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ORIGINAL ARTICLE

Relationships between active school transport and adiposity indicators in school-age children from low-, middle- and high-income countries

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OBJECTIVES: Within the global context of the nutrition and physical activity transition it is important to determine the relationship between adiposity and active school transport (AST) across different environmental and socio-cultural settings. The present study assessed the association between adiposity (that is, body mass index *z*-score (BMIz), obesity, percentage body fat (PBF), waist circumference) and AST in 12 country sites, in the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE).
METHODS: The analytical sample included 6797 children aged 9–11 years. Adiposity indicators included, BMIz calculated using reference data from the World Health Organization, obesity (BMIz $\geqslant$+2 s.d.), PBF measured using bioelectrical impedance and waist circumference. School travel mode was assessed by questionnaire and categorized as active travel versus motorized travel. Multilevel linear and non-linear models were used to estimate the magnitude of the associations between adiposity indicators and AST by country site and sex.
RESULTS: After adjusting for age, sex, parental education and motorized vehicle availability, children who reported AST were less likely to be obese (odds ratio = 0.72, 95% confidence interval (0.60–0.87), $P<0.001$) and had a lower BMIz (−0.09, s.e.m. = 0.04, $P=0.013$), PBF (least square means (LSM) 20.57 versus 21.23% difference −0.66, s.e.m. = 0.22, $P=0.002$) and waist circumference (LSM 63.73 cm versus 64.63 cm difference −0.90, s.e.m. = 0.26, $P=0.001$) compared with those who reported motorized travel. Overall, associations between obesity and AST did not differ by country ($P=0.279$) or by sex ($P=0.571$).
CONCLUSIONS: AST was associated with lower measures of adiposity in this multinational sample of children. Such findings could inform global efforts to prevent obesity among school-age children.

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INTRODUCTION

In less than one generation, the prevalence of childhood and adolescent obesity has increased worldwide.[1] Many low- and middle-income countries (LMIC) have shown similar or even more rapid increments of childhood obesity compared with high-income countries (HIC).[2,3] Although the increment of obesity in some HIC seems to be leveling off, the prevalence remains very high.[1] Unfortunately, the data for time trends in physical activity (PA) and sedentary behaviors among children and adolescents from LMIC are extremely sparse.[4,5] Nonetheless, in some HIC, PA levels among school-age children are decreasing, whereas time spent in sedentary behaviors is increasing.[4]

Within the context of the nutrition and PA transition,[6] in which PA patterns are often the result of environmental and societal changes, it is important to understand the role of activities that can be incorporated into everyday life, including active school transport (AST).The prevalence of AST, unfortunately, has declined in several HIC including Canada,[7] the United States,[8] Australia[9] and Switzerland.[10] In LMIC the data are limited, but studies conducted in Brazil, China, Mozambique and Vietnam have also shown that the AST trend in this countries mirrored HIC trends.[11–14]

Active travel to school is one way in which children can increase their levels of PA and prevent obesity.[15] A recent systematic review showed that there is conflicting, and very low-quality evidence, regarding the association between adiposity indicators and AST.[16] Specifically, Larouche *et al.*[16] found that in only 36% of the studies AST was associated with more favorable body composition. Furthermore, most of these studies assessed only body mass index (BMI), 27% measured body fat and 12% measured waist circumference.[16]

In addition, 82% of the studies assessing the association between body composition indicators and AST have been conducted in HIC in North America, Australia and Europe with

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few studies extending findings to LMIC such as the Philippines, Indonesia, China, Brazil, Colombia and Kenya.

The interpretation of different patterns of adiposity indicators and AST associations across different world regions requires common standardized methods that have not been employed. The limited variability in obesity, AST patterns and nutrition and PA transition within each country may have underestimated the strength of the associations. Further, multinational natural experiments to establish causality are hard to administer and control in this field. Thus, only international studies using comparable methods can help to elucidate the extent to which associations between obesity and AST are generalizable across countries or are country-site specific. Such findings could, in turn, support international and country-specific interventions to prevent obesity and inform global efforts, such as the 'Global Strategy on Diet, Physical Activity and Health' of the World Health Organization (WHO),[17] the United Nations political declaration on non-communicable diseases[18] and the World Bank commitment to sustainable transport.[19]

In this context, the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) provides a unique opportunity to assess whether the relationship between obesity and AST differs across different environmental and socio-cultural settings. The objective of this study was to assess the associations between adiposity indicators (that is, BMI *z*-score (BMIz), obesity, percentage body fat (PBF) and waist circumference) and AST in children from sites in 12 different countries.

MATERIALS AND METHODS

ISCOLE is a multicountry, cross-sectional study conducted on 9–11-year-old children from 12 countries (Australia (Adelaide), Brazil (São Paulo), Canada (Ottawa), China (Tianjin), Colombia (Bogota), Finland (Helsinki, Espoo and Vantaa), India (Bangalore), Kenya (Nairobi), Portugal (Porto), South Africa (Cape Town), the United Kingdom (Bath and North-East Somerset) and the United States (Baton Rouge)). Additional details on study design, participating countries and methodology have been published elsewhere.[20] The institutional review board at the Pennington Biomedical Research Center (coordinating center) approved the overarching protocol, and the institutional/ethical review boards at each participating institution also approved local protocols. Written informed consent was obtained from parents or legal guardians, and child assent was also obtained as required by local institutional/ethical review boards. The data were collected from September 2011 through December 2013.

Participants

Of the 7372 children enrolled in ISCOLE, 6797 remained in the analytic data set after excluding participants who did not have valid/information data on BMI ($n=31$), PBF ($n=68$), waist circumference ($n=6$), main mode of transportation to school ($n=61$), travel time to school ($n=2$), parental education ($n=368$) and motor-vehicle availability ($n=39$). The participants who were excluded in the present analysis were more likely to report walking to school ($P<0.001$) and to report trips to school of <5 min ($P<0.001$).

Measurements

Anthropometry. Anthropometric data (that is, height, weight, PBF and waist circumference) were directly measured by trained ISCOLE researchers during an in-school visit according to standardized procedures.[20] Weight (to the nearest 0.1 kg) and PBF (to the nearest 0.1%) were measured using a portable Tanita SC-240 Body Composition Analyzer (Tanita, Arlington Heights, IL, USA), after outer clothing and shoes were removed. The Tanita SC-240 has shown acceptable accuracy for estimating PBF when compared with dual-energy x-ray absorptiometry, supporting its use in field studies.[21] Height was measured with a portable Seca 213 stadiometer (Seca, Hamburg, Germany) at the end of a deep inhalation with the participant's head in the Frankfort Plane. Waist circumference was measured with a non-elastic tape held midway between the lower rib margin and the iliac crest at the end of a gentle expiration.[22] Waist circumference was measured on the bare skin in all countries except in Australia where it was measured over light clothing. The regression equation ($y=0.994$; $x=-0.42$) developed by McCarthy *et al.*[23] was applied to the Australian data to correct for the over-the-clothes measurement. Each measurement was repeated and the average was used for the analysis. BMI was calculated and then categorized using the 2007 WHO growth reference tables.[24] The participants were classified as obese (BMI *z*-score (BMIz) $>+2$ s.d.) or non-obese (BMIz $\leqslant +2$ s.d.).

Active school transport

AST was assessed via questions adapted for each country from the Canadian component of the 2009–2010 Health Behaviour in School-aged Children Study.[25] The children were asked about the main mode of transport that they used to go to school during the last week. The response options included active modes such as walking, bicycle, roller blades and scooter; and motorized modes such as car, motorcycle, bus, train, tram, underground or boat; and others according to country-specific modes of transport. Other modes of transportation included active modes such as running and jogging; and motorized modes such as the school van, matatu, bus feeder, pedicab; and non-active non-motorized modes such as wheelchair and riding on the top tube of the bike's frame. For this analysis, we classified children's mode of transport into two categories, AST versus motorized travel. To assess biking and other wheeled modes of transport independent from walking we also classified a subsample of children into two categories (motorized travel versus biking or other wheeled modes of active transport). In addition, a question regarding the time spent during the journey from home to school was included. The response options were: <5 min, 5–15 min, 16–30 min, 31 min–1 h and >1 h. To examine dose–response relationships between AST and adiposity, we created a composite variable with the following categories motorized travel, <5 min–15 min of AST and at least 16 min of AST. The common referent category of this composite variable was motorized travel. The cut-points were established according to sample size (Table 1).

Covariates

The socio-demographic variables included age, sex, highest parental education and motorized vehicle availability. Age was computed from date of birth and the date of anthropometry measurements. Sex and parental education were recorded on the demographic and family health questionnaire. The highest parental education variable was created based on the highest education level of the mother or the father (less than high school, complete high school or some college, and university degree or postgraduate degree). Motorized vehicle availability was reported as the number of motorized vehicles available for use in the household (0 versus $\geqslant 1$). Motor vehicles included cars, motorcycles, mopeds and/or trucks.

In addition, time spent in moderate-to-vigorous PA (MVPA) was obtained from 24-h waist-worn accelerometry. An Actigraph GT3X+ accelerometer (ActiGraph, LLC, Pensacola, FL, USA) was worn at the waist on an elasticized belt on the right mid-axillary line. The participants were encouraged to wear the accelerometer 24 h per day (removing only for water-related activities) for at least 7 days (plus an initial familiarization day and the morning of the final day), including weekends. The full accelerometer protocol has been previously reported.[26] The minimal amount of accelerometer data that was considered acceptable for inclusion in the sample was 4 days with at least 10 h of awake wear time per day, including at least one day of the weekend. MVPA was defined as all activity $\geqslant 574$ counts per 15 s. This protocol provided reliable estimates.[27]

Statistical analysis

The descriptive characteristics included the means and standard deviations for continuous variables and the frequencies of categorical variables by study site. Associations between AST and obesity were estimated in terms of odds ratios using generalized linear mixed models (SAS PROC GLIMMIX). Associations between AST and continuous adiposity variables (that is, BMIz, PBF and waist circumference) were estimated using a linear mixed model (SAS PROC MIXED).The models were adjusted for age, sex, highest level of parental education and availability of motorized vehicles. To assess effect modification by study site, an AST × study-site interaction term was included in the multivariable model. To assess dose–response relationships between adiposity and AST, we used the composite variable of travel time. In addition to the primary analyses, three sets of sensitivity analyses were conducted. First, analyses were conducted with sub-samples that included weekend MVPA as a covariate. We did not adjust for mean weekly MVPA

Table 1. Descriptive characteristics of participants stratified by study site ($n = 6797$) in the ISCOLE

	Australia (Adelaide) n = 513	*Brazil (São Paulo)* n = 488	*Canada (Ottawa)* n = 532	*China (Tianjin)* n = 544	*Colombia (Bogota)* n = 915	*Finland (Helsinki, Espoo and Vantaa)* n = 490	*India (Bangalore)* n = 599	*Kenya (Nairobi)* n = 533	*Portugal (Porto)* n = 672	*South Africa (Cape Town)* n = 429	*UK (Bath and North-East Somerset)* n = 467	*USA (Baton Rouge)* n = 615	*Total* n = 6797
Socio-demographic characteristics													
World bank classification[a]	High income	Upper-middle income	High income	Upper-middle income	Upper-middle income	High income	Lower-middle income	Low income	High income	Upper-middle income	High income	High income	NA
Gini index[b]	35.2 (1994)	54.7 (2009)	32.6 (2000)	42.6 (2002)	55.9 (2010)	26.9 (2000)	33.4 (2005)	47.7 (2005)	38.5 (1997)	63.1 (2009)	36.0 (1999)	40.8 (2000)	NA
Motor vehicles per 1000 inhabitants[c]	687	198	605	37	58	534	15	21	509	159	526	809	NA
Estimated road traffic death rate per 100 000 population[d]	6.1	22.5	6.8	20.5	15.6	5.1	18.9	20.9	11.8	31.9	3.7	11.4	NA
Age[e]	10.7 (0.4)	10.5 (0.5)	10.5 (0,4)	9.9 (0.5)	10.5 (0.6)	10.5 (0.4)	10.4 (0.5)	10.2 (0.7)	10.4 (0.3)	10.3 (0.7)	10.9 (0.5)	9.9 (0.6)	10.4 (0.6)
Sex													
Male	43.4	48.8	42.3	53.3	49.6	47.6	47.1	46.5	43.8	40.6	44.5	43.4	46.3
Female	56.6	51.2	57.7	46.7	50.4	52.5	52.9	53.5	56.3	59.4	55.5	56.6	53.7
Highest parent education													
< High school	11.5	24.0	1.9	32.7	31.8	2.9	4.7	14.3	46.6	47.3	3.0	8.6	20.0
Complete high school or some college	47.6	52.9	26.5	44.7	50.7	55.3	21.7	44.7	32.9	39.4	51.4	44.1	42.5
⩾ Bachelor degree	40.9	23.2	71.6	22.6	17.5	41.8	73.6	41.1	20.5	13.3	45.6	47.3	37.5
Availability of motorized vehicles in the household													
Yes	97.5	69.7	96.4	90.3	24.4	90.2	95.7	55.5	89.3	52.2	95.7	91.9	76.7
No	2.5	30.3	3.6	9.7	75.6	9.8	4.3	44.5	10.7	47.8	4.3	8.1	23.3
Anthropometric characteristics													
BMI													
Normal weight[f]	62.0	54.3	69.9	58.8	77.1	75.9	66.8	78.8	53.0	73.4	71.1	59.2	66.8
Overweight[g]	27.5	24.4	18.6	17.5	17.2	18.8	22.7	14.6	29.6	14.5	19.1	22.6	20.7
Obese[h]	10.5	21.3	11.5	23.7	5.8	5.3	10.5	6.6	17.4	12.1	9.9	18.2	12.5
Waist circumference (cm)[e]	65.5 (9.0)	66.9 (10.4)	62.9 (8.4)	65.7 (11.1)	63.1 (6.9)	62.9 (7.5)	65.3 (9.6)	62.2 (7.9)	66.2 (8.7)	62.4 (9.3)	64.4 (8.1)	62.9 (9.9)	64.3 (9.0)
Percentage body fat (%)[e]	21.7 (7.3)	23.1 (9.3)	20.5 (7.4)	20.4 (8.0)	20.0 (5.8)	18.9 (6.8)	21.7 (7.5)	16.6 (7.8)	22.9 (7.5)	20.9 (8.0)	20.8 (6.9)	23.0 (8.2)	20.9 (7.7)
BMI ($kg\ m^{-2}$)[e]	18.9 (3.3)	19.8 (4.4)	18.2 (3.3)	18.9 (4.1)	17.6 (2.5)	17.8 (2.7)	17.9 (3.3)	17.3 (3.1)	19.4 (3.4)	18.0 (3.6)	18.5 (3.1)	19.1 (4.1)	18.4 (3.5)
School transport characteristics													
Mode of transport to school													
Active													
Walking	24.2	40.0	35.0	22.2	71.5	54.9	3.8	41.8	27.1	58.3	50.8	10.1	37.2
Bicycle, roller-blade, skateboard, scooter	7.2	1.0	0.8	10.1	1.8	24.7	1.3	2.8	1.0	0.9	12.0	0.7	4.9
Motorized travel													
Bus, train, tram, underground or boat	4.5	32.0	38.0	12.3	18.7	13.1	61.8	30.0	12.1	4.7	3.2	34.5	22.7
Car, motorcycle or moped	63.7	26.8	26.3	55.2	7.4	7.4	33.1	25.1	59.4	36.1	34.1	54.3	35.0
Other[i],	0.4	0.2	0.0	0.2	0.7	0.0	0.0	0.2	0.5	0.0	0.0	0.5	0.3
Travel time among active and motorized travelers													
< 5 min	31.6	19.9	23.5	14.3	10.6	24.9	8.9	22.3	28.6	34.0	27.2	21.5	21.3
5–15 min	53.6	48.6	51.7	51.1	51.0	55.7	28.2	34.9	55.7	37.8	52.7	48.9	47.7
16–30 min	11.1	18.4	19.4	24.1	25.4	16.1	31.4	21.0	13.4	18.7	17.1	20.7	20.1
31 min–1 h	2.9	8.6	4.7	8.5	10.4	2.9	22.2	10.1	1.2	7.7	2.6	6.0	7.6
> 1 h	0.8	4.5	0.8	2.0	2.6	0.4	9.4	11.6	1.2	1.9	0.4	2.9	3.3

Table 1. (Continued)

	Australia (Adelaide) n = 513	Brazil (São Paulo) n = 488	Canada (Ottawa) n = 532	China (Tianjin) n = 544	Colombia (Bogota) n = 915	Finland (Helsinki, Espoo and Vantaa) n = 490	India (Bangalore) n = 599	Kenya (Nairobi) n = 533	Portugal (Porto) n = 672	South Africa (Cape Town) n = 429	UK (Bath and North-East Somerset) n = 467	USA (Baton Rouge) n = 615	Total n = 6797
Travel time among active travelers													
< 5 min	32.7	27.0	25.8	25.0	13.1	26.4	29.0	29.4	27.5	40.6	31.1	47.0	26.1
5–15 min	55.6	58.0	61.6	57.4	58.8	58.7	54.8	36.1	60.3	34.3	49.2	39.4	53.2
16–30 min	8.6	12.5	11.1	13.1	25.1	13.3	12.9	14.7	11.1	16.5	16.7	6.1	16.0
31 min–1 h	2.5	2.5	1.6	2.3	3.0	1.3	0.0	9.7	0.5	7.1	2.4	3.0	3.2
> 1 h	0.6	0.0	0.0	2.3	0.0	0.3	3.2	10.1	0.5	1.6	0.7	4.6	1.4

Abbreviations: BMI, body mass index; ISCOLE, International Study of Childhood Obesity, Lifestyle and the Environment; NA, not applicable. [a]World Bank Data at country level: World Development Indicators 2012. The World Bank: Washington, DC; 2012. [b]World Bank Data: Gini index at country level. [c]World Bank Data at country level: Motor vehicles (per 1000 people) include cars, buses and freight vehicles but not two-wheelers.[30] [d]World Health Organization data: Global status report on road safety 2013.[31] [e]Mean and s.d. [f]Includes children in thinness and severe thinness categories Severe Thinness (WHO z-score < -3); Thinness (WHO z-score ⩾ − 3 and < − 2); Normal Weight (WHO z-score ⩾ − 2 and ⩽ 1). [g]Overweight defined as WHO z-score > 1 and ⩽ 2. [h]Obesity defined as WHO z-score > 2. [i]Other includes school van, matatu, bus feeder, riding on the top tube of the bike's frame, pedicab and wheelchair.

because it is an intermediate factor in the conceptual model linking AST to adiposity. Second, use of the public bus, which could include walking as part of the trip,[28] was reclassified within the active mode category. Third, we created a variable in which the category of walking, jogging or running was removed and biking and other wheeled modes of transport was compared with motorized travel in a sub-sample of 4275 participants. Study sites and schools nested within study sites were considered as having random effects. The denominator degrees of freedom for statistical tests pertaining to fixed effects were calculated using the Kenward and Roger approximation.[29] All statistical analyses were conducted using SAS version 9.3 (SAS Institute, Cary, NC, USA).

RESULTS

Socio-demographic characteristics

Reflecting the variability in the ISCOLE sample, selected countries differed in several socioeconomic and transport indicators. According to the World Bank classifications, ISCOLE countries differed in income level and income distribution (Table 1). Likewise, ISCOLE sites also differed in number of motor vehicles with the United States having the highest value (809 per 1000 inhabitants) and India having the lowest value (15 per 1000 inhabitants).[30] According to the WHO indicator on road traffic death rates, sites showed large differences with South Africa having the largest rate (31.9 per 100 000 population) and the United Kingdom having the lowest rate (3.7 per 100 000 population).[31]

Table 1 also shows descriptive individual characteristics of participants stratified by study site. Participants were on average 10.4 (s.d. = 0.6) years old, and 46.3% were male. Overall, parental highest education differed by site with India having the highest percentage of parents with at least a college education (73.6%) and South Africa having the lowest percentage (13.3%). Overall, 76.7% of parents reported motorized vehicles in their households ranging from 24.4% in Colombia to 97.7% in Australia.

Adiposity

The overall percentage of obese children was 12.5%, which ranged from 5.3% in Finland to 23.7% in China. The mean PBF was 20.9% (s.d. = 7.7), and the mean waist circumference was 64.3 cm (s.d. = 9.0). The mean PBF ranged from 16.6% in Kenya to 23.1% in Brazil and the mean waist circumference ranged from 62.2 cm in Kenya to 66.9 cm in Brazil.

School transport

Sites also differed by main mode of transport to school (Figure 1) and travel time (Table 1). Within the active mode category, the percentage of children reporting walking to school ranged from 3.8% in India to 71.5% in Colombia. Less than five percent of the children reported other active modes of transport such as biking and wheeled modes of transport, ranging from 0.7% in the United States to 24.7% in Finland. Regarding the non-active mode category, 22.7% reported some kind of public transportation ranging from 3.2% in the United Kingdom to 61.8% in India. About a third of the children reported car or motorcycle as their main modes of transport ranging from 7.4% in Colombia and Finland to 63.7% in Australia. In the subsample of children from the study that reported AST, 26.1% reported spending < 5 min commuting to school, 53.2% spent 5–15 min commuting to school and 20.6% spent > 15 min (Table 1 and Figure 1a). Time spent actively commuting varied considerably by site. In Australia, 88.3% of the children reported < 15 min of AST and in Kenya 19.8% of the children reported > 30 min of AST.

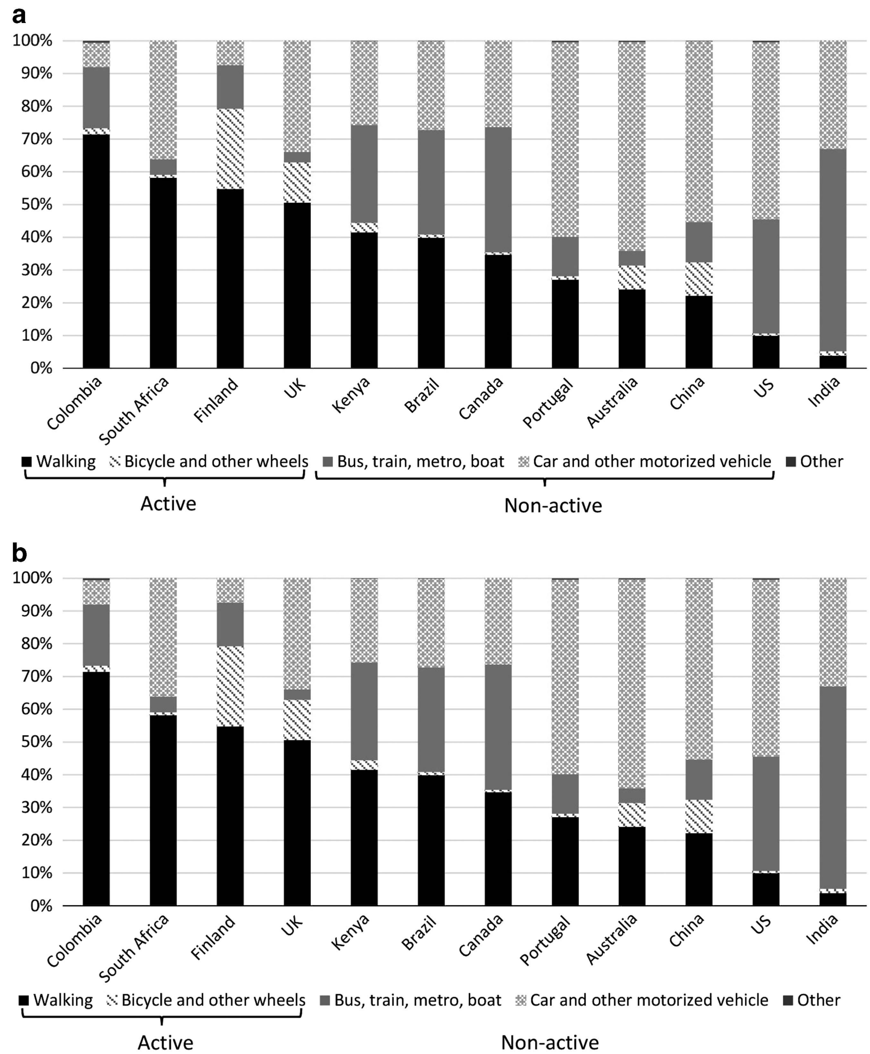

Figure 1. Distribution of modes of transport to school by study site. (**a**) Overall transport to school mode distribution per site (**b**) Mode distribution per site among trips shorter than 5 min.

Associations between AST and adiposity indicators

Children reporting AST were less likely to be obese had lower waist circumference and lower PBF (20.0 versus 21.6%) compared with children who reported motorized transport to school.

Multilevel analyses of the associations between AST and adiposity are presented in Table 2. There were negative associations between AST and obesity (obesity prevalence 9.3% versus 14.9%; OR = 0.72, CI (0.60–0.87); $P < 0.001$), BMIz (−0.09, (s.e.m = 0.04), $P = 0.013$), PBF (PBF (LSM) 20.57% versus 21.23% difference − 0.66, (s.e.m = 0.22); $P = 0.002$) and waist circumference ((LSM 63.73 versus 64.63 difference − 0.90, (s.e.m = 0.26); $P = 0.001$) after adjusting for age, sex, parental education and car availability. Similarly, when we analyzed only AST by bike and other wheeled modes there were negative associations between AST and BMIz (−0.17, (s.e.m = 0.08); $P = 0.036$), and waist circumference (−1.28, (s.e.m = 0.60); $P = 0.033$) after adjusting for age, sex, parental education and car availability. No effect modification by sex and study site was apparent. We did not find a significant trend in the dose–response analysis (P for trend = 0.213). The estimates did not change significantly when adjusting for weekend MVPA. When public bus was included in the active mode category the point estimates decreased in magnitude and was not statistically significant (AST and obesity 0.89, CI (0.75–1.05); $P = 0.17$, AST and BMIz − 0.06, s.e.m = 0.04, $P = 0.067$; AST and PBF − 0.38, s.e.m = 0.21, $P = 0.072$; AST and waist circumference 0.41, s.e.m = 0.25, $P = 0.106$).

DISCUSSION

We believe this study to be the first to examine associations between AST and adiposity indicators in a multinational sample of children from low-to high-income countries. Our findings show that children who used AST were less likely to be obese, had lower BMIz, lower PBF and a smaller waist circumference, compared with those who used a non-active mode of transport. Likewise, children who reported biking as their main mode of transport had a lower BMIz and waist circumference. Overall associations of obesity and AST did not differ by country or sex. The low evidence of heterogeneity in the associations between AST and adiposity indicators among countries, with a wide range of income distribution, transport indicators and stages of PA and nutrition transition, provides evidence of the importance of promoting AST as one of the global strategies to prevent obesity.

Our results are consistent with the few previous smaller studies that found that active travelers to school had lower BMI and were less likely to be obese.[16] Our results differed from other studies

Table 2. Associations of adiposity variables with active school transport in 6797 9–11-year-old children in the ISCOLE

	Unadjusted			*Adjusted*[a]			P-*value*	
	OR	*95% CI*	P-*value*	*OR*	*95% CI*	P-*value*	*AST × site*	*AST × sex*
Obesity[b]								
Boys $n=3149$								
Active transport[c]	0.69	(0.55–0.87)	0.002	0.69	(0.55–0.88)	0.002		
Girls $n=3648$								
Active transport	0.76	(0.59–0.99)	0.038	0.74	(0.56–0.96)	0.025		
Total sample								
Active transport	0.74	(0.62–0.88)	0.001	0.72	(0.60–0.87)	< 0.001	0.279	0.571
Bicycle or other wheels	0.76	(0.51–1.14)	0.185	0.72	(0.48–1.09)	0.124	Did not converge	0.319
	β	*s.e.m*	P-*value*	*β*	*s.e.m*	P-*value*	*AST × site*	*AST × sex*
BMIz[d]								
Boys $n=3149$								
Active transport	− 0.14	0.05	0.007	− 0.12	0.05	0.026		
Girls $n=3648$								
Active transport	− 0.12	0.05	0.012	− 0.08	0.05	0.082		
Total sample								
Active transport	− 0.11	0.04	0.002	− 0.09	0.04	0.013	0.132	0.500
Bicycle or other wheels	0.16	0.08	0.049	− 0.17	0.08	0.036	0.3135	0.481
Waist circumference (cm)								
Boys $n=3149$								
Active transport	− 1.17	0.38	0.002	− 1.10	0.38	0.004		
Girls $n=3648$								
Active transport	− 0.87	0.34	0.012	− 0.88	0.35	0.012		
Total sample								
Active transport	− 0.91	0.26	0.001	− 0.90	0.26	0.001	0.167	0.522
Bicycle or other wheels	− 1.23	0.6	0.044	− 1.28	0.60	0.033	0.588	0.187
Percentage body fat (%)								
Boys $n=3149$								
Active transport	− 1.01	0.30	0.001	− 0.88	0.30	0.004		
Girls $n=3648$								
Active transport	− 0.60	0.30	0.043	− 0.49	0.30	0.105		
Total sample								
Active transport	− 0.81	0.22	< 0.001	− 0.66	0.22	0.002	0.315	0.340
Bicycle or other wheels	− 1.11	0.51	0.031	− 0.88	0.49	0.077	0.603	0.350

Abbreviations: AST, active school transport; CI, confidence interval; ISCOLE, International Study of Childhood Obesity, Lifestyle and the Environment; OR, odds ratio. [a]Models were adjusted for age, parental education, and motorized vehicle ownership. The combined analyses of boys and girls were also adjusted for sex. [b]Obesity defined as BMI WHO *z*-score > 2. [c]Active transport was defined as walking or riding a bike, roller-blade, skateboard or scooter in the main part of the journey to school during the last week. [d]Body mass index *z*-score according to WHO reference data.

that reported null or positive associations between AST and body composition.[16] It has been argued that the absence of significant differences could result from studies with low power, and the lack of analysis differentiating walking versus biking; whereas, the positive associations could be attributed to studies in settings where very short distances between home and school are reported.[16] Our study provides a large, diverse sample with high variability in adiposity, modes of transport and school travel time.

The mechanistic pathway by which AST is associated with lower measures of adiposity indicators may occur in part through small increments of everyday levels of PA.[32] PA could potentially be increased if motorized trips of < 5 min were replaced by active commuting without compensatory decrease of PA in other domains, in a suitable built environment with safe conditions. Specifically, our study shows that 10.3% of all trips to school are non-active and take < 5 min. For example, in the United States (Baton Rouge) 76.5% of trips that take < 5 min are motor-vehicle dependent. In contrast, in Finland (Helsinki, Espoo and Vantaa), only 15.6% of trips that take < 5 min are motor-vehicle dependent.

In low-income adult populations, walking large distances is associated with a low-quality of life,[33,34] to date there is no evidence that walking extremely large distances is associated with lower quality of life or enjoyment in children. In the United States it is reasonable to expect that elementary school students walk up to 1.35 miles per 30-min period to get to school.[35] In our study, however, among the subsample of children who used AST, 19.8% of children in Kenya reported walking to school for > 30 min and 10.1% walk > 1 h for a one-way trip. Before these trips are entirely replaced by non-active modes, programs including multimodal transportation combining active and non-active modes could be considered. For example, drop-off spots could be provided close to the school so that kids could walk the remaining distance. This could potentially be an effective and scalable intervention to increase AST.[36] Multimodal strategies that take into account AST should be implemented before unintended consequences of development negatively affect transport-related activity in those countries undergoing early stages of PA transition.

Despite not finding significant differences in the relationship between AST and adiposity indicators among the countries, our results should take into account differences in built environment

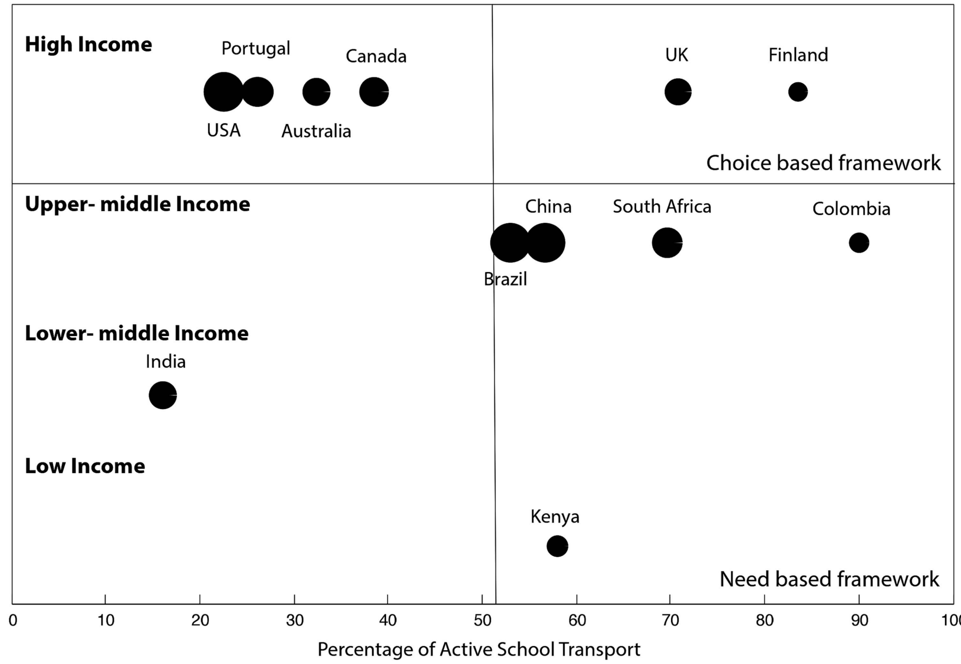

Figure 2. Typology distribution according to AST for trips of less than 5 min by country income level. Size of the dot represents obesity proportion by site.

characteristics of the schools found by Broyles *et al.*[37] In addition, differences in short trips between countries could be understood within the 'need-based framework' of LMIC and the 'choice-based framework' of HIC.[38,39] Specifically, in LMIC where car availability remains relatively low in comparison with HIC, AST may be more reflective of need rather than choice since a significant proportion of the children walk to school because they have no other option for transportation. Therefore, our results could be used to classify countries into four typologies that could be useful for future AST interventions (Figure 2). The first typology includes LMIC with higher proportions of AST, including Colombia, Brazil, South Africa and Kenya. The second typology includes LMIC with lower proportions of AST, including India and China. The third typology includes HIC with lower proportions of AST, including the United States, Portugal and Canada. Finally, the fourth typology includes HIC with higher proportions of AST including Finland and the United Kingdom.

Sites like Colombia and Finland, where a large proportion of AST was observed, have school transportation programs and built environment characteristics that promote AST. For both of these sites, proximity to the school is a key factor. In Bogota 90% of the children who attend public schools live within 2 km,[40] and in Helsinki 70% of the primary school students go to their nearest school.[41] In Bogotá, the District Education Department has a School Transportation Program targeted mainly to public schools from low socioeconomic levels with two main strategies. The first strategy promotes walking to school among children who live within 1 km of the school under the supervision of an adult. The second strategy 'Al colegio en bici' promotes the use of the bicycle to go to school among children located within 1–2 km of the school.[42] In Finland, most of the children attending public schools use an active mode of transport to go to school, and the municipalities provide free public transportation tickets for those children living within distances over 2 km; however, regardless of the mode of transport, Finnish children are very independent in their mobility.[41] In addition, Broyles *et al* (this issue) found that in Finland cycling provision features in schools, like cycle parking, cycle lanes and route signs for cyclists were highly prevalent (76–100%). Nonetheless, Finland differs significantly from Colombia, in car availability, safety and traffic accidents. Both countries are non-car-dependent for different reasons; in Finland, by choice and in Colombia by need owing to low motor-vehicle availability.[43]

This study has several strengths, including a large international sample of children from 12 sites in five continents with different environmental and socioeconomic settings, multiple direct measures of adiposity and standardized instruments and rigorous training protocols to ensure the comparability among sites.[20]

Nonetheless, our findings should be interpreted cautiously considering the following limitations. First, the design of the study is cross-sectional; therefore, we are unable to determine the direction of causality. Second, despite the large internationally diverse sample included, none of the countries had a nationally representative sample; hence the results may not be generalizable to country sites.[44] Third, AST was defined based only on the 'main' mode of transport for the journey 'to school'. Thus we assumed that both journeys were the same. However, the mode of transportation by journey could differ and could be multimodal. This, in part, may explain why we did not find a dose–response relationship. Fourth, biking was combined with other wheeled modes of transportation, and its low prevalence provided very imprecise estimates. Finally, we did not independently assess the short active trips of public transportation or active transportation behaviors for trips to locations other than school.

To our knowledge, ISCOLE is the first multicountry study that shows associations between adiposity indicators and AST in a sample of 9–11-year-old children. Such findings could inform global efforts to prevent obesity among school-age children. The large differences among countries in terms of AST patterns underscore the importance of considering the need-based and choice-based frameworks when designing interventions to prevent obesity by promoting active commuting.

CONFLICT OF INTEREST

MF has received a research grant from Fazer Finland and has received an honorarium for speaking for Merck. AK has been a member of the Advisory Boards of Dupont and McCain Foods. RK has received a research grant from Abbott Nutrition Research and

Development. VM is a member of the Scientific Advisory Board of Actigraph and has received an honorarium for speaking for the Coca-Cola Company. TO has received an honorarium for speaking for the Coca-Cola Company. The remaining authors declare no conflict of interest.

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