Published in final edited form as:
J Phys Act Health. 2016 June ; 13(6 Suppl 1): S78–S83. doi:10.1123/jpah.2015-0721.

Predictive validity of a thigh-worn accelerometer METs algorithm in 5-12 year-old children

Abstract

Background—To validate the activPAL3™ algorithm for predicting metabolic equivalents (TA_{METs}) and classifying MVPA in 5-12 year-old children.

Methods—Fifty-seven children (9.2±2.3y, 49.1% boys) completed 14 activities including sedentary behaviors (SB), light (LPA) and moderate-to-vigorous physical activities (MVPA). Indirect calorimetry (IC) was used as the criterion measure. Analyses included equivalence testing, Bland-Altman procedures and area under the receiver operating curve (ROC-AUC).

Results—At the group level, TA_{METs} were significantly equivalent to IC for handheld e-game, writing/coloring and standing class activity ($p<0.05$). Overall, TA_{METs} were overestimated for SB (7.9±6.7%) and LPA (1.9±20.2%) and underestimated for MVPA (27.7±26.6%); however, classification accuracy of MVPA was good (ROC-AUC=0.86). Limits of agreement were wide for all activities, indicating large individual error (SB: -27.6-44.7%, LPA: -47.1-51.0%, MVPA: -88.8-33.9%).

Conclusions—TA_{METs} were accurate for some SB and standing, but were overestimated for overall SB and LPA, and underestimated for MVPA. Accuracy for classifying MVPA was, however, acceptable.

Keywords

Energy expenditure; physical activity; accelerometry; calorimetry; sedentary behavior

Introduction

Accurate measurement of both sedentary behaviors (SB) and moderate-to-vigorous physical activities (MVPA) is needed to investigate the independent effect of these behaviors on children's health. It is preferable to use one monitor to objectively measure both behaviors to minimize participant burden. The activPAL3™ (PAL Technology Ltd., Glasgow, Scotland) is a thigh-worn activity monitor that uses triaxial acceleration data (20Hz) to assess the position (with respect to gravity) and movement of the limb. Placement on the thigh assists in overcoming difficulties in differentiating between SB and standing or some light-intensity physical activities (LPA), which is common to data analysis approaches used with hip-worn

Conflicts of interest:
The authors declare no financial interests related to the research.

Cover letter:
The following manuscript has not been previously published, is not presently under consideration by another journal, and will not be submitted to another journal before a final editorial decision from JPAH is rendered.

This submission is for the 2016 NCCOR supplement monitors.[1] The activPAL3™ software classifies periods spent sitting/lying, standing or stepping. For studies of physical activity behaviors and obesity prevention in children, it would be useful if activPAL3™ data could also accurately assess time spent in MVPA and estimate metabolic equivalents (METs). The activPAL3™ provides a MET estimate (TA_{METs}) using a proprietary algorithm, based on default values for each posture combined with step rate and duration of the activity. Previous studies have validated the TA_{METs} algorithm in 4-6 year-olds[2] and in 15-25 year-old females.[3] Thigh-accelerometry has shown promising results for assessing SB in 9-10 year-olds.[4] However, to our knowledge, no studies have evaluated TA_{METs} algorithm in school-aged children. Therefore, the aim of this study was to examine the predictive validity of TA_{METs} algorithm and the accuracy for classifying MVPA in 5-12 year-old children.

Methods

Fifty-seven 5-12y children, without physical or health conditions that would affect participation in physical activity, were recruited as part of an activity monitor validation study. The study was approved by the University of Wollongong Health and Medical Human Research Ethics Committee. Parental written consent and participant verbal assent were obtained prior to participation.

Participants were required to visit the laboratory on two occasions. Anthropometric measures were completed using standardized procedures after which BMI (kg/m^2) and weight status[5] were calculated. Children completed a protocol of 14 semi-structured 5-min activities including SB, LPA, and MVPA, described elsewhere.[6] Activities were categorized as SB, LPA and MVPA for descriptive purposes based on the Compendium of Energy Expenditure for Youth.[7]

At each visit, children were fitted with an activPAL3™ placed mid-anteriorly on the right thigh. The activPAL3™ is a small and light-weight (53 x 35 x 7mm, 15.0g) single unit triaxial accelerometer. The activPAL3™ software provides an indirect estimate of TA_{METs} based on default values for sitting/lying (1.25 MET), standing (1.40 MET) and stepping at 120 steps per minute (4 MET). Energy expenditure for cadences of greater or less than 120 steps per minute (spm) are calculated using the formula: $MET.h^{-1} = (1.4 \times d) + (4-1.4) \times (c/120) \times d$, in which c = cadence (spm), d = activity duration (hours). Software version 7.2.32 was used to export TA_{METs} in 15-s epochs.

Oxygen consumption (O_2) and carbon dioxide production (CO_2) were assessed using a portable breath-by-breath respiratory gas analysis system (MetaMax®3B, Cortex, Biophysics, Leipzig, Germany) to provide resting metabolic rate (RMR) and the criterion assessment of physical activity energy expenditure. Prior to every measurement, the analyzer was calibrated according to the manufacturer’s guidelines. At the beginning of each laboratory visit, the thigh-accelerometer and indirect calorimetry (IC) were synchronized with an internal computer clock. RMR was measured at the start of the participant’s second visit, while lying down awake on a mattress in supine position with the arms at the sides, resting with minimal movement for 10 min in a darkened room. Breath-by-breath samples from the data collected between minutes 7.0 and 9.0 were averaged to calculate mean volume of O_2. The participants' measured RMR was used to define one MET. Metabolic data from the activities were converted into youth METs (scaled to the children's RMR) and averaged over 15-s epochs to align with the thigh-accelerometry data using customized software.

Normality of the data was confirmed prior to analyses. The predictive validity of TA_{METs} was examined at the group level using the 95% equivalence test. In order to reject the null-hypothesis of the equivalence test, the 90% confidence interval (CI) of TA_{METs} should entirely fall within the predefined equivalence region of ±10% of the criterion METs assessed by IC.[8] Measurement agreement and systematic bias for TA_{METs} were evaluated at the individual level using Bland-Altman procedures. Sensitivity, specificity, and area under the receiver operating curve (ROC-AUC) were calculated to evaluate the accuracy for classifying MVPA. A dichotomous coding system was created using 1 for ≥3METs and 0 for <3METs. ROC-AUC values were defined as excellent (0.9-1.0), good (0.8-0.9), fair (0.7-0.8) or poor (<0.7).[9] Data reduction and statistical analyses were performed using the statistical computing language R and SPSS version 19.0.

Results

Descriptive characteristics of participants are presented in Table 1. All participants completed the protocol. Data from one child were entirely excluded from the analyses and data from 4 participants for a total of 9 activities were excluded because of IC failure. Some 15-s epochs were partly excluded due to misalignment of thigh-accelerometry data with IC data. A total of 16,337 epochs were included for analysis, accounting for 98.8% of the total data. Mean measured METs for SB, LPA and MVPA activities were 1.17±0.08, 2.50±0.78 and 5.08±1.15, respectively. TA_{METs} were 1.25±0.0, 2.58±0.94 and 3.80±0.23, respectively. Energy expenditure data per activity are presented in Table 2 for the complete sample, as well as additional data per age group. Statistical analyses were performed for the complete sample (5-12y) only (Table 3). At the group level, TA_{METs} were significantly equivalent to IC for handheld e-game (p=0.01), writing/coloring (p<0.01) and standing (p=0.01). All other activities were not equivalent to IC (p>0.05). Mean TA_{METs} were underestimated by 7.1% ±25.9%. TA_{METs} for SB were slightly overestimated by the algorithm (7.9±6.7%). TA_{METs} for slow walk were overestimated by 32.0%; however, TA_{METs} for all other LPAs were underestimated by 4.2%-10.9%, resulting in a small overestimation of mean TA_{METs} (1.9±20.2%) for LPA. TA_{METs} for brisk walk were also overestimated (21.2%), whereas TA_{METs} for the remaining MVPA activities were underestimated by 34.4-47.3%. On average, TA_{METs} for MVPA were underestimated by 27.7±26.6%. Limits of agreement were wide for all activities, indicating large individual error. Systematic bias was found for all activities (p<0.001), with larger overestimation for low intensities and larger underestimation for high intensities (plots not presented). However, TA_{METs} exhibited good classification accuracy for MVPA (ROC-AUC = 0.85, sensitivity = 0.84, specificity = 0.87).

Discussion

This study demonstrated that TA_{METs} were significantly equivalent to IC for handheld e-game, writing/coloring and standing at the group level, whereas no other activities were equivalent to IC. Overall, TA_{METs} for SB were slightly overestimated compared to measured METs. TA_{METs} for slow and brisk walking were also overestimated with a larger error. TA_{METs} for the remaining LPAs were slightly overestimated compared to measured METs, whereas TA_{METs} for the remaining MVPA activities were underestimated by a larger amount. Considerable error was demonstrated at the individual level for all activities. Although TA_{METs} for MVPA were underestimated, classification accuracy was acceptable.

Our findings were consistent with previous studies in preschool children[2] and 15-25 year-old females.[3] These studies reported an overall underestimation of 15% and 11% for TA_{METs} using thigh-accelerometry, respectively. Although the results in our study demonstrated an overall underestimation of TA_{METs}, the mean bias was slightly smaller (7.1%±25.9%) than previous studies. Janssen et al.[2] reported an overestimation of 6% for SB and an underestimation of 15.3% and 32.8% for LPA and MVPA, respectively, among 4-6 year-old children. These values are similar to an overestimation of 7.9% for SB in our study and underestimation of 27.7% for MVPA. In contrast with Janssen et al.,[2] we found an overestimation of 1.9% for LPA. However, when excluding slow walk, the TA_{METs} for remaining LPAs were underestimated by 4.2%-10.9%. Harrington et al.[3] demonstrated that TA_{METs} during walking at lower speed was overestimated, whereas TA_{METs} during higher walking speeds were underestimated. This is in line with the overestimation at the lower intensities and underestimation during higher intensities found in our study and by Janssen et al.[2] The overestimated TA_{METs} during over-ground brisk walk in our study seems to contradict the findings from Harrington et al.[3] at higher treadmill walking speeds, which might be explained by differences in the age of the samples and protocols. Despite the underestimation of TA_{METs} for MVPA activities, the algorithm showed good classification accuracy for this intensity when using a 3-MET threshold. This was likely because the 15-s MET values were consistently underestimated, but were typically above 3 METs and so accurately categorized as MVPA. Therefore, the monitor might be appropriate to use for classification of MVPA in combination with estimating SB in school-aged children.

As suggested in previous studies,[2,3] the predictive validity of the proprietary algorithm might be affected because step rate is included as the only independent variable. A study by Aminian et al.[4] validated the step count function of the monitor in 9-10 year old children. Step counts were overestimated in over-ground fast walking, which might explain the overestimated TA_{METs} during this activity in our protocol. Other potential predictors such as thigh-accelerometry counts,[3] in addition to age, height and weight might improve accuracy.

A strength of this study is the large sample size including a broad age range and a wide range of semi-structured lifestyle activities. A potential limitation was that RMR values were measured pre-exercise and might not reflect true rest. Furthermore, findings in this study need to be confirmed during less structured activities or under free-living conditions.

Conclusion

This study in school-aged children suggests that the TA_{METs} algorithm performed reasonably well at the group level for some SB activities and standing, but estimates were inaccurate for higher intensities and large variability was found at the individual level.

Europe PMC Funders Author Manuscripts

Therefore, the algorithm may need further development and improvement before it can be used to accurately estimate METs. Although estimates of METs were inaccurate for MVPA, classification accuracy for MVPA was good when using a 3 METs threshold. This suggests that the TA_{METs} algorithm may be suitable for classifying MVPA in school-aged children.

Acknowledgments

We would like to thank participating children and parents, and Melinda Smith for her assistance with recruitment and data collection. DPC was funded by a National Heart Foundation of Australia Postdoctoral Research Fellowship (PH 11S 6025) and an Australian Research Council (ARC) Discovery Early Career Researcher Award (DE140101588). TH is funded by a National Health and Medical Research Council (NHMRC) Early Career Fellowship (APP1070571). ADO is supported by a National Heart Foundation of Australia Career Development Fellowship (CR11S 6099).

Funding source/trial registration: This study was funded by the National Heart Foundation of Australia (G11S5975).

References

1. Janssen X, Cliff DP. Issues related to measuring and interpreting objectively measured sedentary behavior data. Meas Phys Educ Exerc Sci. 2015; 19(3):116–124.
2. Janssen X, Cliff DP, Reilly JJ, et al. Validation and calibration of the activPAL™ for estimating METs and physical activity in 4–6 year olds. J Sci Med Sport. 2014; 17(6):602–606. [PubMed: 24289913]
3. Harrington DM, Welk GJ, Donnelly AE. Validation of MET estimates and step measurement using the ActivPAL physical activity logger. J Sports Sci. 2011 Mar; 29(6):627–633. [PubMed: 21360402]
4. Aminian S, Hinckson EA. Examining the validity of the ActivPAL monitor in measuring posture and ambulatory movement in children. Int J Behav Nutr Phys Act. 2012; 9:119. [PubMed: 23031188]
5. Kuczmarski RJ, Ogden CL, Guo SS, et al. 2000 CDC Growth Charts for the United States: methods and development. Vital Health Stat 11. 2002; 246:1–190.
6. van Loo CMT, Okely AD, Batterham M, et al. Validation of the SenseWear Mini activity monitor in 5–12-year-old children. J Sci Med Sport. In press.
7. Ridley K, Ainsworth BE, Olds TS. Development of a compendium of energy expenditures for youth. Int J Behav Nutr Phys Act. 2008; 5(1):45–53. [PubMed: 18782458]
8. Batterham MJ, Van Loo C, Charlton KE, Cliff DP, Okely AD. Improved interpretation of studies comparing methods of dietary assessment: combining equivalence testing with the limits of agreement. British Journal of Nutrition. 2016; 115(07):1273–1280. [PubMed: 26879342]
9. Metz CE. Basic principles of ROC analysis. Semin Nucl Med. 1978; 8(4):283–298. [PubMed: 112681]
10. Weir JBV. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol. 1949; 109(1–2):1. [PubMed: 15394301]

Table 1

Descriptive characteristics of the participants

	n	Age (y)	Height (cm)	Weight (kg)	BMI ($kg \cdot m^{-2}$)	BMI (Percentile)
Total	57	9.2 ± 2.3	135.9 ± 14.6	32.7 ± 10.9	17.1 ± 2.5	53.2 ± 28.6
Girls	29	8.9 ± 2.1	134.4 ± 14.4	30.6 ± 9.5	16.4 ± 2.1	46.7 ± 26.6
Boys	28	9.5 ± 2.4	137.5 ± 14.6	34.8 ± 12.0	17.8 ± 2.8	59.9 ± 29.4
5-9y	32 (20F, 12M)	7.5 ± 1.5	126.4 ± 10.5	26.4 ± 6.7	16.2 ± 1.9	54.3 ± 27.3
10-12y	25 (9F, 16M)	11.3 ± 1.0	148.2 ± 8.8	40.7 ± 10.0	18.2 ± 2.9	51.7 ± 30.6

Notes: BMI, body mass index; y, years; cm, centimeters; kg, kilograms; m, meters; F, female; M, male.

Europe PMC Funders Author Manuscripts

Europe PMC Funders Author Manuscripts

Table 2

Energy expenditure by activities for indirect calorimetry and metabolic equivalents for indirect calorimetry (METs) and the thigh-accelerometer (TA_{METs})

		Indirect Calorimetry								activPAL3™	
Activity	**n**	**kcal/min**	**Min - Max**	**L/min**	**Min - Max**	**ml/kg/min**	**Min - Max**	**METs**	**Min - Max**	**TA_{METs}**	**Min - Max**
RMR											
5-12y	56	1.19 ± 0.24	0.81 - 2.15	0.24 ± 0.05	0.17 - 0.42	7.89 ± 1.80	3.59 - 12.09	-	-	-	-
5-9y	31	1.06 ± 0.13	0.81 - 1.31	0.22 ± 0.03	0.17 - 0.27	8.57 ± 1.71	5.78 - 12.09	-	-	-	-
10-12y	25	1.35 ± 0.26	0.91 - 2.15	0.28 ± 0.05	0.19 - 0.42	7.05 ± 1.57	3.59 - 10.18	-	-	-	-
TV viewing											
5-12y	56	1.24 ± 0.25	0.83 - 2.08	0.26 ± 0.05	0.17 - 0.43	8.29 ± 1.73	5.68 - 12.98	1.09 ± 0.16	0.84 - 1.81	1.25 ± 0.01	1.21 - 1.25
5-9y	31	1.12 ± 0.16	0.83 - 1.50	0.23 ± 0.03	0.17 - 0.31	9.10 ± 1.61	5.95 - 12.98	1.10 ± 0.14	0.84 - 1.56	1.25 ± 0.01	1.21 - 1.25
10-12y	25	1.39 ± 0.27	0.92 - 2.08	0.29 ± 0.06	0.19 - 0.43	7.28 ± 1.31	5.68 - 10.87	1.08 ± 0.18	0.90 - 1.81	1.25 ± 0.00	1.23 - 1.25
Computer game											
5-12y	56	1.28 ± 0.25	0.67 - 1.78	0.27 ± 0.05	0.14 - 0.38	8.55 ± 1.80	5.39 - 12.10	1.13 ± 0.18	0.75 - 1.83	1.25 ± 0.02	1.25 - 1.35
5-9y	31	1.17 ± 0.19	0.67 - 1.50	0.24 ± 0.04	0.14 - 0.31	9.50 ± 1.64	5.70 - 12.10	1.15 ± 0.17	0.75 - 1.54	1.25 ± 0.01	1.25 - 1.33
10-12y	25	1.41 ± 0.26	0.96 - 1.78	0.29 ± 0.06	0.19 - 0.38	7.38 ± 1.23	5.39 - 9.56	1.10 ± 0.20	0.75 - 1.83	1.25 ± 0.02	1.25 - 1.35
Handheld e-game											
5-12y	55	1.36 ± 0.25	0.85 - 2.24	0.28 ± 0.05	0.18 - 0.46	9.12 ± 2.18	5.93 - 14.17	1.19 ± 0.18	0.93 - 1.90	1.25 ± 0.00	1.25 - 1.26
5-9y	30	1.25 ± 0.17	0.85 - 1.70	0.26 ± 0.04	0.18 - 0.35	10.27 ± 2.10	5.99 - 14.17	1.22 ± 0.16	0.94 - 1.50	1.25 ± 0.00	1.25 - 1.26
10-12y	25	1.49 ± 0.28	0.94 - 2.24	0.31 ± 0.06	0.19 - 0.46	7.79 ± 1.37	5.93 - 11.07	1.16 ± 0.20	0.93 - 1.90	1.25 ± 0.00	1.25 - 1.25
Writing/Coloring											
5-12y	55	1.44 ± 0.28	0.91 - 2.18	0.30 ± 0.06	0.19 - 0.45	9.71 ± 2.25	5.41 - 15.99	1.27 ± 0.22	0.94 - 2.26	1.25 ± 0.00	1.25 - 1.29
5-9y	30	1.33 ± 0.20	0.91 - 1.82	0.28 ± 0.04	0.19 - 0.38	10.86 ± 2.11	7.12 - 15.99	1.30 ± 0.17	1.01 - 1.78	1.25 ± 0.01	1.25 - 1.29
10-12y	25	1.58 ± 0.30	1.08 - 2.18	0.33 ± 0.06	0.22 - 0.45	8.28 ± 1.47	5.41 - 12.07	1.24 ± 0.26	0.94 - 2.26	1.25 ± 0.00	1.25 - 1.26
Standing activity											
5-12y	56	1.70 ± 0.34	1.15 - 2.77	0.35 ± 0.07	0.24 - 0.57	11.34 ± 2.25	7.66 - 16.45	1.50 – 0.23	1.11 - 2.58	1.42 ± 0.02	1.40 - 1.51
5-9y	31	1.53 ± 0.24	1.15 - 2.06	0.32 ± 0.05	0.24 - 0.43	12.41 ± 2.07	8.85 - 16.45	1.50 ± 0.19	1.20 - 1.85	1.42 ± 0.02	1.40 - 1.51
10-12y	25	1.90 ± 0.34	1.32 - 2.77	0.40 ± 0.07	0.28 - 0.57	10.02 ± 1.71	7.66 - 13.03	1.49 ± 0.27	1.11 - 2.58	1.41 ± 0.01	1.40 - 1.44
Getting ready											
5-12y	56	2.81 ± 0.63	1.64 - 4.32	0.59 ± 0.13	0.33 - 0.92	18..64 ± 3.07	13.06 - 24.90	2.49 ± 0.45	1.67 - 4.01	2.20 ± 0.13	1.89 - 2.47
5-9y	31	2.52 ± 0.48	1.64 - 3.42	0.53 ± 0.10	0.33 - 0.71	20.17 ± 2.04	15.09 - 24.35	2.48 ± 0.44	1.67 - 3.23	2.23 ± 0.14	1.94 - 2.47

Europe PMC Funders Author Manuscripts

Activity	n	Indirect Calorimetry								activPAL3™	
		kcal/min	Min - Max	L/min	Min - Max	ml/kg/min	Min - Max	METs	Min - Max	TA_{METs}	Min - Max
10-12y	25	3.18 ± 0.59	1.98 - 4.32	0.66 ± 0.13	0.42 - 0.92	16.75 ± 3.11	13.06 - 24.90	2.50 ± 0.48	1.73 - 4.01	2.16 ± 0.12	1.89 - 2.41
Slow Walk											
5-12y	56	3.26 ± 0.66	2.28 - 4.93	0.68 ± 0.14	0.46 - 1.04	21.80 ± 3.86	15.05 - 33.44	2.90 ± 0.50	1.92 - 4.45	3.96 ± 0.23	3.50 - 4.43
5-9y	31	2.97 ± 0.47	2.28 - 4.61	0.62 ± 0.10	0.46 - 0.97	24.04 ± 3.24	16.40 - 33.44	2.92 ± 0.42	2.31 - 3.95	4.06 ± 0.22	3.64 - 4.43
10-12y	25	3.62 ± 0.70	2.43 - 4.93	0.76 ± 0.15	0.51 - 1.04	19.02 ± 2.55	15.05 - 25.17	2.87 ± 0.60	1.92 - 4.45	3.84 ± 0.19	3.50 - 4.42
Dancing											
5-12y	55	3.53 ± 1.22	1.85 - 6.78	0.73 ± 0.25	0.39 - 1.39	22.77 ± 3.85	15.22 - 32.12	3.09 ± 0.85	1.70 - 5.26	2.73 ± 0.31	1.82 - 3.24
5-9y	31	2.98 ± 0.93	1.85 - 5.78	0.62 ± 0.19	0.39 - 1.22	23.45 ± 3.94	15.22 - 31.45	2.91 ± 0.82	1.70 - 5.15	2.73 ± 0.36	1.82 - 3.24
10-12y	24	4.24 ± 1.21	2.43 - 6.78	0.88 ± 0.25	0.50 - 1.39	21.90 ± 3.62	16.27 - 32.12	3.32 ± 0.86	2.12 - 5.26	2.73 ± 0.24	2.21 - 3.08
Brisk Walk											
5-12y	56	3.88 ± 0.95	2.51 - 6.45	0.80 ± 0.19	0.51 - 1.30	25.34 ± 4.05	17.62 - 37.96	3.38 ± 0.63	2.26 - 5.83	4.13 ± 0.18	3.68 - 4.46
5-9y	31	3.41 ± 0.61	2.51 - 5.12	0.70 ± 0.12	0.51 - 1.05	27.13 ± 3.66	21.12 - 37.96	3.29 ± 0.44	2.63 - 4.42	4.20 ± 0.16	3.68 - 4.46
10-12y	25	4.47 ± 0.99	2.99 - 6.45	0.92 ± 0.20	0.63 - 1.30	23.12 ± 3.41	17.62 - 29.10	3.49 ± 0.81	2.26 - 5.83	4.05 ± 0.17	3.75 - 4.40
Tidy up											
5-12y	55	4.07 ± 1.16	2.21 - 7.05	0.85 ± 0.24	0.45 - 1.49	26.31 ± 3.84	19.72 - 36.75	3.57 ± 0.84	2.14 - 7.42	2.98 ± 0.21	2.45 - 3.31
5-9y	30	3.52 ± 0.85	2.21 - 6.01	0.73 ± 0.18	0.45 - 1.26	27.72 ± 3.84	20.73 - 36.75	3.42 ± 0.65	2.14 - 4.71	3.06 ± 0.16	2.70 - 3.31
10-12y	25	4.74 ± 1.15	2.73 - 7.05	0.99 ± 0.24	0.58 - 1.49	24.63 ± 3.16	19.72 - 30.61	3.75 ± 1.02	2.79 - 7.42	2.87 ± 0.22	2.45 - 3.24
Running											
5-12y	56	6.66 ± 2.12	2.76 - 11.61	1.36 ± 0.44	0.57 - 2.46	42.18 ± 6.99	21.05 - 59.34	5.68 ± 1.34	2.85 - 10.41	3.87 ± 0.38	3.16 - 4.61
5-9y	31	5.28 ± 1.21	2.76 - 7.18	1.08 ± 0.25	0.57 - 1.46	41.59 ± 8.07	21.05 - 59.34	5.05 ± 1.01	2.85 - 6.96	3.75 ± 0.37	3.16 - 4.57
10-12y	25	8.37 ± 1.73	5.18 - 11.61	1.72 ± 0.36	1.06 - 2.46	42.92 ± 5.43	33.05 - 52.75	6.47 ± 1.30	4.09 - 10.41	4.02 ± 0.33	3.45 - 4.61
Locomotor course											
5-12y	54	7.14 ± 2.28	2.68 - 12.17	1.47 ± 0.47	0.56 - 2.54	45.16 ± 7.63	10.08 - 62.81	6.05 ± 1.20	2.81 - 8.22	3.74 ± 0.16	3.38 - 4.05
5-9y	29	5.87 ± 1.34	3.88 - 9.62	1.20 ± 0.27	0.78 - 1.94	45.43 ± 5.68	37.06 - 60.59	5.58 ± 0.91	3.82 - 7.26	3.71 ± 0.16	3.38 - 4.04
10-12y	25	8.62 ± 2.26	2.68 - 12.17	1.78 ± 0.47	0.56 - 2.54	44.85 ± 9.52	10.08 - 62.81	6.59 ± 1.28	2.81 - 8.22	3.77 ± 0.16	3.47 - 4.05
Soccer											
5-12y	55	7.21 ± 2.08	3.53 - 12.76	1.47 ± 0.44	0.73 - 2.73	46.23 ± 7.06	35.19 - 70.82	6.22 ± 1.42	3.48 - 12.28	3.74 ± 0.29	2.85 - 4.29
5-9y	31	6.05 ± 1.41	3.53 - 10.13	1.23 ± 0.29	0.73 - 2.04	47.03 ± 6.27	36.63 - 64.26	5.78 ± 1.18	3.48 - 7.67	3.65 ± 0.26	3.22 - 4.25
10-12y	24	8.70 ± 1.87	5.99 - 12.76	1.79 ± 0.40	1.20 - 2.73	45.19 ± 7.99	35.19 - 70.82	6.77 ± 1.53	4.29 - 12.28	3.86 ± 0.30	2.85 - 4.29
Basketball											

		Indirect Calorimetry								activPAL3™	
Activity	**n**	**kcal/min**	**Min - Max**	**L/min**	**Min - Max**	**ml/kg/min**	**Min - Max**	**METs**	**Min - Max**	**TA_{METs}**	**Min - Max**
5-12y	54	6.64 ± 2.15	3.27 - 11.65	1.36 ± 0.44	0.66 - 2.33	41.44 ± 5.99	28.83 - 54.42	5.65 ± 1.41	2.97 - 11.44	3.51 ± 0.27	2.84 - 4.00
5-9y	29	5.29 ± 1.36	3.27 - 7.90	1.08 ± 0.27	0.66 - 1.59	40.89 ± 6.10	28.83 - 54.42	5.06 ± 1.15	2.97 - 7.04	3.40 ± 0.28	2.84 - 3.84
10-12y	25	8.19 ± 1.81	5.24 - 11.65	1.69 ± 0.37	1.10 - 2.33	42.07 ± 5.93	30.68 - 52.00	6.33 ± 1.39	4.27 - 11.44	3.64 ± 0.20	3.26 - 4.00

Notes: Mean volume of oxygen consumption and carbon dioxide production were converted into units of energy expenditure (kcal/min) using the Weir equation.10 RMR, resting metabolic rate.

Europe PMC Funders Author Manuscripts

Europe PMC Funders Author Manuscripts

Table 3

Statistical analyses for the measurement agreement of metabolic equivalents for indirect calorimetry and the thigh-accelerometer (TA_{METs})

		Equivalence testing[a]			Bland-Altman analysis[b]		
Activity	***n***	**90% CI TA_{METs}**	**Equivalence zone IC**	**p-value**	**Mean bias (%)**	**95% LoA**	**Slope p-value**
TV	56	1.25 – 1.25	0.98 – 1.20	0.992	-14.50	-39.13 – 10.12	0.0001
Computer game	56	1.25 – 1.26	1.02 – 1.24	0.715	-11.80	-42.58 – 18.99	0.0001
Handheld e-game	55	1.25 – 1.25	1.07 – 1.31	0.011	-6.00	-34.00 – 22.06	0.0001
Writing/coloring	55	1.25 – 1.25	1.14 – 1.40	0.000	0.61	-29.64 – 30.86	0.0001
Standing activity	56	1.41 – 1.42	1.35 – 1.65	0.011	4.21	-23.21 – 31.63	0.0001
Getting ready	56	2.17 – 2.23	2.24 – 2.74	0.752	10.86	-25.34 – 47.06	0.0001
Slow walk	56	3.91 – 4.01	2.61 – 3.19	1.000	-32.02	-64.93 – 0.89	0.0001
Dancing	55	2.66 – 2.80	2.78 – 3.40	0.684	9.24	-33.03 – 51.50	0.0001
Brisk walk	56	4.09 – 4.17	3.04 – 3.72	1.000	-21.24	17.36 – 12.77	0.0001
Tidy up	55	2.93 – 3.02	3.21 – 3.93	0.979	15.82	-25.61 – 57.24	0.0001
Basketball	54	3.45 – 3.57	5.00 – 6.12	1.000	43.88	18.36 – 79.87	0.0001
Running	56	3.79 – 3.96	5.11 – 6.25	1.000	35.35	-6.41 – 77.11	0.0001
Locomotor course	54	3.70 – 3.77	5.11 – 6.25	1.000	44.92	5.00 – 84.83	0.0001
Soccer	55	3.67 – 3.80	5.60 – 6.84	1.000	47.26	9.29 – 85.22	0.0001

Notes: LoA, limits of agreement; CI, confidence interval; IC, indirect calorimetry.

[a] 95% equivalence test for TA_{METs}. Methods are equivalent if 90% confidence intervals lie entirely within the equivalence region of indirect calorimetry.

[b] Mean bias was calculated as: measured METs – TA_{METs}; a positive value indicates underestimation of TA_{METs}; a negative value indicates overestimation TA_{METs}.