Original article

Development and validation of GT3X accelerometer cut-off points in 5- to 9-year-old children based on indirect calorimetry measurements

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Abstract

The ActiGraph accelerometer is commonly used to measure physical activity in children. Count cut-off points are needed when using accelerometer data to determine the time a person spent in moderate or vigorous physical activity. For the GT3X accelerometer no cut-off points for young children have been published yet. The aim of the current study was thus to develop and validate count cut-off points for young children.

Thirty-two children aged 5 to 9 years performed four locomotor and four play activities. Activity classification into the light-, moderate- or vigorous-intensity category was based on energy expenditure measurements with indirect calorimetry. Vertical axis as well as vector magnitude cut-off points were determined through receiver operating characteristic curve analyses with the data of two thirds of the study group and validated with the data of the remaining third.

The vertical axis cut-off points were 133 counts per 5 sec for moderate to vigorous physical activity (MVPA), 193 counts for vigorous activity (VPA) corresponding to a metabolic threshold of 5 MET and 233 for VPA corresponding to 6 MET. The vector magnitude cut-off points were 246 counts per 5 sec for MVPA, 316 counts for VPA - 5 MET and 381 counts for VPA - 6 MET. When validated, the current cut-off points generally showed high recognition rates for each category, high sensitivity and specificity values and moderate agreement in terms of the Kappa statistic. These results were similar for vertical axis and vector magnitude cut-off points. The current cut-off points adequately reflect MVPA and VPA in young children. Cut-off points based on vector magnitude counts did not appear to reflect the intensity categories better than cut-off points based on vertical axis counts alone.

Zusammenfassung

ActiGraph Akzelerometer werden häufig zur Messung der körperlichen Aktivität bei Kindern eingesetzt. Um die Zeit zu ermitteln, während der sich ein Kind mit mittlerer oder hoher Intensität bewegt hat, werden entsprechende Grenzwerte der Akzelerometer Counts benötigt. Bisher wurden für den ActiGraph GT3X Akzelerometer noch keine solchen Grenzwerte für jüngere Kinder publiziert. Das Ziel der aktuellen Studie war deshalb, Count-Grenzwerte für jüngere Kinder zu entwickeln und validieren.

32 Kinder im Alter von 5 bis 9 Jahren führten vier Fortbewegungsaktivtäten und vier spielerische Aktivitäten durch. Die Einteilung der Aktivitäten in tiefe, mittlere und hohe Intensität wurde anhand von Energieverbrauchsmessungen mittels Ergospirometrie vorgenommen. Receiver Operating Characteristic Curve Analysen dienten zur Ermittlung der Count-Grenzwerte für die vertikale Achse und die Vektorgrösse aus allen drei Achsen. Die Daten von zwei Dritteln der Kinder wurden zur Entwicklung der Grenzwerte eingesetzt, diejenigen des übrigen Drittels zur Validierung.

Die Grenzwerte für die vertikale Achse lagen bei 133 Counts pro 5 sec für mindestens mittlere Intensität und bei 193 respektive 233 Counts für hohe Intensität, je nachdem, ob ein metabolischer Grenzwert von 5 MET oder 6 MET als Grundlage genommen wurde. Grenzwerte für die Vektorgrösse betrugen 246 Counts pro 5 sec für mittlere Intensität, 316 für hohe Intensität ab 5 MET und 381 für hohe Intensität ab 6 MET. Die Validierung der Count-Grenzwerte ergab generell hohe Erkennungsraten für jede Kategorie, hohe Sensitivitäts- und Spezifitätswerte sowie moderate Übereinstimmungen gemäss der Kappa Statistik. Diese Resultate fielen für die vertikale Achse und die Vektorgrösse ähnlich aus.

Die hier präsentierten Count-Grenzwerte widerspiegeln mittlere bzw. hohe Aktivitäts-Intensitäten bei jüngeren Kindern in angemessener Weise. Dabei scheinen die Grenzwerte, welche auf der Vektorgrösse aus allen drei Achsen bestehen, keine besseren Einschätzungen zu liefern als die Grenzwerte, welche allein auf der Messung mit der vertikalen Achse beruhen.

Introduction

In the past decade, accelerometry has become increasingly popular in physical activity research, as it is a cost effective method of providing objective data on fairly large samples. Accelerometers produce a unit-free figure referred to as counts that needs to be translated into new variables that are physiologically interpretable to be used in epidemiological research or intervention studies. The time children spend in moderate or vigorous activity is such a variable of interest to researchers. To obtain this variable the count value which reflects the lower limit of moderate and of vigorous activity is needed. This value is referred to as the cut-off point. While cut-off points for children under 10 years of age have been developed for the ActiGraph 7164 (Evenson et al., 2008; Pate et al., 2006; Puyau et al., 2002; Sirard et al., 2005) and the GT1M (Jimmy et al., 2012; Pulsford et al., 2011; van Cauwenberghe et al., 2011), no GT3X cut-off points have been published for this age group, so far.

Studies designed to determine cut-off points should include a wide range of activities including locomotion as well as common lifestyle or play activities of an intermittent nature (Freedson et al., 2005; Welk, 2005). Furthermore, activities should cover a continuum from light to vigorous intensity and be typical for the age group to be investigated. Studies in adults have shown that MVPA cut-off points are lower when lifestyle activities are included in the protocol as opposed to locomotor activities alone (Matthews, 2005). In studies involving children under 10 years of age, lower count outputs in relation to energy expenditure have been observed for intermittent activities compared to locomotion (Eston et al., 1998; Evenson et al., 2008; Jimmy et al., 2012; Puyau et al., 2002; Puyau et al., 2004; Rowlands et al., 2004), except for activities involving jumps (Evenson et al., 2008; Jimmy et al., 2012; Puyau et al., 2002).

In addition, a criterion measure is needed in order to determine cut-off points. If the differences in effort between children performing the same activity are to be taken into account, the best criterion measure is a metabolic threshold based on energy expenditure measurements. While measures of energy expenditure per kg body weight often do not adequately cancel out growth-related differences in body size, particularly in children (Welsman & Armstrong, 2007), Metabolic Equivalents (METs) indicate the relation of a person's energy expenditure during an activity to his or her resting energy expenditure. Therefore, they are considered the most suitable energy expenditure unit to be used. However, there has been debate about whether the metabolic thresholds of 3 MET for moderate to vigorous physical activity (MVPA) and 6 MET for vigorous activity (VPA) used in adults are also applicable to children. In their meta-analysis, Ridley and Olds (2008) found large age differences in running with a MET value of 6.05 for a 5-year old and 7.40 for a 10-year old at 8 km/h, compared to 8 MET (Ainsworth et al., 2011) for an adult. These findings support the results from Harrell et al.'s (2005) study, where over 250 children aged 8 to 18 years participated in a range of activities showing that MET values for the youngest age group (8-11/12 years) were about 1 MET lower for running at 8 km/h, rope skipping, shovelling, bench press and leg press compared to adult values. Furthermore, comparisons of various studies with children of a mean age from 4.4 to 12.1 years show that MET values are slightly lower for walking and at least 1 MET lower for jogging and other vigorous activities in younger children (Evenson et al., 2008; Jimmy et al., 2012; Maffeis et al., 1993; Pate et al., 2006; Tanaka et al., 2007). This evidence thus indicates that the MET threshold for MVPA may be similar in young children and adults, but the VPA threshold needs to be clearly lower than the adult value in 5- to 9-year-old children.

Uniaxial models of the ActiGraph accelerometer that are capable of measuring acceleration in the vertical direction have been shown to be valid and reliable for estimating physical activity intensity in children (Corder et al., 2007; Freedson et al., 1997; Puyau et al., 2002; Trost et al., 1998). However, they reflect locomotor activities (walking and running) better than lifestyle activities (e.g. children's games, sports, household chores) (Matthews, 2005; Welk, 2005). To address this problem, the triaxial model GT3X was released. Counts on the three axes are commonly expressed as a compound measure, the vector magnitude ($VM=(x^2 + y^2 + z^2)^{0.5}$). Some studies conducted with children found indeed improved energy expenditure estimates based on vector magnitude counts compared to vertical counts alone (Eston et al., 1998; Louie et al., 1999; Rowlands et al., 2004), while others found no difference (Kavouras et al., 2008; Tanaka et al., 2007). No study so far appears to have compared the validity of cut-off points based on vector magnitude compared to vertical counts. Therefore, the question whether physical activity intensity is really better reflected by triaxial than uniaxial accelerometry remains to be answered (Bassett et al., 2012).

The purpose of the current study was thus to develop and validate GT3X cut-off points for the vertical axis and the vector magnitude in 5- to 9-year old children on the basis of measured metabolic thresholds during locomotor and play activities. Due to the evidence mentioned above, a second aim was to present cut-off values on the basis of 5 MET as a VPA metabolic threshold in addition to the traditional 6 MET threshold. A final aim was to compare the validity of the vertical axis cut-off points to the vector magnitude cut-off points.

Methods

Study population

Measurements were conducted with participants of a holiday sports camp and children of a local pre-school. Children aged 5-9 years were invited to enrol in the study if they had no medical contraindications to exercise. Children and their guardians received written information on the study before signing an informed consent/assent. The study protocol and information leaflets were approved by the regional ethics committee.

Measurement devices

The children's weight and height were measured in light clothing without shoes. Weight was measured with a calibrated mechanical scale (seca, Hamburg, Germany) to the nearest 0.1 kg and height with a portable stadiometer (model 214, seca, Hamburg, Germany) to the nearest 0.1 cm.

Acceleration was measured with the ActiGraph, model GT3X (ActiGraph, LLC, Pensacola, FL, USA). It was strapped around the children's waist with a belt, so that it was placed on the anterior side of the body slightly to the left of the right iliac crest. The accelerometer was programmed with the ActiLife Lifestyle Monitoring System Software Version

3.8.3 (ActiGraph, LLC, Pensacola, FL, USA) to record counts every 5 seconds with the standard filter. The GT3X has yielded high intra- and inter-instrument reliability on shaker table experiments (Santos-Lozano et al., 2012) and has been shown to be valid for estimating energy expenditure in adults exercising on a treadmill (Sasaki et al., 2011) and in youth aged 8 to 15 years (Crouter et al., 2012).

Energy expenditure was measured with a portable breath-by-breath calorimeter (Meta Max 3B; Cortex, Leipzig, Germany), which has been shown to provide reliable and valid measurements (Vogler et al., 2010). The Meta Max was calibrated with a three point calibration process (ambient air pressure, gas and volume) according to the manufacturer's guidelines before each use. The unit was worn on the upper body and connected to a paediatric face mask (Hans Rudolph, Inc., Kansas City, KS, USA) with a twin tube.

Measurement protocol

The measurement protocol has been described in detail previously (Jimmy et al., 2013). Briefly, children came to the laboratory for one visit lasting 1 hour and were equipped with one ActiGraph GT3X, a mask and a Meta Max 3B. Then children engaged in four researcher-paced locomotor activities reflecting speeds of approximately 2 km/h, 4 km/h, 6 km/h and 8 km/h. The researcher and the children walked for 3 minutes and 15 seconds at each speed, followed by a break of at least 5 minutes. The children then engaged in free play, a predetermined soccer course, a toy train activity and playing tag for 4 minutes and 15 seconds each with breaks of at least 4 minutes in between.

Data reduction

Data were downloaded from the Meta Max 3B unit with the Meta Soft Program Version 3.9.7 (Cortex, Leipzig, Germany) and averaged over 5-second intervals. Mean O_2 consumption and mean CO_2 production per activity were calculated in an Excel file for minute 3 in locomotor activities and minutes 3 and 4 in play activities. The equation proposed by Elia and Livesey (1992) was used to convert O_2 and CO_2 values into energy expenditure in kcal. The Schofield weight equation (Schofield, 1985) was chosen to calculate resting energy expenditure (REE) on the basis of a study by Rodriguez et al. (2002), who compared the validity of five REE equations. The mean total energy expenditure for each activity was divided by the REE to obtain the MET value. Energy expenditure was expressed in MET in preference to overall energy expenditure or activity energy expenditure in kcal per kg body weight, because MET values were not correlated to body weight while the latter two outcome measures were.

Accelerometer data in 5 second epochs were downloaded to an Excel file and integrated into the file with the energy expenditure data. Mean accelerometer counts per epoch were calculated for the same time interval of activity as for the energy expenditure analysis before data for each child and each trial were collated and exported to SPSS version 19 (IBM Corporation, Armonk, NY, USA) for further statistical analysis.

Statistical analysis

After splitting the sample into 5 age groups, two thirds of the children from each age group were randomly chosen as the development group (21 children). To determine the cut-off points, eight activity measurements from 21 children were thus available for analysis, totalling 168 observations. The 88 observations from the remaining 11 children served as validation data.

Two sets of metabolic thresholds to distinguish between light, moderate and vigorous activity were used. Firstly, the commonly used adult values of 3 MET to mark the onset of MVPA and 6 MET for VPA were applied. Secondly, the threshold of 3 MET for MVPA was retained but the threshold for VPA was lowered to 5 MET.

Receiver operating characteristic (ROC) curve analysis was used to determine cut-off points with optimal sensitivity and specificity values (Greiner et al., 2000; Jago et al., 2007; Zweig & Campbell, 1993). For this purpose, an index equalling sensitivity plus specificity was calculated and the count value with the highest index was chosen as cut-off value.

For validation, the predicted intensity categories according to the cut-off points were determined for the 88 observations of the 11 children who served as validation group and compared to the measured intensity categories according to the metabolic thresholds. To assess agreement between predicted and measured intensity categories, confusion matrices were computed to determine the percentage of observations correctly identified as light, moderate or vigorous intensity (Staudenmayer et al., 2012). In addition, sensitivity and specificity values for the MVPA and the VPA cut-off points were calculated. Finally, the Kappa statistic was computed and its 95% confidence interval was calculated in order to compare the validity between vertical axis and vector magnitude cut-off points. Kappa coefficients were interpreted according to the recommendation by Landis and Koch (1977).

Results

Study population characteristics

The data of one boy had to be discarded due to an equipment failure. The remaining 20 boys and 12 girls were between 5.14 and 9.23 years old. One child was overweight according to the international standard definition provided by Cole et al. (2000). Further characteristics of the development group and the validation group are shown in *Table 1.*

Table 1: Characteristics of the study group (mean ± SD)

Variable	Development group n=21	Validation group n=11
Age (yrs)	7.54 ± 1.31	7.57 ± 1.37
Height (cm)	125.66 ± 12.83	124.84 ± 9.60
Weight (kg)	25.59 ± 7.32	24.95 ± 5.22
BMI (kg/m^2)	15.86 ± 1.81	15.82 ± 1.28

Energy expenditure

Figure 1 shows the box plots for MET values per activity measured in the whole study group. It shows that the MET value for jogging was below 6 MET for almost all the children. Furthermore, a MET value below 6 is also seen for the majority of the children in soccer and for more than 25% of the children in playing tag.

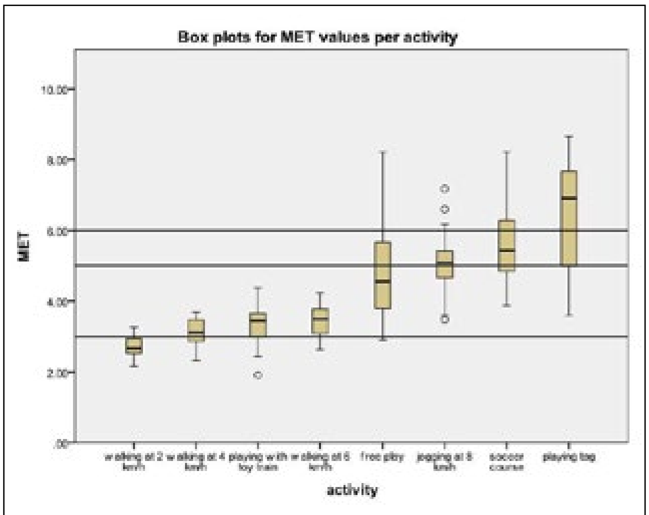

Figure 1: Box plots for MET values per activity in ascending order of mean MET value. Horizontal lines mark the metabolic thresholds of 3, 5 and 6 MET. n = 32 children per activity.

Determination of cut-off points

Vertical axis and vector magnitude cut-off points determined by means of ROC curve analysis on the basis of the metabolic thresholds are shown in *Table 2*, including sensitivity and specificity and area under the curve for each cut-off point.

Validation of cut-off points

Table 3 shows agreement between measured and classified activity intensity categories in the validation group for vertical axis cut-off points and vector magnitude cut-off points in confusion matrices. The overall recognition rate was 64% for the vertical axis cut-off point according to the 3 MET – 6 MET metabolic thresholds as well as the 3 MET – 5 MET metabolic thresholds. For the vector magnitude cut-off points it was 59% according to both sets of metabolic thresholds. *Table 4* shows the sensitivity, specificity and Kappa values for all the cut-off points. Fair agreement according to the Kappa statistic was seen for the vertical axis VPA-6MET cut-off point, good agreement for the vector magnitude VPA-5MET cut-off point and moderate agreement for all other cut-off points (p=0.001 or smaller for all cut-off points). There was considerable overlap in 95% confidence intervals for Kappa values of each vertical axis cut-off point and its respective vector magnitude cut-off point.

Discussion

In this study with 32 children aged 5 to 9 years cut-off points for ActiGraph GT3X vertical axis and vector magnitude counts were determined by means of ROC analysis. The validation results for vertical axis cut-off points showed a 64% recognition rate of activity intensity category overall, sensitivity values ranging from 53 to 85% and specificity values ranging from 79 to 85%. The overall recognition rate for the vector magnitude cut-off points was 59%, sensitivity ranged from 67 to 89% and specificity from 80 to 94% *(Table 4)*. Differences between Kappa values for the vertical axis and the vector magnitude cut-off points were small.

The current study provides count cut-off points corresponding to energy expenditure values of 3 MET for moderate intensity and 6 MET of vigorous intensity as done in previous studies. In addition, cut-off points determined on the basis of metabolic thresholds of 3 MET for moderate intensity and 5 MET for vigorous intensity are presented as an alternative. As outlined in the introduction, there is ample evidence that young children's MET values for running are about 1 MET lower than in adults. Box plots of the current MET values for running, playing tag and soccer *(Fig. 1)* confirm that a lower MET threshold for children under 10 years appears necessary to define vigorous intensity: e.g. when playing tag, nearly all the children put in maximum efforts, yet a considerable proportion of them showed a MET value below 6.

The current ROC analysis for all cut-off points yielded high values of sensitivity, specificity and area under the curve for vertical axis as well as vector magnitude counts *(Table 2)*. These values are comparable to those obtained with ROC curve analysis in most previous child studies with ActiGraph accelerometers (Evenson et al., 2008; Hanggi et al., 2012; Jimmy et al., 2012; Sirard et al., 2005; van Cauwenberghe et al., 2011). In one previous study slightly higher values were obtained (Mackintosh et al., 2012).

In five other studies vertical cut-off points with previous ActiGraph models were developed based on data that included locomotor as well as play activities with children. The current vertical axis cut-off points *(Table 2)* were comparable to those of one of these studies, in which similar methods were applied (Jimmy et al., 2012), but somewhat lower than the cut-off points found in three studies, where the criterion method was direct observation or type of activity rather than energy expenditure (Evenson et al., 2008; Mackintosh et al., 2012; van Cauwenberghe et al., 2011). Puyau et al. (2002), on the other hand, found much higher cut-off values than all other studies. This may be due to the fact that they examined older children (6- to 16- year-olds) and possibly to the fact that they based their analysis on linear regression while the other studies used ROC analysis.

No other studies with young children are available to draw comparisons with the current GT3X vector magnitude cut-off points *(Table 2)*. However, a study with 49 participants aged 10–15 years resulted in slightly higher vector magnitude cut-off points for moderate activity (56 counts per second). No cut-off point for vigorous activity was determined in that study (Hanggi et al., 2012). In addition, 36 adults exercising on a treadmill at various speeds produced a similar moderate intensity cut-off point (2690 counts/min) based on the 3 MET

Table 2: Results of the ROC curve analysis to determine accelerometer count cut-off points. Cut-off points per 5 sec for moderate to vigorous (MVPA) and for vigorous physical activity (VPA) are shown. Results are based on 168 observations.

Metabolic Threshold	**Counts**	**Cut-off Point**	**Sens**	**Spec**	**AuC**	**CI for AuC**	**p-Value**
MVPA	Vertical axis	133	0.76	0.86	0.88	0.82 – 0.93	<0.001
3 MET	Vector magnitude	246	0.75	0.91	0.89	0.84 – 0.94	<0.001
VPA	Vertical axis	193	0.86	0.79	0.88	0.83 – 0.94	<0.001
5 MET	Vector magnitude	316	0.90	0.86	0.94	0.90 – 0.97	<0.001
VPA	Vertical axis	233	0.89	0.83	0.87	0.82 – 0.93	<0.001
6 MET	Vector magnitude	381	0.89	0.84	0.92	0.88 – 0.97	<0.001

Sens = sensitivity, Spec = specificity, AuC = Area under the curve, CI for AuC = 95% confidence interval for area under the curve.

Table 3: Confusion matrices of measured intensity category versus classified intensity category. Classifications according to the cut-off points based on the two different sets of metabolic thresholds are shown. Observations per category are indicated in brackets, total: 88 observations.

a) For vertical axis counts

	3 MET – 6 MET metabolic thresholds			**3 MET – 5 MET metabolic thresholds**		
	classified intensity			classified intensity		
measured intensity	*light*	*moderate*	*vigorous*	*light*	*moderate*	*vigorous*
light	**81% (13)**	19% (3)	0% (0)	**81% (13)**	19% (3)	0% (0)
moderate	19% (11)	**61% (35)**	19% (11)	20% (9)	**51% (23)**	29% (13)
vigorous	0% (0)	47% (7)	**53% (8)**	7% (2)	19% (5)	**74% (20)**

b) For vector magnitude counts

	3 MET – 6 MET metabolic thresholds			**3 MET – 5 MET metabolic thresholds**		
	classified intensity			classified intensity		
measured intensity	*light*	*moderate*	*vigorous*	*light*	*moderate*	*vigorous*
light	**94% (15)**	6% (1)	0% (0)	**94% (15)**	6% (1)	0% (0)
moderate	35% (20)	**47% (27)**	18% (10)	44% (20)	**29% (13)**	27% 12)
vigorous	0% (0)	33% (5)	**67% (10)**	0% (0)	11% (3)	**89% (24)**

bold: correctly classified intensity category

Table 4: Validation results. Sensitivity, specificity and Kappa values for the moderate to vigorous activity (MVPA) cut-off points and the vigorous activity (VPA) cut-off points based on metabolic thresholds of 3 MET, 5 MET and 6 MET. Results are based on 88 observations.

	MVPA (3 MET)			**VPA (5 MET)**			**VPA (6 MET)**		
	sens	*spec*	*K (CI)*	*sens*	*spec*	*K (CI)*	*sens*	*spec*	*K (CI)*
Vertical axis	85%	81%	0.55 (0.35–0.75)	74%	79%	0.50 (0.31–0.69)	53%	85%	0.35 (0.11–0.59)
Vector magnitude	72%	94%	0.45 (0.27–0.63)	89%	80%	0.63 (0.47–0.78)	67%	86%	0.47 (0.24–0.70)

Sens = sensitivity, spec = specificity, K = Kappa, CI = 95% confidence interval, MVPA = moderate to vigorous physical activity, VPA = vigorous activity metabolic threshold as the current study (2952 counts/min) but a higher count value for the vigorous intensity cut-off point (6167 vs 4572 counts) based on a 6 MET threshold (Sasaki et al., 2011). This difference may partly be explained by the fact that Sasaki et al. only included locomotor activities in their protocol. A further explanation may be elevated acceleration values due to the higher body weight in adults, which plays an increasing role as the activity intensity rises.

The confusion matrices in the current study *(Table 3)* show good recognition rates of activity intensity categories for vertical axis cut-off points according to both sets of metabolic thresholds. For vector magnitude cut-off points, the recognition of moderate activity is somewhat low (47% according to the 3 MET – 6 MET thresholds and 29% according to the 3 MET – 5 MET thresholds) due to a large number of moderate observations being classified as light activity. However, sensitivity and specificity values for the vector magnitude cut-off points were good ranging from 67 to 94%. For vertical axis count cut-off points they ranged from 53 to 85% *(Table 4)*. Trost et al. (2011) conducted a validation of several child cut-off points for the ActiGraph 7164 with 206 participants aged 5 to 15 years. The MVPA and VPA cut-off points developed with the involvement of children under the age of 10 years yielded predominantly similar sensitivity and specificity values as in the current study, yet large differences were seen between studies with values ranging from 7.5% to 100%.

The current Kappa values imply that vertical axis cut-off points may be better in classifying MVPA while vector magnitude cut-off points are to be favoured for VPA. However, the considerable overlap of the 95% confidence intervals indicates that these differences may also be due to chance *(Table 4)*. In any case, this finding implies that field studies aiming to determine the daily time children spend in MVPA may be well served with uniaxial accelerometers. Similarly, evidence on the advantage of vector magnitude over vertical axis counts to estimate energy expenditure is inconclusive, as outlined in the introduction.

A major strength of the current study was that the protocol consisted of a range of typical child activities of continuous as well as intermittent nature. Furthermore, the cut-off points were developed on the basis of measured energy expenditure as a criterion reference. In addition, they were validated with an independent group of children. In a recent review on studies developing cut-off points in youth, four evaluation criteria were listed, all of which are met in the current study (Kim et al., 2012).

Readers have to bear in mind that mostly lean children took part in this study which may limit the applicability of the cut-off points to a group of overweight children. Furthermore, the participating children were very enthusiastic and thus performed most self-paced activities with a bigger effort than expected. Therefore, there were only few observations among the activities of an intermittent nature which were relevant for determining the threshold of moderate intensity.

Conclusions

The current study is the first to the authors' knowledge to report GT3X accelerometer cut-off points for children under the age of 10 years. Cut-off points for the vertical axis as well as vector magnitude counts were developed on the basis of indirect calorimetry measurements in a range of typical child activities by means of ROC curve analysis. The validation with an independent group of children yielded good results that were comparable to validations of previous vertical axis cut-off points (Trost et al., 2011). The current study further revealed a tendency of vertical axis cut-off points showing better validity for MVPA and vector magnitude cut-off points for VPA. These cut-off points serve researchers who want to evaluate their intervention project or further investigate the link between physical activity behaviour and aspects of health in young children.

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