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Original article

The relationship between transport-to-school habits and physical activity in a sample of New Zealand adolescents

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Abstract

Objectives: Adolescents using active transport (AT) to school have higher levels of physical activity (PA) compared with motorized transport (MT) users. This study compared school day and weekend day PA in adolescents using AT, MT, or combined AT and MT (AT + MT) to travel to school.

Methods: Adolescents ($n = 314$; age: 14.7 ± 1.4 years; 32.8% boys) from Dunedin (New Zealand) wore an accelerometer for 7 days and completed a self-reported survey regarding mode of transport to school (73 AT, 56 AT + MT, and 185 MT). Data were analyzed using t tests, analysis of variance, and χ^2 tests.

Results: Although the proportion of adolescents meeting PA guidelines significantly differed among transport groups (AT, 47.9%; AT + MT, 46.4%; MT, 33.5%; $p = 0.048$; overall, 39.2%), the observed differences were due mainly to girls. Compared with MT, AT and AT + MT engaged in more moderate-to-vigorous PA (MVPA) per day (AT: 61.2 ± 23.2 min; AT + MT: 59.6 ± 21.7 min; MT: 52.5 ± 19.6 min; $p = 0.004$; $p < 0.001$, adjusted for gender), per school day and before school. Immediately after school (15:00−16:00), AT engaged in significantly more MVPA compared with AT + MT and MT. No differences in MVPA between the groups were observed in the late afternoon/early evening period during school days or on weekend days.

Conclusion: Compared with MT users, adolescent girls using AT or AT + MT accumulated more MVPA during school commute time. AT + MT to school is also a plausible way to increase adolescent girls' PA when AT only is not feasible.

Keywords: Accelerometer; Adolescent; Physical activity; Schools; Transportation; Walking

1. Introduction

Despite numerous health benefits, adolescents' physical activity (PA) levels have been declining in many countries. In New Zealand, PA participation is satisfactory in children but not in adolescents.[1] Declining PA opportunities and increasing sedentary behaviors (e.g., sitting) among adolescents contribute at least in part to increasing levels of overweight and obesity in this age group.[2] Active transport (AT) to school provides a potential source of regular PA.[3,4−11] However, in many developed countries, including New Zealand, the majority of adolescents rely on motorized transport (MT) to school.[12] This factor further limits adolescents' opportunities for PA, making it more challenging for them to meet daily PA recommendations.[13]

Several previous studies of adolescents in Canada,[14] the United States,[4,5] Europe,[6−8] and the Philippines[9] used accelerometers to examine the relationship between AT to school and PA, and 2 New Zealand studies used pedometers to examine this relationship.[10,11] In these studies, compared with MT users, adolescents using AT to school had higher levels of weekly moderate-to-vigorous PA (MVPA),[5−8,14] school day MVPA,[15] and step counts,[10,11] as well as higher levels of PA before school and during after-school hours.[4,5,16] Only 2 of these previous studies examined energy expenditure[9] and

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MVPA[8] among adolescents using combined AT and MT (AT + MT).

The present study contributes to the literature on accelerometer-measured MVPA among New Zealand adolescents by using MVPA data related to school commute periods and taking into account AT + MT to school. The overall aim of this study was to examine the relationship between transport-to-school habits and PA levels in a sample of New Zealand adolescents. Specifically, this cross-sectional study compared objectively measured PA during school days and weekend days, as well as before and after-school hours among New Zealand adolescents travelling to school using AT, MT, or AT + MT.

2. Methods

2.1. Participants

Adolescents ($n = 1780$; age: 13−18 years) from all 12 secondary schools in Dunedin, New Zealand, participated in the Built Environment and Active Transport to School (BEATS) Study in 2014−2015.[17] After excluding participants who had invalid surveys ($n = 38$), missing survey data ($n = 48$), invalid survey consent ($n = 20$), no required parental consent ($n = 59$), no consent for PA assessment ($n = 1041$), or incomplete or invalid accelerometer data ($n = 98$), as well as those who boarded at schools ($n = 162$), 314 adolescents (67.2% girls) were included in this analysis. All participants included in our sample were recruited through the schools and signed consents. For adolescents under 16 years of age included in our study, parents consented following opt-out or opt-in procedures based on the school's preference. Our study was approved by the University of Otago Ethics Committee (reference number 13/203).

Study procedures have been described in detail elsewhere.[17] Participants completed an online survey, and anthropometry measurements were collected during class time under supervision by research staff. Participants received accelerometers 1−3 weeks after survey completion.

Sociodemographic characteristics were self-reported. Home address data were used to determine the New Zealand Index of Deprivation (a neighborhood area deprivation score) as a surrogate for students' socioeconomic status and calculate distance from home to school using the Geographic Information Systems network analysis.[17]

As described elsewhere,[18] the frequency of transport to school using different transport modes was assessed for each transport mode separately. Those modes of transport to school (car passenger, car driver, school bus, public bus, walking, cycling, and other modes) that were used most or all of the time were classified as dominant transport modes. Participants were also asked if they used more than 1 mode of transport on a single journey to school. Participants were classified into AT only, MT only, or combined AT + MT based on a combination of dominant modes of transport to school and the use of multimodal transport on a single journey to school.[18]

Height (measured using a custom-built portable stadiometer), weight (measured using the A&D scale UC321; A&D Medical, San Jose, CA, USA) and waist circumference (measured using a metal measurement tape, MURATEC-KDS CORP, Chicago, IL, USA) were obtained using standard procedures.[19] Weight was recorded to the nearest 0.01 kg and reduced by 0.5 kg to account for clothing.[19] As described previously,[19] international age- and gender-specific cut-points for body mass index were used to determine weight status category.

Participants wore an accelerometer (GT3XPlus; ActiGraph, Pensacola, FL, USA) above the right hip for 7 consecutive days.[17] They received verbal and written instructions at school about using the device. To promote compliance, participants were provided with a log to record the wear/removal times, and reasons for removal. They also received e-mails or texts to remind them about wearing the accelerometer. Accelerometer data were downloaded using ActiGraph software (ActiLife 6), and data were stored in 10-s epochs to detect short bursts of vigorous PA. The wear-time validity was set at 5 or more days, with 10 or more h/day (inclusive of 3 school days and 1 weekend day)[20, 21] and 75% or more of wear time for periods before, after, and late after school. Data were analyzed by the MeterPlus Data Analysis Service (MeterPlus, San Diego, CA, USA) in 2016 using Evenson cut-points[22] and included total minutes of accumulated PA. Nonactivity periods were determined based on bouts of 20 min or more of inactivity. Accelerometer-derived variables included PA (light, moderate, vigorous, and MVPA) and sedentary time per day, per school day and per weekend day. PA and sedentary time variables were also analyzed 1 h before school (08:00−09:00), 1 h after-school (15:00−16:00), and late afterschool hours (16:00−20:00), accounting for school-specific start/end times. Participants who accumulated 60 min or more of MVPA/day on all valid days met the minimum PA guidelines.[13]

Data were analyzed using SPSS Version 24.0 (IBM Corp., Armonk, NY, USA). Although participants were nested within schools, which could have resulted in dependency among observations, there were far too few schools and participants within schools to warrant any type of cluster or multilevel analyses.[23] Thus, PA and sedentary times were compared across AT, MT, and AT + MT using one-way analysis of variance with Tukey *post hoc* multiple comparisons, or, when the assumption of homogeneity of variance was violated, with the Kruskal-Wallis test for continuous variables and χ^2 test for categorical variables. Owing to previously reported gender differences in adolescents' PA,[1,24,25] gender-adjusted analyses were also performed using analysis of variance with gender as a covariate or using the Kruskal-Wallis test for boys and girls separately. An α of $p < 0.05$ was considered statistically significant.

3. Results

Among the 314 participants (age: 14.7 ± 1.4 years; 32.8% males), 23.2% used AT only, 58.9% used MT only, and 17.9% used AT + MT to school (Table 1). Compared with participants using MT and AT + MT, AT participants lived closer to school and had fewer vehicles at home (Table 1). Age, gender, ethnicity, neighborhood area deprivation score, and the

Table 1
Sociodemographic characteristics across the 3 transport groups.

	AT only ($n = 73$)	AT + MT ($n = 56$)	MT only ($n = 185$)	χ^2 (*df*)	*p*
Age (year)	14.7 ± 1.2	14.5 ± 1.3	14.8 ± 1.5	0.975	0.614
Gender					
Boys	28 (38.4)	19 (33.9)	56 (30.3)		
Girls	45 (61.6)	37 (66.1)	129 (69.7)	1.592	0.451
Ethnicity					
New Zealand European	59 (81.9)	40 (71.4)	142 (76.8)		
Māori	3 (4.7)	9 (16.1)	12 (6.5)		
Other	10 (13.9)	7 (12.5)	31 (16.8)	7.737	0.102
Neighbourhood deprivation score					
1 (least deprived)	15 (20.5)	17 (30.9)	65 (36.1)		
2	17 (23.3)	16 (29.1)	41 (22.8)		
3	13 (17.8)	9 (16.4)	31 (17.2)		
4	18 (24.7)	9 (16.4)	24 (13.3)		
5 (most deprived)	10 (13.7)	4 (7.3)	19 (10.6)	10.003	0.265
Distance to school (m)	1509 ± 1245*,#	7577 ± 7228	7696 ± 7349	115.147	<0.001
Number of bikes available to use to get to school					
None	15 (20.5)	13 (23.2)	38 (20.5)		
1	17 (23.3)	10 (17.9)	44 (23.8)		
≥2	41 (56.2)	33 (58.9)	103 (55.7)	0.925	0.921
No. of vehicles at home					
None	4 (5.5)	1 (1.8)	3 (1.6)		
1	36 (49.3)	15 (26.8)	34 (18.4)		
≥2	33 (45.2)	40 (71.4)	148 (80.0)	30.737	<0.001

Notes: Due to missing data, ethnicity data in AT group were available in 72 participants (missing data for 1 participant) and neighbourhood deprivation score data were available in 55 participants in AT+MT group (missing data for 1 participant) and 180 participants in MT only group (missing data for 5 participants). In addition, due to rounding of numbers, in a few cases in this table, the percentages do not add up to 100.0% exactly. Data are presented as mean ± SD; The others are presented as *n* (%). All the "(*df*)"= "(2, 312)".
* $p < 0.05$ AT only *vs.* AT + MT, # $p < 0.05$ AT only *vs.* MT only.
Abbreviations: AT = active transport; *df* = degrees of freedom; MT = motorized transport.

availability of bicycles at home were not significantly different among the groups.

On average, the participants wore an accelerometer for 13.7 h/day. Throughout the day, they spent 69.7% of their time being sedentary (9.5 h/day), 23.5% in light PA (3.2 h/day), and 6.8% in MVPA (0.9 h/day). Overall, 39.2% met minimum PA guidelines (45.6% of boys and 36.0% of girls; $p = 0.101$), including 47.9% of AT, 46.4% of AT + MT, and 33.5% of MT users. When gender was taken into account, this difference in PA across different transport modes was observed only in adolescent girls. In addition, the proportion of adolescents using MT and meeting PA guidelines was consistently higher in boys versus girls. Compared with MT, AT and AT + MT accumulated on average 8.7 min/day and 7.1 min/day more MVPA, respectively. Time spent being sedentary was not different across the groups (Table 2).

Overall, 42.4% of participants met PA guidelines on school days, with significant differences across the transport groups. AT and AT + MT groups accumulated significantly more MVPA on school days compared with the MT group. On average, AT and AT + MT groups accumulated 10.9 min/day and 8.8 min/day more of MVPA than the MT group, respectively. Time spent being sedentary was not different across the groups (Table 2).

Overall, 28.3% of participants met PA guidelines on weekend days, with no significant differences across the transport groups. Time spent in MVPA and being sedentary were not statistically significantly different among the groups (Table 2).

In the hour before and after school, participants spent between 53% and 56% of their time being sedentary, approximately 30% of their time in light PA, and between 13% and 17% of their time (between 8 min and 10 min) in MVPA. During this period, the AT group accumulated 39.8% of the total school day MVPA compared with 31.2% and 25.7% of MVPA in AT + MT and MT groups, respectively. During the hour before and after school, AT and AT + MT users accumulated, on average, 26.0 min and 19.7 min of MVPA, respectively, compared with 14.0 min among MT users. During both the hour before and after school, AT participants spent significantly more time in MVPA compared with either AT + MT or MT participants. In addition, compared with MT users, AT + MT users accumulated more MVPA in the hour before school but not in an hour immediately after school. The proportion of adolescents using AT only to school was significantly different across tertiles of PA (<45 min/day MVPA, 17.0% AT; 45−65 min/day MVPA, 23.1% AT; >65 min/day MVPA, 30.6% AT; $\chi^2 = 11.184$, $p = 0.025$). Among adolescents using AT only to school, MVPA accumulated during the school commute time was positively correlated with average daily MVPA ($r = 0.55$; $p < 0.001$) and average weekday MVPA ($r = 0.60$; $p < 0.001$) (Table 3).

During the 4-h period late after school (16:00−20:00), participants spent 69.1% of their time being sedentary, 23.3% of their

Table 2
PA throughout the week, on school days and weekend days across 3 transport groups.

	Total sample ($n = 314$)	AT only ($n = 73$)	AT + MT ($n = 56$)	MT only ($n = 185$)	F (df) or χ^2 (df)	F (df) or χ^2 (df), adjusted for gender
Average daily activity throughout the week (min/day)						
Sedentary	575.9 ± 81.1	583.6 ± 75.6	564.3 ± 72.1	576.4 ± 85.6	$F = 0.913$	$F = 1.005$
Light PA	193.2 ± 47.5	179.3 ± 49.3[a,b]	203.3 ± 44.4	195.6 ± 46.8	$F = 4.730$**	$F = 5.044$**
Moderate PA	33.4 ± 11.5	34.6 ± 13.9	36.7 ± 10.6[c]	32.0 ± 10.6	$\chi^2 = 8.790$*	Boys: $\chi^2 = 2.332$ Girls: $\chi^2 = 9.467$**
Vigorous PA	22.4 ± 13.9	26.6 ± 16.3[b]	22.9 ± 15.6	20.5 ± 11.8	$\chi^2 = 7.314$*	Boys: $\chi^2 = 1.316$ Girls: $\chi^2 = 5.154$
MVPA	55.8 ± 21.1	61.2 ± 23.2[b]	59.6 ± 21.7	52.5 ± 19.6	$F = 5.759$**	$F = 5.252$***
Met PA guidelines (%)						
Total	39.2	47.9	46.4	33.5	$\chi^2 = 6.082$*	
Boys	45.6	50.0	42.1	44.6		$\chi^2 = 0.333$
Girls	36.0	46.7	48.6	28.7		$\chi^2 = 7.788$*
Average daily activity on school days (min/day)						
Sedentary	591.7 ± 86.4	596.9 ± 75.0	582.1 ± 84.7	592.5 ± 91.1	$F = 0.480$	$F = 0.561$
Light PA	192.9 ± 49.0	179.8 ± 49.1[a]	204.0 ± 47.4	194.7 ± 48.6	$F = 4.261$*	$F = 4.704$*
Moderate PA	34.9 ± 11.7	36.6 ± 14.0[b]	39.5 ± 11.8[c]	32.8 ± 10.1	$\chi^2 = 14.919$**	Boys: $\chi^2 = 1.160$ Girls: $\chi^2 = 17.160$***
Vigorous PA	23.6 ± 14.5	28.7 ± 16.7[b]	23.7 ± 15.8	21.6 ± 12.6	$\chi^2 = 10.103$**	Boys: $\chi^2 = 1.329$ Girls: $\chi^2 = 8.383$*
MVPA	58.5 ± 21.0	65.3 ± 22.4[b]	63.2 ± 21.9[c]	54.4 ± 19.1	$F = 9.322$***	$F = 8.699$***
Met PA guidelines (%)						
Total	42.4	57.5	51.8	33.5	$\chi^2 = 14.852$*	
Boys	50.5	53.6	47.4	50.0		$\chi^2 = 0.186$
Girls	38.4	60.0	54.1	26.4		$\chi^2 = 20.621$***
Average daily activity on weekend days (min/day)						
Sedentary	531.5 ± 103.3	543.2 ± 101.9	513.6 ± 95.4	532.2 ± 105.9	$F = 1.312$	$F = 1.304$
Light PA	193.8 ± 64.1	177.5 ± 64.9[b]	198.0 ± 66.0	198.9 ± 62.5	$F = 3.106$*	$F = 3.006$
Moderate PA	29.2 ± 19.7	29.4 ± 21.5	28.3 ± 16.6	29.4 ± 20.0	$F = 0.068$	$F = 0.075$
Vigorous PA	18.9 ± 19.0	21.6 ± 21.5	20.6 ± 22.8	17.4 ± 16.5	$\chi^2 = 0.850$	Boys: $\chi^2 = 0.752$ Girls: $\chi^2 = 0.642$
MVPA	48.1 ± 34.6	50.9 ± 36.2	48.9 ± 35.9	46.8 ± 33.7	$F = 0.387$	$F = 1.037$
Met PA guidelines (%)						
Total	28.3	30.1	26.8	28.1	$\chi^2 = 0.188$	
Boys	35.9	32.1	42.1	35.7		$\chi^2 = 0.490$
Girls	24.6	28.9	18.9	24.8		$\chi^2 = 1.091$

Note: Continuous variables are presented as mean ± SD. All the "(df)"= "(2, 312)".
[a] $p < 0.05$, AT only *vs.* AT + MT; [b] $p < 0.05$, AT only *vs.* MT only; [c] $p < 0.05$, AT + MT *vs.* MT only.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Abbreviations: AT = active transport; MT = motorized transport; MVPA = moderate-to-vigorous physical activity; PA = physical activity.

time in light PA, and only 6.3% (15 min) of their time in MVPA. Overall, adolescents accumulated only one-quarter of their school day MVPA (a total of 15 min) during this period. Time spent in PA (light PA, moderate PA, vigorous PA, and MVPA) and being sedentary were not statistically significantly different across the transport groups (Table 3).

4. Discussion

Our findings revealed that nearly one-half of the adolescents using AT and AT + MT to school met minimum PA guidelines compared with one-third of adolescents relying on MT only, owing mainly to differences in PA levels across different transport modes in adolescent girls. Second, AT and AT + MT users accumulated more daily MVPA compared with MT users on school days but not on weekend days. Third, AT users accumulated more MVPA in the hour before and after school compared with AT + MT and MT users, whereas no difference in MVPA was observed between the transport groups in the late afternoon/early evening period or on weekends. These findings suggest that AT during school commute time provided an opportunity for adolescents to accumulate PA, even if they combine AT and MT.

In the present study, adolescents spent 9.5 h/day in sedentary activities, 3.2 h/day in light PA, and 0.9 h/day in MVPA. Overall, 4 in 10 adolescents met minimum PA guidelines, with an average MVPA of 56 min/day, with no statistically significant gender differences. Previous research has reported considerable variation in MVPA levels (36−55 min/day[1,24,25]) and the proportion of adolescents who met PA guidelines (1%−41%[1,24−26]), with gender differences reported in some studies.[24,25]

Similarly, adolescents living in developed countries engage in high levels of sedentary time (~6−10 h/day[24−26]). These findings reiterate concerns regarding adolescents' PA levels,

Table 3
PA in the hour before school, the hour after school, and late after-school hours.

	Total sample ($n = 314$)	AT only ($n = 73$)	AT + MT ($n = 56$)	MT only ($n = 185$)	F (df) or χ^2 (df)	F (df) or χ^2 (df), adjusted for gender
Average daily activity in the hour before school (08:00–09:00) (min/day)						
Sedentary	32.3 ± 8.1	28.7 ± 9.6[b]	31.8 ± 8.3	33.9 ± 6.8	χ^2= 25.485***	F= 12.952***
Light PA	17.6 ± 6.0	15.7 ± 6.7[b]	17.3 ± 5.7	18.5 ± 5.7	F= 5.527**	F= 4.662**
Moderate PA	4.5 ± 3.8	6.8 ± 5.2[b]	5.7 ± 4.3[c]	3.3 ± 2.0	χ^2= 33.726***	Boys: χ^2= 3.874 Girls: χ^2= 30.410***
Vigorous PA	3.4 ± 4.3	5.9 ± 5.6[a,b]	4.1 ± 4.9[c]	2.3 ± 2.9	χ^2= 35.120***	Boys: χ^2= 10.407** Girls: χ^2= 23.909***
MVPA	8.0 ± 6.4	12.7 ± 7.5[a,b]	9.8 ± 6.7[c]	5.6 ± 4.3	χ^2= 66.658***	Boys: χ^2= 20.562*** Girls: χ^2= 44.524***
Average daily activity in the hour after school (15:00–16:00) (min/day)						
Sedentary	32.1 ± 8.0	30.2 ± 8.1[b]	30.7 ± 8.0	33.3 ± 7.9	F= 5.079**	F= 4.895**
Light PA	17.8 ± 5.6	16.3 ± 5.4[a]	19.0 ± 5.7	18.0 ± 5.6	F= 3.984*	F= 4.080*
Moderate PA	5.6 ± 3.7	7.0 ± 4.4[b]	6.1 ± 3.7	4.8 ± 3.2	χ^2= 17.762***	Boys: χ^2= 3.934 Girls: χ^2= 17.864***
Vigorous PA	4.2 ± 3.6	6.3 ± 4.9[a,b]	3.8 ± 2.8	3.6 ± 2.9	χ^2= 17.831***	Boys: χ^2= 5.731 Girls: χ^2= 11.090**
MVPA	9.8 ± 5.8	13.3 ± 6.4[a,b]	9.9 ± 5.3	8.4 ± 5.1	F= 20.856***	F= 20.636***
Average daily activity late after school (16:00–20:00) (min/day)						
Sedentary	165.8 ± 23.9	169.1 ± 24.9	161.9 ± 23.3	165.6 ± 23.7	F= 1.342	F= 1.272
Light PA	55.8 ± 17.7	53.8 ± 19.0	57.5 ± 18.7	56.2 ± 16.9	F= 0.704	F= 0.641
Moderate PA	8.4 ± 4.9	7.9 ± 5.2	9.6 ± 5.2	8.3 ± 4.7	F= 1.988	F= 1.921
Vigorous PA	6.5 ± 6.8	6.3 ± 5.7	7.1 ± 8.8	6.5 ± 6.6	F= 0.226	F= 0.268
MVPA	15.0 ± 10.3	14.2 ± 9.5	16.7 ± 11.9	14.8 ± 10.1	F= 0.978	F= 1.002

Notes: Continuous variables are presented as mean ± SD. All the "(df)"= "(2, 312)".
[a] $p < 0.05$, AT only *vs.* AT + MT; [b] $p < 0.05$, AT only *vs.* MT only; [c] $p < 0.05$, AT + MT *vs.* MT only.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Abbreviations: AT = active transport; MT = motorized transport; MVPA = moderate-to-vigorous physical activity; PA = physical activity.

which include not only a small amount of daily MVPA, but also a considerable amount of time spent in sedentary pursuits. Future interventions should focus on developing programs and policies aimed at increasing PA and reducing time spent being sedentary (e.g., sitting while consuming screen time) in this age group.

We found that Dunedin adolescents using AT or AT + MT to school accumulated more MVPA throughout the week compared with those relying solely on MT, mainly for girls. During the 2-h school commute period, AT and AT + MT accumulated 26.0 min (39.8% of daily MVPA) and 19.7 min (31.2% of daily MVPA) of MVPA, respectively, compared with 14.0 min (25.7% of daily MVPA) among MT users. Hence, PA accumulated during school commute periods (before and after school) also provides a consistent source of daily PA, which could add up to a substantial amount of weekly PA for adolescents. Most previous studies have reported that a greater proportion of adolescents using AT to school met recommended PA levels[6] and had higher daily MVPA[6,7,14,15] and energy expenditure[9] compared with their peers who relied on MT to school. Therefore, this study provides further evidence that New Zealand adolescents using AT as a part of their journey to and from school achieve higher levels of daily PA compared with adolescents relying solely on MT to travel to school, with the observed differences being mainly for girls. However, previous New Zealand studies also found lower rates of sport participation in adolescent girls versus boys,[27] as well as a lower proportion of girls in the physically active profile (resulting from a cluster analysis),[19] reflecting previously documented gender differences in PA during adolescence.[28] Therefore, promotion of AT may be one way to address the lower rates of participation in PA among girls in New Zealand[19,27] and throughout the world.[28]

However, only 2 previous studies have examined PA levels in adolescents using AT + MT to travel to and from school.[8,9] AT to school predicted greater levels of MVPA compared with AT + MT and MT among Spanish and French adolescents.[8] Based on a single-day assessment, male adolescents using AT (walking) or AT + MT (walking and MT) to school had a greater daily energy expenditure compared with MT users.[9] In the present study, adolescents wore accelerometers for 7 consecutive days and yielded accelerometer data for 3 or more valid school days and at least 1 valid weekend day, which provided reliable measurements of PA throughout the school day and to examine school day and weekend differences.[20,21,29] Therefore, the present study provides further support for the notion that adolescents using AT + MT to school accumulate more MVPA during school days compared with MT users. Taken together, these findings suggest that combining AT + MT in a single journey to and/or from school could be an alternative way of increasing PA in adolescents when AT only is not feasible. These findings are encouraging and can at least in part alleviate some of the negative consequences associated with the increasing distance to school that students experience during the transition from primary to secondary school, as well as the negative implications of school choice policies on adolescents' rates of AT to school.[30]

Future interventions should consider strategies to encourage the inclusion of AT as a part of the journey to and from school for adolescents, even if combined with MT. Distance to school is one of the major determinants of AT in adolescents.[3,12,31] Previous studies have reported threshold distances ranging from 2 km to 3 km for adolescents' who walk to school, with variations across geographical settings.[32–35] Given that the distance from home to school likely increases when students transition from primary to secondary schools[36] and that some countries like New Zealand have policies where adolescents do not have to enroll in the closest school,[30,37]our results have important implications for encouraging AT, even when AT only is not feasible owing to the distance to the school. Potential interventions could include designing safe drop-off and pick-up points along a safe route for walking and/or cycling to school, advocating for school-based walking or cycling groups, and/or offering cycling skills training. Interventions could also focus on promoting the use of public transport to school as an alternative to driving or being driven to school when the distance from home to school poses a barrier to AT. Public transport interventions could include reducing the cost of public transport for adolescents or supporting cycling by providing free-of-charge bicycle racks on buses. Future studies should examine the use and benefits of multimodal transport to school among adolescents in different geographical settings.

Overall, Dunedin adolescents accumulated 11 min/day more MVPA on school days compared with weekend days (59 min/day *vs.* 48 min/day, respectively). When transport to school was considered, AT and AT + MT users accumulated more daily MVPA compared with MT users during school days but not on weekend days. Higher levels of adolescents' MVPA on school days versus weekend days have been previously reported among adolescents in the United States (49 min/day *vs.* 35 min/day),[38] Canada (56 min/day *vs.* 39 min/day),[39] and Singapore (24 min/day *vs.* 9 min/day)[26] and among Scottish[15] and Australian[40] adolescents using AT to school.[15,40]Among New Zealand adolescents, AT users accumulated more steps on school days versus weekend days compared with MT users.[10,11] Given the lower levels of MVPA accumulated by adolescents on weekend days compared with school days, future initiatives could focus on providing family- and/or community-based PA opportunities during weekends (e.g., organized family outdoor trekking or camping activities and/or community sports events).

In addition to differences in PA between school days and weekend days, the findings of this study show that the differences in adolescents' school day MVPA in the AT and AT + MT groups compared with MT took place during the school commute periods. AT users accumulated significantly more MVPA during the hour before and after school compared with AT + MT and MT users, which accounted for the respective differences in total school day MVPA among the transport groups. Specifically, AT accumulated 39.8% of the total school day MVPA during the school commute time compared with 31.2% and 25.7% of MVPA in AT + MT and MT, respectively. Similarly, previous studies conducted in the United States have found that AT during school commute times (before and after school) contributed to a greater amount of daily MVPA compared with MT to school in adolescents.[4,5,16] Those previous studies also used longer durations for the before school (between 2.0 h and 2.5 h) and after-school (between 1.5 h and 2.0 h) periods[4,5] compared with the present study (1 h each for both periods). Nevertheless, taken together, these findings suggest that promoting AT during school commute times would allow adolescents to capitalize on their daily school journeys to increase PA. Although the daily contribution of AT to MVPA during the school journey seems modest, this consistent source of PA could add up to a substantial contribution to adolescents' PA and replace or minimize sedentary time associated with MT to school.

In the present study, no difference in MVPA was observed among the transport groups during late after-school hours. This finding could be attributable to the end of the school day when most adolescents, regardless of the transport modes to school, had returned home or engaged in extracurricular activities. The period after school was critical for Portuguese adolescents' engagement in MVPA,[41] particularly the late afternoon period (15:00–18:00), which contributed to the main amount of MVPA for less-active female adolescents. In the present study, New Zealand adolescents accumulated one quarter of their school day MVPA time (a total of 15 min) during the 16:00–20:00 period. Among European adolescents, the time after school until midnight was considered as an important part of the school day for promoting[42] and engaging adolescents in PA.[8] Future interventions could promote after-school PA opportunities for adolescents through sports councils and community centers, which could provide affordable and easily accessed sports facilities and equipment as well as offer sports or game activities after school hours within the community (e.g., in schools, community centers or sports hubs). Differences in geographical and cultural contexts need to be taken into account when designing PA promotion initiatives for adolescents, especially during the after-school period on school days.

Study limitations include a cross-sectional design, a relatively small sample size that may have been underpowered to detect some medium-sized effects in the nonparametric analyses, data collection in 1 city only, and the participation of predominately female adolescents, all of which may limit the generalizability of these findings. The study's strengths include an objective measure of PA, inclusion of an AT + MT group, and PA analyzed at various time intervals throughout the school day. Future studies should recruit similar proportions of male and female adolescents to examine the effects of AT, MT, and AT + MT to school on adolescents' PA levels in different geographical settings.

5. Conclusion

Compared with MT users, adolescents relying on AT or AT + MT accumulated more MVPA during school commute periods and were more likely to meet PA guidelines, owing mainly to differences observed in adolescent girls. PA levels were not different across the transport groups during the late afternoon/early evening on school days or on weekends. Therefore, both AT only and AT + MT to school are potential avenues to increase daily PA in adolescents, particularly in adolescent girls. Future PA promotion interventions should encourage adolescents to use AT, either alone or in combination with MT, as an alternative to relying solely on MT to school. Multisector efforts and collaborations among schools, local governments, health promotion agencies, communities, and parents are necessary for implementing policies, programs, and built environment changes to encourage the incorporation of AT to school even when AT only is not feasible.

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Authors' contributions

CCK conceptualized data analysis, analyzed data, and drafted the manuscript; SM is the principal investigator who conceptualized the overall study, obtained research funding, led the project implementation, and assisted with analyzing the data and drafting and revising the manuscript; EGB contributed to the study design, interpretation of results, and manuscript revisions; JCS contributed to the study design, funding acquisition, interpretation of the results, and manuscript revisions. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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