Modeling Frequency and Duration of Out-of-Home Participation in Physical Activity by School-Age Children

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This paper investigates the frequency and the duration of participation in physical activity by children who go to school in the city of Dhaka, Bangladesh. The study uses data from a 2012 activity-based travel diary survey of 245 students in Grades 6 to 10 in the Dhaka metropolitan area. To explore the trade-offs between factors that affect the frequency of out-of-home physical activity, including the use of active transportation, this study used a zero-inflated Poisson (ZIP) regression model. Additionally, parametric hazard models were estimated to examine the duration of physical activities. The results of the ZIP count model suggest that personal and household characteristics, attributes of the built environment, and time commitments for other mandatory and discretionary activities influence the frequency of participation in physical activity. For example, an increase in the number of children in the household and the presence of sidewalks increased the frequency of out-of home, out-of-school physical activity if everything else was held equal. In contrast, travel time to school, the presence of traffic intersections, and the time commitment for tutoring sessions negatively affected participation in physical activity. In the modeling of the duration of out-of-home physical activity, this study found that a Weibull parametric hazard model outperformed a log logistic model. The duration was influenced by sociodemographic characteristics, spatial context, and escort arrangements. For instance, car ownership and a parental escort increased the duration of physical activity. The paper offers an in-depth behavioral understanding of children's physical activities in a developing country.

This paper presents findings on models of the participation in and the duration of physical activity by children who go to school in the city of Dhaka, Bangladesh. Children's regular physical activities directly affect their physical and mental health. Participation in daily physical activities and the use of active transportation during childhood help reduce the risk of a number of serious health problems (*1*). Transportation researchers are increasingly becoming interested in the study of participation in physical activity and time use because of paradigm shifts toward activity-based travel behavior analysis and the potential association between the built environment and levels of participation in physical activity (*2, 3*).

The focus of analysis in existing activity-based research has predominantly been on the activity–travel patterns of adults (*4*). However, the participation in physical activity and travel characteristics of children are unique; for example, they participate in many fixed activities, such as attending tutoring sessions (i.e., specialized daily lessons from private tutors in a fixed location outside the school curriculum), and require escort arrangements for out-of-home activities. Therefore, children should be treated as a distinct group, and in-depth investigations are required to understand the determinants of their physically active travel patterns and activities (*5*). This paper aims to explore the factors that affect the frequency of physical activities, including the use of active transportation, and the duration of such activities.

Although several authors have recently investigated children's activity patterns in the context of developed countries, studies of children in the context of developing countries are limited. Given the changing complexity of urban life in many developing countries, it is necessary to examine how children are participating in physical activities within that context. Recent economic growth and changing family structures in many cities in developing countries are altering the pace of people's lives and their patterns of activity, which are affecting children's participation in physical activity and their health. In fact, little is known about the activity and travel patterns of children in many high-density cities in emerging economies.

Recent evidence suggests that the rapid densification of cities is reducing the amount of public space and environments conducive to walking in many neighborhoods of populous cities. Traffic congestion, pedestrian safety, and personal security concerns further restrict children's use of physically active forms of transportation and engagement in out-of-home physical activities. In this context, this study attempts to fill some gaps in the understanding of the physical activity patterns of children in Dhaka, which is one of the megacities of the world. The paper specifically investigates the frequency and duration of out-of-home physical activities of children who go to school through the use of data from an activity-based travel diary survey.

The rest of the paper is organized as follows: it begins with a brief review of the recent literature in the modeling of participation in physical activity and the duration of such activity. Next, it provides an overview of the data that form the basis of the subsequent estimation of a model. This is followed by a discussion of the empirical results. Finally, the paper concludes with a summary of the study's contributions.

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LITERATURE REVIEW

The physical and psychosocial well-being of children is challenged by the decline in children's involvement in physical activities in recent years (*6*). Since the 1970s, the percentage of children who are overweight has more than doubled, and the rates among adolescents have more than tripled in the United States (*7*). The American Academy of Pediatrics recommends that children be physically active for at least 60 min/day (*8*). Such physical activity can include structured activities, such as sports and school-based physical education classes, or activities promoted through an active lifestyle, including outdoor play and walking or biking for daily travel. However, studies suggest that a significant percentage of school-aged children in developed countries, including the United States (*6*), Canada (*9*), and Australia (*10*), fails to meet this recommended level of daily physical activity.

In developing countries, because of rapid urbanization and increased competition for land, open spaces and playfields are disappearing and are being replaced by different profit-generating land uses (*11*). Places for outdoor recreation for children are therefore shrinking at a fast pace, and fewer places for outdoor recreation reduce the opportunities for out-of-home physical activities. Recent economic growth and increased rates of auto ownership are further influencing the way in which children are traveling to school and to other activities. Additionally, the changing patterns of family life (for instance, patterns in which both parents work and work longer hours) are negatively affecting children's opportunities to play outdoors and to use active transportation because both types of activities require suitable arrangements to be made to have children be accompanied (*12*). Increased traffic congestion, road safety issues, and personal security concerns are also possibly contributing to reduced amounts of out-of-home activities in exchange for in-home recreational activities.

Because evidence from activity-based travel behavior research in the context of cities located in developing countries (such as Dhaka) is limited, children's activity patterns and travel behaviors are mostly unknown. This study attempts to fill some gaps, mainly through investigation of the determinants of the frequency and duration of children's participation in physical activity, which include the use of active transportation, such as walking and biking.

The body of recent activity-based travel behavior research is enormous in both the North American and the European contexts. The literature on participation in and the amount of time spent on different types of activities includes studies on the home-stay duration of in-home activity episodes (*13*), mandatory skeletal activities (*14*), shopping (*15*), intershopping (duration between successive shopping episodes) (*16*), out-of-home nonwork activities (*17*), recreation (*18*), and social activities (*19*). Several studies have investigated the amount of time spent on multiple activities by consideration of the total time allocation for all activities (*20*) as well as modeling of joint activities (*21*). Activity generation and scheduling processes have also been investigated to microsimulate activity patterns (*22*).

The current activity-based transportation research follows two major streams: (*a*) the instances of activities and the time allocation of individuals (*13, 14, 19, 20*) and (*b*) activity generation and scheduling models (*22*). In the transportation field, the main purpose of modeling of activities is to contribute to the development of activity-based travel models. The majority of studies, however, have focused only on modeling of adults' activities. Because children are often required to be chauffeured by adults, modeling of the activity generation and the scheduling process of the adults has perhaps been given higher priority in earlier studies. Copperman and Bhat (*4*) argue that most children (those younger than 16 years of age) do not have a choice to drive and do not put extra cars in the transportation network; it may be presumed, therefore, that less attention is given to the modeling of children's participation in activity and travel patterns.

Several recent studies have contributed to the analysis of children's activity patterns and have included analyses of children's participation in leisure activities (*23*), weekend physical activities (*24*), and discretionary activities (*25*) and teenagers' recreational activities (*26*). Earlier research also examined children's out-of-home time use (*27*) as well as the use of active transportation, specifically, the mode choice for travel to school (*28*). Copperman and Bhat found that children spent, on average, 3.5 h on recreational activities during weekdays (*24*). Another study suggested that almost 26% of students in Grades 9 to 12 do not participate in any form of extracurricular activities after school (*27*). Sener and Bhat investigated children's engagement in discretionary leisure activity (*25*). The study suggested that children spent the largest amount of time at home on in-home passive activities, such as watching television, playing video and computer games, and communicating via electronic devices.

Many studies have established linkages between children's physical inactivity and conditions in the home, the built environment (e.g., walkable streets), and the availability of outdoor facilities for physical activity within reasonable distances (*1*). The lifestyle of children is becoming more sedentary as a result of technological changes as well. Time spent on the Internet, computers, video games, and hand-held electronic devices is supplanting time devoted to structured and spontaneous physical activities outside the home (*29*). Levels of physical activity are also influenced by the need for children to be accompanied, road safety, and personal security issues for children. Parents are allowing children to stay home instead of engaging in outdoor activities, particularly if the neighborhood is not conducive to walking (*30*). Moreover, longer distances from home to other activity locations reduce the probability that children will use active forms of transportation (*31*). The time budget is also an issue, because children need to participate in more fixed organized activities after school (such as homework) than adults. Given the complexity of the factors that might affect children's ability to participate in physical activity, further research is required to better understand their participation in physical activity.

In general, children's physical activities are investigated through the use of information on the amount of time that they use for structured and unstructured physical activities recorded in activity diary surveys. In contrast, when activity-based data are not available, only the use of active transportation is investigated (*32*). This study, however, investigates engagement in both of these types of physical activity.

Several methodological approaches have been used in the activity analyses described in the literature. Sener and Bhat have proposed a discrete–continuous modeling method that requires enormous amounts of data (such as in-home and out-of-home time allocations of activity as well as detailed travel attributes for all types of activities), which are difficult to obtain for Dhaka (*25*). For modeling of single types of activities, several authors have used count data models, such as Poisson regression models (*33*), to explain the frequency of participation in activity. Because of the existence of excessive zeros (i.e., no participation in physical activities), the study described in this paper used a zero-inflated Poisson (ZIP) model. For analysis of activity duration, the proportional hazard model is the most widely used. Previous transportation studies, however, have provided considerable evidence that the assumption of a proportional effect within the proportional hazard model is violated (*19*). As such, this paper examines a parametric accelerated failure-time hazard model. Applications of such models are still limited in transportation and related fields, specifically, in the modeling of the amount of time that children spend on physical activity. The next section sets out the methodology used in this paper.

METHODOLOGY

Zero-Inflated Poisson Regression Model

In the modeling of the frequency of children's participation in physical activity in Dhaka, this study estimates a ZIP regression model. To illustrate the modeling approach taken in this paper, let y_i be the number of physical activities in which child i participates in on a given day. Then, a Poisson model can be written as

$$P(y_i) = \frac{\exp(-\mu_i)\mu_i^{y_i}}{y_i!} \tag{1}$$

where $P(y_i)$ is the probability that child i will participate in y_i activities and μ_i is the expected value of y_i, $E(y_i)$, which can be represented as

$$E(y_i) = \mu_i = \exp(\beta X_i) \tag{2}$$

where β represents a vector of regression parameters to be estimated, and X_i is a vector of variables describing children's personal and household characteristics, attributes of the built environment, and other relevant conditions that affect the frequency of participation in physical activities.

One important property of this Poisson model is that it restricts the mean and variance of the distribution to equality [i.e., $E(y_i) = \text{var}(y_i)$], which limits its use for modeling of the overdispersion in the count data set. A particular kind of overdispersion occurs when more zeros than are consistent with a Poisson distribution are present in the data. For instance, a large proportion of respondents may not be found to engage in any physical activity on a given day. In this study, about 43% of children in Dhaka reported no physical activity during the weekday surveyed.

Because the number of zero observations was quite high, the basic assumption of a Poisson model was violated and the use of a zero-inflated methodology was therefore required. A suitable approach for analysis in such a case is use of a ZIP model, which assumes that two latent classes contribute to the excess zeros (*34*). Within the context of physical activity, the first latent class consists of a subgroup of children who never participate in any physical activity and will continue not participating. The second latent class consists of a subgroup that reports no physical activity but that is more amenable to the idea of participation in physical activity and has the potential to increase their physical activity. They simply have not yet reached a reporting threshold beyond zero; therefore, they are a part of the Poisson process (*35*).

The ZIP model tackles excess zeros mathematically by changing the mean structure to allow zeros to be generated by a dual-state process. Let ψ_i represent the probability that the response Y_i for the ith child is necessarily zero. Then, the probability that an outcome of zero will be observed, $P(Y_i = 0)$, and the probability that any particular nonzero count will be observed, $P(Y_i = y_i)$, can be written by the following two equations:

$$P(Y_i = 0) = \psi_i + (1 - \psi_i)\exp^{-\mu_i} \tag{3}$$

$$P(Y_i = y_i) = (1 - \psi_i)\frac{\mu_i^{y_i}\exp^{-\mu_i}}{y_i!} \tag{4}$$

where $0 < \psi < 1$ so that it incorporates more zeros than the Poisson model allows (i.e., Equation 1). The conditional expectation and variance of Y_i [$E(y_i)$ and $V(y_i)$, respectively] are given as

$$E(Y_i) = (1 - \psi_i)\mu_i \tag{5}$$

$$V(Y_i) = (1 - \psi_i)\mu_i(1 + \psi_i\mu_i) \tag{6}$$

where $V(Y_i) > E(Y_i)$ for $\psi_i > 0$, unlike the Poisson model (in Equation 1), in which the expected value equals the variance.

Estimation of this ZIP model requires maximization of a combined log likelihood function (L) for the response variable, y_i, obtained from the relationships in Equations 3 and 4:

$$\begin{aligned} L &= \sum_{i=1}^{n}\left[\begin{array}{l} K_{y_i=0}\log_e\left(\psi_i + (1-\psi_i)\exp^{-\mu_i}\right) \\ + K_{y_i>0}\log_e\left((1-\psi_i) + \dfrac{\mu_i^{y_i}\exp^{-\mu_i}}{y_i!}\right) \end{array}\right] \\ &= \sum_{i=1}^{N} K_{y_i=0}\log_e\left(\psi_i + (1-\psi_i)\exp^{-\mu_i}\right) \\ &\quad + K_{y_i>0}\left(\log_e(1-\psi_i) + y_i\log_e\mu_i - \mu_i - \log_e y_i!\right) \end{aligned} \tag{7}$$

where K is an indicator function for the given event. The parameters μ_i and ψ_i can be obtained via the following link functions:

$$\log_e(\mu_i) = \beta X_i \tag{8}$$

$$\log_e\left(\frac{\psi_i}{1-\psi_i}\right) = \omega Z_i \tag{9}$$

As mentioned earlier, X_i is a vector of variables that describes factors affecting nonzero outcomes. Z_i, however, represents a vector of regressors that explain membership to the zero state. β and ω are the corresponding parameters. Although the estimation of two sets of regressors is possible, a potential identifiability problem may not render meaningful interpretation of the resulting two sets of parameters (*36*). Therefore, this paper restricts, $\log_e(\psi_i/1 - \psi_i)$ so that it is equal to τ_0, a constant with an assumption that the probability of membership to the zero-state latent class is identical for all observations. Now, only β parameters are required to be estimated in relation to the X_i regressors. In this application, parameter estimates are obtained by the use of the expectation and maximization algorithm (*37*) to maximize the log likelihood function defined in Equation 7.

Hazard-Based Duration Models

To enhance the understanding of the factors that affect the amount of time spent on physical activities, the paper uses a continuous-time hazard-based duration modeling approach. Hazard models recognize the dynamics of the duration of physical activity of children on a given weekday because the likelihood of termination of physical activity is measured on the basis of the amount of time spent from the initiation of an activity. The key principles and statistical properties of the hazard-based duration models have been discussed by Hougaard (*38*). Let T be a continuous, nonnegatively valued random variable representing time until the termination of a physical activity of a given child. If the probability that the child will terminate the event within a short interval, Δt, at or after t is $P(t \leq T < t + \Delta t \mid T \geq t)$, then the hazard function, $\lambda(t)$, which is the instantaneous rate of failure at t, can be written as

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t} = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{S(t)} \tag{10}$$

where $f(t)$ represents the probability density function. The cumulative distribution function is $F(t) = P(T \leq t)$, and the survival function is $S(t) = P(T > t) = 1 - F(t)$.

This basic hazard model formulation can be extended to different types of model structures, including semiparametric and parametric models. In semiparametric models, the baseline hazard function $[\lambda_0(t)]$ is assumed to be parametrically unspecified. The most widely used semiparametric model, introduced by Cox (*39*), is given by

$$\lambda(t, x) = \lambda_0(t)\exp(x(t)) \tag{11}$$

where $x(t)$ is the vector of observed covariates and $\lambda_0(t)$ is the baseline hazard, which is not parametrically specified.

In contrast, the parametric models assume a specific distribution defining the baseline hazard function. Although it is possible to uncover the baseline distribution in semiparametric models, parametric models are preferred in this study because they provide a direct inference on the dependence on duration. Empirical applications in different research fields have used a wide variety of distributions for the parametric models. This paper examines a monotonic (Weibull) and a nonmonotonic (log logistic) distribution for the parameterization of the baseline hazard. The hazard rates for Weibull and log logistic distributions, respectively, are given as follows:

$$\lambda(t) = \varphi p(\varphi t)^{p-1} \tag{12}$$

$$\lambda(t) = \frac{\varphi p(\varphi t)^{p-1}}{\left(1 + (\varphi t)^{p}\right)} \tag{13}$$

where φ is a positive scale parameter and p is the shape parameter. For a Weibull model, when p is <1, the baseline hazard decreases monotonically, and vice versa. For a log logistic model, the hazard decreases monotonically if p is ≤ 1, but it takes a nonmonotonic shape if p is >1, increasing from the origin ($t = 0$) to a maximum of $t = ((p - 1)^{1/p})/(\varphi)$ and decreasing thereafter as t approaches infinity.

To accommodate the effects of external covariates in the models, this paper assumes that the covariates directly rescale time. This accelerated failure time assumption implies that the covariates either accelerate or decelerate the termination of physical activity duration. Now, by specification of the scale parameter $\varphi = \exp^{(-\beta' x)}$ for the Weibull and log logistic models, the model can be expressed as a log-linear model of duration (T):

$$\log_e(T) = \beta' x + \varepsilon \tag{14}$$

where β' is a vector of parameters for the external covariates x, and ε is a stochastic error term with a Type I extreme value distribution.

The parameters of the parametric hazard models are estimated by the use of full information maximum likelihood estimation procedures, unlike the partial likelihood estimation procedures used in semiparametric models (*38*). The likelihood function of the model can be written as

$$L = \prod_{i=1}^{N} f(t_i, x_i) = \prod_{i=1}^{N} [\lambda(t_i, x_i)][S(t_i, x_i)] \tag{15}$$

where N represents the number of observations, and t_i is the activity duration for the ith activity. x_i represents external covariates.

The corresponding hazard and survival functions for the Weibull and log logistic models in Equation 15 generate the log likelihood functions for each type of parametric model. Maximization of the resulting log likelihood functions provides β' parameters for external covariates and the shape parameter (p) for the baseline hazard functions. The final model is selected on the basis of the Akaike information criterion (AIC). The lower that the AIC value is, the better is the model.

DATA USED FOR EMPIRICAL APPLICATION

Activity-Based Travel Survey

This study used data from an activity-based travel survey, which was conducted in 2012 among students from Grades 6 to 10 in the metropolitan area of Dhaka, Bangladesh. Each student reported all engagements in activity over a 24-h period for the surveyed weekday. A stratified random sampling method was used to recruit participants to take the survey. First, schools from two parts of the Dhaka metropolitan area (north and south) were chosen. With the approval of the administrations of the selected schools, the survey was presented to the students. Then, the participants were recruited with the help of the teachers.

Students completed an activity-based travel diary, mainly reporting various types of structured and nonstructured in-home and out-of-home activities for the given weekday. The structured activities involved those in which they regularly participated, such as extracurricular pursuits, lessons, enrichment activities, scouting, clubs, and organized games and meets. In contrast, the nonstructured activities included unorganized hobbies and sports, outings, playing, television viewing, and listening to music. The travel diary also collected detailed information about the activity, such as the start time, end time, location, travel mode used, travel time, travel cost, any accompanying person, and the number of accompanying people for different types of activities. This questionnaire was completed in the classroom under the teachers' supervision.

A second questionnaire for parents was designed to collect socioeconomic and other relevant information and was distributed to the students. Parents completed the questionnaire at home and returned it to the teacher within a specified time period. Information collected through this survey included the age of the parent, household income, car ownership, tenure type, household size, employment status, number of children, and their associated travel arrangements. Because geographic information system-based detailed data on the built environment are currently unavailable for Dhaka, parents were also asked to report certain attributes of the built environment around their homes, such as the presence of sidewalks and the presence of traffic intersections nearby. In total, 510 surveys were distributed;

however, only 276 complete responses were obtained. After the responses were cleaned for missing information, responses from 245 participants were found to be usable for further analysis.

Data Preparation

Paper-based surveys were coded in SPSS. Data preparation for this study involved several stages: data entry and validation, preparation of the database (i.e., data tables and relationships), preparation of a code book, and running of queries to generate data sets for modeling. The activities reported by the students were initially recoded on the basis of the activity typology used by Bhat and Lockwood (*40*).

Structured query language-based data queries were applied to identify out-of-home nonschool activities (sports, playing at a park or playfield, social activity, extracurricular activity, etc). In this study, participation in physical activities included engagement in activities in which the child was physically active as well as the use of active transportation, such as walking. Because mode choice was identified separately in the survey (i.e., the information was not included in the chronological reporting of activities), queries were used to identify and merge attributes required for this type of physical activity within the data set. Reported travel time was considered the duration of the physical activity if active transportation was used to reach any type of out-of-home activities. For other structured and nonstructured activities, the duration was calculated on the basis of the start time and the end time of the reported activities. Finally, an activity-based data set was generated for modeling of duration. A person-based data set that identified total counts of participation in physical activity by each student on a given weekday was generated for ZIP modeling. In both cases, children's personal characteristics, household characteristics, and other relevant attributes were merged for hypothesis testing during the modeling process.

Summary Statistics

The descriptive analysis revealed that among the 245 respondents, about 57% engaged in at least one physical activity. The average count of physical activity was approximately 1.41, with a standard deviation of 1.45 (minimum = 0 and maximum = 6). The average (total) duration of activity of the surveyed children was 33.69 min on a given day, which is below the level recommended by the American Academy of Pediatrics. In total, 356 continuous episodes of physical activity were reported. The average continuous length of physical activity in the sample was 23.18 min, with a standard deviation of 24.92 min and a maximum of 150 min. These continuous episodes (sometimes referred to as a "spell" or a "bout" in the literature) were used as the dependent variable in the modeling of the duration of physical activity.

Table 1 shows the summary statistics of the dependent variables considered in the ZIP model and the duration model and the independent variables (such as children's personal attributes, household socioeconomic characteristics, built environment, escort arrangement, and activity attributes) retained in the final model specification.

DISCUSSION OF MODELS

Modeling Process

Before the modeling was performed, tests for correlations between all pairs of explanatory variables were performed. Variables that exhibited low correlations (<0.4) among pairs of independent variables

TABLE 1 Summary Statistics of Variables Used in Models

Variable	Mean or Percentage	SD	Min.	Max.
Dependent Variables				
Physical activity count	1.41	1.45	0	6
Duration of physical activity (min)	23.18	24.92	5	150
Independent Variables				
Person and household attributes				
Age of children (years)	14.13	1.154	11	16
Number of children in household	1.83	0.77	1	4
Age of parents	42.54	5.19	25	58
Monthly household income (2012 US$)	331.39	284.14	150	2,800
Total household size	4.33	0.86	3	7
Home ownership (dummy, 1 if the household is a homeowner; 0 otherwise)	29.5%	na	na	na
Car ownership (dummy, 1 if the household owns at least one car; 0 otherwise)	11.2%	na	na	na
Built environment				
Presence of sidewalk around home (dummy, 1 if sidewalk exists adjacent to the home; 0 otherwise)	43.7%	na	na	na
Presence of intersection nearby home (dummy, 1 if any intersection exists near home; 0 otherwise)	41.6%	na	na	na
Activity attributes				
Parental escort (dummy, 1 if the child is accompanied by a parent; 0 otherwise)	40.2%	na	na	na
Accompanied by friends (dummy, 1 if the child is accompanied by friends; 0 otherwise)	49.4%	na	na	na
Activity performed in playfield or park location (dummy, 1 if the activity is performed in playfield or park location; 0 otherwise)	12.9%	na	na	na
Total travel time to school (min)	48.30	29.69	5	150
Total travel time to tutoring (min)	17.37	19.24	5	85
Duration of mandatory activity (min)	813.37	101.19	480	1,065
Duration of homework (min)	281.97	84.75	15	570
Duration of tutoring (taking lessons from a tutor outside school in a fixed time and location) (min)	127.62	94.01	0	360
Number of out-of-home out-of-school activities (passive)	1.61	1.53	0	4

NOTE: SD = standard deviation; min. = minimum; max. = maximum; na = not applicable.

were considered in the final model specification. For example, household income was correlated with car and home ownership, but car ownership and home ownership were not correlated with each other. Therefore, household income was not considered with the correlated variables (car and home ownership) in the same model. Various model specifications were tested with a comprehensive list of variables identified in the existing literature. The final model was selected on the basis of the model fit, agreement with prior hypotheses, and the statistical significance of explanatory variables.

Model Results for Frequency of Participation in Physical Activity

The parameter estimation results of the ZIP count model that examined the frequency of participation in physical activity among children who go to school in Dhaka are presented in Table 2. The majority of independent variables retained in the ZIP model were statistically significant at least at the 95% confidence interval (i.e., *t*-statistics were greater than 1.96 for a two-tailed test). Few variables exhibited *t*-statistics less than the threshold value. These variables were retained in the final model because they offer important behavioral insights, with the assumption that if a larger set of data was available, these parameters might show statistical significance.

The model results suggest that the key determinants of the frequency of participation in physical activity are the presence of sidewalks around the home, the presence of a traffic intersection nearby, and the total number of out-of-home, out-of-school activities performed by the children. Although the presence of sidewalks increases the frequency of physical activity, the presence of a traffic intersection nearby decreases the frequency of participation, with all else being equal. The relative contributions of the presence of sidewalk and intersection were 0.513 and –0.454, respectively.

TABLE 2 Parameter Estimation Results of ZIP Regression Model for Frequency of Participation in Physical Activity

	ZIP Regression Model	
Variable	Coefficient	*t*-Statistic
Age of children	–0.086	–1.65
Number of children in household	0.137	1.73
Age of parents	–0.029	–2.92
Total household monthly income (US$)	–0.001	–1.71
Presence of sidewalk around home (dummy, 1 if sidewalk exists adjacent to the home; 0 otherwise)	0.513	3.61
Presence of intersection near home (dummy, 1 if any intersection exists near home; 0 otherwise)	–0.454	–2.91
Duration of tutoring	–0.002	–2.18
Duration of homework	–0.001	–1.81
Total travel time to school	–0.008	–2.39
Total travel time to tutoring	–0.027	–3.95
Number of out-of-home out-of-school activities	0.552	7.21
Constant	2.986	3.37

NOTE: Data are for 245 individuals. Log likelihood of the constant-only model = –371.94646; log likelihood of the full model = –276.65103; pseudo-rho-square = .256207.

Of children's personal characteristics, age exhibits a negative relationship, implying that older children participate in physical activity less frequently than younger children. This finding is consistent with the prior expectation. Older children usually take more household responsibilities and are required to spend more time on their studies. The model results also suggest that the frequency of physical activity increases for a given child as the number of children in a household increases. The presence of multiple children in a household presumably results in greater opportunities for out-of-home physical activities. For instance, parents may allow a younger child to go to a nearby playfield with his or her older siblings. Similarly, children can walk or bike together to school or other places close to their home.

The age of the parent was also found to be significant in the model. A negative parametric value of the variable suggests that children with an older parent had a lower propensity to participate in out-of home physical activity. Recent evidence suggests that younger parents in Dhaka are more educated and health conscious than parents of the previous generation. As such, they are possibly more concerned about their children's health and may try to offer an increased number of opportunities for engaging in physical activities.

The results also reveal that household monthly income has a negative impact on children's physical activities. Poor facilities for walking or biking as well as road safety and personal security concerns often make outdoor activities less desirable for children in Dhaka. Hence, parents with greater purchasing power might prefer to arrange for sedentary in-home activities for their children by purchasing electronic devices (such as video games, hand-held gaming devices, and computers) as a means to provide alternative recreational activities.

As indicated earlier, attributes of the built environment exhibit a significant influence on the frequency of out-of-home activities of children in Dhaka. Walking is an incidental physical activity that depends on the quality of the built environment, such as the availability of sidewalks in the residential neighborhood. As expected, the sign of the dummy variable, the presence of a sidewalk around the home, is positive, which means that children's rates of participation in out-of-home physical activities will increase if sidewalks are available near their home. In addition to the potential use of active transportation for trips over short distances, the availability of sidewalks may also offer possibilities for children to engage in out-of-home activities in a nearby playfield or park that can be reached by walking or biking.

Another aspect of the built environment that affects participation in physical activity is the presence of traffic intersections near the home. This dummy variable is used as a proxy variable to account for traffic interference. As expected, the coefficient value of this variable is negative. Traffic intersections raise road safety concerns, and children need to be accompanied to travel to locations where out-of-home physical activities can be performed. As such, it is hypothesized that the presence of an intersection near the home decreases the frequency of participation in out-of-home activities, which is confirmed by the results of the model with reasonable statistical significance (at the 99% confidence level).

The results of the model also reveal that activity-related attributes influence participation in physical activity, particularly certain fixed activities that are considered nearly mandatory in the context of developing countries. For instance, private tutoring before or after school is common in Dhaka and is considered mandatory because the level of education provided in the schools does not match parents' expectations. As expected, the total time commitment for tutoring is found to affect negatively the frequency of participation in physical activity. Similarly, the total amount of time spent on homework (mainly in the home) is found to reduce the amount of time spent on out-of-home physical activity, with all else being equal.

Dhaka has no designated school-zone boundary for any public or private school. Students compete for admission to quality schools, which in many cases could be far from their homes. Therefore, the total travel time to the school could be an important factor explaining participation in physical activity. It is hypothesized that the longer it takes for a child to reach school, the lower the frequency of out-of-home physical activity will be. Because travel over a longer distance increases the total time spent for schooling, opportunities for a child to engage in discretionary types of physical activities are reduced. Additionally, if a school is far from home, the possibility that a child can walk to school might be reduced. A similar effect was expected for the total travel time to attend a private tutoring location (which is extra routine travel for the child). As expected, the parameter values of the travel time to school and the tutoring location were found to be negative for the sample: –0.008 and –0.027, respectively.

Finally, the results of the ZIP count model suggest that the increase in the total number of out-of-school and out-of-home passive activities (such as grocery shopping with parents) increases the frequency of participation in physical activity by children and vice versa. Increased numbers of out-of-home activities perhaps create opportunities to walk to take short trips, which are common in Dhaka, which predominantly has an urban structure based on mixed land uses.

Several other variables were tested during model estimation. However, those hypotheses could not be confirmed because of a lack of reasonable statistical significance. For example, it was hypothesized that the mother's employment status could have an impact on the frequency of children's participation in physical activity since households in which both parents work might have scheduling challenges. The dummy variable exhibited poor statistical significance, however. The goodness-of-fit statistics of the model were evaluated according to the pseudo-rho-squared value, which indicates 1 minus the ratio of the log likelihood of the full model to the log likelihood of the constant-only model. The pseudo-rho-square value was 0.256, which indicates a reasonable model fit.

Model Results for Duration of Physical Activity

The parameter estimation results for the model for the of duration children's physical activities are presented in Table 3. As mentioned earlier, monotonic (Weibull) and nonmonotonic (log logistic) baseline distributions were assumed in the duration model. The models were evaluated according to the AIC. The model results suggest that the Weibull model outperforms the log logistic model. The AIC value of the Weibull model (86.36) was considerably lower than that of the log logistic model (94.16). Hence, the Weibull model was selected as the final model. All variables in the Weibull model were statistically significant at least at the 99% confidence interval. Because the shape parameter (p) of the Weibull model was greater than 1, the effect of duration is monotonically increasing and vice versa. This study takes an accelerated failure-time assumption; therefore, the interpretation of the effects of the explanatory variables is quite straightforward. A positive coefficient for a variable in the model implies that the duration of physical activity increases with an increase in the value of that variable.

The final model results reveal that car and home ownership, escort arrangements, and activity location (a dummy variable, if the activity is performed in a playfield or park) are the most important predictors of the duration of physical activity for the sample of children from Dhaka. Among the children's personal characteristics, the parameter of age was found to have a negative value, which implies that the duration of activity per activity episode for older children is less than that for their younger counterparts. Household size also influences the duration of physical activities, which shows a positive parametric size. If the household size is larger, the opportunity to arrange for children to be accompanied is presumably higher, which might increase the duration of an activity episode.

In addition, the parameter of the age of the parent is positive in the model. This finding implies that children of older parents spend more time on an activity episode than those of younger parents.

TABLE 3 Results of Parametric Hazard Models for Duration of Physical Activity

	Weibull Duration Model		Log Logistic Duration Model	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic
Age of children	–0.120	–2.42	–0.087	–1.70
Household size	0.099	2.21	0.058	1.17
Age of parents	0.032	3.86	0.024	2.46
Car ownership (dummy, 1 if the household owns at least one car; 0 otherwise)	0.363	2.47	0.399	2.62
Home ownership (dummy, 1 if the household is a homeowner; 0 otherwise)	–0.271	–2.39	–0.213	–1.89
Parental escort (dummy, 1 if the child is accompanied by a parent; 0 otherwise)	0.218	4.56	0.131	2.59
Accompanied by friends (dummy, 1 if the child is accompanied by friends; 0 otherwise)	–0.212	–4.41	–0.124	–2.45
Duration of mandatory activities (time spent in school and sleeping)	–0.004	–8.93	–0.004	–7.41
Duration of homework	–0.004	–5.07	–0.003	–5.34
Activity performed in a playfield or park location (dummy, 1 if the activity is performed in playfield or park location; 0 otherwise)	1.560	6.54	1.746	6.46
Constant	6.057	6.79	6.045	6.30

NOTE: Data are for 356 activities. Shape parameter = 3.353 and 5.019 for Weibull and log logistic duration models, respectively; log likelihood for the constant-only model = –109.44 and –82.42 for Weibull and log logistic duration models, respectively; log likelihood for full model = –29.18 and –33.08 for Weibull and log logistic duration models, respectively; AIC = 86.36 and 94.16 for Weibull and log logistic duration models, respectively.

The ZIP count model (discussed in earlier) suggests that children of older parents have less of a chance to engage in physical activities. Collective interpretation of the results of the two models allows the conclusion that although children of older parents have the chance to engage in fewer physical activities, they spend a longer time engaged in an activity than children with younger parents.

The home ownership dummy showed a negative coefficient value (–0.271). This result implies that the duration of physical activity is shorter for children whose parents own their own home than for children whose parents are tenants. This variable acts as a proxy for household income, because homeownership is costly in Dhaka. Car ownership was, interestingly, found to have a positive effect on the duration of time that children engaged in out-of-home physical activity. Participation in organized out-of-home physical activities generally requires a vehicle. If convenient transport is available, children can easily travel farther to get involved in activities at places where more organized extracurricular physical activities are available. As a result, they can possibly spend more time per activity episode than those who do not have access to a private vehicle.

Escort arrangements were also found to be significant as an explanation for the duration of out-of-home physical activities. The dummy representing parental escort showed a positive coefficient value in the duration model. This finding indicates that the time spent on out-of-home physical activities by a child is longer if the child is accompanied by his or her parents. In contrast, if a child is accompanied by friends only, the duration is shorter for a particular out-of-home physical activity.

The model results also show that the amount of time spent on mandatory activities and homework reduces the amount of time spent on out-of-home physical activities. This is because when more time is allocated to fixed activities, less time is available for discretionary activities, such as physical activities. Finally, the dummy representing playfields or parks as activity locations exhibits a positive parameter value. The duration of activities in those locations will be longer because children might get involved in sports or other types of organized physical activity.

CONCLUSION

This paper presents the findings of models that investigated children's physical activities in Dhaka, Bangladesh. A ZIP regression model was used to explore the frequency of children's physical activities, including the use of active transportation. The results of the ZIP model reveal that the key determinants of the frequency of out-of-home participation in physical activity are attributes of the built environment. It was found that although the presence of sidewalks increases the frequency of physical activity, the presence of traffic intersections nearby decreases the frequency of participation.

Parametric hazard models were used to examine the determinants of the duration of physical activity episodes. The results suggest that a Weibull model outperforms the log logistic model according to model fit. Parameters estimates revealed that car ownership, tenure type, activity location, and escort arrangements are the most notable predictors of the duration of physical activity. For instance, parental escort increases the duration of physical activities and vice versa.

The results of both models offer some interesting behavioral insights. It was found that older children engage in fewer physical activities and also spend less time per activity episode than their younger counterparts. However, although children of older parents get fewer chances to engage in physical activity, they spend more time per activity than children of younger parents.

This paper contributes in several ways. Although abundant analyses of adults' activity are available, less attention has been given to the determination of children's activity patterns. This study enhances the understanding of these patterns. This is a pioneering study in the context of Dhaka that takes an activity-based approach to the analysis of children's time use and travel behavior. Because studies on participation in physical activity and time-use patterns for children who go to school are surprisingly absent in the context of developing countries, this study fills the gap, specifically in the provision of an understanding of the factors affecting participation in out-of-home physical activities, including the use of active transportation.

The study has certain limitations. Parents' detailed activity patterns (except for information on escort arrangements) were not collected to reduce the burden on the respondents. Future studies should consider collection of this type of information because children's participation in physical activity is closely related to the availability of time and the schedule of their parents. In addition, because of the small sample size, the study could not examine separately physically active out-of-home activities and active travel on journeys to evaluate whether different factors influence each of these. Furthermore, this study could not examine the day-to-day variation in the levels of participation in physical activity because only 24 h of data were available from the activity diary. It would be interesting if a subsequent study could focus on duration analysis for a multiweek period in the context of a developing country through a panel survey.

The immediate next task with the data from this study is to examine the factors affecting nonparticipation (i.e., zero instances), which were assumed to have a fixed probability in the ZIP model proposed in this paper. However, such an examination could be challenging, given the small sample size. It would be useful if a larger set of data could be examined.

The findings presented in this paper have important policy implications. The model results provide evidence that the provision of sidewalks in residential neighborhoods will increase the frequency of participation in physical activity in Dhaka. Preservation of playfields and parks is also important, because playfields and parks are rapidly disappearing from the city because of the high demand for housing and other uses of the land. The city should also consider demarcation of school-zone boundaries to reduce longer trips to school for children in Dhaka's congested network. Furthermore, the quality of public schools should be improved so that the need for additional tutoring (a fixed activity) can be reduced. Such initiatives will allow more time for physical activities that are essential for the physical and psychosocial well-being of the children in the developing nation of Bangladesh.

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