



## Active commuting to school: A longitudinal analysis examining persistence of behavior over time in four New Jersey cities

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### ABSTRACT

Evidence suggests that healthy behaviors initiated during childhood may continue over time. The objective of this study was to determine whether active commuting to/from school (ACS) at baseline predicted continued ACS at follow-up two to five years later.

Two cohorts of households with 3–15 year-olds in four low-income New Jersey cities were randomly sampled and followed for two to five year periods between 2009 and 2017. Children who walked, bicycled, or skateboarded to/from school at least one day/week were classified as active commuters. Children with complete data at both time points were included in this analysis (n = 383). Multivariate logistic regression was used to examine the association between ACS at T1 and T2. Models adjusted for child age, sex, and race/ethnicity; parent's education and nativity status (native-born vs foreign-born); household poverty level; car availability; neighborhood level characteristics; and distance from home to school.

Children who engaged in ACS at T1 had over seven times the odds of ACS at T2 compared to children who did not actively commute at T1 (p < 0.001), after adjusting for distance to school and other relevant covariates. Distance, regardless of active commuting status at T1 was inversely associated with active commuting at T2.

Policies and interventions encouraging ACS, and those that decrease the distance between a child's home and school, may result in increased, habitual active commuting and physical activity behavior throughout childhood and possibly into adulthood.

### 1. Introduction

Over the life course, physical activity (PA) is a vitally important component of a healthy lifestyle. In children PA positively impacts bone health, weight status, cardiorespiratory and muscular fitness, cardiometabolic health, cognition, and mental health. Similar to the World Health Organization guidance (World Health Organization, 2020), Physical Activity Guidelines for Americans advise that school-age children engage in at least 60 min per day of moderate to vigorous physical activity (US Department of Health and Human Services, 2018). However, in the US only 42.5% of 6–11 year-olds, 7.5% of 12–15 year-olds, and 5.1% of 16–19 year-olds currently meet the recommendations (Katzmarzyk et al., 2016).

Children's daily commute to/from school provides an opportunity to

accumulate PA, but only 11% of children actively commute (e.g., walking, bicycling, skateboarding) to or from school (ACS) in the US; this rate has not changed in the last decade (Kontou et al., 2017). Barriers to ACS vary based on location of both the school and the child's home, but may include neighborhood characteristics such as traffic (Huertas-Delgado et al., 2017; Lu et al., 2015), crime (Huertas-Delgado et al., 2017; Baek et al., 2016), overall lack of safety (Murtagh et al., 2016; Salahuddin et al., 2016), mixed land use (Lu et al., 2015), aesthetics (DeWeese et al., 2013; Noonan et al., 2017), lack of social cohesion (Salahuddin et al., 2016), or a combination of barriers interacting with one another (Ross et al., 2017). These barriers affect children differently by age (Kontou et al., 2017; Huertas-Delgado et al., 2017), gender (Huertas-Delgado et al., 2017; Easton and Ferrari, 2015), mode of ACS (e.g., walking vs bicycling) (Huertas-Delgado et al., 2017),

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socioeconomic status (Kontou et al., 2017; Lu et al., 2015), urbanicity of the school locale and/or child's home (Lu et al., 2015; Murtagh et al., 2016), and parent education levels (te Velde et al., 2017).

The greatest, and most persistent, barrier to ACS by far, however, is the distance between home and school (Kontou et al., 2017; Huertas-Delgado et al., 2017; Lu et al., 2015; Murtagh et al., 2016; Easton and Ferrari, 2015; Chillón et al., 2015; Gutiérrez-Zornoza et al., 2015). Distance to school often increases as children age due to school feeder patterns, in which multiple elementary and/or middle schools funnel into one high school. (School Feeder Patterns, 2014) As a result, ACS likelihood tends to decrease once children reach high school (Rothman et al., 2018).

A large portion of the variation in ACS rates among children remains unexplained, particularly when examining changes in ACS over time. (Rothman et al., 2018) Studies examining behavior persistence have found that PA and sedentary behaviors established in early childhood tend to continue into later childhood years (Jones et al., 2013) or even into adulthood (Telama et al., 2005; Yang et al., 2014). Evidence suggests that the more often a behavior is performed, the longer it will persist (Harris and Kessler, 2019). Economists note that higher frequency and duration of exercise at an initial time period increases the probability of continuing the exercise (Harris and Kessler, 2019), citing status quo bias or inertia as explanations for why individuals continue certain behaviors over time (Thaler and Sunstein, 2003). Cross-sectional studies demonstrate that ACS distribution among children tends to be bimodal, with most children practicing ACS either every school day or no school days (DeWeese et al., 2013; Gutiérrez-Zornoza et al., 2015; DeWeese and Ohri-Vachaspati, 2015). Few studies have examined the persistence of ACS over time.

This longitudinal study assesses whether ACS practices persist over time. We also investigate the interaction between prior ACS behavior and current distance to school to understand whether the persistence of ACS over time is affected by the current proximity to school.

## 2. Methods

The New Jersey Child Health Study (NJCHS) followed two cohorts of low-income, largely racial/ethnic minority children 3–15 years of age over a 2–5-year period. Comprehensive data were collected at the individual, household, and community levels. The Rutgers and Arizona State University Institutional Review Boards approved the study protocol.

### 2.1. Household survey

Between 2009 and 2017, survey data were collected in Camden, New Brunswick, Newark, and Trenton, New Jersey at two time points for each of the two panels of households. Panel 1, Time 1 (P1, T1) interviews were conducted in 2009–10. Data for this panel were collected from a random-digit-dial sample of households with landline telephones. Time 2 (T2) interviews for P1 were completed in 2014–15. Panel 2 (P2) used a multi-frame landline and cell phone sampling method within the geographical areas of the four cities. Cell phones were added to the sampling frame because of declining use of landline phones. T1 and T2 interviews for P2 were conducted in 2014 and 2016–17, respectively. The sample was drawn by Survey Sampling Inc., and provided a probability sample of households containing one or more children aged 3 to 18 years. Responses were weighted to account for the survey design, non-response, non-telephone households, and number of children in the household so that the sample is representative of households with children residing in the four study cities.

In both panels households located within the study city, and with at least one child between 3 and 15 years old were eligible for inclusion in the study. Computer-aided telephone interviews were conducted in English or Spanish by trained interviewers. Respondents provided oral consent before the survey was administered. Data were collected on the

respondent and on one child (referred to as the index child). In households with multiple age-eligible children, a computer program randomly selected the index child. The respondent reporting on children for both panels was an adult, at least 18 years old, and primarily responsible for food purchasing decisions for the family; in over 94% of cases this was a parent or grandparent and is referred to as “parent” hereafter. Interviews took 30–36 min to complete, on average. Survey questions were derived from previous research and included relevant demographic characteristics at T1, including mother's highest level of education and whether the respondent was born outside the US. At both time points respondents were asked about their own and the index child's height, weight, food and physical activity behaviors; car availability; household socio-economic status; home address; name of the child's school; and how many days of the week the child actively commuted to school. Fig. 1 provides details on sample size for the two panels. From the two panels combined, completed interviews at two time points were available for 599 households, 587 of which provided responses about ACS at both times.

### 2.2. Outcome measure: active commuting to or from school at time 2 (T2 ACS)

Parents were asked: *On how many days during a typical week does the index child walk, bicycle, or skateboard to or from school?* Similar questions used in previous research (Heelan et al., 2013; Kerr et al., 2006) have shown moderate test–retest reliability (Kappa = 0.60). The distribution of responses at T2 was bimodal, with 45% answering 0 days/week, and 46% answering 5 days/week. Therefore, instead of using frequency of ACS as a count variable, the outcome was dichotomized; those who actively commuted to school one or more days per week were coded as 1 and those who never walked, bicycled, or skateboarded were coded as 0. This approach has been widely used in the literature (DeWeese and Ohri-Vachaspati, 2015; Kerr et al., 2006; Babey et al., 2009; Evenson et al., 2006; Gallimore et al., 2011; Heelan et al., 2005; Robertson-Wilson et al., 2008; Rossen et al., 2011; Voorhees et al., 2010).

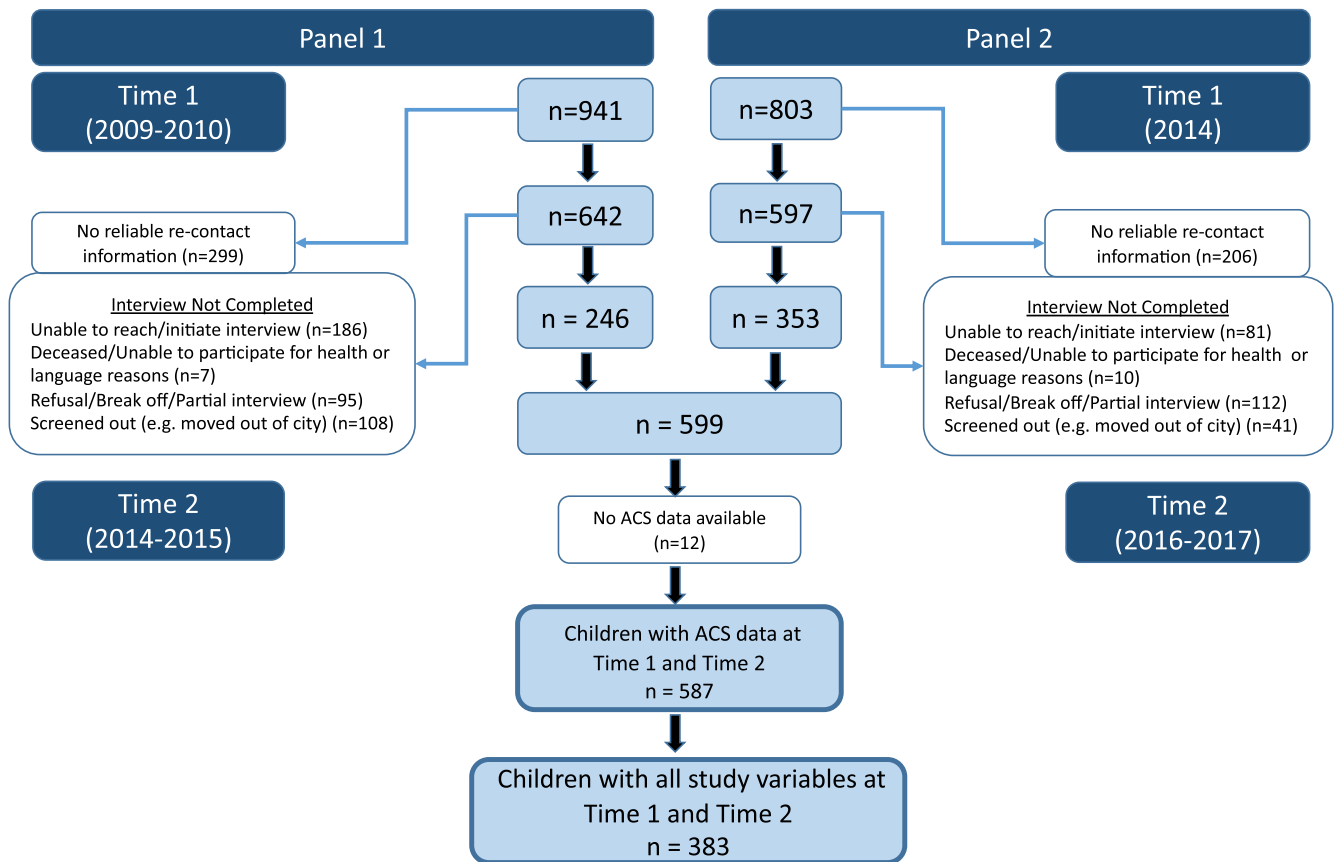
### 2.3. Explanatory variables: active commuting to/from school at time 1, demographics, distance to school, neighborhood environment

The social ecological model (SEM), the theoretical framework for the NJCHS design, suggests that children's behaviors can be influenced by child, household, school, and neighborhood environmental factors (McLeroy et al., 1988). The following variables representing the various levels of the SEM have been associated in previous literature with ACS, and were therefore included in the present analysis (Kontou et al., 2017; Huertas-Delgado et al., 2017; Lu et al., 2015; Baek et al., 2016; Murtagh et al., 2017; Salahuddin et al., 2016; DeWeese et al., 2013; Noonan et al., 2017; Ross et al., 2017; Easton and Ferrari, 2015).

**Demographics.** Children's age, sex, and race/ethnicity, as well as household income were reported by parents in the household survey. Based on race/ethnicity, children were classified as non-Hispanic white, non-Hispanic black, Hispanic, and other. Household poverty level was calculated as the ratio between reported household income and the federal poverty level (FPL) for the year in which the survey was conducted. Total population and median household income for the census block in which each respondent lived were collected from the American Community Survey 5-year data files corresponding with the years of household surveys.

**Active commuting at time 1 (T1 ACS).** Like T2 ACS responses, the distribution of responses for ACS at T1 was similar and bimodal, with 49% answering 0 days/week, and 43% answering 5 days/week; therefore, it was also recoded into a binary variable (0 = non-active commuters; 1 = active commuters).

**Distance from home to school.** Home addresses (or nearest cross-streets) were provided by participating households during T1 and T2 interviews, with over 97% providing complete information. All



**Fig. 1.** Description of the study timeline and the longitudinal analytic sample: New Jersey Child Health Study (2009–2017). Abbreviations: ACS: active commuting to/from school.

addresses were geocoded. Distance from a child's home to the school they attended in the year of the household survey was calculated using modified versions of NJ Department of Transportation roadway network data in ArcGIS software. The roadway network data for each were checked against detailed aerial photography, edited for errors, and had segments removed where pedestrian uses were strictly prohibited. Sidewalks are highly prevalent in the four study cities, with over 95% of respondents reporting having sidewalks around their home at both T1 and T2. Descriptive statistics are presented using distance in miles. In multivariate models, distance was computed in units representing 1/10th mile and was mean-centered for ease of interpreting regression coefficients for interaction terms. Use of the variable in its original form would result in an estimation of the coefficient for the variable (ACS at T1) interacted with distance at distance = 0, which is not meaningful.

**Neighborhood environment.** Walkability and bikeability around children's homes were assessed by use of Walk Score rankings and Bike Score indices purchased from Walk Score ([Walkability, 2021](#)). Walk Score is a measure of walkability on a scale from 0 to 100 based on the distance to destinations such as grocery stores, schools, parks, restaurants, and retail. The shorter the walk to an amenity, the more points are awarded; after a 30-minute walk, no points are given. Bike Score measures bike accessibility on a scale from 0 to 100 based on bike infrastructure, topography, destinations, and road connectivity ([Walkability, 2021](#)).

Parents were asked: *Thinking about traffic, how safe is it to walk, run, bike, or play in your neighborhood?* Responses were captured on a 4-point Likert-type scale ranging from very safe to very unsafe. The variable was dichotomized, with respondents perceiving their neighborhood as very safe or safe with regard to traffic coded as 1, and very unsafe or unsafe coded as 0 ([DeWeese et al., 2013](#)). A parallel question was asked with regard to crime and coded in the same manner. Parents were also asked:

*How pleasant is it to walk, run, bike, or play in your neighborhood? For example, are there trees and proper lighting, no graffiti or abandoned buildings?* Responses were provided on a 4-point Likert-type scale ranging from very unpleasant to very pleasant. The variable was dichotomized, with those perceiving their neighborhood as very pleasant or pleasant coded as 1, and very unpleasant or unpleasant coded as 0.

#### 2.4. Statistical analysis

All analyses were conducted using Stata, version 15.1. Bivariate analyses were used to compare rates of children who engaged in ACS at T2 by ACS at T1, child and parent demographics, neighborhood characteristics, and distance from home to school at T2.

Multivariate logistic regression analyses were used to examine the association between ACS at T1 and T2. All models adjusted for distance from home to school at T2; change in distance from T1 to T2; child's age (6–11 years old or 12–15 years old), sex, and race/ethnicity (Non-Hispanic Black, Hispanic, White/Other); mother's education at T1 (high school or less, some college or more); foreign-born parent; household poverty level at T2; car availability at T2; city of residence (New Brunswick, Camden, Newark, Trenton); and length of time between T1 and T2 interviews. A second model included all these variables and added neighborhood-level characteristics. A third model added the interaction between ACS at T1 and distance from home to school at T2 to test whether and how the association between ACS at T1 and ACS at T2 is affected by distance at T2. This interaction model allowed us to estimate predicted probabilities of engaging in ACS at T2 for children who actively commuted at T1 and for those who did not, over several distances. All models included longitudinal survey weights and adjusted for clustering at the city level.

### 3. Results

The children in the sample were on average 9.4 years-old, with equal representation of males and females (Table 1). Over half of children in the sample were non-Hispanic black, approximately 30% were Hispanic, and 12.4% were non-Hispanic white or another race/ethnicity. At T2, 56% of children actively commuted to school, compared to 51% at T1. Seventy-eight percent of the children who engaged in ACS at T1 continued to do so at T2, while only 34% of those who did not actively commute at T1 took it up at T2. Most children maintained their initial ACS behavior over time.

Table 2 displays the results of multivariate logistic regression. Model 1 shows that children who engaged in ACS at T1 had more than seven times the odds of actively commuting at T2 compared to children who did not actively commute at T1 (OR = 7.37; 95% CIs: 3.34–16.25;  $p < 0.001$ ). For every 1/10th mile (0.16 km) increase in distance from home to school at T2, children's odds of actively commuting decreased by 8% (OR = 0.92; 95% CIs: 0.87–0.98;  $p = 0.007$ ). Several parent and household characteristics were significant predictors of ACS at T2. Children with a parent born outside of the US had lower odds of ACS compared to those whose parents were born in the US (OR = 0.32; 95% CIs: 0.13–0.79;  $p = 0.014$ ). Children whose mother had attended some college (comparison group: high school or less) had higher odds of ACS at T2 (OR = 2.35; 95% CIs: 1.09–5.05;  $p = 0.029$ ), as did children from families with a higher ratio of income to FPL (OR = 0.84; 95% CIs: 0.72–0.98;  $p = 0.023$ ). Of the neighborhood characteristics added in Model 2, children of parents who perceived their neighborhood as safe from crime were more than 2.5 times as likely to engage in ACS (OR = 2.53; 95% CIs: 1.04–6.18;  $p = 0.041$ ). Adding neighborhood characteristics did not alter the coefficients for variables previously included.

**Table 1**  
Demographic, behavioral, perception, and distance to school characteristics of the analytical sample (n = 383)<sup>a</sup>.

	Means $\pm$ SD or percent
Age at T1 (%)	
6–11	44.2
12–15	55.8
Female (%)	46.5
Race/Ethnicity (%)	
White/Other	12.4
Non-Hispanic black	56.8
Hispanic	30.8
Foreign-born parent (%)	36.6
Mother's education (%)	
HS or less	60.2
Some college or more	39.8
T2 Poverty level (Range: 0 – 32.5)	2.34 $\pm$ 4.08
Car available (%)	93.0
City (%)	
Camden	18.7
Newark	53.0
New Brunswick	9.5
Trenton	18.8
Walk Score (Scale: 0 – 100)	75.6 $\pm$ 12.1
Bike Score (Scale: 0 – 100)	63.8 $\pm$ 7.0
Parental perceptions of neighborhood (%)	
Safe from crime	44.0
Safe from traffic	54.2
Pleasant	61.6
Time between T1 and T2 (months)	39.1 $\pm$ 17.8
Distance to school at T2 (miles)	1.39 $\pm$ 1.16
Distance change from T1 to T2	0.31 $\pm$ 1.09
ACS (%)	
T1	50.6
T2	55.9

<sup>a</sup>Unweighted n; reported frequencies weighted to be representative of the population of the four cities.

Abbreviations: T1: time 1; T2: time 2; HS: high school; ACS: active commuting to/from school.

Fig. 2 illustrates the findings from Model 3, which added an interaction term, T1 ACS \* T2 distance. It displays adjusted probabilities of engaging in ACS at T2 over selected home-to-school distances. For the overall sample and for both T1 ACS conditions, each incremental increase in distance at T2 decreased the probability of ACS at T2. Children who engaged in ACS at T1 were more likely to engage in T2 ACS, regardless of distance to school. While distance was, as expected, associated with T2 ACS, it did not affect the association between T1 ACS and T2 ACS. Persistence in ACS over time was independent of current (T2) distance to school.

To ensure the consistency of our results, two sensitivity analyses were performed. In the first we replicated the three models without the car availability variable because of the small variability (93% of households in the sample had a car). The results were virtually unchanged, with both coefficients and standard errors almost identical to those from the main analysis. In the second, we controlled for the month of the interview. The question about actively commuting to school did not refer to a specific time period and was intended to capture the 'typical,' or average, behavior of the child. Nonetheless, the response to this question may have been influenced by the specific time of year when an interview was conducted. Adding month of the interview to the models did not substantially alter the results. The only difference detected was that after controlling for the interview month, the coefficient of the household poverty variable ceased to be significant.

### 4. Discussion

This longitudinal analysis examined the persistence of ACS among school age children over a 2–5-year period and found that ACS at T1 was strongly predictive of ACS at T2. Additionally, consistent with previous literature (Kontou et al., 2017; Rothman et al., 2018), the odds of ACS decreased as the distance between a child's home and school increased. Notably, however, the association between ACS at T1 and ACS at T2 was independent of distance to school. ACS persisted even among those students whose commute increased in distance over time. Active commuters at T1 were significantly more likely than were T1 non-active commuters to engage in ACS at T2 at any given distance, even up to 2.5 miles (4 km). Other individual- and household-level factors, such as child's age and parent/household characteristics and perceptions were also associated with ACS.

At each time point, almost half of the children in this sample actively commuted to school, compared to the US national average of 11% (Kontou et al., 2017). This difference is likely due to study participants living in densely populated communities located in older urban US cities; these communities tend to have schools located within neighborhoods, as evidenced by the fact that about half of the children in the sample lived within a mile (1.6 km) of the school they attended. The higher prevalence of ACS in this sample provided the variability necessary to examine factors associated with ACS over time.

Behaviors, healthy as well as unhealthy, are strongly resistant to change, and thus, tend to persist over time, creating a high degree of predictability. Children in this study had over seven times higher odds of practicing ACS at T2 if they actively commuted at T1, controlling for all other factors, including distance to school. Other health behaviors also persist over time in children. For example, Lioret et al. (Lioret et al., 2015) and Luque et al. (Luque et al., 2018) observed that infant dietary patterns predict continuing dietary patterns up to eight years of age. Lifestyle behaviors such as outdoor time and television viewing (Lioret et al., 2015), as well as physical activity and sedentary time may also persist throughout various stages of childhood (Jones et al., 2013). Jones et al. provided evidence of moderate tracking of PA and moderate to large tracking of sedentary behaviors from early to middle childhood (Jones et al., 2013). The Young Finns Study investigated the persistence of PA from youth into adulthood, observing that childhood PA predicted PA in adults up to 21 years later (Telama et al., 2005). Higher adult PA scores have been observed in those who maintained ACS during



**Table 2**  
Multivariate logistic regression analysis predicting active commuting to school at Time 2.

	Model 1 <sup>a</sup>		Model 2 <sup>b</sup>		Model 3 <sup>c</sup>	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
T1 ACS (ref: No ACS)						
ACS	7.37 (3.34–16.25)	<0.001	7.34 (3.39–15.90)	<0.001	7.34 (3.39–15.90)	<0.001
<sup>d</sup> Distance to school at T2 (1/10th mile)	0.92 (0.87–0.98)	0.007	0.93 (0.88–0.98)	0.005	0.93 (0.86–0.99)	0.035
T1 ACS × <sup>d</sup> distance to school at T2					1.00 (0.23–1.08)	0.972
Change in distance to school from T1–T2	1.00 (0.96–1.05)	0.901	0.99 (0.95–1.04)	0.805	0.99 (0.95–1.04)	0.803
T2 Age (years) (ref: 6–11)						
12–15	3.22 (1.30–8.03)	0.012	3.24 (1.31–8.01)	0.011	3.24 (1.31–8.03)	0.011
Sex (ref: Male)						
Female	0.94 (0.45–1.95)	0.859	1.03 (0.48–2.19)	0.938	1.03 (0.48–2.20)	0.939
Race/Ethnicity (ref: White/Other)						
Non-Hispanic Black	2.73 (0.83–9.04)	0.099	1.84 (0.50–6.76)	0.360	1.83 (0.49–6.88)	0.368
Hispanic	2.52 (0.65–9.72)	0.179	2.07 (0.52–8.27)	0.304	2.06 (0.50–8.43)	0.313
Mother's Education (ref: HS or less)						
Some college or more	2.35 (1.09–5.05)	0.029	2.70 (1.26–5.77)	0.011	2.70 (1.25–5.83)	0.011
Foreign-born parent	0.32 (0.13–0.79)	0.014	0.29 (0.12–0.72)	0.008	0.29 (0.12–0.72)	0.008
T2 Poverty level	0.84 (0.72–0.98)	0.023	0.85 (0.72–0.99)	0.036	0.85 (0.72–0.99)	0.036
T2 Car availability (ref: No car available)						
Car available	1.78 (0.28–11.42)	0.544	1.31 (0.20–8.79)	0.779	1.31 (0.20–8.82)	0.780
City (ref: New Brunswick)						
Camden	0.45 (1.07–1.92)	0.282	0.39 (0.09–1.66)	0.200	0.38 (0.09–1.63)	0.194
Newark	1.55 (0.42–5.65)	0.508	1.80 (0.50–6.34)	0.371	1.79 (0.49–6.51)	0.376
Trenton	1.00 (0.23–4.41)	0.999	0.71 (0.17–3.00)	0.643	0.71 (0.16–3.09)	0.646
Amount of time between T1 and T2	1.00 (0.98–1.02)	0.999	1.00 (0.98–1.02)	0.936	1.00 (0.98–1.02)	0.934
Walk Score			0.91 (0.80–1.04)	0.186	0.91 (0.80–1.04)	0.188
Bike Score			1.02 (0.90–1.16)	0.736	1.02 (0.90–1.16)	0.737
Neighborhood perceptions						
T2 Crime (ref: Unsafe)						
Safe			2.53 (1.04–6.18)	0.041	2.53 (1.04–6.18)	0.041
T2 Traffic (ref: Unsafe)						
Safe			0.93 (0.38–2.26)	0.867	0.93 (0.37–2.28)	0.866
T2 Pleasantness (ref: Unpleasant)						
Pleasant			0.75 (0.30–1.92)	0.554	0.75 (0.29–1.92)	0.552

<sup>a</sup>Model 1 includes child ACS behavior at T1, distance to school at T2, change in distance to school between T1 and T2, length of time between T1 and T2 surveys, along with child and household level variables.

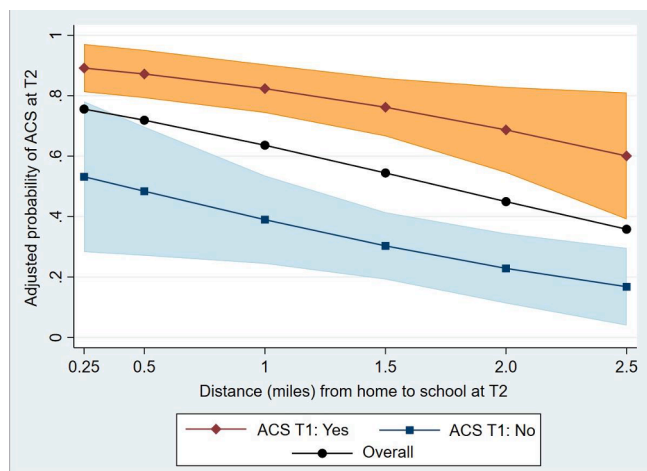
<sup>b</sup>Model 2 adds neighborhood features to the set of predictors used in Model 1.

<sup>c</sup>Model 3 adds to Model 2 the interaction between ACS at T1 and distance from home to school at T2.

<sup>d</sup>Distance from home to school was mean centered to facilitate meaningful interpretation of coefficients.

Abbreviations:

ACS: active commuting to/from school; T1: time 1; T2: time 2; HS: high school



**Fig. 2.** Adjusted probabilities<sup>a</sup> and 95% CI of children engaging in ACS at Time 2 for selected distance from school at Time 2. <sup>a</sup>Predicted probabilities based on Model 3 (Table 2) with an interaction term (ACS at T1 \* distance at T2). Shaded areas around lines represent 95% CI. Abbreviations: ACS: active commuting to/from school; T1: time 1; T2: time 2.

childhood (Yang et al., 2014); ACS may also be associated with lower rates of overweight and obesity in children (DeWeese and Ohri-Vachaspati, 2015). These findings illustrate the importance of forming the habit of engaging in ACS during childhood to ensure children continue to practice this healthy behavior from elementary school through high school.

However, distance between home and school is a major predictor of ACS, as observed in this analysis and others (Kontou et al., 2017; Rothman et al., 2018). Among children in the current sample, the odds of engaging in ACS decreased by 8% with every 1/10th mile (0.16 km) increase in distance. In the US, changing trends in locating schools have led to decreased rates of ACS, as larger schools have been built farther from neighborhoods (School siting, 2020), and school choice policies (i. e., permitting students to attend schools outside their neighborhood<sup>21</sup>) have resulted in children living farther from the school they attend. Safe Routes to School has recommended changing policies that favor new construction over renovations to existing neighborhood schools and eliminating minimum acreage requirements that result in schools being built outside of neighborhoods (School siting, 2020). Removing the primary barrier to ACS may encourage greater ACS rates, and result in this daily activity becoming a habitual behavior among more children.

Similar to the results of a number of other studies (Rothman et al., 2018; Yang et al., 2014), older children in this study were more than three times as likely as younger children were to actively commute. Data suggest that the rate of ACS increases with age until children reach 10–15 years old (Murtagh et al., 2016; Costa et al., 2012; Pabayo et al.,

2010), and then it declines. Distance may play a part in this decline among adolescents, as multiple elementary and middle schools tend to consolidate into fewer high schools (School Feeder Patterns, 2014).

We found that children's odds of ACS were over twice as high when parents perceived their neighborhood as safe from crime as when they perceived it as unsafe. Neighborhood environments and perceptions about these environments are key aspects of the SEM that influence PA behaviors. Therefore, community-level interventions aimed at increasing safety and parents' comfort with the safety of the neighborhood may reduce barriers to forming the habit of ACS, particularly among younger children.

This study has significant policy implications. Our key finding that the habit of ACS persists over time calls for designing effective interventions that promote ACS during early school years. This will ensure that students continue to practice ACS as they progress through school and possibly into adulthood. Policies that remove barriers to ACS, such as building or retaining neighborhood schools that decrease the distance from home to school and making neighborhoods safer, will potentially result in increased rates of ACS. Recent evidence indicates that improvements to infrastructure that would increase the safety and pleasantness of practicing ACS would generate societal economic benefits, such as reductions in traffic-related injuries and fatalities and a reduction in motorized transport (Jacob et al., 2021). Policy-makers, practitioners, and researchers' efforts (Bleich et al., 2018; Matwiejczyk et al., 2018), to design interventions aimed at encouraging habitual ACS may therefore result in persistent ACS and higher levels of PA with its associated benefits (Reiner et al., 2013).

Limitations of this study include measuring ACS using parent report; while reporting bias may have occurred, similar measures have been used previously (DeWeese et al., 2013; Ross et al., 2017; DeWeese and Ohri-Vachaspati, 2015). Sample size may also be a limitation, resulting in large confidence intervals for specific subgroups. The study had several strengths, including being among the first to examine persistence of ACS over time using a longitudinal sample. Further, the study investigated the role distance plays in continued ACS over time among a diverse group of school age children. The study used objective GIS-based measures of distance between home and school and adjusted for a variety of individual, household, and contextual factors associated with ACS.

## 5. Conclusions

While distance from home to school predicted the likelihood of children engaging in ACS at T2, ACS behavior at T1 was a much stronger predictor. Even at increasing distances, children who had engaged in ACS at T1 were more likely to actively commute at T2 than were children who did not actively commute at T1, indicating that once this behavior has been established it is likely to continue. Creating interventions that encourage ACS at younger ages could result in habitual, and thus persistent, active commuting and PA behavior over time.

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## CRedit authorship contribution statement

**Robin S. DeWeese:** Writing – original draft. **Francesco Acciai:** Formal analysis, Writing – review & editing. **David Tulloch:** Data curation, Writing – review & editing. **Kristen Lloyd:** Data curation,

Writing – review & editing. **Michael J. Yedidia:** Conceptualization, Methodology, Writing – review & editing. **Punam Ohri-Vachaspati:** Conceptualization, Methodology, Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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