Evaluation of School Transportation Patterns and the Associated Impact on BMI in 2 Midwestern Communities

Kate Heelan, H. Jason Combs, Bryce M. Abbey, Paul Burger, and Todd Bartee

Background: The decline in active commuting to and from school in the United States is, in part, due to urban design standards and public policies that promote automobile travel and discourage pedestrian activity. Purpose: The current investigation examines active commuting at neighborhood schools and how it is altered by distance to school, student age and its potential impact on Body Mass Index. Methods: Demographic and transportation datasets were obtained for 5367 elementary students (K–5th grade) and middle school students (6th–8th grade) in 2 Midwestern communities. Results: 4379 (81.6%) students were successfully geocoded and 21.9% actively commute to school at least half of the time meeting the Healthy People 2010 objective 22–14. Of those students who could potentially actively commute to school (0.5 mile for grades K–5 and 1 mile for grades 6–8) 36.6% are passive commuters. No significant negative associations were found between BMI z-score or BMI percentile with accumulation of activity through active commuting (frequency × distance) for elementary (r = –0.04, P = .27) or middle school students (r = .027, P = .56). Conclusion: Many elementary students living within 0.3–0.4 miles are being driven to school. Promoting pedestrian-friendly communities and making healthy and sustainable transportation choices should be priorities for community leaders and school administrators.

Keywords: active commuting, GIScience, urban design

Biking and walking to school were once commonplace activities for many American school children.1 Now, however, it is estimated that less than one-quarter of elementary-aged children in the United States actively commute to school.2 Specifically, national commuting rates suggest 14%–19% of children actively commute which stand in contrast with 35 years ago when an estimated 42% of all children walked or bicycled to school.3–5 A number of factors have contributed to this decline. Most often survey responses point to distance, traffic and other safety concerns, school policies, and weather as reasons why parents do not let children actively commute to school.2,6–8 Of these factors, distance has been reported as the main barrier to active commuting to school.3,9,10 School location and urban design also impact pedestrian activity rates.11 Over the past several decades the trend in school development has been to build bigger schools on the outskirts of a community where land is less expensive12 and major roads feed the facility. As a consequence, schools draw students from larger areas, with children living so far from school it is not often feasible for them to walk or bicycle. Several studies have indicated that in contrast to more traditional, pedestrian oriented urban developments, newer and more auto-oriented designs have marginalized pedestrians.13–15

Modes of transportation to and from school vary from day to day and may impact the accumulated distance achieved by active commuting. In the United Kingdom, commuting distances are approximately 1.6 miles for children in elementary school while in an Irish study distances up to 2.5 miles were achieved for active commuting children. However, feasible walking distances have been recommended in both Europe16 and America7 to better target and support walk to school promotion programs to increase moderate-to-vigorous physical activity (MVPA). D’Haese16 determined that 0.9 miles kilometers from school was a feasible distance for 6th graders in Belgium and Falb used 0.5 miles for grades K–5 and 1.0 miles for grades 6–8 in Georgia, USA.

It has been well established that active commuting to and from school increases daily physical activity.18–22 Daly-Smith et al23 suggested that every day of active commuting in the United Kingdom doubled the chances of students obtaining the recommended amount of weekly moderate to vigorous physical activity. Data indicated that even 1 additional day of active commuting helps to meet those criteria and older girls (> 10 years old) who actively commuted were 6.45 times more likely to achieve 300 minutes per week of MVPA (60 min/day × 5 days/week).19 In the United States, children who actively commute are more active than their car/bus riding peers and have the potential to obtain health benefits.9,18 Data indicate, for instance, that only 15 minutes more of daily MVPA is associated with lower odds of obesity among 12-year-old children.24 Studies are still inconclusive about...
the influence of active commuting to school on BMI, but walking to school enhances physical activity which is associated with more favorable biological cardiovascular disease risk factor profiles in children and adolescents, enhanced psychological health and appropriate skeletal development.25

The potential benefits of increased physical activity in youth have led to public health promotions of active commuting as one strategy to meet physical activity recommendations. It is important that initiatives target potential active commuters (PAC) who live within a reasonable and safe walking distance from their school. By determining the prevalence of active commuting among only those students who reside within reasonable and safe distances, researchers and practitioners can begin to view a different priority population that should be targeted for active commuting initiatives including formative assessments to determine specific barriers and enablers for PAC. In this study, PAC are defined by those K–5 who live within 0.5 miles and 6–8 who live within 1.0 mile of neighborhood schools in 2 micropolitan communities in the Midwest.

The primary purpose of this study was to evaluate commuting patterns (frequency and distance) based on transportation mode for PAC. A secondary purpose was to determine the association between weekly physical activity accumulated through active commuting (frequency × distance) by age and gender with BMI.

**Methods**

**Transportation Mode**

Elementary and middle school students in Kearney and Lexington, Nebraska completed surveys which focused on mode of transportation both to and from school each day over a 1-week period. The surveys were conducted in September, several weeks after the beginning of classes when regular transportation patterns had been established and temperatures in the Midwest are typically in the mid-70s (Fahrenheit) and conducive to outdoor activity. Posters depicting a range of transportation choices (walking, biking, bus, or car) were placed in every classroom at all elementary and middle schools in the 2 districts. Each morning students circled how they arrived at school and in the afternoon indicated how they anticipated returning home. This method has previously been validated with this age group.9

**Demographics**

Local school districts provided home address information and various demographic data including date of birth, height and weight for all students. Body mass index (BMI) was calculated as body mass divided by height squared. BMI z-scores and percentiles were calculated using the age- and gender-adjusted calculations provided by the Centers for Disease Control and Prevention.26 The current project was approved by the University of Nebraska-Kearney Institutional Review Board.

**Geocoding**

Following the pattern established by Cohen et al12 who collected addresses and then calculated the shortest route to school via the street network, this project merged demographic and mode of transportation datasets into a single file through a common identifier and used ArcGIS to geocode addresses for each student’s record to residential streets and examine pedestrian and vehicular commuter distances across networks. The final dataset contained a total of 5367 students in K–8 grades. Of that number, 4379 (81.6%) were successfully geocoded. Of those not geocoded, most had incorrect or incomplete address information, or were missing demographic information. Spatial information tied to the student records through geocoding along with transportation data produced an active commuter rate—the number of students who actively commute compared with the number of PAC. Active commuters are defined as students who recorded at least half of their weekly trips to school as biking, walking or a combination of the 2 as suggested by Healthy People 2010.27 Infrequent active commuters were defined as students who reported biking and/or walking less than half of their trips, while passive commuters were driven for all trips to and from school.

**Data Analysis**

Percentages of active, infrequent, and passive commuters were calculated for the entire population and PAC. Statistical analyses were then performed on PAC K–5 students living within a half mile and 6–8 students living within 1 mile of their school, which is similar to other studies17 with this age group.

Weekly physical activity accumulated through active commuting was estimated by multiplying frequency of active commuting by distance traveled. This was analyzed by age and gender. An analysis of variance with a Duncan’s post hoc was computed between active commuters, infrequent commuters and passive commuters at the elementary and middle school level for descriptive characteristics of age, BMI, distance traveled, frequency of active commuting, and weekly physical activity of active commuting variables.

Weekly physical activity from active commuting was then evaluated using Pearson correlation coefficients with BMI z-scores and BMI percentiles specific for age and gender, adjusting for age. BMI z-scores have been shown to be the most accurate at classifying children who were overweight.28 Data were analyzed using SAS version 9.1 (Cary, North Carolina).

**Results**

Of the total number of students (4379) with successfully geocoded addresses, 959 (21.9%) actively commuted to school while 700 (16.0%) were infrequent active commuters and 2,720 (62.1%) were passive commuters (bus or personal car commuters) (Table 1; Figures 1 and 2).
Table 1  Proportion of Active Commuting Trips Made to School by K–8th-Grade Students by Population and Potential Active Commuters (PAC)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Entire population n</th>
<th>PAC n</th>
<th>Active commuters Population %</th>
<th>PAC %</th>
<th>Infrequent active commuters Population %</th>
<th>PAC %</th>
<th>Passive commuters Population %</th>
<th>PAC %</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>589</td>
<td>198</td>
<td>11.2%</td>
<td>25.3%</td>
<td>13.4%</td>
<td>15.2%</td>
<td>75.4%</td>
<td>59.6%</td>
</tr>
<tr>
<td>1st</td>
<td>531</td>
<td>173</td>
<td>13.9%</td>
<td>30.6%</td>
<td>14.1%</td>
<td>15.0%</td>
<td>71.9%</td>
<td>54.3%</td>
</tr>
<tr>
<td>2nd</td>
<td>532</td>
<td>151</td>
<td>15.0%</td>
<td>33.1%</td>
<td>14.5%</td>
<td>21.2%</td>
<td>70.5%</td>
<td>45.7%</td>
</tr>
<tr>
<td>3rd</td>
<td>502</td>
<td>156</td>
<td>19.7%</td>
<td>41.7%</td>
<td>14.7%</td>
<td>22.4%</td>
<td>65.5%</td>
<td>35.9%</td>
</tr>
<tr>
<td>4th</td>
<td>476</td>
<td>168</td>
<td>33.8%</td>
<td>60.7%</td>
<td>13.7%</td>
<td>16.1%</td>
<td>52.5%</td>
<td>23.2%</td>
</tr>
<tr>
<td>5th</td>
<td>476</td>
<td>172</td>
<td>33.0%</td>
<td>59.9%</td>
<td>18.5%</td>
<td>20.9%</td>
<td>48.5%</td>
<td>19.2%</td>
</tr>
<tr>
<td>6th</td>
<td>426</td>
<td>174</td>
<td>27.5%</td>
<td>51.2%</td>
<td>18.3%</td>
<td>22.4%</td>
<td>54.2%</td>
<td>26.4%</td>
</tr>
<tr>
<td>7th</td>
<td>432</td>
<td>157</td>
<td>23.8%</td>
<td>45.2%</td>
<td>21.5%</td>
<td>28.7%</td>
<td>54.6%</td>
<td>26.1%</td>
</tr>
<tr>
<td>8th</td>
<td>415</td>
<td>163</td>
<td>24.6%</td>
<td>43.6%</td>
<td>17.1%</td>
<td>21.5%</td>
<td>58.3%</td>
<td>35.0%</td>
</tr>
<tr>
<td>Total</td>
<td>4379</td>
<td>1512</td>
<td>21.9%</td>
<td>43.3%</td>
<td>16.0%</td>
<td>20.2%</td>
<td>62.1%</td>
<td>36.6%</td>
</tr>
<tr>
<td>K–5th</td>
<td>3106</td>
<td>1018</td>
<td>21.1%</td>
<td>41.6%</td>
<td>14.8%</td>
<td>18.3%</td>
<td>64.1%</td>
<td>40.2%</td>
</tr>
<tr>
<td>6th–8th</td>
<td>1273</td>
<td>494</td>
<td>25.3%</td>
<td>46.8%</td>
<td>19.0%</td>
<td>24.1%</td>
<td>55.7%</td>
<td>29.2%</td>
</tr>
</tbody>
</table>

Abbreviations: PAC, potential active commuters: students who live within a 0.5-mile radius of their school for grades K–5 and 1.0-mile radius for grades 6–8; Active Commuter = actively commute to/from school at least 5 times per week; Infrequent Active Commuter, actively commute to/from school < 5 times per week; Passive Commuter, passively commute to/from school.

Figure 1 — Public school commuting patterns in Kearney, Nebraska.
Figure 2 — Public school commuting patterns in Lexington, Nebraska.
Both districts combined contained a total of 3101 students in grades K–5 with many students living outside of each community’s respective city limits. As a result, only one-third (32.8%, n = 1018) were PAC residing within 0.5 miles of their respective school. Of those elementary students who reside within the reasonable threshold, 41.6% actively commuted (≥ 5 times a week) to or from school while 18.3% were infrequent active commuters (1–4 times per week; Table 1). In comparison with grades K–5, there were 1512 students in grades 6–8 and 494 (32%) lived within 1.0 mile of their respective school facility. Of these potential pedestrian commuters, only 231 (46.8%) actively commuted at least 5 times per week with an additional 24% actively commuting on an infrequent basis (Table 1).

Demographic characteristics of the PAC at the elementary and middle school levels are provided in Table 2. At the elementary-level, there was a significant difference in age between active commuters, infrequent active commuters and passive commuters (P < .05). Among PAC, at the elementary-level the average passive commuter lives 0.34 ± 0.1 mile from school while middle school passive commuters live 0.76 ± 0.21 miles from school. A trend in active commuting frequency with age from kindergarten through middle school is depicted in Figure 3. It appears that 10- and 11-year-olds actively commuted most frequently.

Evaluating the association between active commuting and BMI within these 2 districts among potential active commuters did not suggest a significant association. Neither BMI z-scores nor BMI percentiles based on age and gender significantly correlated with active commuting frequency (r = −0.02 to −0.03, P > .05), distance (r = −0.02, P > .05), or accumulated physical activity (frequency × distance) (r = −0.03, P > .05) at the elementary-level when adjusting for age. Similar results were found in the middle school grades; however, significant negative correlations were found for distance from school with BMI z-scores (r = −0.11, P = .01) and BMI percentiles for age and gender (r = −0.12, P = .01) suggesting the further distance traveled within 1.0 mile the lower the BMI percentile among PAC.

**Discussion**

Overall, a large percentage (36.6) of potential active commuters in this study were actually passive commuters—those students who were car/bus riders on a regular basis. At the elementary-level, these PAC lived three- to four-tenths of a mile from school, which significantly highlighted trip distance and traffic generation issues. There are 409 K–5 students (40.2%) who lived within 0.5 miles of a school and were passive commuters. In addition, 144 6th–8th graders (29.2%) who lived within 1.0 miles of campus were passive commuters. These passive commuters who live in close proximity to neighborhood schools generate enormous amounts of traffic which has been, ironically, cited on recent surveys in the same community as one of the primary reasons why parents do not let children actively commute to school.7 The high number of passive commuters is in part a cultural issue. Compared with other developed nations, United States residents make a large number of short trips, and by far

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**Table 2 Descriptive Characteristics of Active, Passive and Infrequent Active Commuters at the Elementary- and Middle-School Levels Who Are Potential Active Commuters**

<table>
<thead>
<tr>
<th></th>
<th>Elementary (K–5)</th>
<th></th>
<th>Middle School (6th–8th grade)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active commuter</td>
<td>Infrequent active commuter</td>
<td>Passive commuter</td>
<td>Active commuter</td>
</tr>
<tr>
<td>n (%)</td>
<td>423 (41.6)</td>
<td>186 (18.3)</td>
<td>409 (40.1)</td>
<td>231 (46.7)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>8.9 ± 1.8 A</td>
<td>8.5 ± 1.8 B</td>
<td>7.7 ± 1.7 C</td>
<td>12.7 ± 1.0</td>
</tr>
<tr>
<td>BMI (%ile)</td>
<td>70.6 ± 26.2</td>
<td>72.3 ± 24.9</td>
<td>72.3 ± 25.3</td>
<td>75.2 ± 25.4</td>
</tr>
<tr>
<td>BMI z score</td>
<td>0.78 ± 0.99</td>
<td>0.84 ± 0.97</td>
<td>0.86 ± 1.0</td>
<td>0.95 ± 0.98</td>
</tr>
<tr>
<td>Distance (miles)</td>
<td>0.23 ± 0.13 A</td>
<td>0.33 ± 0.11 B</td>
<td>0.34 ± 0.1 B</td>
<td>0.49 ± 0.25 A</td>
</tr>
<tr>
<td>Frequency (week)</td>
<td>8.04± 2.11 A</td>
<td>2.46 ± 1.2 B</td>
<td>0 C</td>
<td>7.85 ± 2.12 A</td>
</tr>
<tr>
<td>Physical activity accumulated (miles/week)</td>
<td>1.67 ± 1.01 A</td>
<td>0.66 ± 0.50 B</td>
<td>0 C</td>
<td>2.98 ± 1.86 A</td>
</tr>
</tbody>
</table>

**ABC** Letters that are different imply significant difference within groups (P < .05).

Abbreviations: BMI, Body Mass Index; Distance, commute distance from home to school; Frequency, frequency of active commuting; Physical Activity Accumulated, Distance × Frequency; Active Commuter, actively commute to/from school at least 5 times per week; Infrequent Active Commuter = actively commute to/from school < 5 times per week; Passive Commuter, passively commute to/from school.

**Note.** BMI %ile based on age and gender (Centers for Disease Control).
the majority of these trips are taken in cars—approximately 25% of all trips are less than 1 mile and of these 75% are by car. Moreover, in the United States 9% of all trips are walking and only 1% of trips are made by bicycle. In comparison, most European countries have more compact cities and much higher active commuting rates. In 10 European nations at least 5% of the all trips are by bike and at least 20% are walking trips.

Overall, 37.9% of the entire population and 63.5% of the PAC walked or biked at least once a week—which is a high percentage compared with national data. These high percentages may be attributed to the timing of the survey and the perceived safety in small Midwestern communities. Although our percentages are high, more than 1 out of 3 children is still being driven 3 blocks to school. Evaluating the data based on potential commuters and not the entire population puts the data into context for public health advocates. Knowing the percentage of children who could potentially walk to school allows the development and implementation of sensible evaluations and programs after setting appropriate objectives.

Previous research has also suggested that busy streets or even the perceived danger of traffic detours affect active commuting. A tertiary analysis indicated that our active commuting rates are indeed impacted by the presence of connector streets with traffic counts of 2000+ vehicles per day which are often found adjacent to neighborhood schools (Figure 4). Traffic data were combined with the existing transportation data to create 2 categories—students who cross no barriers commuting to school and those who must cross at least 1 thoroughfare with 2000 vehicle trips per day. Of those 1512 students who live within reasonable commuter zones (0.5 mile and 1.0 respectively) and have no barriers, 43.8% actively commute. However, the percentage of active commuters dramatically declines to 29.0% when only 1 barrier is present (Figure 4).

In addition to busy streets, incorporating pedestrian-friendly design measures—limiting block length and speed limits—which are often associated with population density have produced positive results. Boarnet et al contend, for example, that in California research has demonstrated that small projects, such as, traffic signals and sidewalk improvements, increase walking. In general, older urban neighborhoods tend to have more destinations, in this case schools within a safe walking distance. Kearney and Lexington have 12 public elementary attendance zones and active commuting rates vary not only due to location but population density as well (Table 3). Based on the percent of students who actively commute by attendance zone, the more dense areas of Kearney and Lexington tend to have a greater number of walkers.

In regard to age, the current study suggests that fewer younger elementary school students are actively commuting, even those who live a short distance from school. Specific reasons are not known, it is plausible that local school policies, parental safety concerns, and the lack of pedestrian infrastructure attribute to the parental decision at this young age. It does appear that 10- to 11-year-olds are actively commuting most frequently. Since the population analyzed all lived within a reasonable distance from their respective school, the association with frequency of walking indicates it may be more habit forming at this age. It is also possible that older students are becoming more trustworthy and independent. As a
**Figure 4** — Barriers to active commuting in Kearney, Nebraska.

<table>
<thead>
<tr>
<th>Attendance zone*</th>
<th>Density**</th>
<th>Percent of active commuters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryant</td>
<td>64.95</td>
<td>15.9</td>
</tr>
<tr>
<td>Park</td>
<td>113.28</td>
<td>21.5</td>
</tr>
<tr>
<td>Central</td>
<td>157.63</td>
<td>7.4</td>
</tr>
<tr>
<td>Meadowlark</td>
<td>197.41</td>
<td>14.5</td>
</tr>
<tr>
<td>Northeast</td>
<td>203.46</td>
<td>17.0</td>
</tr>
<tr>
<td>Windy Hills</td>
<td>221.59</td>
<td>13.1</td>
</tr>
<tr>
<td>Kenwood</td>
<td>258.25</td>
<td>12.5</td>
</tr>
<tr>
<td>Emerson</td>
<td>266.83</td>
<td>17.1</td>
</tr>
<tr>
<td>Pershing</td>
<td>360.8</td>
<td>20.8</td>
</tr>
<tr>
<td>Sandoz</td>
<td>401.5</td>
<td>21.1</td>
</tr>
<tr>
<td>Morton</td>
<td>420.91</td>
<td>20.1</td>
</tr>
</tbody>
</table>

* Glenwood Elementary School in Kearney was excluded from the calculation based on location. It is north of Kearney on the extreme suburban fringe in a sparsely populated area.

** Number of students per square mile.
result, parents are allowing them to walk or bicycle to and from school, which is a social outlet for upper elementary students. Social dynamics change in middle school and students may no longer perceive active commuting as a social outlet.

It has been well documented that students who actively commute to and/or from school increase daily physical activity and long-term interventions suggest these students may gain less weight over time. The reported relationship between active commuting to school and weight status has been mixed. Recently, Mendoza et al. found significant inverse associations with BMI z-scores and skinfolds with active commuting in adolescents (age 12–19 years). Greater minutes of active commuting were associated with lower BMI z-scores after controlling for dietary energy intake although active commuting only accounted for less than 1% of the variance in BMI z-score. Although the current study did not find significant inverse associations between BMI z-score or BMI percentile with accumulated physical activity (frequency × distance) from active commuting, there were significant inverse associations between distance from school and BMI z-scores for middle school students who lived within a reasonable distance from their respective school. We know that as students progress in school, they commute farther distances and therefore may be accumulating more activity as they reach the adolescent age. These results from middle school students appear to support the work by Mendoza et al. The elementary school PAC in our study simply did not accumulate enough activity to impact BMI z-scores, although some activity is better than none.

Although health implications associated with active commuting are unclear, the enhanced physical activity is of great importance and should be continually encouraged for prevention of chronic disease associated with inactivity. There is great concern that students living within three- to four-tenths of a mile from school are being driven to school, increasing traffic congestion at neighborhood schools and potentially escalating pedestrian/traffic safety concerns among parents. As physical activity levels rapidly decline when children enter adolescence it is important to provide safe environments for children to be active and promote walking and bicycling to school among those who could potentially walk to school.

When planning future active commuting programs, coordinators should consider focusing on those families who reside within a reasonable distance. Conducting formative assessments with this specific population segment may lead program planners to identify different barriers and enablers to active commuting than is found among the entire population of students and parents. By conducting a formative assessment with all who live a reasonable distance, protective factors related to why parents and children choose to actively commute can be communicated to passive commuter parents and students, for example. These may be more positive messages than those created to assist in overcoming barriers.

Conclusion

Several disciplines—health and wellness to urban planning—are currently examining issues related to the built environment and transportation. There appears to be an increasing public interest in community walkability, as reflected in the growing number of state and federal initiatives on Safe Routes to School, concern over a national obesity epidemic (especially in children), and a wide range of policy initiatives designed to convince travelers to switch from auto trips to more environmentally sustainable alternatives.

The public schools examined in this study have approximately 21.9% of their students actively commuting, which is in range of national estimates. One factor that limits the number of active commuters is school location. Using thresholds—0.5 miles for grades K—5 and 1.0 miles for grades 6—8—reveals that just over 30% of the students reside within a reasonable walking distance. This sheds a new focus on who should become the priority population for active commuting programs. Future research should center on the barriers and enablers of active commuting among populations who live within a reasonable distance. Future walk-to-school initiatives could be planned and marketed more strategically based on data from this specific priority population.

Acknowledgments

The authors would like to thank both Kearney and Lexington Public Schools for their devotion to children and enhancing their health and well-being. We would also like to thank Jacob McGlade for his time and contribution to the analysis. This project was funded by the University of Nebraska-Kearney Research Services Council.

References


