),

Table 1 Demographic factors and baseline characteristics of the study participants

	All	Independent walking	Assisted walking	P value
n	16	6	10	
Orthopaedic clinic, n (%)	7 (43.8)	5 (83.3)	2 (20.0)	
Elderly day care facility, n (%)	9 (56.3)	1 (16.7)	8 (80.0)	
Male, n (%)	5 (31.2)	4 (66.7)	1 (10.0)	
Age, years	89 (75–94)	83 (75–93)	90 (82–94)	0.12
Height, cm	147.5 (137.5–166.1)	159.3 (143.7–166.1)	143.0 (137.5–155.8)	<0.01
Weight, kg	55.4 (35.1–65.2)	60.8 (38.2–65.2)	50.9 (35.1–63.9)	0.07
BMI, kg/m^2	23.4 (18.1–30.1)	23.3 (18.5–26.7)	23.7 (18.1–30.1)	0.59
Medical history				
Orthopaedic disease, n (%)	14 (87.5)	6 (100)	8 (80.0)	
Cerebrovascular disease, n (%)	2 (12.5)	0 (0)	2 (20.0)	
Heart disease, n (%)	2 (12.5)	1 (16.7)	1 (10.0)	
Kihon Checklist	8 (5–15)	8 (5–12)	11 (5–15)	0.17

Values are expressed as median (minimum–maximum).
BMI, body mass index;

Table 2 Comparison of variables between the independent and assisted walking group

	All (n=16)	Independent walking (n=6)	Assisted walking (n=10)	P value
Measured BMR, kcal/day	985 (718 to 1370)	1166 (718 to 1370)	962 (739 to 1052)	0.04
TEE_{DLW}, kcal/day	1732 (1197 to 2274)	1750 (1197 to 2274)	1732 (1437 to 2079)	0.87
TEE_{ACC}, kcal/day	1543 (1108 to 2014)	1635 (1120 to 2014)	1470 (1108 to 1676)*	0.18
$TEE_{ACC}–TEE_{DLW}$, kcal/day	−257 (−749 to 36)	−142 (−260 to 36)	−282 (−749 to −15)	0.02
PAL_{DLW}	1.73 (1.36 to 2.15)	1.64 (1.36 to 1.67)	1.87 (1.51 to 2.15)	0.02
PAL_{ACC}	1.51 (1.31 to 1.69)	1.45 (1.31 to 1.68)	1.54 (1.33 to 1.69)*	0.36
$PAL_{ACC}–PAL_{DLW}$	−0.24 (−0.77 to 0.03)	−0.15 (−0.21 to 0.03)	−0.30 (−0.77 to −0.01)	0.02

Values are expressed as median (minimum–maximum).
*P<0.01 vs measured values.
Measured BMR, basal metabolic rate measured by indirectly calorimeter; PAL_{ACC}, physical activity level estimated by the tri-axial accelerometer; PAL_{DLW}, physical activity level calculated as the total energy expenditure measured by the double labelled water method and divided by the basal metabolic rate measured by an indirect calorimeter; TEE_{ACC}, total energy expenditure estimated by the tri-axial accelerometer; TEE_{DLW}, total energy expenditure measured by the double labelled water method.

and there was only one man using the walking aids. Height and weight were higher in the independent walking group than in the assisted walking group, while the BMI was approximately the same in the two groups (p=0.59). The assisted walking group tended to be higher scores of the Kihon Checklist (p=0.17) than the independent walking group.

Energy outcomes

Table 2 shows that the measured BMR was significantly higher in the independent walking group than in the assisted walking group (p=0.04). There was no significant difference for TEE_{DLW} between both groups (p=0.87); however, TEE_{ACC} tended to be higher in the independent walking group (p=0.18). The estimation errors of TEE_{ACC} were −142 kcal/day (−260kcal/day to 36 kcal/day) in the independent group and −282 kcal/day (−749 kcal/day to −15 kcal/day) in the assisted walking group, and there was a significant difference in that error between both groups (95% CI for difference, 11 kcal/day to 366 kcal/day, p=0.02). Furthermore, the estimation error of PAL in the independent and assisted walking groups were −0.15 (−0.21, 0.03) and −0.30 (−0.77, −0.01), respectively, and the underestimation of PAL was also significantly larger in the assisted walking group than that in the independent walking group (95% CI for difference, 0.05 to 0.41, p=0.02). Figure 1 shows that the estimation error of PAL_{ACC} was significantly correlated with PAL_{DLW} (r=−0.80, p<0.01).

DISCUSSION

To the best of our knowledge, this is the first study to examine the estimation error of physical activity using the tri-axial accelerometer among frail older adults, who used the walking aids under free-living conditions, compared with that evaluated with the DLW method.

Reason for higher PAL in the assisted walking group

Most of the participants in this study had multiple osteoarthritis of the knee, hip or lumbar. A cane is useful for diminishing pain and improving function in patients with osteoarthritis[11]; thus, the patients in this study might be more active when using walking aids than without using it. Meanwhile, older adults demand higher energy costs when walking with assistive devices such as a wheeled walker and Merry Walker.[12] Furthermore, Fujika *et al* showed that greater upper-extremity support during walking caused higher energy costs.[13] The present assisted walking group tended to be frailer than the independent walking group and there was a possibility that PAL_{DLW} was higher in the assisted group as they relied too much on their walking aids.

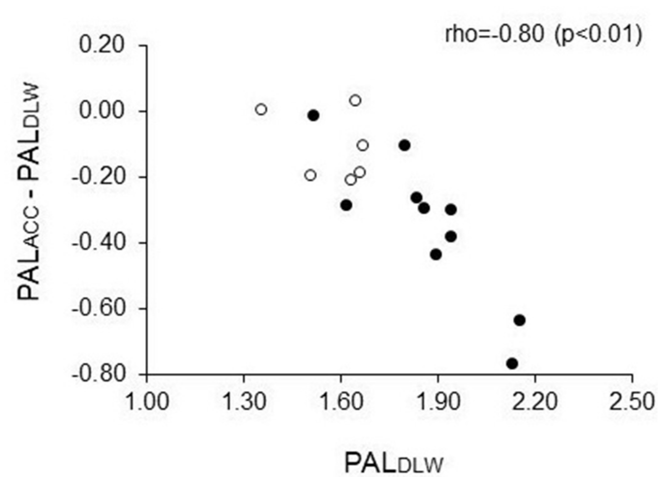

Figure 1 Relationship between the estimation error of PAL using the tri-axial accelerometer and PAL_{DLW}. The black and white dots represent assisted walking group and independent walking group, respectively. PAL, physical activity level; PAL_{ACC}, PAL estimated by the tri-axial accelerometer; PAL_{DLW}, PAL calculated as the total energy expenditure measured using the doubly labelled water method and divided by the basal metabolic rate measured using an indirect calorimeter.

Features for the present algorithm of the accelerometer

The present algorithm for estimating METs was developed based on young to middle-aged adults[14] and its estimated METs values were underestimated in elderly adults, particularly for higher intensity activities.[15] Our study showed that PAL_{DLW} was significantly higher in the assisted walking group than in the independent walking group; thus, underestimation of PAL_{ACC} may have occurred in the former group regardless of the use of walking aids.

Comparisons to previous research

Our previous study[9] showed a negative correlation between PAL_{DLW} and the estimation error of PAL_{ACC} using the same accelerometer in elderly patients with diabetes. $PALs_{DLW}$ in the high and middle activity groups were 1.90 and 1.70, which were close to the present assisted and independent walking groups, respectively. However, the difference in underestimation between the previous high activity group and middle activity group (−0.04) was smaller than that between the present assisted and independent walking group (−0.15). Therefore, we considered that the use of walking aids has an effect on the PAL_{ACC} underestimation.

Moreover, Yamada *et al* showed that the underestimation of PAL_{ACC} was larger in care home residents, including some participants using walking aids than in the other independent walking groups, although PAL_{DLW} was the lowest in care home residents. These findings suggest that the use of walking aids affects the underestimation of PAL_{ACC}.

Limitation

Our study has a significant limitation in that the sample size was small since this measurement was interrupted owing to the COVID-19 pandemic.

CONCLUSION

Using the accelerometer, PAL was underestimated for older adults who used walking aids but not for those who walked independently under free-living conditions.

Acknowledgements The authors would like to thank Chifumi Shimomura and Jun Yasukata for their technical assistance. We are also grateful to Shigeyuki Muraki, Daisuke Kimizuka and Hiroyuki Shirato for recruitment of participants.

Contributors YN: study design, collection, analysis and interpretation of data, and wrote the manuscript. ST: study design, collection and interpretation of data, and critical review of the manuscript. YHa: study design, data collection and critical review of the manuscript. MH: collection of data and critical review of the manuscript. KI-T: study design, collection of data and critical review of the manuscript. TA and YHi: study design and critical review of the manuscript. FK: study design, collection and interpretation of data, and critical review of the manuscript.

Funding This work was supported by the Japan Agency for Medical Research and Development (grant number: JP20ek0210112).

Competing interests ST and FK report a grant from Japan Agency for Medical Research and Development during the conduct of the study (grant number: JP20ek0210112).

Patient consent for publication Not required.

Ethics approval The study protocol was approved by the Ethics Committees of the National Institutes of Biomedical Innovation, Health and Nutrition (number: NIBIOHN104), Keio University (number: 2019-02) and Kagawa Nutrition University (number: 297) in accordance with the Declaration of Helsinki. All participants provided written informed consent after being informed of the study procedures.

Provenance and peer review Not commissioned; externally peer reviewed.

ORCID iD

Yuki Nishida http://orcid.org/0000-0002-8056-1515

REFERENCES

1 Fried LP, Tangen CM, Walston J, *et al*. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001;56:M146–57.
2 Negm AM, Kennedy CC, Thabane L, *et al*. Management of frailty: a systematic review and network meta-analysis of randomized controlled trials. *J Am Med Dir Assoc* 2019;20:1190–8.
3 Park J, Ishikawa-Takata K, Tanaka S, *et al*. Accuracy of estimating step counts and intensity using Accelerometers in older people with or without assistive devices. *J Aging Phys Act* 2017;25:41–50.
4 Racette SB, Schoeller DA, Luke AH, *et al*. Relative dilution spaces of 2H- and 18O-labeled water in humans. *Am J Physiol* 1994;267:E585–90.
5 Kobayashi S, Murakami K, Sasaki S, *et al*. Comparison of relative validity of food group intakes estimated by comprehensive and brief-type self-administered diet history questionnaires against 16 D dietary records in Japanese adults. *Public Health Nutr* 2011;14:1200–11.
6 Black AE, Prentice AM, Coward WA. Use of food quotients to predict respiratory quotients for the doubly-labelled water method of measuring energy expenditure. *Hum Nutr Clin Nutr* 1986;40:381–91.
7 WEIR JBDEB. New methods for calculating metabolic rate with special reference to protein metabolism. *J Physiol* 1949;109:1–9.
8 Ganpule AA, Tanaka S, Ishikawa-Takata K, *et al*. Interindividual variability in sleeping metabolic rate in Japanese subjects. *Eur J Clin Nutr* 2007;61:1256–61.
9 Nishida Y, Tanaka S, Nakae S, *et al*. Validity of the use of a Triaxial Accelerometer and a physical activity questionnaire for estimating total energy expenditure and physical activity level among elderly patients with type 2 diabetes mellitus: CLEVER-DM study. *Ann Nutr Metab* 2020;76:62–72.
10 Yamada Y, Nanri H, Watanabe Y, *et al*. Prevalence of frailty assessed by fried and Kihon checklist indexes in a prospective cohort study: design and demographics of the Kyoto-Kameoka longitudinal study. *J Am Med Dir Assoc* 2017;18:733.e7–733.e15.
11 Jones A, Silva PG, Silva AC, *et al*. Impact of cane use on pain, function, general health and energy expenditure during gait in patients with knee osteoarthritis: a randomised controlled trial. *Ann Rheum Dis* 2012;71:172–9.
12 Protas EJ, Raines ML, Tissier S. Comparison of spatiotemporal and energy cost of the use of 3 different walkers and unassisted walking in older adults. *Arch Phys Med Rehabil* 2007;88:768–73.
13 Fujika Y, Hamada H, Sekikawa K, *et al*. Effect of body weight support on predicted locomotive physical activity. *J Phys Ther Sci* 2018;30:759–63.
14 Ohkawara K, Oshima Y, Hikihara Y, *et al*. Real-time estimation of daily physical activity intensity by a triaxial accelerometer and a gravity-removal classification algorithm. *Br J Nutr* 2011;105:1681–91.
15 Nagayoshi S, Oshima Y, Ando T, *et al*. Validity of estimating physical activity intensity using a triaxial accelerometer in healthy adults and older adults. *BMJ Open Sport Exerc Med* 2019;5:e000592.