Associations Between Active Commuting to School and Objectively Measured Physical Activity

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Background: To provide more accurate assessment of commuting behavior and potential health effect, it is important to have accurate methods. Therefore, the current study aimed to a) compare questionnaire reported mode of commuting with objectively measured data from accelerometer and cycle computer, b) compare moderate vigorous physical activity (MVPA) among children cycling vs. walking to school, and c) thus calculate possible underestimated MVPA, when using accelerometers to measure commuter cycling. Methods: A total of 78 children, average age 11.4 (SD = 0.5), participated in the study. Physical activity was measured with cycle computers and accelerometers for 4 days. Mode of commuting and demographic information was self-reported in a questionnaire. Results: Children who reported to cycle to school spent significantly more time cycling than those who walked to school, 53.6 (SD = ± 33.9) minutes per day vs. 25.5 (SD = ± 24.6) minutes per day (P = .002) (ie, showing that MVPA, measured by accelerometers, underestimated 28.1 minutes per day among children cycling to school vs. those not cycling to school). Conclusion: To provide more accurate assessment of active commuting in children and adolescents future studies should incorporate multiple methodologies such as global position systems (GPS), accelerometers, cycle computers, and self-reported measurements.

Keywords: active transport, children, accelerometer, cycling

Active commuting to school includes various modes of transport such as walking and cycling. Bicycling is a very common activity in northern Europe and has been identified as an important source of physical activity for young people.1–3 There is some evidence to suggest that active commuting to school is associated with a healthier body composition4 and higher levels of cardiorespiratory fitness among youth.5,6 However, there seem to be different health benefits associated with different modes of active commuting. Cycling is a form of physical activity that effectively taxes the cardiorespiratory and metabolic functions of the whole body in a wide range of intensities and can result in a number of health benefits.7 Commuter cycling is normally of higher physiological intensity than walking, and has been categorized as an activity reaching moderate intensity level.8,9 In addition, recent studies have reported a consistent association between cycling to school and lower body weight;10–12 and cardiovascular fitness.5,6,13 In spite of that, many studies of active commuting do not separate cycling from walking in their analyses. Accurate assessment of active commuting is vital when examining the dose-response relationship between commuting exposure and health related outcomes such as cardiovascular disease and obesity.14 Accelerometers are recognized as a valid and objective tool of assessment of body movement,15–17 and are increasingly being used to assess active commuting in children and adolescents.18–20 The device has shown high feasibility, and moderate to good accuracy and validity to assess frequency, duration and intensity of physical activity.2,21 However, there are several challenges. The measurement outputs are a simplification of actual biological and physical processes, and outputs are prone to measurement error in free-living activity. The device is usually attached at the hip or lower back, and this has obvious limitations in measuring bicycle activities.22–24 In cycling, the accelerometers capture some counts, but the counts do not indicate the person’s true activity level during cycling. It has been estimated that approximately 1/20 of expected counts are usually registered during cycling, and recorded MVPA during cycling is close to zero even if some counts are captured.25 The possibility to make better predictions of energy expenditure for bicycling might therefore be to include measurements from a cycle computer.26 This computer mechanically count the number of rotations of a bicycle wheel by a magnet mounted to the crank arm, and a sensor mounted to the frame. The data output of the cycle computer can be interpreted into minutes in MVPA,8,9 by summarizing time of cycling during a period. To our knowledge, no study has published data on commuter

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cycling, measured by cycle computers. Therefore, the current study aimed to a) compare questionnaire reported commuting with objective measured data from accelerometer and cycle computer, b) compare MVPA among children cycling vs. walking to school, and c) thus calculate possible underestimated MVPA, when using accelerometers to measure commuter cycling.

Methods

Study Sample

In fall 2009, 2 public primary schools, labeled as school A and B, in the Kristiansand municipality of southern Norway were randomly selected and invited to participate in the study, and both agreed. The criteria for selection of schools were a) public school with mixed gender in Kristiansand municipality and b) location in high or middle social status areas with safety and pleasant physical environment that’s promote walking and cycling for the children. The school timetables were similar in both schools, and all classes had the same number of lessons per week. There was a minor difference in start time and end time of the school day. School A started the school day at 8:30 AM and closed at 2:15 PM each day, except Wednesdays and Fridays, when the school day ended at 1:15 PM. School B started the day at 8:40 AM and closed at 2:25 PM each day, except Wednesdays, when the school day finished at 12:40 PM.

All 6th and 7th graders (10- to 12-year-old boys and girls), a total of 131 pupils, in these 2 schools were invited to take part in the study. The children received oral classroom information about the study. The inclusion criteria’s, the aims and implications were verbally explained by the principal investigator. Inclusion criteria’s for participation in the study were age (10–12 years old), health (no physician-identified contraindication for physical activity), active commuter (ie, regularly walking or cycling to school most school day during the week), and having access to a bicycle. Afterward, the children delivered a letter informing their parent/guardians about the study where inclusion criteria’s, the aims, implications, and measurements method were explained. Those children whose consider to reach the inclusion criteria’s could sign up for the study. Written consent was obtained from the children’s parents/guardians. In total, 78 (59.5%) children participated in the trial. The recruitment process was carried out in August 2009.

Research clearance was obtained from the Norwegian Social Science Data Services (ID = 22405).

Instrument

Physical activity was objectively measured with cycle computers and accelerometers. Mode of commuting and demographic information was self-reported by a questionnaire. Independent of self-reported mode of commuting to school, all children received the 3 measurements instruments for data collections. All instruments were delivered and collected by the present of the principal investigator and 3 research assistants at the respective schools. Hence, the first measurement day the children completed the questionnaires, got installed the cycle computers and mounted the accelerometers at the hips. The research team returned to the schools 5 days later, downloaded data from the cycle computers, and collected the accelerometers.

Questionnaire. The ATN-questionnaire is a self-administered 5-page questionnaire designed to obtain information about active commuting in school children. The survey contains 41 questions and requires circa 20 minutes completing. All children completed the questionnaire to assess demographic information, gender and age. Information about commuting were assessed by a matrix, the pupils filled out how many days a week they normally 1) walk, 2) cycle, 3) are driven by car, or 4) bus to and from school during fall season (see Bere and Bjørkelund, 2009 for details25). The row had to add up to 5 days/week (days attending school). The to/from school variables were added giving the number of trips walking, cycling, car commuting, and bus commuting (score ranging from 0–10); presenting the mean number of trips per week for each of the 4 different modes of transportation. Based on the average number of trips/week in fall season, the pupils were categorized into one specific mode of commuting if more than 50% of the trips were conducted by that specific mode. If mean number of trips did not count up to 10 (trips to and from school in a normal school week) they were not categorized into mode of commuting. Despite the information about the inclusion criteria, we found that 2 children were not categorized into one specific mode of commuting, and these children were therefore excluded from the further analyses. All data and objective assessment in the current study were collected within the same time period, during fall season in 2009. Distance from home to school was calculated from the pupil’s home address using the length of the “optimal route by foot” option, by http://maps.google.com in September 2009.

Cycling Computer Data. All children received a cycle computer, 34–4532 Sigma 500 (Sigma-elektro GmbH, Neustadt, Germany),26 to measure total distance, time for distance and average speed for 4 consecutive school days. Consistent with previous research, all number of minutes completing. All children completed the questionnaire to assess demographic information, gender and age. Information about commuting were assessed by a matrix, the pupils filled out how many days a week they normally 1) walk, 2) cycle, 3) are driven by car, or 4) bus to and from school during fall season (see Bere and Bjørkelund, 2009 for details25). The row had to add up to 5 days/week (days attending school). The to/from school variables were added giving the number of trips walking, cycling, car commuting, and bus commuting (score ranging from 0–10); presenting the mean number of trips per week for each of the 4 different modes of transportation. Based on the average number of trips/week in fall season, the pupils were categorized into one specific mode of commuting if more than 50% of the trips were conducted by that specific mode. If mean number of trips did not count up to 10 (trips to and from school in a normal school week) they were not categorized into mode of commuting. Despite the information about the inclusion criteria, we found that 2 children were not categorized into one specific mode of commuting, and these children were therefore excluded from the further analyses. All data and objective assessment in the current study were collected within the same time period, during fall season in 2009. Distance from home to school was calculated from the pupil’s home address using the length of the “optimal route by foot” option, by http://maps.google.com in September 2009. Consistent with previous research, all number of minutes capture by the cycle computer was defined as MVPA.8,9 The computers were installed on the children’s bikes while parked at school by the project leader and research assistants. The computers were mounted in the morning on the first day of measurement and were initiated immediately after. In the current study we used a basic wire device, which displayed the current speed, maximum speed, trip distance, trip time, total distance commuted, and the current time. The participants were instructed to leave the computers on the bicycles throughout the whole school week, given 3 full days and 2 half days, for measuring the total amount of cycling. The bicycle computers were returned to the project leader at school.
by the participants on the last day of the measurement period. The data from the computer was then downloaded immediately as total distance (kilometers), time for distance (minutes) and average speed (km/hour) for the 4 school days. Reasons for exclusion of cycle data were instrument malfunction of the cycle computer (n = 11) and not returning back the cycle computer (n = 1). Full data from the cycle computers was available from 66 subjects.

**Accelerometer Data.** General physical activity was assessed using the accelerometer GT1M Actigraph (MTI Actigraph, Manufacturing Technology, Fort Walton Beach, FL, USA). The accelerometer was programmed to start at 7:00 AM Monday and stop at 10:00 PM Thursday. Regarding that children got the device Monday morning at school, approximately at 8:30 AM, total measurement days were 4 consecutive school days. The monitors were set at 10 seconds epoch length. Accelerometers were distributed at the respective schools by the research team. A demo was given in how to wear the accelerometer with an elastic belt around the waist, positioned above the right hip. In addition, the participants were given assistance when attaching the device, and adjusting the straps around the waist. They were asked to wear the accelerometer continuously throughout the day, except when swimming, bathing and sleeping. In addition, the children were asked to follow their usual daily routine. Written instructions and contact details to the principal investigator were given to parents to increase compliance. Strategies to promote compliance were teacher based (ie, the children’s teacher reminded the participants to wear the accelerometer on a daily basis). Raw acceleration data files from each individual were processed using customized software, Properio (Jan Brønd, University of Southern Denmark, Odense, Denmark). In line with other studies, missing data or monitor “non-worn time” was consistently excluded from runs of zeros > 10 minutes. Night wear time and activities after the 4 days were sorted out and also included from the analyses. Data were processed in 10-second epochs, which also was the epoch set when monitoring. Day parts analyses were created with 1 hour length using Properio software. In line with other studies, accelerometer counts were converted to counts per minute (cmp) for recording between 7:00 AM and 10:00 PM. Given that the measurements period only was 4 consecutive days, participants with 3 days were included in the analyses, and the criteria for successful recording were therefore a minimum of 3 days of 10 hours of recording per day. In total, 4 children failed to achieve at least 3 days of accelerometer measurements, 5 did not wear the accelerometer at all, 6 had instrument malfunctions, and 1 did not return the accelerometer. Full data from accelerometers was available from 62 subjects.

Three different activity variables were estimated from the accelerometer data: general physical activity, hourly mean counts (per min) of the day and adjusted MVPA. General physical activity was considered to be the total accelerometer counts per valid minute of monitoring (counts/min). To investigate when differences in activity between commuting groups occurred, accelerometer data were plotted for each hour of the day between 7 AM and 10 PM. The third variable represents the total time in adjusted MVPA (more than 3 metabolic equivalents). The average time the accelerometer was worn was 12 hours per day, and the number of minutes in MVPA was proportionally adjusted to 15 hours per day (estimated awake time for this population), with the following equation: adjusted minutes = (observed minutes in MVPA) x (15 x 60/total minutes). MVPA were calculated using age-specific cut-points. Intensity thresholds for moderate- and vigorous-intensity activity were defined to > 2296 counts/minute.

**Statistical Analyses**

Descriptive statistics for participants’ characteristics are displayed as means with standard deviation (SD). Of the 78 children who initially participated and completed the questionnaire, 58 had valid data for all 3 measurements (the questionnaire, the accelerometer, and the cycle computer). Characteristics between individuals with complete data and those who were excluded did not differ with respect to sample descriptions: gender, age, and distance to school tested by independent sampling t test. Spearman correlation coefficient was used to estimate the rank order agreement between the questionnaire-reported average number of trips per week and respectively accelerometer- and cycle computer outputs. To investigate possible differences in physical activity levels between walkers and cyclists during the day, accelerometer data were plotted for each hour of the day between 7 AM and 10 PM; the hourly differences between transports groups were tested using independent sampling t test. Total MVPA was calculated adding data from the cycle computers and accelerometers (minutes in adjusted MVPA from the accelerometer and minutes cycling per day measured by the cycle computer). Linear mixed model adjusted for gender, age and distance were conducted with data from cycle computer, accelerometer, and pooled data from both devices as dependent variables to assess potential differences between walkers and cyclists. Analyses were performed, using PASW 18 (Predictive Analytics Software and STATA IC 10 (StataCorp, College Station), and level of significance was set to \( P < .05 \).

**Results**

The average age of the children was 11.4 years (SD = 0.5), and 46% (CI = 35.0–57.0) were boys. In general, the proportions of the participants categorized as cyclists and walkers were 60.5% (n = 46) and 39.5% (n = 30), respectively. The cyclist bicycled average 9.5 (SD = 1.4) trips per week to/from school vs. the walkers bicycled average 0.9 (SD = 1.3) trips per week to/from school in fall season (\( P = .001 \)). The cyclists lived further away from school (2.5 (SD = 2.1) vs. 0.8 (SD = 0.6) km; \( P = \ldots \)
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and cycled significantly more kilometers and minutes per day than the walkers [7.1 (SD = 4.1) vs. 2.8 (SD = 2.5) km, \( P = .033 \) vs. 54.7 (SD = 33.4) vs. 21.4 (SD = 21.2) min; \( P = .001 \)] (Table 1).

The rank order agreement between the self-reported number of trips per week, and respectively counts per minute and kilometers cycled per week showed significant correlations between kilometers cycled per week and questionnaire reported number of commuting trips per week. Self-reported number of trips cycled to school was positively associated with kilometers cycled measured by the cycle computer (\( r = .599; P < .001 \)), and self-reported number of walking trips per week to school was negatively associated with kilometers cycled per week measured by the cycle computer (\( r = –0.610; P < .001 \); Table 2). No significant association was observed between mode of commuting and accelerometer data.

Results of the independent sampling \( t \) tests analyses examining the hourly differences of the day between 7 AM and 10 PM in accelerometer counts between transport groups showed that the pattern of physical activity, and levels of activity were quite similar throughout the day for those commute on foot and those commute by bicycle (Figure 1). No significant differences between commuting groups in the different hourly periods were found.

Children cycling to school spent significantly more time bicycling than those who walked to school, 54.6 (CI = 45.5–63.8) vs. 22.3 (CI = 9.1–35.6) min per day (\( P < .001 \)). Examining the association between cycling vs. walking to school, MVPA measured by accelerometer showed no significant differences (Table 3). When adding data from minutes of cycling from the cycle computers and minutes in MVPA from the accelerometers; total time in MVPA was not significantly higher among children cycling vs. children walking to school [158.2 (CI = 130.7–185.7) vs. 130.7 (CI = 105.1–156.3)] min per day (\( P = .163 \)).

### Discussion

This study investigates the relationship between active commuting to school and daily physical activity patterns in a sample of Norwegian primary school-age children. Self-reported cycling to school (compared with walking) was related to a higher total amount of objectively measured cycling, but not general physical activity measured by accelerometers. These findings add to the existing literatures earlier assumptions that accelerometers underestimate cycling, and its limitations in measuring bicycling activities. This is probably one of the key biases that are encountered when using accelerometers to predict the total level of physical activity. This study is, to our knowledge, the first to investigate the association between self-reported modes of commuting to school and objectively measured physical activity by cycle computers combined with accelerometers.

Data from the accelerometer output showed a quite similar pattern and level of physical activity throughout the day among children walking and cycling to school.

### Table 1  Characteristic of Participants by Self-Reported Mode of Commuting to School, Mean (SD)

<table>
<thead>
<tr>
<th></th>
<th>Walkers (n = 24) Mean SD</th>
<th>Cyclist (n = 34) Mean SD</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>11.5</td>
<td>11.2</td>
<td>0.004*</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>% boys</td>
<td></td>
<td>0.846</td>
</tr>
<tr>
<td>Distance to school</td>
<td>km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking trips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>per week</td>
<td>0.8</td>
<td>2.5</td>
<td>0.011*</td>
</tr>
<tr>
<td>Cycling trips</td>
<td>per week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>per week</td>
<td>9.1</td>
<td>1.4</td>
<td>0.001*</td>
</tr>
<tr>
<td>Counts</td>
<td>per minute</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1012.2</td>
<td>1063.4</td>
<td>853.3</td>
<td>0.571</td>
</tr>
<tr>
<td>Cycling</td>
<td>km per day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minutes per day</td>
<td>21.4</td>
<td>21.2</td>
<td>0.033*</td>
</tr>
<tr>
<td>km/t (intensity)</td>
<td>17.2</td>
<td>12.6</td>
<td>0.847</td>
</tr>
</tbody>
</table>

*All comparisons of continuous variables are \( t \) test; comparisons of dichotomous variables are chi-square analyses.

### Table 2  Spearman’s Correlation Between the Questionnaire, the Cycle Computer, and the Accelerometer (n = 58)

<table>
<thead>
<tr>
<th></th>
<th>Cycling per week, km (rho (n = 58))</th>
<th>Counts per minute (rho (n = 58))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trips per week as a walker</td>
<td>–0.610*</td>
<td>0.122</td>
</tr>
<tr>
<td>Number of trips per week as a cyclist</td>
<td>0.599*</td>
<td>–0.168</td>
</tr>
</tbody>
</table>
At the time of going to/from school (circa 8 AM to 9 AM) children cycling and walking recorded quite similar accelerometer counts, despite different transport modes. This may be explained by the fact that the accelerometers capture some counts during cycling, but the counts do not indicate the person’s true activity level during cycling. Recorded MVPA during cycling is close to zero even if some counts are captured. However, when adding data from cycle computers and accelerometers; total time in MVPA was not significantly different between children cycling to school and children walking to school. Consequently, due to lack of capturing cycling, both groups (walkers and cyclists) had underestimated MVPA using the accelerometer only. Among children cycling to school 53.5 minutes and among walkers, 25.5 minutes in MVPA were underestimated per day (ie, the cycling time). Unfortunately, the extent of this under-reporting is hard to compare with accelerometer data. However, the accumulation of daily MVPA by the children cycling vs. walking to school may give a difference in energy expenditure that might lead to differences in body mass between the 2 groups over time, and might therefore explain why those cycling to school are less overweight than those not cycling to school as previously reported.\textsuperscript{10,12,35}

Despite limitations of the accelerometers there is consistent evidence, across different countries that those children who actively commute to school have significantly higher levels of physical activity, than those who commute by motorized transport.\textsuperscript{18,36,37} However, only Cooper and colleagues reported differences between cyclists and walkers.\textsuperscript{18} Our findings contributes to previous studies showing that total physical activity levels in children actively commuting to school are underestimated when solely based on accelerometers. Increasing levels of physical activity in children are considered to be a public health priority, and there is evidence that active commuting is an important contributor to total physical activity in children.\textsuperscript{18,19,38} Researchers and practitioners need valid and reliable measures

\begin{table}[h]
\centering
\begin{tabular}{ llll }
\hline
 & \textbf{Cycle computer} & \textbf{Accelerometry} & \textbf{Cycle computer and} \\
 & \textbf{Adj. mean} & \textbf{CI} & \textbf{accelerometry} & \textbf{Adj. mean} & \textbf{CI} & \textbf{Adj. mean} & \textbf{CI} \\
\hline
\textbf{Group} & & & & & & & \\
Cyclist (n = 34) & 54.6 & (45.5–63.8) & 106.4 & (88.2–124.7) & 158.2 & (130.7–185.7) \\
Walkers (n = 24) & 22.3 & (9.1–35.6) & 105.7 & (87.9–123.5) & 130.7 & (105.1–156.3) \\
P-value & 0.001* & 0.956 & 0.163 & & & & \\
\hline
\end{tabular}
\caption{Adjusted* Means, (CI) of Children Cycled to School and Children Walked to School; Daily Minutes of Moderate-to-Vigorous Physical Activity Based on Cycle Computers, Accelerometry, and Pooled Data From Both Devices, Mean (SD) (n = 58)}
\end{table}

\* Linear mixed model adjusted for gender, age, and distance.
of children’s physical activity to assess, motivate and supervise physical activity and active commuting. These results may help in predicting biases as a function of the accelerometers computation of output to others interested in predicting MVPA, total levels of physical activity and active commuting.\textsuperscript{18,36,39} It is a feature of the current study to highlight the range of errors that can be expected when using an accelerometer to assess commuting to school.

Researchers and practitioners should consider the biases that may encounter when using accelerometers to measure active commuting in future studies. Future validation studies that include habitual physical activity should focus on developing an algorithm which combines accelerometer counts with cycling data. It would then be possible to translate cycling minutes into adjusted mean counts per minute, which is often used as a measure of total volume of physical activity.

Study Strengths and Limitations

The main strengths of this study are the use of 3 different measurements to assess active commuting and total MVPA. In the self-reported questionnaire, which has been newly reported to be a reliable tool for measuring active commuting to school,\textsuperscript{28} cycling trips (in general) was associated with objectively measured data from cycle computers. In addition, this study confirms previous suggestions that accelerometers underestimate MVPA among children cycling to school. One of the weaknesses of this study was the limited number of observations. The cycling computers were not calibrated for size of the wheel for each bicycle and this is clearly a limitation because different wheel size will translate to different measures of speed and distance for a given number of rotations. However, in the current study most children had the same size on the bike, and only a few of them had different wheel size. Moreover, distance was assessed by “optimal route by foot” using http://maps.google.com, since “bike” option was not available in this software. This may have resulted in over- or underestimating actual routine taken by bike. Walkers and cyclists were categorized based on usual mode of commuting during fall period. This may have resulted in misclassification in relation to a specific week, and limit the association between the measurements. However, more studies a needed to substantiate these results. Maybe the most appropriated design for future studies is to incorporate global position system (GPS) in combination with accelerometer and cycle computer.

Conclusion

These findings show that self-reported cycling to school was related to the total amount of objectively measured cycling, but not to general physical activity measured by accelerometers. Furthermore, the current study confirms earlier assumptions that accelerometers under-estimate the total level of physical activity among children cycling to school. Such evidence has been lacking to date.

Acknowledgments

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References


