

# The Associations of Active Travel to School with Physical Activity and Screen Time Among Adolescents: Do Individual and Parental Characteristics Matter?

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## Research article

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## Abstract

**Background:** Little is known about the relationship of active travel to school (ATS) with physical activity (PA) and screen time (ST) by individual and parental characteristics among adolescents, especially in China. To address the research gap, this study aimed to explore the difference of sex, age, geographical location, parental occupation and education level in the relationship of ATS with PA and ST among students of grades 7-12 using cross-sectional data.

**Methods:** In 13 cities of Hubei province, China, students from 39 public schools were recruited to engage in the survey. In total, 5898 students (response rate = 89.6%) were invited into this study. Participants were required to report their ATS (including its types), PA and ST as well as sociodemographic information using validated questionnaire. Descriptive analyses were used to report the information of all variables. Regression models were used to analyze the relationships of ATS and its types with PA and ST.

**Results:** In a total of 4128 participants (boy: 50.9%; younger adolescents: 61.9%) included in the final analysis, the proportion of those with ATS was 47.3%. Regarding the types of ATS, walking accounted for over 30%, while cycling was 13.2%. Participants with ATS were more likely to have sufficient PA (OR = 1.26, 95% CI: 1.14-1.39), especially among boys, younger adolescents and those with lower parental education level. However, ATS was not associated with ST (OR = 0.94, 95% CI: 0.86-1.01). Participants with cycling had higher odds ratio of being physically active (OR for cycling = 1.47, 95% CI: 1.27-1.70; OR for walking = 1.18, 95% CI: 1.06-1.32). The association of ATS types with PA and ST differed by gender, age, geographical location and parental educational level as well as occupations.

**Conclusions:** ATS may be a useful approach to increase PA among adolescents, but this should be explained by individual and parental characteristics.

## Background

A markedly ubiquitous international trend is that only a small proportion of adolescents fulfil the pervasively recognised physical activity (PA) and screen time (ST) guidelines [1–3]. Recent data based on objective measures indicate that just 44.1% of children and adolescents met the PA guidelines ( $\geq 60$  min of moderate to vigorous PA (MVPA)), while 39.3% of participants met the ST guidelines ( $< 2$  hours per day) [4]. Conversely, meeting the PA and ST recommendations is correlated with more desired health outcomes [5–8]. For example, higher PA levels were conversely related to (and greater time spent in ST was positively related to) the odds ratio of being obese [9]. For more desirable health outcomes, concurrently promoting PA and discouraging ST among adolescents is an essential public health action.

Given the insufficient PA and higher ST among adolescents globally, researchers have sought effective interventions to change these harmful health behaviours [10, 11]. In order to more effectively promote PA and limit ST among adolescents, active travel to school (ATS) plays a significant role. ATS is an essential source of PA behavioural components among adolescents. Well-documented evidence has presented how ATS is positively correlated with PA among adolescents [12]. For example, Roth et al. [13] demonstrated that children and adolescents participating in walking or cycling (types of ATS) were more likely to meet the PA recommendation (OR = 1.31). A further recent investigation of Ecuadorian students similarly demonstrated that participants engaged in ATS were approximately 3 times more likely to be engaged in sufficient PA as opposed to their peers [14]. Comparable results were established in another study conducted in the United Kingdom [15]. Overall, the extant research supports the position that ATS can promote PA among adolescents. However, concerning the relationship of ATS with ST among adolescents, an ambiguous relationship remains [12]. For example, certain researchers have posited that active travellers among adolescents had a reduced chance of spending time in ST [16–18], although this conclusion contrasted with other studies [19, 20]. Collectively, the relationship of ATS with ST should be clarified further, drawing on the accumulated evidence. Through drawing on the available literature, ATS may pose an effective means of increasing PA and ST, albeit with the relationship between ATS and ST being ambiguous [12].

With the increasing importance of ATS on overall PA, Chinese researchers have been devoted to ATS-related studies among Chinese young people. For example, Sun et al. [21] explored the health benefits of ATS, including lower body mass index and lower odds of depressive symptoms among nationally representative Chinese samples. In a cross-sectional study, Yang et al. [22] reported that there was a decline in ATS among Chinese adolescents. Also, some recent studies identified the social or environmental factors of ATS [23,24]. Within the limited literature, few studies investigated the relationship of ATS with PA and ST. Gao et al. [25] reported that, using a pedometer device, male schoolchildren with more steps during before- and after- school time showed higher levels of activity time, while female schoolchildren who had more steps during after-school time reported high activity. In Hong Kong, Huang et al. [26] found that ATS was related to maintaining a relatively higher level of PA. However, little is known about the relationship of ATS with ST among Chinese young people. Despite studies having presented evidence regarding the relationship of ATS with PA and ST, several research gaps still exist. One gap concerns the fact that the recent studies concerning ATS and PA, as well as ST, were based on adolescents from western countries [12, 21], whereas there is

limited understanding about them with respect to Chinese adolescents. Since evidence suggests that Chinese adolescents are insufficiently active [22], it is anticipated that ATS offers the potential to enhance their PA based on the findings of western studies. Such a relationship has not been investigated conclusively among Chinese samples. Understanding the relationship of ATS with PA is conducive to designing efficient interventions for enhanced PA among Chinese adolescents. Additionally, the correlation between ATS with ST continues to be unclear; thus, this correlation is worth investigating through additional studies [12]. In this regard, replicating comparable studies is necessary to advance our knowledge of PA behaviour, which may also provide strategies for reducing ST among Chinese adolescents.

The ATS, PA, and ST are associated with the substantial differences in individual and parental characteristics among adolescents. For example, Yang et al. [22] reported that adolescent ATS was significantly higher among younger groups, participants with lower educational attainment, or those residing in rural areas. Certain studies in western countries established that socioeconomic status parameters, for example living geographical location, parental education, and working status, were linked with ATS among adolescents [13,15,17]. Such variables are associated with PA and ST among adolescents in accordance with the Social Ecological Model [27]. Given the correlations between ATS, PA, ST, and socio-demographic variables, the correlation of ATS with PA and ST among adolescents may vary according to their individual and parental characteristics. As suggested in the review by Lubans et al. [28], investigating the overall relationship of ATS with outcomes (e.g., fitness or lifestyles behaviour) ignores the wider personal or social level correlates of behaviour. Therefore, it is necessary to investigate the correlation of ATS with PA and ST further, in accordance with the individual and parental characteristics. Nevertheless, across the limited literature, less research has scrutinised the relationship of ATS with PA and ST in relation to socio-demographic factors. For instance, one study indicated that the relationship of ATS with PA was only significant among younger adolescents in Ecuador [14]. Another study found that sex is a potential moderator of the relationship between ATS and PA among children and adolescents [19]. Unfortunately, there is a dearth of relevant evidence in this regard from China, which restricts our comprehension of the relationship of ATS with PA and ST among Chinese adolescents. Furthermore, there is limited understanding concerning investigations into the role of parental characteristics in this relationship.

Certain parental characteristics, for example, education and occupation, are associated with school travel choices. For instance, higher parental educational attainment represents advantages in terms of income, with those parents potentially more likely to deliver their children at school using private vehicles [13,16,19]. Subsequently, this could affect their children's active lifestyles. Nonetheless, whether the relationship of ATS with PA and ST varies according to parental characteristics has not yet been investigated. This is necessary to advance the knowledge in this field and capture information regarding the finer practical implications for adolescents affected by various parental characteristics.

Therefore, as a means of contributing to resolving the evidence shortcomings in the extant literature and to develop an evidence foundation for PA- and ST-focused interventions for Chinese adolescents, this research aimed to analyse the relationship of ATS with PA and ST in accordance with the individual and parental characteristics among adolescents in China.

## Methods

### Study design and research ethics

The data collection method adopted in this cross-sectional study was a questionnaire survey, undertaken between May and June 2019, in Hubei province of China. Contact was made with the commission of education in 13 cities of Hubei province. Applying a convenience sampling method, we invited three public schools (one primary school, one middle school, and one high school) per city to participate in this survey. Through the administrative support provided by the commissions of education, 3rd to 12th grade students in 39 public primary, middle, and high schools were selected across all the cities. Among the entire student sample obtained, 6583 students (aged 10 to 18 years) were invited to participate in the survey. Of these, 5898 responses with a complete self-reported questionnaire, providing a response rate of 89.6%. The research protocol and procedure were approved by the Institutional Review Board (IRB) of the Wuhan University of Technology in March 2019. The student participants and their legal guardians provided written consent. The anonymity and confidentiality of participants was ensured in accordance with the *Declaration of Helsinki*.

### Measurements

#### Sociodemographic information

The participants were asked, during their break time on schooldays, to provide self-reported data regarding sex (1 = boy, 2 = girl), grade (from 4 to 12) and current living geographical locations (1 = urban, 2 = rural). A self-reported questionnaire was implemented to collect

information from parents, including the parental educational attainment (less than college/university; college/university or higher), and occupation (office worker or manual laborer). The parents completed the paper-based questionnaire at home using a pencil.

## Exposures (ATS)

A single-item question was included for measuring the ATS, which asked the participants: 'In the last 7 days, how did you usually get to your school?' [21]. This measure has been used in previously published studies [21]. Participants were asked to indicate which of the travel modes represented their principal means of travelling to school and returning home. They were only given the option to select one principal transport mode, and data relating to multimode journeys (walking to or from public transport hubs, for example) was not obtained. Participants could select the following options as their responses: 1) walking independently; 2) cycling independently; 3) walking with parents or guardians; 4) cycling with parents or guardians; 5) taking school bus; 6) delivered by parents using automobile/private car/other motorized instruments; 7) other public transportation, such as public bus/underground/taxi. Overall, participants selecting options from 1 to 4 were considered *active*, whereas others were considered *passive*. According to the type of ATS, participants selecting 1 and 3 were regarded as walking; 2 and 4 were regarded as cycling; 5 were regarded as using school bus; 6 were regarded as delivered by parents; and 7 were regarded as using public transportation.

## Outcomes (PA and ST)

PA was measured using the items derived from the Health Behavior School-aged Children (HBSC) questionnaire, which has acceptable validity and reliability in the Chinese context [29]. Two items collected the information on PA, namely, 1) 'How many days did you engage in moderate to vigorous PA (MVPA) for at least 60 minutes on weekdays over the past week?', with responses: 0 = none, 1 = 1 day, 2 = 2 days, 3 = 3 days, 4 = 4 days, 5 = 5 days; and 2) 'How many days did you engage in MVPA for at least 60 minutes during the weekend over the past week?', where responses included: 0 = none, 1 = 1 day, 2 = 2 days. Consistent with the Canadian 24-Hour Movement Guideline [4], sufficient PA in accordance with the definition of fulfilling the MVPA recommendation was equivalent to the participants reporting 60 minutes of MVPA daily for seven days.

The following items of the HBSC questionnaire were used to obtain information relating to ST [29]: 1) 'How many hours did you spend watching TV or movies during your leisure time on weekdays and on the weekend over the past week?' (responses: 1 = none, 2 = around half an hour, 3 = around one hour, 4 = around two hours, 5 = around three hours or more); 2) 'How many hours did you spend playing computer games during your leisure time on weekdays and on the weekend over the past week?' (responses: same as the above item); and 3) 'How many hours did you spend on activities using electronic screen-based devices during your leisure time on weekdays and on the weekend over the past week?' (responses: same as the above item). Consistent with the Canadian 24-Hour Movement Guidelines [8], limited ST was considered to be daily screen time of participants—including time watching TV/movies, playing computer games, and using electronic screen-based devices—of less than 2 hours per day.

## Statistical analysis

Prior to initiating the formal analysis process, all responses with missing data were omitted from the sample. We opted to concentrate our analysis on adolescents (grades 7–12) only, with data pertaining to further school grades being excluded. Ultimately, the final sample size, included in the analysis, was 4128. Descriptive statistical analysis was applied to report the percentage of sociodemographic variables (e.g. sex, age, geographic location, parental occupation and education), exposures (ATS: passive versus active; its types: school bus, delivery by parents, or public transportation as passive, or walking or cycling as active) and outcomes (PA: sufficient versus insufficient; ST: limited versus excessive). Chi square test was performed to investigate the difference in PA and ST by ATS (its types), alongside the individual as well as parental characteristics. Logistic regression was undertaken to analyse the relationship of ATS and its types (exposure) with PA and ST (outcome). All variables were incorporated into the regression analysis as categorical variables. This research presents the logistic regression results as odds ratios (ORs) with 95% confidence intervals (CIs). When examining the relationship of ATS and its types with PA and ST, all sociodemographic variables were adjusted in the models, and  $p < 0.05$  was established as the level of statistical significance. The statistical analyses procedures were performed using SPSS 24.0 (IBM Corp, Chicago, IL, USA).

## Results

Table 1 presents the characteristics of participants in this study. Of all the included participants ( $n = 4128$ ), boys accounted for 50.9%. Younger adolescents accounted for over 60% of the participants. Over 70% of the participants lived in urban areas. Approximately 70% of participants had parents who were office worker or had an education degree of less than college/university. The proportion of participants using passive mode of ATS was 52.7%. Regarding the types of ATS, participants who walked to school accounted for 34.1% (the largest proportion), while participants using the school bus made up the smallest proportion (0.8%). The prevalence of sufficient PA and limited ST was 17.3% and 67.9%, respectively.

Table 1  
Characteristics of participants in this study

	n	%
Overall	4128	100
Sex		
Boy	2101	50.9
Girl	2027	49.1
Age group		
Younger adolescent	2555	61.9
Older adolescent	1573	38.1
Geographical location		
Urban	3059	74.1
Rural	1069	25.9
Parental occupation		
Officer worker	2881	69.8
Manual laborer	1247	30.2
Parental education level		
Less than college/university	2935	71.1
College/university or higher	1193	28.9
Travel to school		
Passive	2175	52.7
Active	1953	47.3
Modes of travel to school		
School bus	33	0.8
Delivered by parents	1102	26.7
Public transportation	1040	25.2
Walking	1408	34.1
Cycling	545	13.2
MVPA*		
Insufficient	3414	82.7
Sufficient	714	17.3
ST**		
Excessive	1325	32.1
Limited	2803	67.9
*MVPA Moderate to vigorous physical activity, insufficient denotes not meeting the guidelines; sufficient denotes meeting the guidelines [4]; **ST Screen time, excessive denotes not meeting the guidelines; limited denotes meeting the guidelines [4].		

In Table 2, the results of the difference in PA and ST by ATS and its types are presented. Participants with active ATS showed a higher percentage of sufficient PA compared to their counterparts (20.1% vs. 14.8%,  $p = 0.000$ ). Participants taking cycling as ATS mode had the highest percentage of sufficient PA compared to others (23.0%,  $p = 0.000$ ). There was no significant difference in the levels of limited ST among participants with different ATS groups. Participants taking the school bus as their mode of ATS had the lowest percentage of limited ST compared to those using other types of ATS (53.3%,  $p = 0.000$ ).

Table 2  
Difference of PA and ST by ATS and its types

	Sufficient PA (n = 714)	<i>p</i>	Limited ST (n = 2803)	<i>p</i>
	%		%	
ATS				
Passive	14.8	0.000	68.4	0.213
Active	20.1		67.3	
Types of ATS				
School bus	15.2	0.000	53.3	0.000
Delivered by parents	15.9		73.0	
Public transportation	13.6		64.0	
Walking	19.0		69.5	
Cycling	23.0		61.7	
<i>ATS</i> Active travel to school, <i>PA</i> Physical activity, <i>ST</i> screen time.				

The results of the difference of PA and ST by ATS and its types as well as individual characteristics are shown in Table 3. Regardless of sex, and living geographical location, a difference of PA was observed between the passive and active ATS groups as well as the types of ATS (all  $p < 0.005$ ). However, there was no significant difference of PA between the passive and active ATS groups among older adolescents ( $p = 0.116$ ). Further, a significant difference was observed across groups of different types of ATS irrespective of sex, age, and living geographical location for limited ST. However, there was no significant difference of ST across groups of ATS except for younger boys ( $p = 0.000$ ).

Table 3  
Difference of PA and ST by ATS and its types as well as individual characteristics

	Sufficient PA (n = 714)				Limited ST (n = 2803)				
	%	<i>p</i>	%	<i>p</i>	%	<i>p</i>	%	<i>p</i>	
	Boy		Girl		Boy		Girl		
ATS									
Passive	17.8	0.000	12.3	0.040	66.5	0.562	70.0	0.621	
Active	24.6		14.1		65.7		69.4		
Types of ATS									
School bus	18.2	0.000	10.8	0.010	58.2	0.000	45.9	0.000	
Delivered by parents	19.6		13.3		70.8		74.5		
Public transportation	16.3		10.9		63.1		64.9		
Walking	24.5		13.4		68.7		70.3		
Cycling	24.9		17.5		60.5		65.2		
		Younger adolescents		Older adolescents		Younger adolescents		Older adolescents	
ATS									
Passive	17.4	0.000	11.6	0.116	72.0	0.010	63.9	0.559	
Active	23.2		13.2		69.2		63.1		
Types of ATS									
School bus	12.5	0.000	17.3	0.002	55.0	0.000	51.9	0.000	
Delivered by parents	17.3		12.6		73.5		71.8		
Public transportation	17.7		10.9		69.8		60.0		
Walking	21.9		11.0		70.9		65.5		
Cycling	27.8		16.6		63.6		59.2		
		Urban		Rural		Urban		Rural	
ATS									
Passive	14.9	0.000	14.6	0.000	68.5	0.050	68.0	0.414	
Active	19.5		21.8		66.5		69.4		
Types of ATS									
School bus	16.9	0.000	12.1	0.000	55.9	0.000	48.5	0.000	
Delivered by parents	16.2		14.9		73.3		72.2		
Public transportation	13.4		14.3		63.9		64.2		
Walking	17.9		21.9		68.7		71.8		
Cycling	23.5		21.7		61.0		63.6		
<i>ATS</i> Active travel to school, <i>PA</i> Physical activity, <i>ST</i> screen time.									

In Table 4, more participants with an active ATS had sufficient PA regardless of parental education levels compared to those with a passive ATS (less than college/university: 20.7% > 14.6%,  $p < 0.001$ ; college/university or higher: 18.7% > 15.2%,  $p = 0.006$ ), and particularly, participants who selected cycling had the highest percentages compared with the other ATS types. In terms of limited ST, participants who were delivered by parents had the highest percentages (less than college/university: 70.6%,  $p < 0.001$ ; college/university or higher: 77.9%,  $p = 0.004$ ). Similar to the parental education level groups, more participants using active form of travel to school had sufficient PA regardless

of their parent's occupations compared with those with passive ATS (office worker: 20.4% > 14.9%, manual laborer: 19.6% > 14.6%, both  $p < 0.001$ ), and participants using cycling had the highest percentages compared with other ATS types (both 23.0%, both  $p < 0.001$ ). Participants who were delivered by parents had the highest percentages of limited ST compared to those with other ATS types (office worker: 74.6%, manual laborer: 68.6%, both  $p < 0.001$ ).

Table 4  
Difference of PA and ST by travel to school and its types as well as parental characteristics

	Sufficient PA				Limited ST			
	%	<i>p</i>	%	<i>p</i>	%	<i>p</i>	%	<i>p</i>
Parental education	Less than college/university		College/university or higher		Less than college/university		College/university or higher	
ATS								
Passive	14.6	0.000	15.2	0.006	65.5	0.819	75.4	0.076
Active	20.7		18.7		65.2		72.7	
Types of ATS								
School bus	13.6	0.000	18.2	0.005	45.8	0.000	66.7	0.004
Delivered by parents	15.8		16.0		70.6		77.9	
Public transportation	13.5		14.0		61.1		72.3	
Walking	19.7		17.3		67.7		74.1	
Cycling	23.3		22.3		58.7		69.1	
Parental occupation	Officer worker		Manual laborer		Officer worker		Manual laborer	
ATS								
Passive	14.9	0.000	14.6	0.000	70.3	0.833	63.7	0.205
Active	20.4		19.6		70.1		61.6	
Types of ATS								
School bus	16.9	0.000	11.1	0.000	60.0	0.000	37.0	0.000
Delivered by parents	15.2		17.7		74.6		68.6	
Public transportation	14.4		11.8		65.8		59.9	
Walking	19.3		18.4		71.8		64.8	
Cycling	23.0		23.0		65.7		52.8	
<i>ATS</i> Active travel to school, <i>PA</i> Physical activity, <i>ST</i> screen time.								

In Table 5, the results from the logistic regression model revealing the relationships of ATS with PA and ST are shown. Overall, participants with ATS were more likely to have sufficient PA (OR = 1.26, 95% CI: 1.14–1.39). In examining the relationships of ATS with PA and ST by sex, only boys with ATS had a higher chance of being sufficiently active (OR = 1.41, 95% CI: 1.24–1.61), compared with their counterparts. Significant relationships were also observed in participants of the younger age group (OR = 1.35, 95% CI: 1.20–1.52) and those whose parental education level were less than college/university (OR = 1.30, 95% CI: 1.16–1.47). Regardless of geographical location and parental occupation, participants with ATS were more likely to have sufficient PA (all OR > 1.20). However, participants with ATS showed a non-significant relationship with ST.

Table 5  
The relationships of travel (modes) to school with MVPA and ST by different characteristics

	MVPA			ST								
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Active	<b>1.26</b>	<b>1.14</b>	<b>1.39</b>				0.94	0.86	1.01			
Passive	Ref			Ref								
	Boys			Girls			Boys			Girls		
Active	<b>1.41</b>	<b>1.24</b>	<b>1.61</b>	1.05	0.90	1.23	0.93	0.83	1.03	0.94	0.84	1.06
Passive	Ref			Ref			Ref			Ref		
	Younger adolescents			Older adolescents			Younger adolescents			Older adolescents		
Active	<b>1.35</b>	<b>1.20</b>	<b>1.52</b>	1.07	0.88	1.29	0.91	0.82	1.01	0.98	0.86	1.12
Passive	Ref			Ref			Ref			Ref		
	Urban			Rural			Urban			Rural		
Active	<b>1.23</b>	<b>1.09</b>	<b>1.38</b>	<b>1.40</b>	<b>1.15</b>	<b>1.70</b>	0.89	0.81	0.98	0.91	1.07	1.25
Passive	Ref			Ref			Ref			Ref		
	Less than college/university			College/university or higher			Less than college/university			College/university or higher		
Active	<b>1.30</b>	<b>1.16</b>	<b>1.47</b>	1.16	0.96	1.39	0.98	0.89	1.07	0.84	0.72	0.99
Passive	Ref			Ref			Ref			Ref		
	Officer worker			Manual laborer			Officer worker			Manual laborer		
Active	<b>1.26</b>	<b>1.11</b>	<b>1.41</b>	<b>1.26</b>	<b>1.05</b>	<b>1.51</b>	0.95	0.86	1.05	0.90	0.78	1.04
Passive	Ref			Ref			Ref			Ref		
<i>MVPA</i> Moderate to vigorous physical activity, <i>ST</i> Screen time. Bold fonts denote statistical significance.												

Table 6 shows the results from regression model for the relationships of types of ATS with PA and ST by individual and parental characteristics. In general, participants who selected walking or cycling were more likely to have sufficient PA overall, in boy, younger adolescents, and urban participants, and those who had parents with less than college/university education level or office worker occupation. Conversely, cycling had a likelihood of increasing the sufficient PA among girls, older adolescents, or those who had parents with a higher education level (college/university or higher) or manual laborer. With reference to the relationship of types of ATS with ST, participants with walking (OR = 1.17, 95% CI: 1.05–1.30) and delivered by parents (OR = 1.34, 95% CI: 1.19–1.50) were more likely to have limited ST. Significant relationships were also found among boys and girls, older adolescents, those living rural areas, those having parents with less than college/university education level, or with office workers.

Table 6  
The relationships of types of active travel to school with MVPA and ST by different characteristics

	MVPA			ST								
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Walking	<b>1.23</b>	<b>1.07</b>	<b>1.41</b>				<b>1.17</b>	<b>1.05</b>	<b>1.30</b>			
Cycling	<b>1.52</b>	<b>1.29</b>	<b>1.79</b>				<b>0.88</b>	<b>0.77</b>	<b>0.99</b>			
School bus	1.06	0.59	1.89				<b>0.60</b>	<b>0.39</b>	<b>0.92</b>			
Delivered by parents	1.06	0.92	1.23				<b>1.34</b>	<b>1.19</b>	<b>1.50</b>			
Public transportation	Ref			Ref								
	Boys			Girls			Boys			Girls		
Walking	<b>1.41</b>	<b>1.18</b>	<b>1.69</b>	0.99	0.79	1.23	<b>1.16</b>	<b>1.01</b>	<b>1.34</b>	<b>1.17</b>	<b>1.01</b>	<b>1.37</b>
Cycling	<b>1.57</b>	<b>1.29</b>	<b>1.91</b>	<b>1.47</b>	<b>1.07</b>	<b>2.00</b>	<b>0.83</b>	<b>0.70</b>	<b>0.98</b>	0.97	0.77	1.23
School bus	1.10	0.54	2.22	0.98	0.34	2.82	0.75	0.43	1.30	<b>0.43</b>	<b>0.22</b>	<b>0.83</b>
Delivered by parents	1.07	0.88	1.32	1.01	0.81	1.27	<b>1.25</b>	<b>1.06</b>	<b>1.48</b>	<b>1.42</b>	<b>1.21</b>	<b>1.66</b>
Public transportation	Ref			Ref			Ref			Ref		
	Younger adolescents			Older adolescents			Younger adolescents			Older adolescents		
Walking	<b>1.29</b>	<b>1.08</b>	<b>1.53</b>	1.04	0.81	1.33	1.06	0.91	1.23	<b>1.23</b>	<b>1.04</b>	<b>1.44</b>
Cycling	<b>1.56</b>	<b>1.26</b>	<b>1.93</b>	<b>1.34</b>	<b>1.03</b>	<b>1.74</b>	<b>0.76</b>	<b>0.63</b>	<b>0.92</b>	0.99	0.82	1.20
School bus	0.65	0.25	1.69	1.71	0.81	3.60	<b>0.47</b>	<b>0.25</b>	<b>0.90</b>	0.69	0.39	1.20
Delivered by parents	1.01	0.84	1.22	1.23	0.95	1.58	1.15	0.98	1.34	<b>1.62</b>	<b>1.36</b>	<b>1.92</b>
Public transportation	Ref			Ref			Ref			Ref		
	Urban			Rural			Urban			Rural		
Walking	<b>1.21</b>	<b>1.03</b>	<b>1.42</b>	1.25	0.95	1.64	1.11	0.98	1.26	<b>1.33</b>	<b>1.08</b>	<b>1.65</b>
Cycling	<b>1.66</b>	<b>1.38</b>	<b>2.01</b>	1.09	0.78	1.51	0.86	0.74	1.01	0.94	0.73	1.23
School bus	1.17	0.58	2.35	0.95	0.32	2.83	0.65	0.38	1.09	0.52	0.26	1.05
Delivered by parents	1.17	0.98	1.38	0.77	0.56	1.04	<b>1.36</b>	<b>1.19</b>	<b>1.55</b>	<b>1.30</b>	<b>1.03</b>	<b>1.65</b>
Public transportation	Ref			Ref			Ref			Ref		
	Less than college/university			College/university or higher			Less than college/university			College/university or higher		
(Continued)												
Walking	<b>1.22</b>	<b>1.04</b>	<b>1.43</b>	1.22	0.93	1.60	<b>1.25</b>	<b>1.11</b>	<b>1.42</b>	0.97	0.78	1.20
Cycling	<b>1.50</b>	<b>1.24</b>	<b>1.82</b>	<b>1.53</b>	<b>1.12</b>	<b>2.09</b>	0.90	0.77	1.05	0.82	0.63	1.07
School bus	0.97	0.45	2.09	1.29	0.52	3.24	<b>0.53</b>	<b>0.32</b>	<b>0.90</b>	0.70	0.33	1.48
Delivered by parents	0.99	0.83	1.18	1.23	0.93	1.62	<b>1.40</b>	<b>1.23</b>	<b>1.60</b>	1.19	0.95	1.49

MVPA Moderate to vigorous physical activity, ST Screen time. Bold fonts denote statistical significance.

	MVPA						ST					
Public transportation	Ref			Ref			Ref			Ref		
	Officer worker			Manual laborer			Officer worker			Manual laborer		
Walking	<b>1.19</b>	<b>1.01</b>	<b>1.41</b>	<b>1.30</b>	<b>1.01</b>	<b>1.69</b>	<b>1.17</b>	<b>1.02</b>	<b>1.33</b>	1.18	0.98	1.42
Cycling	<b>1.39</b>	<b>1.14</b>	<b>1.69</b>	<b>1.85</b>	<b>1.36</b>	<b>2.50</b>	0.95	0.80	1.11	<b>0.75</b>	<b>0.59</b>	<b>0.94</b>
School bus	1.09	0.56	2.12	0.92	0.27	3.15	0.73	0.44	1.22	<b>0.37</b>	<b>0.17</b>	<b>0.82</b>
Delivered by parents	0.99	0.83	1.18	1.27	0.96	1.69	<b>1.33</b>	<b>1.16</b>	<b>1.53</b>	<b>1.38</b>	<b>1.12</b>	<b>1.70</b>
Public transportation	Ref			Ref			Ref			Ref		
<i>MVPA</i> Moderate to vigorous physical activity, <i>ST</i> Screen time. Bold fonts denote statistical significance.												

## Discussion

To the best of our knowledge, this study is one of the first cross-sectional investigations into the relationship of ATS and its types with PA and ST among adolescents of the Chinese samples. This research analyses the correlation of ATS and its types with PA and ST in relation to different individual and parental characteristics, which potentially offers significant practical implications and advances the knowledge in this field.

## Key findings

In this current study, the proportion of the sample engaging in ATS was 47.3%, with participants who walked (34.1%) constituting a greater percentage than those who cycled (13.2%). Regarding the question relating to levels of adequate PA and limited ST among the adolescents, only 17.3% attained the former, whereas the latter was under acceptable levels. Furthermore, we found that participants engaged in ATS had a greater chance of also participating in adequate PA levels, while ATS was not connected with limited ST. Regarding types of ATS, participants engaged in walking or cycling both had a higher chance of undertaking sufficient PA rather than being characterised by limited ST. The relationships of ATS and its types with PA and ST differed according to individual and parental characteristics.

## Interpretations of findings

Low PA levels among adolescents have been demonstrated across the literature [1, 3, 30]. The present research indicated that only approximately 20% of adolescents participated in the recommended level of PA (60 minutes of moderate to vigorous PA daily [4]), indicating a lower level of PA among adolescents. This result is consistent with the previously published studies of a regional nature [31, 32]. Nevertheless, in contrast with the nationally representative surveys in China [30], the PA level established in the present study is lower. This reduced level is potentially explained by the varying measures adopted, which possibly produced inconsistencies in terms of estimating the amount of PA. Concerning the level of ST among adolescents in this study, our level is in accordance with studies based on Chinese adolescent samples [30-32]. Despite the ST level exceeding 60%, limiting ST is a necessary mission for the promotion of adolescent health. Likewise, given the health benefits linked to sufficient PA among adolescents [5, 8], increased PA is further imperative. The Social Ecological Model has summarised the correlates of PA and ST [27]. Nevertheless, given the significant variations in China's economy, society and geography, investigating the correlates and determinants of PA and ST among adolescents across the country's various regions requires additional research [31].

The current study indicates that just below half of the participants (47.3%) engaged in ATS from home to school, which corroborates other studies on Chinese [21,22] and North American samples [34,35]. Regardless, in contrast with studies of European countries [36,37], the adolescents in our study showed reduced ATS performance. Inconsistencies in the ATS levels between our study other research are primarily due to different measures used. Nevertheless, it is evident that the ATS among Chinese adolescents has declined over the past decade [22], suggesting that they are less physically active (through walking or cycling). From this perspective, the ATS level among adolescents in our study is potentially unsatisfactory. This is a somewhat concerning situation that should be explained in relation to local

contexts and across various regions or cities [38]. Given the health benefits of ATS for adolescents [28], the promotion of ATS among adolescents is to be encouraged.

Our research is one of the few investigations assessing types of ATS among Chinese adolescents. Among the participants engaged in ATS, the majority walked between school and home. This finding is consistent with previous studies [21]. For instance, Yang et al. [22] clarified that participation in walking or cycling between home and school has declined over the years. Presently, there is a dearth of understanding regarding walking or cycling trends among Chinese adolescents at the national or regional level. We suggest that future studies should seek to more effectively explore the patterns of either walking or cycling, thus providing evidence-based information for promoting ATS.

Reflecting the findings of numerous previous studies [14,19,25,26], the current study reaffirms that participants engaged in ATS have a greater chance of participating in sufficient PA. Potential reasons may be that 1) ATS is an aspect of daily PA; thus, participants engaged in ATS are more likely to report higher PA; 2) participants engaged in ATS were similarly or more intensely engaged in other types of PA. Collectively, these two potential reasons may be responsible for the association of ATS with sufficient PA. Nevertheless, the ATS and PA were affected by different variables across various regions.

Accordingly, the mechanism connecting ATS and PA varies depending upon the social and environmental factors. Therefore, it is advocated that further studies should investigate the correlation of ATS and PA to a greater extent, implementing enhanced study designs and multiple data sources. Nevertheless, this study finds that ATS was not associated with ST among adolescents. A systematic review indicated that the relationship of ATS with ST was inconsistent across the literature [12], meaning the correlation between these two variables remains ambiguous. However, informed by the findings of this study, ATS potentially plays a role in promoting PA, as opposed to diminishing ST among adolescents.

We further discovered that the relationship of ATS with PA varies according to sex, age, and parental education. Specifically, the relationship of ATS and PA was found to be significant among boys, suggesting that only boys engaging in ATS are potentially involved in sufficient PA [13]. However, such a significant relationship was not observed among girls. This may be potentially because parents grant greater freedom to boys to engage in ATS as opposed to girls. Thus, girls may be exposed to fewer opportunities to engage in ATS behaviour, ultimately restricting their ability to engage in sufficient PA levels. Moreover, the sex difference in the relationship of ATS with PA was similar to the age difference.

The present research found that younger adolescents, as opposed to their older peers were engaged more in ATS and had a greater chance of also participating in sufficient PA. This result is explainable according to the Chinese context. In our study, older adolescents were those in grades 10–12, which is a vital period that covers the college entrance test. During this period, adolescents tend to be delivered to school by their parents for timesaving reasons, allowing a greater amount of time to be spent on studying. Conversely, such a situation would not arise among younger adolescents due to lower academic pressure.

Among participants whose parents had lower educational attainment, those engaged in ATS had a greater prospect of attaining sufficient PA levels. Nevertheless, this significant relationship was not detected among participants whose parents had higher educational attainment levels. A potential reason is that parents with lower levels of educational attainment have lower levels of income compared with their counterparts. Consequently, it is less likely that those parents possess automobiles, which potentially causes their children to travel between home and school through walking or cycling.

This research has established that the relationships between types of ATS with PA and ST vary according to individual and parental characteristics. We primarily identified that participants engaged in walking or cycling had a greater likelihood of participating in sufficient PA compared with their counterparts. Unsurprisingly, when assessing the odds ratio of walking and cycling in relation to sufficient PA, the former is lower than the latter. This finding is consistent with the results of the study of Roth et al. [13], where the association between cycling and overall PA (OR = 1.93) was stronger than that between walking and overall PA (OR = 1.17). Another study also provided a similar finding that there was a difference in the PA level between active walkers and cyclists [39]. However, there is still no well-recognized explanation for this finding and more research is required into the social and environmental determinants of ATS with PA.

A similar relationship was identified among boys, younger adolescents, participants whose parents had reduced education levels, or were office workers. Significantly, only girls engaged in cycling showed sufficient PA in our study, providing an inconsistency with the results for boys. Future studies should attempt to answer this difference for the relationship of types of ATS with PA based on the different subpopulations' characteristics and other factors.

A noticeable distinction is apparent in the relationship of types of ATS with PA according to the geographical location. Specifically, in urban areas, adolescents engaged in cycling were more likely to be involved in sufficient PA, whereas adolescents in rural areas who were engaged

in walking had a greater prospect of undertaking sufficient PA. Unfortunately, no data provided by our study were able to clarify the variation. The differences of built environment between urban and rural settings may provide a plausible explanation to this. A similar finding was established for participants with different parental education levels and occupations. Given the limited evidence across the extant literature, more studies should address these research questions in the future.

When looking at the difference of individual and parental characteristics in the relationship of types of ATS with limited ST, some novel findings should be mentioned. In the current study, participants who walked and were delivered by parents had higher odds of having limited ST compared with their counterparts. To our knowledge, no data provided by previous studies were comparable with our study findings. Some possible reasons for explaining the findings are that 1) participants who walked to school could be regarded as a lower level of socio-economic status, and may not be able to afford as many screen-based devices, ultimately reducing their ST; 2) participants delivered by parents would be exposed to much stricter supervision that limits the time spent for screen-based activities. Owing to less research, more studies should confirm our assumptions. In addition to the overall findings, the individual and parental differences in the relationship of types of ATS with ST were found. Such variations should be explained by more factors, whereas the present study failed to provide this indicative information, future studies should answer the variations found by our study, which can provide more specific practical implications.

## Implications and future recommendations for research

Irrespective of the preliminary nature of the evidence regarding the variations in the relationship of ATS and its types with individual and parental characteristics, the present study affirmed the role of ATS in promoting PA among adolescents. This research has expanded on prior research, demonstrating that individual and parental characteristics show different relationships regarding ATS compared to PA. Nevertheless, given that ATS and PA are two complex behaviours that are affected by numerous variables, the relationships of ATS and its types with PA according to various characteristics requires further replication and clarification of the results to provide more robust evidence. Practically, the current study should prove beneficial in encouraging adolescent PA through ATS, with the design of effective policies and actions being necessary.

When designing ATS interventions for enhancing PA among adolescents, individual and parental characteristics must be considered. It is recommended that future research should concentrate on the mechanisms linking ATS with PA within various contexts (for example sex and geographical location). Based on the cross-sectional nature of our research, prospective longitudinal studies are necessary to confirm the relationships we observed, as well as to elucidate whether a potential causal relationship is apparent between ATS and PA. Moreover, it is necessary to undertake further experimental research in order to analyse the extent to which ATS interventions offer further effectiveness for promoting PA among adolescents.

## Study strengths and limitations

This study offered certain advantages. First, the study adopted a relatively large sample size as a means of investigating the relationship of ATS with PA and ST, thus enhancing the generalizability of research findings. Second, the present study is one of the very limited number of investigations analysing the associations of ATS with PA and ST as they relate to different individual and parental characteristics. The research findings are potentially beneficial for designing specific PA and ST interventions. However, there are certain limitations to this study that should be clarified. Due to the cross-sectional nature of the study, the findings of the study should be interpreted with caution. Moreover, our study used a self-reported questionnaire to assess the ATS, PA, and ST, which was subjective to recall bias of measurement. Third, this study did not include/explore more potential confounders, such as time spent during ATS and car ownership, that may affect the relationship of ATS with PA and ST. Fourth, to better explain the relationship of ATS with PA or ST, additional psychological (e.g., attitude towards to ATS), social (e.g., safety and parental awareness of ATS) and physical environmental (e.g., distance to school) factors should be considered for more reliable interpretations. Finally, the ATS and PA, as well as ST, are also affected by other factors, such as income level. We recommend further study of the relationship of ATS with PA and ST by income and other sociodemographic factors, particularly of longitudinal nature. Future studies should address these limitations to provide an improved evidence base.

## Conclusions

Overall, our study indicated that approximately half of adolescents engaged in ATS, with a majority of participants preferring to travel through cycling between home and school. ATS among adolescents was linked with sufficient PA as opposed to ST. Therefore, the relationships of ATS and its types with PA require further clarification in accordance with different contexts, including sex, age differences,

and parental characteristics. Nevertheless, this study retains its specific significance to the implementation of PA promotional activities among adolescents.

## Abbreviations

ATS: Active travel to school; CI: Confidence interval; HBSC: Health Behavior School-aged Children; IRB: Institutional Review Board; MVPA: Moderate to vigorous physical activity; OR: Odds ratio; PA: Physical activity; ST: screen time; TV: television

## Declarations

## Ethics approval and consent to participate

The survey was approved by the Institutional Review Board (IRB) of the Wuhan University of Technology. All participants provided written informed consent before the start of the investigation.

## Consent for publication

Not applicable.

## Availability of data and materials

The datasets analysed in this study are available from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interests.

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The study did not receive any external funding.

## Authors' contributions

CH, YL, YL and STC conceptualised and designed this study. CH, CL and YL analysed, interpreted data, and drafted the manuscript. ARM and STC provided important intellectual roles in revision. All authors read and approved the final manuscript.

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