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Exploring the Association between Air Pollution and Active School Transportation: Perceptions of Children and Youth in India

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Abstract: Active school transportation (AST), including walking or cycling, is a common practice across India contributing to physical activity accumulation among children and youth. Despite the proven health benefits of AST, rising air pollution levels may offset these benefits and discourage AST. With climate change and severe heat waves exacerbating poor air quality, this study aimed to examine the association between perceptions of air pollution as a problem and AST among children and youth in India. No previous studies have assessed AST determinants from a child or youth perspective in India; thus, this cross-sectional, observational study surveyed 1042 children and youth from 41 urban and rural schools. Logistic regression models were conducted and stratified by age group, gender, and urban vs. rural location. Children and youth who perceived air pollution to be a problem were less likely to engage in AST (OR = 0.617, 95% CI = 0.412, 0.923, $p < 0.001$), with AST varying based on age, gender, and location. The perception of air pollution as a problem was associated with a lower likelihood of engaging in AST in the 5- to 12-year age group (OR = 0.366, 95% CI = 0.187, 0.711, $p = 0.003$) but not in the 13- to 17-year age group. Similarly, males (OR = 0.528, 95% CI = 0.306, 0.908, $p = 0.021$) and rural residents (OR = 0.569, 95% CI = 0.338, 0.956, $p = 0.033$) who perceived air pollution as a problem were less likely to engage in AST; however, this association was not found in females or urban residents. These findings highlight the importance of child and youth perceptions of the environment in not only informing public health advisories for air quality and safe outdoor activity, but also for designing targeted interventions considering sociodemographic differences in AST among children and youth in India.

Keywords: air pollution; active school transportation; children and youth; climate change; global health; global south; non-communicable diseases; physical activity

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1. Introduction

The prevalence of non-communicable diseases has become a leading cause of mortality globally [1–5], with low-and-middle-income countries such as India experiencing higher rates of cardiovascular diseases, diabetes, and respiratory diseases compared to the global average [6–8]. Research has shown that many chronic non-communicable diseases are largely considered preventable, with lifestyle factors including poor diet, physical inactivity, and sedentary behaviour showing strong associations with chronic disease risk [9,10]. Many health behaviours adopted at a young age track into adulthood, making it imperative to promote active behaviours among children and youth to prevent chronic disease onset later in life [11].

While recreational physical activity and outdoor play are common among younger cohorts [12], active school transportation (AST), including biking or walking to school, is a major contributor to overall physical activity levels among children and youth in low-and-middle-income countries [10,13–15]. AST has not only been connected to decreased incidence of cardiovascular diseases, type 2 diabetes, and all-cause mortality [16], but it has also been associated with improved mental health outcomes among children and youth [17]. In addition to the health benefits, AST can be an important aspect of environmental sustainability efforts, especially given the global climate crisis [18] as AST can help to decrease greenhouse gas emissions and noise pollution in populous nations such as India [19–21]. Evidence indicates that AST contributes to a positive feedback loop, where reduced carbon emissions improve a range of health outcomes across the life span [22]. Moreover, AST is a common mode of transportation in India, as it received the highest grade (B−) out of all indicators in the 2022 India Report Card on Physical Activity for Children and Adolescents [23].

Participation in AST is influenced by a myriad of socioecological determinants, ranging from household income and parental education to community infrastructure and safety [24–27]. Research has shown that despite the numerous benefits of AST, there are several barriers that can deter children and youth from regular engagement. Related to the physical environment, air pollution is a serious issue, particularly in India's urban centres where transportation, industrial emissions, and farming release numerous pollutants including particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide, and ozone [28,29]. As climate-change-related heat waves have become more frequent and severe [30], air quality is adversely impacted [31,32], which makes it unsafe for vulnerable populations such as children and youth to spend significant amounts of time outdoors during poor air quality advisories [33]. In 2023, 27 poor air quality days were issued in the city of Mumbai alone between January and February, while there were only six poor air quality days issued during the same period in 2022 [34]. Moreover, the consequences of air pollution are profound, with recent reports indicating that air pollution shortens the life expectancy of the average Indian resident by an estimated 5.3 years [35]. Poor air quality has been associated with reduced commute-related physical activity, including walking, running, and biking to and from destinations such as work and school [36]. In these circumstances, the risks of AST may outweigh the benefits, as frequent exposure to air pollution [37] can lead to a higher risk of non-communicable diseases such as lung cancer, stroke, and ischaemic heart disease, with children being highly susceptible [38].

While air pollution is associated with numerous health risks, citizens' perception of the severity of this issue ultimately influences time spent outdoors engaging in health behaviours such as active transportation [39]. For vulnerable populations such as children and youth, most studies to date have focused on parental perceptions of air pollution [40–44]. There is a dearth of studies examining how child and youth perceptions of air pollution influence their engagement in AST, particularly in India where AST is a common practice in urban and rural populations [45]. Thus, the primary objective of this study was to understand the relationship between child and youth perceptions of air pollution in India and engagement in AST. The secondary objective was to identify potential differences in the relationship between air pollution and AST across various sociodemographic groups. We hypothesized that children and youth who perceived of air pollution to be a problem would have a lower likelihood of engaging in AST due to the perceived health risks associated with poor air quality. Additionally, given that perceptions of air pollution can be influenced by personal experiences and cultural factors, we expected variations in the relationship between air pollution perceptions and AST across age, gender, and location.

2. Methods

2.1. Design

This cross-sectional, observational study was conducted in 2021 during the Coronavirus disease pandemic lockdown in India as a part of a multi-centre cohort study conducted across five Indian states (Maharashtra, Gujarat, Telangana, Madhya Pradesh, and Tamil Nadu). The study included children and youth aged 5 to 17 years from 28 cities and villages (urban and rural regions). A multistage, stratified random sampling method was used to collect data on a range of health behaviours and perceptions of the environment from participants through an online survey. The Ethics Committee Jehangir Clinical Development Centre Pvt. Ltd. In Pune, Maharashtra (EC registration number—ECR/352/Inst/MH/2013/RR-19) provided ethics approval for this study.

2.2. Study Recruitment and Participants

As a part of the multistage stratified random sampling method [46,47] cities (i.e., urban) and nearby villages (i.e., rural) were randomly selected, and a list of schools from each of these locations was generated. Principals of the schools on this list were contacted with study information, and 41 out of the 50 school principals who were invited gave permission for their respective schools to be recruited.

Study information and consent forms were shared electronically with both students and their parents attending each school. After receiving online informed consent and assent from parents and students, respectively, surveys were sent out to children and youth using Google Forms and were available to answer between 15 March and 20 May 2021. Surveys were answered individually and anonymously, with children under 13 years receiving parental/guardian assistance. The survey requested participants to answer a series of questions including sociodemographic characteristics, active living behaviours (active transportation, physical activity, sedentary behaviour), and perceptions of their environment (community, built environment, air pollution).

2.3. Measures

2.3.1. Sociodemographic Characteristics

Participants were asked a series of sociodemographic questions pertaining to their age, gender, and geographic location. The age of participants was collected through their date of birth and sorted into one of two categories: "child" (5 to 12 years) or "youth" (13 to 17 years). The gender of participants was determined by asking whether they identified as "male" or "female". With 41 schools engaging in the study, geographic location was determined by classifying the schools as rural or urban based on their distance from population centres [46,47]. The full list of questions can be found in the Supplementary File.

2.3.2. Active Transportation

To assess engagement in active transportation, children and youth were asked about their mode of transportation to school: "Do you bike to school?" and "Do you walk to school?" with "yes" or "no" response options. A new dichotomous variable was created to classify participants who responded "yes" to either biking or walking to school as "yes" to AST. The test–retest reliability and convergent validity for self-reported AST were deemed to be substantial to perfect [48].

2.3.3. Perception of Air Pollution

Children and youth reported their perceptions of air pollution by responding to the statement: "There is an air pollution problem in my city/village" using a 5-point Likert scale. The response options included: strongly disagree, disagree, neither agree nor disagree, agree, strongly agree. The responses were dichotomized into disagree (strongly disagree or disagree) and agree (strongly agree or agree). Responses that were "neither agree nor disagree" (n = 98) were coded as missing data and not included in the analyses.

2.3.4. Community and Built Environment

To gather information on the community and built environment, children and youth were asked to respond to a series of statements and choose the answer which best applied to their neighbourhood. The response options were rated on a 5-point Likert scale, including strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. The responses were dichotomized into disagree (strongly disagree or disagree) and agree (strongly agree or agree). Participants who responded "neither agree nor disagree" were excluded from analyses (n = 176). Participants were asked the following questions: "The crime rate in my neighbourhood makes it unsafe to go on walks during the day", "The crime rate in my neighbourhood makes it unsafe to go on walks during the night", "There is so much traffic that it makes it difficult or unpleasant to walk in my neighbourhood", "My neighbourhood streets are well lit at night", and "There are trees along the streets in my neighbourhood".

2.4. Statistical Analysis

The primary independent variable for this study was child and youth perceptions of air pollution, and the dependent variable was engagement in AST. Given that the outcome variable (AST) was dichotomous (yes or no responses), we utilized logistic regression, a commonly used approach for analyzing relationships with a dichotomous outcome variable. Logistic regression accounts for potential confounders and provides a nuanced understanding of the relationship between independent and dependent variables (air pollution perceptions and AST, respectively) [49]. A total of seven logistic regression models were generated by stratifying the overall sample by age group (5 to 12 years and 13 to 17 years), gender (male and female), and location (urban and rural). The overall model, which included all variables, and the age-specific models, were adjusted for gender and location. The gender-specific models were adjusted for age and location, and the location-specific models were adjusted for age and gender. Chi-square analyses were also conducted to assess whether there were statistically significant differences in the proportion of child and youth responses for the independent and dependent variables of interest. All reported results in this study were considered statistically significant at a threshold of p-value < 0.05. All analyses were conducted in R studio [50].

3. Results

A total of 1042 children and youth participated in this study, with 992 included in the analyses after excluding participants who did not meet the study inclusion criteria for age (aged 5 to 17). The sociodemographic characteristics of the study sample are presented in Table 1. There was an even gender distribution in the sample with 49.7% of the participants reporting as female and 50.3% reporting as male. Most of the participants were urban residents (59.7%), while 40.3% were rural residents. The majority of participants were aged 5–12 years (55.1%), while 44.9% were aged 13–17 years.

Table 2 shows the proportion of child and youth perceptions of air pollution, as well as the engagement in AST for different demographic groups. The chi-square analyses found that AST differs significantly across gender, location, and age. In particular, males and rural residents were significantly more likely to engage in AST than females (p = 0.030) and urban residents (p < 0.001). Similarly, participants in the 13- to 17-year age group were significantly more likely to engage in AST compared to the 5- to 12-year age group (p < 0.001). The results also indicated that more urban residents, and participants aged 5 to 12 perceived air pollution as a problem compared to rural residents (p < 0.001) and participants aged 13 to 17 (p < 0.001).

The logistic regression conducted for the overall sample is presented in Table 3 and Figure 1. Perception of air pollution as a problem was associated with a lower likelihood of AST (Odds Ratio (OR) = 0.617, 95%, Confidence Interval (CI) = 0.412, 0.923, p < 0.001) compared to those who did not perceive air pollution to be a problem. In terms of the neighbourhood environment, the perceived crime rate was associated with a lower like-

lihood of AST (OR = 0.486, 95% CI = 0.269, 0.875, $p = 0.016$). Similarly, reporting of trees along the streets in a city/town was associated with a lower likelihood of AST (OR = 0.600, 95% CI = 0.388, 0.924, $p = 0.021$). However, reporting of high traffic in the neighbourhood and neighbourhood streets being well lit at night were not associated with AST.

Table 1. Children and youth sample summary by gender, age, and location.

	Total (*n* = 992)	
Sample Characteristics	N	%
Gender		
Male	499	50.3
Female	493	49.7
Location		
Rural	400	40.3
Urban	592	59.7
Age Group		
5 to 12 years	547	55.1
13 to 17 years	445	44.9

Table 2. The proportion of children and youth reporting the perception of air pollution and engagement and active school transportation ($N = 992$).

	Perception of Air Pollution as a Problem		**Active School Transportation**	
Category	**Agree** ***n*** **(%)**	**Disagree** ***n*** **(%)**	**Yes** ***n*** **(%)**	**No** ***n*** **(%)**
Male	269 (58.3%)	192 (41.7%)	186 (37.3)	312 (62.7)
Female	259 (60.1%)	172 (39.9%)	151 (30.6)	342 (69.4)
Urban	366 (73.5%)	132 (26.5%)	87 (14.7)	504 (85.3)
Rural	162 (41.1%)	232 (58.9%)	250 (62.5)	150 (37.5)
Aged 5 to 12	287 (59.9%)	192 (41.1%)	153 (28.9)	376 (71.1)
Aged 13 to 17	228 (57.4%)	169 (42.6%)	181 (40.8)	263 (59.2)
Overall	528 (59.1%)	364 (40.9%)	337 (34.0)	654 (66.0)

Note: Children and youth were asked about their perceptions of air pollution, where "yes" indicates air pollution as a problem in their city/town, and "no" indicates there is no perceived problem. Respondents were also asked if they cycled or walked to school (yes/no) to determine if they engaged in active school transportation.

In addition to the model for the overall sample, this study analyzed six additional logistic regression models stratified by age, gender, and location (Table 4 and Figure 2). The results indicated that the perception of air pollution as a problem was associated with a lower likelihood of AST in the 5-to-12 age group (OR = 0.366, 95% CI = 0.187, 0.711, $p = 0.003$), but this association was not significant in the 13- to 17-year age group. Perceiving air pollution as a problem was associated with a lower likelihood of engaging in AST among males (OR = 0.528, 95% CI = 0.306, 0.908, $p = 0.021$); however, the association was not significant in females. Similarly, the perception of air pollution as a problem was associated with a lower likelihood of AST among rural children and youth (OR = 0.569, 95% CI = 0.338, 0.956, $p = 0.033$) but not among urban children and youth. The perception of crime was associated with a lower likelihood of engaging in AST among males (OR = 0.465, 95% CI = 0.217, 0.980, $p = 0.045$); however, this association was not significant in females. Having neighbourhood streets lit at night was associated with a higher likelihood of engaging in AST among rural residents (OR = 2.018, 95% CI = 1.142, 3.589, $p = 0.016$) but not urban residents.

Table 3. Overall logistic regression model examining the perception of air pollution as a problem and active school transportation controlling for sociodemographic characteristics (N = 992).

Outcome Variable—Active School Transport: Yes	
	Odds Ratio (95% Confidence Intervals)
Air pollution problem: Agree	0.617 * (0.412, 0.923)
Disagree—(Ref)	
The crime rate in my neighbourhood makes it unsafe to go on walks: Agree	0.486 * (0.269, 0.875)
Disagree—(Ref)	
There is so much traffic that it makes it difficult or unpleasant to walk in my neighbourhood: Agree	0.662 (0.433, 1.008)
Disagree—(Ref)	
My neighbourhood streets are well lit at night: Agree	1.590 (0.993, 2.568)
Disagree—(Ref)	
There are trees along the streets in my neighbourhood: Agree	0.600 * (0.388, 0.924)
Disagree—(Ref)	

* Indicates a statistically significant relationship at $p < 0.05$. Note: The logistic regression model was adjusted for age, gender, and location.

Table 4. Logistic regression model examining the perception of air pollution as a problem and active school transportation segregated by age, gender, and location (N = 992).

Outcome Variable—Active School Transport: Yes						
	Odds Ratio (95% Confidence Intervals)					
	Age Group (Years)		**Gender**		**Location**	
	5 to 12 [a]	**13 to 17** [a]	**Male** [b]	**Female** [b]	**Urban** [c]	**Rural** [c]
Air pollution problem: Agree	0.366 * (0.187, 0.711)	0.963 (0.558, 1.671)	0.528 * (0.306, 0.908)	0.744 (0.402, 1.390)	0.845 (0.424, 1.730)	0.569 * (0.338, 0.956)
Disagree—(Ref)						
The crime rate in my neighbourhood makes it unsafe to go on walks: Agree	0.808 (0.307, 2.199)	0.632 (0.279, 1.402)	0.465 * (0.217, 0.980)	0.489 (0.187, 1.300)	0.643 (0.328, 1.264)	0.635 (0.131, 2.385)
Disagree—(Ref)						
There is so much traffic that it makes it difficult or unpleasant to walk in my neighbourhood: Agree	0.580 (0.289, 1.159)	0.837 (0.473, 1.473)	0.744 (0.420, 1.315)	0.594 (0.312, 1.124)	0.789 (0.402, 1.533)	0.617 (0.351, 1.085)
Disagree—(Ref)						
My neighbourhood streets are well lit at night: Agree	1.713 (0.784, 3.792)	1.582 (0.853, 2.987)	1.431 (0.774, 2.687)	1.847 (0.887, 3.933)	0.943 (0.425, 2.285)	2.018 * (1.142, 3.589)
Disagree—(Ref)						
There are trees along the streets in my neighbourhood: Agree	0.655 (0.327, 1.305)	0.562 (0.308, 1.015)	0.504 * (0.271, 0.927)	0.722 (0.386, 1.350)	0.466 (0.202, 1.150)	0.630 (0.376, 1.042)
Disagree—(Ref)						

* Indicates a statistically significant relationship at the $p < 0.05$ level. [a] The logistic regression models were adjusted for age, gender, and location. [b] The logistic regression models were adjusted for age and location. [c] The logistic regression models were adjusted for age and gender.

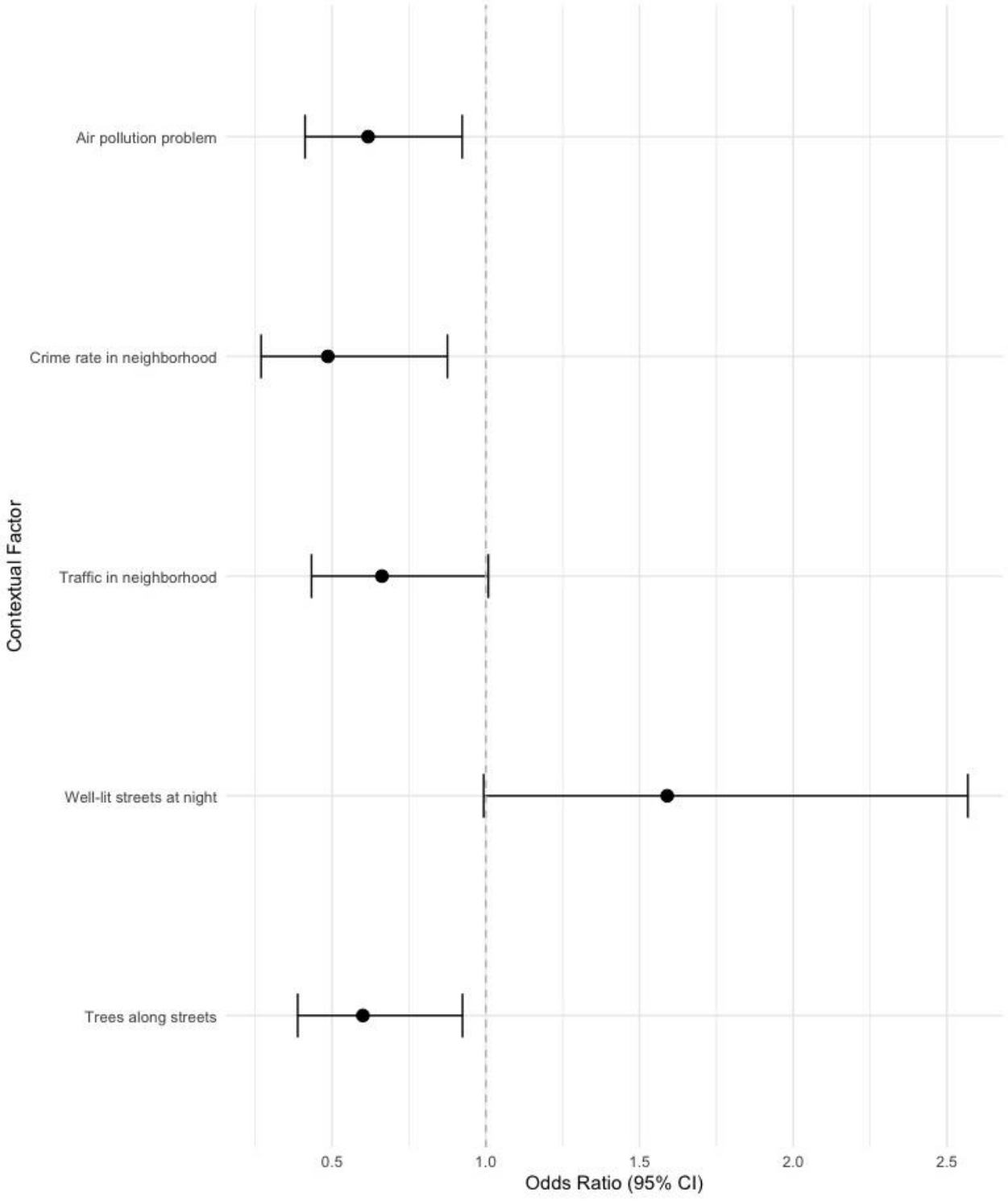

Figure 1. Forest plot displaying odds ratios for active school transport. Note: Each point estimate represents the odds ratio, and the horizontal lines indicate 95% confidence intervals. The reference line (dashed vertical line) represents an odds ratio of 1. Odds ratio values greater than 1 indicate a higher likelihood of active school transport.

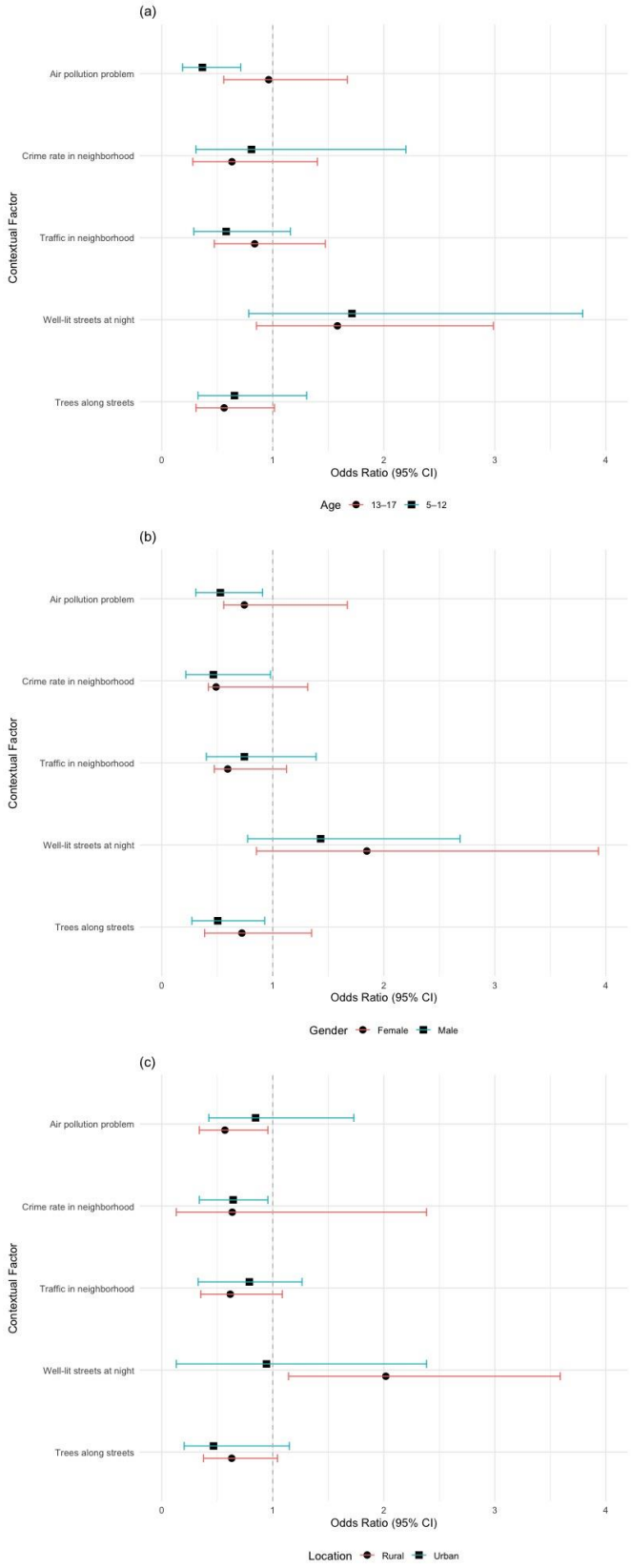

Figure 2. Forest plot displaying odds ratios for active school transport. Note: The plot presents subgroup analyses based on age (**a**), gender (**b**), and location (**c**). Each point estimate represents the odds ratio, and the horizontal lines indicate 95% confidence intervals. The reference line (dashed vertical line) represents an odds ratio of 1. Odds ratio values greater than 1 indicate a higher likelihood of active school transport.

4. Discussion

AST is an important source of physical activity among children and youth and can have potential benefits for mitigating air pollution, as well as forming healthy active living behaviours which often track into adulthood [17,21,51]. Despite numerous studies exploring the relationships between air pollution and AST on child and youth health [52,53], no studies to date have explored these associations from a child or youth perspective in India. This study found that children and youth who perceived air pollution as a problem were less likely to engage in AST.

A similar association was found in one other study in Zhengzhou, China, where adults (mean age: 29.6 years) who perceived air pollution to be a problem were more likely to transition from active transportation to other non-active modes of transportation, i.e., driving [54]. Another study conducted in Zhengzhou, China, found that the perception of air pollution may mediate the relationship between certain streetscape characteristics and lower AST among adolescents aged 12 to 18 years [55]. In a study conducted in 2020, several common barriers have been identified that negatively affect AST among adolescents in Chennai, India, including distance to school, parental restriction of mobility, and excessive traffic; however, the study's focus on child and youth perceptions was limited to neighbourhood crime and traffic and did not include perceptions of air pollution [56].

Given that poor air quality has been associated with reductions in commute-related physical activity [36], and that air pollution is one of the leading threats to life expectancy in India [35], the rising air pollution levels and frequency of poor air quality days in India can deter children and youth from engaging in AST [23,34,57,58]. Moreover, walking and cycling make pedestrians and cyclists, respectively, more vulnerable to air pollution exposure compared to closed transportation modes (i.e., riding in a car or bus) [59].

This existing evidence aligns with our study's findings which not only examined air pollution perceptions but also controlled for perceptions of the neighbourhood environment, including crime, traffic, and streetscape. For instance, we found that children and youth who perceived high crime in their neighbourhoods were less likely to engage in AST. Previous studies have found that children and youth may be more cautious about engaging in AST if they perceive issues of crime in their neighbourhood as people are more likely to be physically active in outdoor spaces where they feel safe [60]. This contrasts with a previous study which found that perceptions of crime safety are not associated with AST among adolescents in Chennai, India [56]; however, our findings may differ from the previous study findings as we included children and youth from several urban and rural centres in India.

Moreover, we found that child and youth perceptions of high traffic in their neighbourhood were not associated with AST. This finding aligns with Kingsly et al.'s (2020) study which found that the perception of high traffic among adolescents in India was not associated with engagement in AST when adjusting for all significant correlates [56]. The lack of association between high traffic perceptions and AST in children and youth may be because, regardless of high traffic, children and youth still need to find a way to get to school, potentially leading to the acceptance of traffic as an unavoidable part of their daily routine. Our study also found that children and youth who agreed that there were trees along the streets of their neighbourhood were less likely to engage in AST than those who disagreed. The presence of large or hanging tree branches on sidewalks can reduce the amount of space available for individuals to walk or bike, which are important predictors of engagement in active transportation [61]. These results highlight that in order to promote AST among children and youth, it is crucial to prioritize the development of effective policies that prioritize the neighbourhood environment, including public safety, pedestrian routes, and infrastructure, as these factors collectively influence their transportation choices.

By comparing air pollution perceptions and AST based on location (urban vs. rural), our study enabled a nuanced understanding of how air pollution and the neighbourhood environment influence AST among children and youth in India. Consistent with the evidence on greater air pollution in urban centres, we found that more urban residents per-

ceived air pollution to be a problem than rural residents [62,63]. One potential explanation is that children and youth living in urban regions may be exposed to more media coverage of air pollution issues than their rural counterparts. Notably, a report found that urban residents were more likely to perceive local news topics as important for their daily lives compared to rural residents [64], which may make media coverage of air pollution more influential to the perceptions of urban residents.

Despite the higher perception of air pollution as a problem among urban residents, our results indicate that children and youth living in rural centres of India who perceived air pollution to be a problem were less likely to engage in AST—a finding that was not significant among children and youth living in urban centres. Although previous evidence indicates that individuals living in rural centres may not be as aware of the impacts of air pollution on health [62], children and youth in urban centres may be desensitized to air pollution, and consequently, it may have a weaker influence on their behaviour. However, these factors across urban and rural residents have not been examined among children and youth, particularly in India. Future research should further investigate these factors to unpack whether it is the presence of higher air pollution in urban vs. rural centres or other factors that are influencing awareness and perception of air pollution among children and youth.

Our study also found that more children and youth living in rural regions of India engaged in AST than those living in urban regions, which aligns with the findings of the 2016, 2018, and 2022 India Report Cards on Physical Activity for Children and Youth that describe rural children and youth as engaging in more active transportation than their urban counterparts [23,57,58,65]. This difference in AST among urban and rural residents may be explained by various other factors that are specific to the locations examined in this study, including the built environment. For instance, this study found that having neighbourhood streets well lit at night was associated with a higher likelihood of AST in rural but not urban residents. Well-lit streets have been associated with creating a sense of perceived safety and security [66], which may make children and youth feel more comfortable engaging in AST during the day. However, in urban areas where infrastructure is often more developed [67], street lighting might not significantly affect children and youth's decision to engage in AST in the same way as they do for rural residents, as they are a standard part of the urban landscape. Policymakers and urban planners need to consider aspects of the built environment which make it more conducive to safe physical activity and work to tailor strategies to address these disparities in AST between urban and rural residents.

The results of our study also revealed differences in the relationship between air pollution perceptions and AST among different age groups. Although more children and youth aged 13 to 17 engaged in AST than children and youth aged 5 to 12, the perception of air pollution as a problem was only associated with a lower likelihood of AST among the 5-to-12 age group. These findings may be explained by younger children and youth having less independent mobility than older children and youth [68–70]; thus, their perceptions of air pollution and their behavioural response may be influenced to a greater extent by their parents' perceptions of the environment rather than their own.

In addition to age group differences, there were gender differences when examining the relationship between air pollution perceptions and AST. More males engaged in AST than females, but only males perceiving air pollution as a problem were less likely to engage in AST. Similarly, males who perceived a high crime rate were less likely to engage in AST, but this relationship was not significant among females. This finding is noteworthy considering the abundance of literature indicating that females express more fear of criminal victimization than males [71–73]. However, one possibility is that air pollution perceptions and high crime might not have a strong influence on AST among females due to barriers to facilitated school transportation for females in some regions. For instance, a previous article [74] described one Indian state's decision to only allow school buses to carry female children and youth when female bus attendants or drivers are on board due to safety concerns for females, highlighting potential safety concerns for females using non-active transportation methods such as public transportation. Future studies should examine

the complex mechanisms by which various sociocultural and contextual factors in India influence decisions regarding transportation modes, particularly among female children and youth.

In light of these study findings on the negative impact of perceived air pollution on AST among children and youth in India, public health authorities should consider prioritizing strategies that raise awareness about air quality and implement measures aimed at improving the safety of school transportation routes. Moreover, schools should consider further integrating air quality education into their curriculum to enhance child and youth awareness of air pollution and its impact on health to allow them to make informed decisions about their transportation choices.

Strengths and Limitations

By examining child and youth perceptions of air pollution, this study provides unique insights into factors that have not been previously explored among children and youth in India. However, given the focus on self-reported survey data, we were unable to assess objective measures of air quality or identify the specific reasons driving certain behaviours which could be elucidated through in-depth interviews or focus groups. Nevertheless, a previous study has found self-reported AST to have high test–retest reliability among adolescents [75]. Another limitation of this study was that air pollution perceptions were only measured through a single question, which may oversimplify child and youth perspectives. In–depth interviews and focus groups may be useful for gaining a deeper understanding of participants' perceptions of air pollution. Moreover, future studies should assess the test–retest reliability of self-reported air pollution perceptions to allow for more robust analyses and explore digital means of engagement with children and youth across India, including digital citizen science and mHealth approaches, particularly due to the high penetration of smartphone use which can enable representative samples across the most populous country in the world [76–78]. It is also important to acknowledge that this study used a cross-sectional design that did not account for weather conditions, which can potentially influence outdoor physical activity such as AST among children and youth. Future studies should use a longitudinal design to capture weather variation's impact on how air pollution influences AST [79–82]. This study also did not consider parental perceptions as potential confounders to engagement in AST, which are particularly important to consider when examining the behaviours of younger children and youth since they have a strong influence on children's participation in AST and independent mobility in general [83]. Previous studies have examined how parental perceptions influence AST among children and youth [40–44]; however, future studies should explore how child and youth perceptions of air pollution and parental perceptions interact to influence AST. Lastly, our study was not able to collect the full suite of socioecological determinants of health; thus, future studies are required to address this important gap.

5. Conclusions

No studies to date have examined the relationship between perceptions of air pollution and AST among children and youth in India while considering the nuanced variations across age, gender, and location. Given AST's established contribution to child and youth physical activity, this study provides valuable insights that could potentially inform both air pollution mitigation as well as active living policies. The study findings that air pollution and various community and built environment factors were associated with a lower likelihood of AST among children and youth highlight the need for policies and interventions to address these barriers to promote AST. These results also reinforce the findings of previous evidence indicating that involving communities in the design and implementation of interventions is crucial [84,85]. For instance, the use of digital citizen science can enable child and youth perspectives to be captured and utilized for location-specific real-time interventions and decision-making [76,84,86] to respond to constantly evolving air pollution crises.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/youth3040088/s1, File S1: Physical Activity Questionnaire.

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