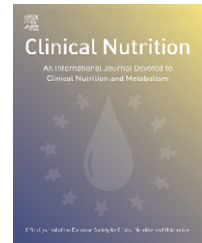




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ORIGINAL ARTICLE

# Reliability of physical activity measures from accelerometry among preschoolers in free-living conditions

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## KEYWORDS

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## Summary

**Background & aims:** Physical activity (PA) is a major determinant of obesity. Accelerometers have been reported to provide valid measures among adults. However, studies among preschoolers rarely report positive findings. To assess the day-to-day variability of accelerometers in preschoolers.

**Methods:** Uni-axial accelerometer (Actigraph monitor AM 7164-2.2) counts including one weekend from the time of getting up in the morning until bedtime.

**Results:** On average, boys showed 899 counts per minute (cpm) compared to 764 for girls ( $p < 0.01$ ; overall mean 828 cpm). Intra-individual correlation for accelerometry data between single days of examination was low with Pearson correlation coefficients between  $r = 0.31$  and  $0.51$ . Furthermore, child's body mass index (BMI) and accelerometer measures were not related to each other (Pearson's correlation coefficient  $r = -0.06$ ). Subsequent analyses showed higher measures (+50% cpm;  $p < 0.01$ ) for instruments placed in front of the umbilicus compared to instruments placed at the right hip.

**Conclusions:** Measurements of uni-axial accelerometers showed a low reliability among preschoolers. Uni-axial accelerometers placed on elastic belts might measure PA with low precision among preschoolers under free-living conditions possibly due to slipping instruments. This might explain lacking findings of an association between PA and obesity in studies among preschoolers.

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## Introduction

There is strong evidence that a number of chronic diseases such as obesity and subsequent cardiovascular disease as well as all-cause mortality in developed countries are related to the modern living environment like low daily energy expenditure.<sup>1</sup> Moreover, a low daily energy expenditure is supposed to be one of the major risk factors accounting for the ongoing obesity epidemic in children.<sup>2,3</sup> However, measurement of physical activity in children remains a major challenge in epidemiological studies due to poor reliability of self-report measures, intrusiveness of direct observation, intermittent activity or complexity of heart rate monitoring.<sup>4</sup> Accelerometry measurements have been reported to validly measure physical activity under field conditions and thus, seem to be a valuable solution.<sup>5,6</sup> Additionally, instruments for the use in children are available.<sup>4</sup>

The objective of the study was to assess the day-to-day reliability of accelerometers in a longitudinal study to describe activity patterns in preschool children under free-living conditions.

## Material and methods

### Procedure and subjects

Children aged 5 and 6 years and their parents were invited to participate in the Instrument of Children's Activity-Measurement Study (INCA) in the course of the mandatory school entry health examination in Munich, Germany, from October 18 until December 23, 2004. Purpose of the INCA study was to measure children's physical activity by accelerometry. Parents and their children were informed about the purpose of the study, the accelerometer measurement and its harmlessness verbally and by an information sheet. It was emphasized that participation in the study was voluntary. Written parental informed consent was obtained prior to participation. Data on  $n = 205$  children and parents were collected and analyzed anonymously. The local ethics committee and the local office for data protection approved the study.

### Accelerometry

Accelerometers are an established tool to measure physical activity. The measurement is considered objective, valid and simple to handle, which is important to guarantee high compliance in children.<sup>4</sup> In this study, the accelerometer Actigraph monitor AM 7164-2.2 by MTI Health Services (709 Anchors St., Fort Walton Beach, FL 32548, USA) was used. It has a small size (5.1 cm × 3.8 cm × 1.5 cm), low weight (43 g) and a robust design. The Actigraph monitor has been reported to measure physical activity of children under field conditions validly.<sup>7</sup>

Children were asked to wear the monitors over the right hip with an elastic belt for 5 consecutive days including one weekend from the time of getting up in the morning until bedtime. Parents were called at home at regular intervals to resolve potential problems related to the accelerometer measurement. During these calls, parents were also re-

minded to place the accelerometers correctly and to document the accelerometer carriage in the daily logs.

The monitor was initialized as described by the manufacturer and a 1-min recording interval was used. The total amount of physical activity from the activity monitor was expressed as average of total activity counts per minute (cpm) of registered time. The Actigraph monitor has a real-time clock and thus offers to program the exact start time to allow for an exact calculation of the total wearing time per day.

### Daily log

Parents recorded the time the monitor was attached and removed on a daily log. Additionally any time it was taken off during the day, e.g. for swimming or bathing should be noted. Accelerometers count invalidly measurements while biking. Thus, parents were asked to estimate the time the child traveled by bike.

### Statistical analysis

Activity cpm were compared between boys and girls by an unpaired *t*-test and additionally by an unpaired Mann-Whitney *U*-test due to slight positive skewness. The random error level was set to  $\alpha = 0.05$  for all analyses. To assess the reliability of the accelerometer measurements, intra-individual correlation coefficients between daily average cpm were calculated for each day separately. Additional analyses included the assessment of inter-individual correlation coefficients. For this purpose, we randomly defined pairs of children by permutation of the study sample (100,000 times) and subsequent allocation of the accelerometry data of the first child of the entire sample to the accelerometry data of the first child of the second half of the sample. This analysis was repeated with sex- and age-specific samples.

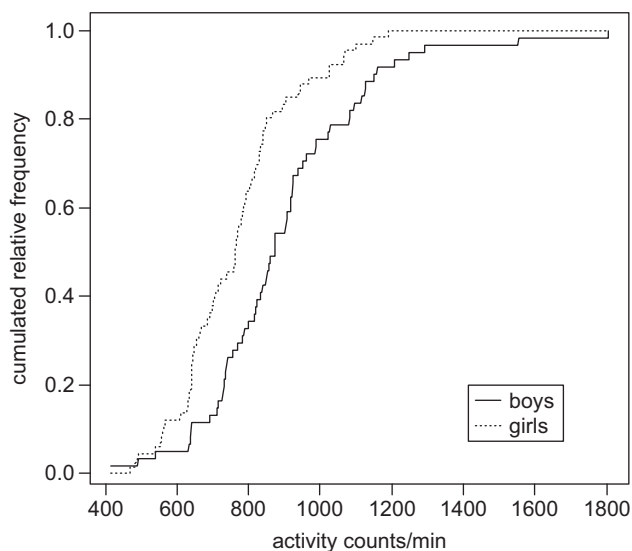
All calculations were carried out with either the statistical software package SAS 9.1 (SAS Institute Inc., Cary, NC, USA) or the statistical software package R 2.4.0 (<http://www.r-project.org>).

## Results

This study enrolled 205 children, 51% boys and 49% girls. The majority was 6 years old (82%). We only considered accelerometer measurements with a daily wearing time  $\geq 6$  h for analysis. Thirteen children were excluded because of refusal to carry the accelerometer ( $n = 9$ ) or loss of the instrument ( $n = 4$ ) leaving accelerometer data of  $n = 192$  children.

The distribution of activity cpm was slightly positively skewed with a value of 1.2 (Fig. 1). The overall mean was 828 cpm, while the median was observed at 804 cpm. The SE was 19 cpm and the minimum and maximum could be observed at 414 and 1805 cpm. Boys showed on average 135 counts more per minute compared to girls with mean values of 899 for boys and 764 for girls ( $p < 0.01$  for unpaired *t*-test and Mann-Whitney *U*-test) (Fig. 1).

Intra-individual correlation for accelerometry data between single days of examination was low with Pearson correlation coefficients between  $r = 0.31$  and  $0.51$  adjusted



**Figure 1** Cumulative density function of activity counts per minute by sex among  $n = 192$  preschoolers.

**Table 1** Intra-individual correlation coefficient (Pearson) between single accelerometer measurement days among  $n = 192$  preschoolers.

	Day 1	Day 2	Day 3	Day 4	Day 5
Day 1	1.00	0.40	0.42	0.46	0.31
Day 2	0.40	1.00	0.44	0.40	0.32
Day 3	0.42	0.44	1.00	0.51	0.45
Day 4	0.46	0.40	0.51	1.00	0.45
Day 5	0.31	0.32	0.45	0.45	1.00

for weekday or weekend day, respectively (Table 1). The maximum of inter-individual correlation coefficients in the entire sample was  $r = 0.54$ . When examining sex- and age-specific inter-individual correlations, maximum values of  $r = 0.71$  for girls and  $r = 0.81$  for boys could be observed.

Additionally, child's body mass index (BMI) and accelerometer measures had a Pearson's correlation coefficient of  $-0.06$  and were not related to each other.

## Discussion

Average activity counts were higher in boys than in girls. However, comparison of activity counts on different days revealed a low reliability of accelerometer measures among preschoolers under free-living conditions.

Accelerometers as well as the doubly labeled water method are discussed as gold standard to measure physical activity among adults.<sup>7</sup> In several studies, a good correlation between physical activity measured by accelerometry and total energy expenditure (TEE) measured by doubly labeled water method was reported.<sup>6,8</sup> In recent years, accelerometers were used to validate activity estimates by questionnaires in school age children<sup>9</sup> or by direct observation of 3- and 4-year-old children.<sup>10</sup> Additionally, sedentary

behavior was quantified by accelerometry under field conditions.<sup>11</sup> Altogether, accelerometers are regarded as valid and useful instruments for the measurement of physical activity.<sup>4,5,12</sup>

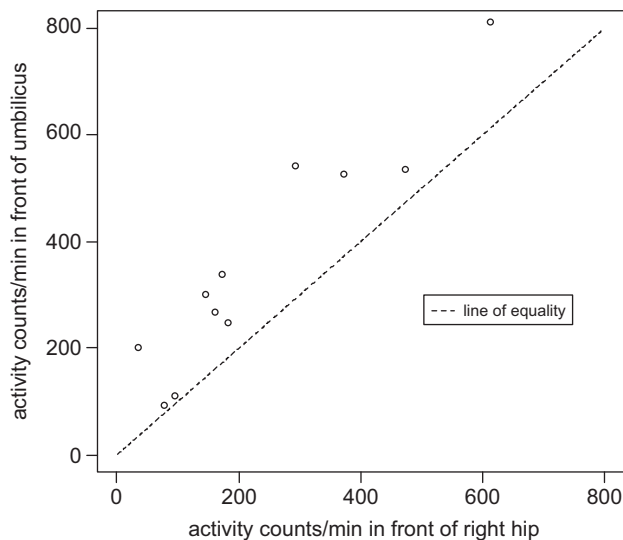
Most studies under supervised field conditions among children reported valid activity measurements by accelerometry.<sup>10,13–15</sup> We observed higher average counts in boys compared to girls, which is in accordance with a recent study on adolescents<sup>16</sup> and suggests adequate average measures of accelerometers in this age group.

However, low intra-individual correlations of accelerometer data between single measurement days were in the same range as maximum values of a sample of inter-individual correlations suggesting inappropriate measures among preschoolers under every day life conditions. The Pearson correlation coefficient can assess linear relations, while non-linear relations might be underestimated. However, the inspection of the scatter plots suggested a linear relationship and there was no evidence for a non-linear relationship (data not shown). Additionally, Spearman correlation coefficients, which can also assess non-linear relationships, showed similar estimates ranging from 0.32 to 0.48. Therefore, the low intra-individual correlations might be due to incorrect and varying placement of instruments fixed at elastic belts by preschoolers and subsequent measurement errors. Unfortunately, the placement of the accelerometers was not recorded in the daily logs. Therefore, we could not assess an incorrect placement among the  $n = 192$  children from the main study.

However, in order to assess whether incorrect placement has an impact on accelerometry measures, we additionally analyzed data of  $n = 11$  individuals, each wearing 2 accelerometers at the same time under field conditions. Pearson's correlation coefficient was high with  $r = 0.95$  for hip and umbilicus measurements. However, Pearson's correlation cannot assess an average difference in variables. Although placement of the instrument at different body sites showed a high correlation in our study and two other studies<sup>17,18</sup> placing instruments in front of the umbilicus changed the absolute counts remarkably. Umbilicus instruments showed always increased values compared to instruments at the right hip (Fig. 2). On average, umbilicus measurements were 121 cpm or 1.5 times (+50% cpm) higher than measurements of instruments at the right hip (paired  $t$ -test,  $p < 0.01$ ). The higher change of the average cpm observed in our study compared to the Swedish studies might be explained by (1) a different body site comparison (hip versus back), (2) controlled activity only (walking) or (3) different age groups (adults) in the Swedish studies.<sup>17,18</sup>

We used the accelerometers exactly as recommended. Children and their parents were instructed carefully how to wear the instruments and how to fill out the daily log. Additionally, parents were called during the measurement period to solve possible problems with the accelerometers. According to the literature, a measurement period of 5 days including one weekend was chosen<sup>19</sup> and a 1 min recording interval was used. Thus, methodological limitations due to lack of parental information or incorrect predefined measurement periods seem to be unlikely.

Thus, a variable involuntary or highhanded placement by corresponding children might explain low intra-individual correlations between single measurement days. Doubly



**Figure 2** Scatterplot: intra-individual correlation of accelerometer data—hip versus umbilicus among  $n = 11$  individuals.

labeled water measurements are referred to as gold standard for measuring energy expenditure.<sup>7</sup> Unfortunately, we had no possibility to perform doubly labeled water measurements and thus, could not assess associations between accelerometer measurements and doubly labeled water measurements or intra-individual correlations of doubly labeled water measurements. Although this issue was not addressed in the paper “wandering” accelerometers might also have contributed to the poor correlation between activity counts of tri-axial accelerometers and energy expenditure measured by doubly labeled water method in another recent study on 4- to 6-year-old American children under free-living conditions.<sup>20</sup> Additionally, a study on physical activity among 3- to 4-year-old preschoolers comparing parental reports and measurements of tri-axial accelerometers could only observe moderate correlations.<sup>21</sup> Using tri-axial instead of uni-axial accelerometers as supposed by a recent study on adults<sup>22</sup> seems to be unlikely to explain low reliability among preschoolers.

Variable placement of accelerometer instruments among preschoolers might be the reason for low reliability. Such measurement errors have to be considered in studies on physical activity measured by accelerometry and obesity among preschoolers. Future studies on physical activity measured by accelerometry should rather guarantee a fixed placement of the monitors during the entire measurement period among preschoolers under free-living conditions than use elastic belts for fixing instruments.

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J.A.T. carried out the studies, performed the statistical analysis and drafted the manuscript. R.v.K. conceived of the study, and participated in its design and coordination. E.R. participated in the design of the study and data collection and coordination. A.M.T. conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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