Research Article

Wendy Y. Huang*, Jie Feng and Stephen H. Wong

Independent mobility and physical activity among children residing in an ultra-dense metropolis

https://doi.org/10.1515/teb-2024-0006
Received April 28, 2024; accepted July 5, 2024;
published online July 30, 2024

Abstract

Objectives: Independent mobility (IM), which is defined as the freedom of children moving without adult supervision, has been found to be positively associated with physical activity (PA). This study explored IM by sociodemographic factors and type of neighborhoods and its association with PA among children in Hong Kong.

Methods: A convenience sample of 330 children aged 8–12 years and their parents was recruited. The children wore an ActiGraph accelerometer for eight consecutive days to measure PA and sedentary time (ST). Parents reported parents' license and children self-reported their actual mobility. Generalized estimating equations were conducted to examine the associations of IM with sociodemographics (e.g., children's age, sex, body weight status, parents' age, sex, maternal education) and type of neighborhood. Linear mixed models were performed to determine the associations of IM with PA and ST.

Results: Valid data from 296 children (8.8±0.6 years old, 42.2 % boys) were included in analysis. Children residing in sprawl and rural areas had greater parents' license and actual mobility than those in urban areas. Greater parents' license was associated with more moderate-to-vigorous intensity PA (MVPA) on weekend days (β=1.33, 95% CI: 0.15–2.51), while children's actual mobility was positively associated with MVPA on weekdays (β=1.14, 95% CI: 0.10–2.18).

Conclusions: In densely populated metropolis, children living in highly urbanized areas with higher SES experienced reduced parental license and actual mobility compared to their peers in less affluent neighborhoods, irrespective of the level of urbanization.

Keywords: active transport; exercise; accelerometry

Introduction

Insufficient physical activity (PA) and high levels of sedentary behavior have been well documented as risk factors for cardiometabolic diseases in children and adolescents [1, 2]. Current public guidelines recommend that children and youth should accumulate at least 60 min of moderate to vigorous PA (MVPA) daily and limit sedentary time (ST) [3]. Despite this, less than half of children and youth in Hong Kong met these recommendations [4]. To tackle the problem of inactive lifestyle, it is imperative to explore opportunities for accumulating PA on a daily basis.

Outdoor play and active travel have been regarded as valuable sources of PA. A recent systematic review found that active home-school trips contribute nearly half of the recommended PA amount in children and adolescents [5]. Both outdoor play and active travel are related to children's independent mobility (IM), which is defined as the freedom of children to move around their neighborhood without adult supervision [6]. IM could be for the purposes of travel (walking, cycling, or taking public transport) to various destinations or play within or beyond their neighborhood [7]. Studies have found that less than half of parents in New Zealand allowed their children roaming the neighborhood unsupervised by adults [8]. For Spanish children, four over 10 practiced no IM to school [9]. Of further concern, secular decline in IM observed in many western countries during the last two decades [10] is coinciding with the dramatic declines in overall PA levels in youth [11]. With greater IM, children are more likely to use active modes of travel and roam in their neighborhood, thus reduce the time indoors in sedentary pursuits. For example, a recent study conducted in Canada found that parental license for children's IM was

***Corresponding author: Wendy Y. Huang**, Department of Sport, Physical Education and Health, Hong Kong Baptist University, Kowloon Tong, Hong Kong, China; Dr Stephen Hui Research Centre for Physical Recreation and Wellness, Hong Kong Baptist University, Kowloon Tong, Hong Kong, China, E-mail: wendyhuang@hkbu.edu.hk. https://orcid.org/0000-0003-3995-1121
Jie Feng, Department of Sport, Physical Education and Health, Hong Kong Baptist University, Kowloon Tong, Hong Kong, China; and Department of Sports Science and Physical Education, The Chinese University of Hong Kong, Shatin, Hong Kong, China
Stephen H. Wong, Department of Sports Science and Physical Education, The Chinese University of Hong Kong, Shatin, Hong Kong, China

positively associated with children's active transportation and total steps [12].

Current evidence linking IM and activity behavior is limited and has been primarily conducted in several western countries. Both sociodemographic and environmental factors have been found to be associated with children's IM [13]. Furthermore, relationships between IM and PA may vary by environmental features and socioeconomic status (SES) [7]. As an ultra-dense metropolis with a mixture of Western and Chinese cultures, the social and environmental features in Hong Kong have been shown to be related to children's PA [14, 15]. For example, a qualitative study found that environmental attributes specific to an ultra-dense context, e.g. the public transport network, were perceived as the important factors for PA among Hong Kong children aged 10–11 years [14]. The convenient public transport network may facilitate short bouts of walking during transit between different transport methods. To the best of our knowledge, there was only one study that has examined IM for Hong Kong children, which was based on the travel diary data from a government report in 2002 [16]. This study was limited in its focus on home-school journeys only and using indirect measurement of IM extracted from a travel characteristics survey.

Although the definition of IM has been widely accepted, both parental 'licenses' for children's IM and children's reported mobility behavior have not been measured in previous studies. Distinction between these two concepts is needed as children may be granted independence of travel but eventually being driven to the destinations due to some reasons [17]. Furthermore, the use of PA measures during discrete time (e.g., weekend days) is suggested since mobility trips may rarely occur during school time. Therefore, the current study aimed to: (1) examine if parental license for children's IM and children's self-reported IM varied by sociodemographic factors and type of neighborhoods, and (2) investigate the relationships between IM and physical activity for children residing in an ultra-dense metropolis. The summary of this article is presented in Figure 1.

Methods

Studying setting and participants

Children in grade 3 (typically aged 8–9 years) were the target population since it is considered to be the time period when IM starts to develop [17]. To select a sample of children residing in a variety of neighborhoods in Hong Kong, a two-stage stratified sampling strategy were applied. First, the selection of neighborhoods was based on Tertiary Planning Units (TPUs), the smallest census-based geographic unit used in Hong Kong. The TPUs were classified to represent different levels of urbanization (urban, sprawl, and rural areas) in Hong Kong as suggested by other researchers [16]. The mean monthly household income data from each TPU were decided based on Census data, and then was dichotomized based on median value (HK$24,890) to either high or low SES [18]. Schools located in 8 TPUs representing four types of neighborhoods (urban/high SES, urban/low SES, sprawl/low SES, and rural/low SES) were approached and nine schools agreed to participate in this study. The characteristics of these TPUs are presented in Supplementary Table 1. Second, children studying in grade 3 of these schools and their parents were invited and were considered eligible if they: (1) had lived in their neighborhood for at least six months before participating, and (2) were free of disability and illness precluding engagement in PA. Eventually, 330 children' parents (either the mother or the father) provided written consent forms. This study was approved by the University Research Ethics Committee (HASC/16-17/0072).

Measures

Physical activity and sedentary time

Children were instructed to wear a wGT3X+ ActiGraph accelerometer (Pensacola, Florida, USA) during waking hours for eight consecutive days and to remove it only during water activities (swimming and showering) and sleeping. MVPA and ST were assessed using data from the vertical axis. Accelerometers data were integrated into 15 s as epoch for data processing. Participants were included in analyses if they wore the accelerometers for ≥600 min/day on ≥3 days, after exclusion of non-wear time [19]. Periods of more than 60 min of consecutive zero counts were considered as non-wear time [20]. MVPA was defined as ≥574 counts per 15 s [21]. ST was defined as ≤25 counts per 15 s [22] and Light-intensity PA (LPA) was calculated as between 25 and 574 counts per 15 s.

Independent mobility

Children's IM were defined in two domains in this study: (1) IM license: parents' license granted to their children to travel independently and play outdoors without adults, and (2) the actual mobility behavior. IM license was measured by the degree to which parents allowed their children to travel or play outdoors independently without an adult [23, 24]. Parents were asked two questions, firstly, *"How often do you allow your child to go to the following places on his/her own or with friends (without an adult)?"* and, secondly, *"How often is your child allowed to roam on his or her own/with*

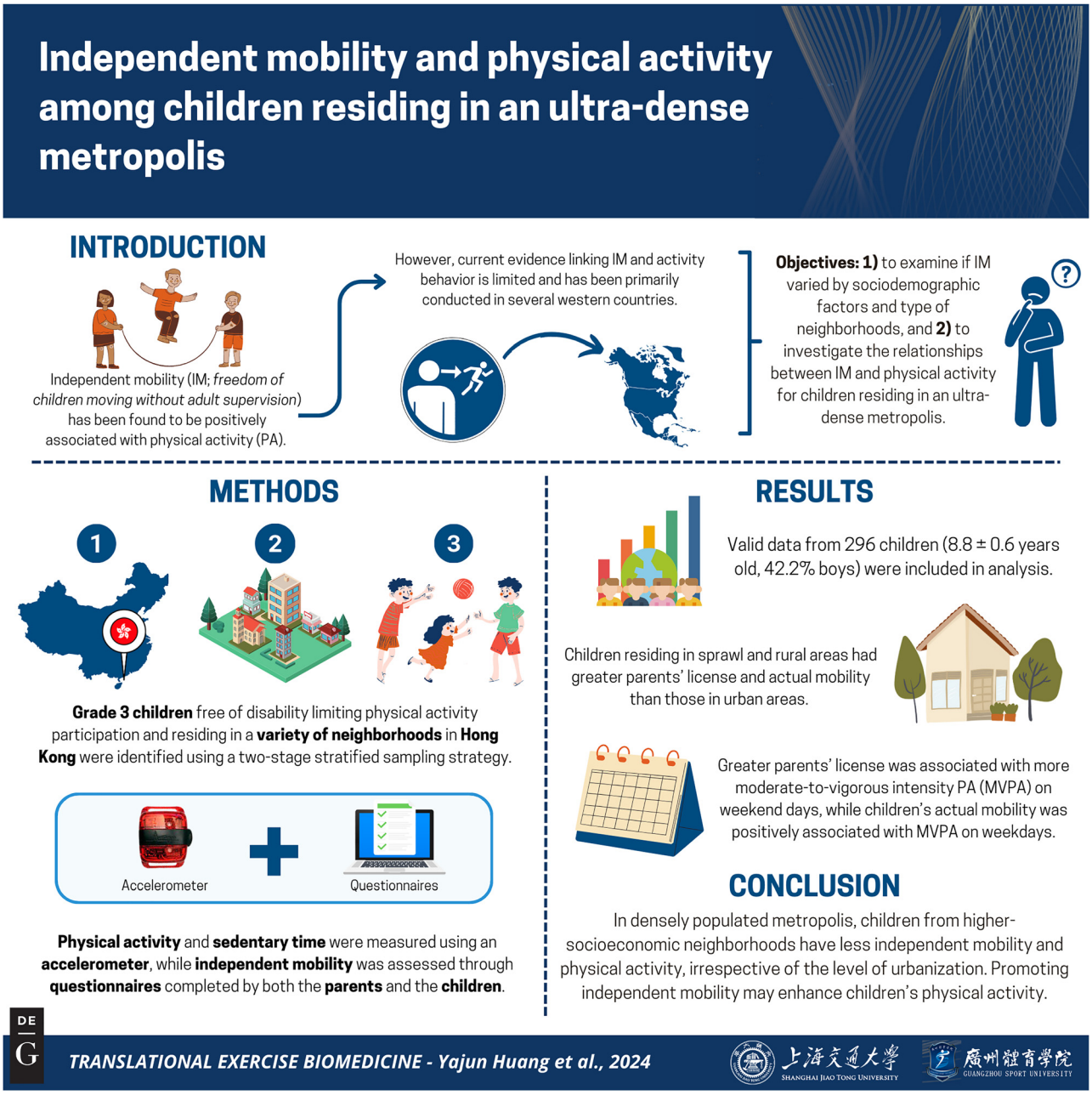

Figure 1: Graphical representation of this study. Key points: (1) Both parental 'license' for children's independent mobility and children's reported mobility behavior were examined in their relationships with children's physical activity and sedentary behavior. (2) In densely populated metropolis, children from higher-socioeconomic neighborhoods have less independent mobility and physical activity, despite urbanization level. (3) Promoting independent mobility may enhance children's physical activity. Figure created with BioRender.
[Correction added after online publication, 20 November 2024: the original caption "Graphical representation of this article. Figure created with BioRender." was updated as seen above.]

friends (without an adult) in your neighborhood?" Ten destinations (home, friend's or relative's house, indoor recreation or exercise facility, outdoor recreation place, food store or restaurant, other retail stores, big shopping center, school, non-school social or educational activities, public transportation stop) were provided in response to the first question. These response options were based on the common destinations reported in our previous study in Hong Kong adolescents [25] and were hypothesized to represent children's IM to visit the local and wider neighborhood during discretionary time. Three options were provided in responses, i.e., "0, never", "1, sometimes", and "2, mostly". To check the consistency of the composite IM scale for travel, principal components analysis (PCA) with varimax rotation was conducted. Two items with loading of less than 0.30 ("Food store/restaurant" and "Big shopping centre/supermarket") were excluded. A composite scale was summed up from the other nine items reflecting the total sum of IM

license. The Cronbach's alpha for the mobility scale was 0.88 and considered acceptable [24].

To measure their actual mobility behavior, children were asked to respond to two questions to assess: (1) IM destination: *"How often do you usually travel to and from the following places on your own or with friends (without an adult)?"*; and (2) IM outdoor: *"How often do you usually play outdoors in your neighborhood on your own or with friends (without an adult)?"* [17]. Same destinations as the parent's report were used. Four options were provided in responses, "0, never", "1, 1–2 days per week", "2, 3–4 days per week", and "3, 5 or more days per week". PCA with varimax rotation were conducted for IM destination and two subscales were generated: one pertaining to school-related destinations (IM-school) and the other relevant to destinations other than school (IM-non-school).

Covariates

During the school visits, trained research staff measured body weight and height of the participating children. Body mass index (BMI) was then calculated by dividing weight (kg) by height squared (m^2). Body weight status was classified as underweight, normal weight, or overweight and obesity based on the age- and sex-specific BMI cutoffs [26]. The responding parents reported their age, sex, highest educational attainment, body weight and height, as well as age, sex and number of siblings of their children. Parental educational attainment was classified based on the categories in Hong Kong which have been reported elsewhere [27].

Statistical analyses

Descriptive statistics were presented as mean and standard deviation or median and interquartile range where appropriate. Generalized estimating equations were performed to determine the associations of IM with sociodemographic factors and type of neighborhood. Linear mixed models were conducted to assess the associations of IM with MVPA, LPA and ST on weekdays and weekend days separately, adjusted for children's age, sex, and body weight status (underweight, normal weight, or overweight and obesity), sibling, parents' age, sex, BMI, maternal education, accelerometer wear time, and type of TPU (random effect). SPSS 26 software (IBM, Armonk, New York, USA) was used to conduct all statistical analyses. The significance level was set at $p<0.05$.

Results

Of the 330 recruited children, 34 were excluded from data analysis due to device loss (n=1), accelerometer malfunction (n=5), no downloadable accelerometer data (n=6), and having valid data for only one or two days (n=22). As a result, 296 children (125 boys) with an average age of 8.8 years provided valid data for at least 3 days and were included in analysis. No differences in socio-demographic characteristics were found between the included and excluded children except that the included children were older than the excluded ones (8.9±0.6 vs. 8.7±0.6, p=0.028). The distribution of children in the four types of TPUs was 23.3 % (urban/high SES), 23.6 % (urban/low SES), 45.6 % (sprawl/low SES), and 7.4 % (rural/low SES). The current sample size was sufficient to detect an effect size f^2 of 0.04, based on a power of 0.80, a p value of 0.05 and 10 predictors in a regression model. Characteristics of the participants are shown in Table 1. The majority of the responding parents (78.9 %) were mothers and most of the children (78.1 %) had at least one sibling at home. On average, boys spent more time in MVPA (45.0±15.6 min/day vs. 38.7±14.9 min/day, $p<0.05$) and less time in ST (518.5±74.2 min/day vs. 535.5±68.7 min/day, $p<0.05$) than girls.

As shown in Table 2, parents' license was higher for children who were older (b=2.80, 95% CI: 1.29–6.12), being overweight or obese (b=3.86, 95% CI: 1.07–13.96), having older parents (b=0.92, 95% CI: 0.86–1.00), and having lower maternal education (secondary school vs. junior high or below: b=0.14, 95% CI: 0.04–0.52). Boys perceived higher level

Table 1: Characteristics of the participants.

	All (n=296)	Boys (n=125)	Girls (n=171)
	Mean (SD) or %		
Child's age, year	8.8 (0.6)	9.1 (0.7)	8.8 (0.6)
Child's BMI, kg/m^2	16.2 (2.5)	18.0 (3.4)	16.2 (2.5)
Parents' sex, % (mothers)	78.9	80.6	77.6
Parents' age, year	40.4 (6.4)	40.7 (7.0)	40.4 (6.5)
Parents' BMI, kg/m^2	22.5 (3.3)	22.7 (4.9)	22.6 (3.3)
Sibling, % (≥1)	78.1	71.6	82.9
Parental education, %			
Junior high or below	27.9	38.2	20.1
Secondary school	37.8	45.6	31.9
Post-secondary	34.2	16.3	48.2
Wear time, min/day	819.4 (71.1)	826.4 (73.6)	814.3 (69.0)
Light PA, min/day	226.6 (56.1)	240.7 (52.9)	216.4 (56.5)
MVPA, min/day	41.4 (15.5)	45.0 (15.6)	38.7 (14.9)
ST, min/day	528.3 (71.4)	518.5 (74.2)	535.5 (68.7)
	Median (interquartile range)		
IM license [0–18]	4 (8)	5 (7)	2 (6)
IM destination			
IM-school [0–6]	2 (4)	3 (5)	1 (3)
IM-non-school [0–24]	5 (8)	7 (8)	4 (7.5)
IM outdoor [0–3]	1 (2)	1 (2)	1 (2)

BMI, body mass index; IM, independent mobility; MVPA, moderate-to-vigorous physical activity; PA, physical activity; ST, sedentary time.

Table 2: Sociodemographic factors and children's independent mobility. The significant results are shown in bold.

	IM license		IM-school		IM-non-school		IM outdoor[a]	
	Exp(B)	95% CI	Exp(B)	95% CI	Exp(B)	95% CI	Exp(B)	95% CI
Child's age, year	**2.80**	**1.29, 6.12**	1.08	0.66, 1.76	0.89	0.22, 3.68	1.27	0.85, 1.89
Child' sex (reference=girls)	2.16	0.70, 6.68	1.13	0.62, 2.08	**4.30**	**1.17, 15.84**	1.08	0.65, 1.81
Sibling (reference=none)	0.95	0.33, 2.69	0.91	0.49, 1.69	1.54	0.34, 7.07	1.27	0.72, 2.24
Child's body weight status (reference=normal weight)								
Underweight	0.99	0.28, 3.53	**0.49**	**0.25, 0.97**	0.60	0.13, 2.79	0.73	0.41, 1.30
Overweight and obese	**3.86**	**1.07, 13.96**	1.06	0.54, 2.08	1.09	0.23, 5.23	1.76	0.95, 3.25
Parents' sex (reference=mothers)	1.01	0.34, 3.28	0.89	0.47, 1.69	2.44	0.48, 12.44	1.47	0.79, 2.73
Parents' age, year	**0.92**	**0.86, 1.00**	0.99	0.93, 1.05	0.91	0.83, 1.01	0.99	0.95, 1.03
Parents' BMI, kg/m^2	1.09	0.95, 1.26	0.99	0.92, 1.06	1.04	0.90, 1.20	0.99	0.94, 1.05
Maternal education (reference=junior high or below)								
Secondary school	**0.14**	**0.04, 0.52**	1.06	0.48, 2.33	1.10	0.20, 6.11	0.64	0.33, 1.23
Post-secondary	0.53	0.13, 2.09	0.88	0.41, 1.88	0.71	0.14, 3.56	0.69	0.36, 1.32
Type of neighborhood (reference=urban/high SES)								
Urban/low SES	**7.10**	**1.48, 34.12**	**3.33**	**1.40, 7.92**	0.84	0.14, 5.21	1.97	0.88, 4.44
Sprawl/low SES	**23.18**	**5.31, 101.28**	**8.44**	**3.75, 18.99**	**8.10**	**1.19, 55.20**	**2.45**	**1.13, 5.29**
Rural/low SES	**16.97**	**1.69, 170.08**	**3.74**	**1.11, 12.64**	1.17	0.08, 16.28	1.98	0.76, 5.18

[a]GEE ordinal logistic models, all the others are GEE linear models. BMI, body mass index; IM, independent mobility; SES, socioeconomic status.

Table 3: Association of independent mobility with physical activity and sedentary behavior.

	IM license		IM-school		IM-non-school		IM outdoor	
	β	95% CI	*β*	95% CI	*β*	95% CI	*β*	95% CI
Weekdays								
Light PA	−0.71	−2.62, 1.20	2.08	−1.69, 5.84	−0.64	−2.38, 1.11	1.15	−6.78, 9.08
MVPA	0.37	−0.16, 0.90	**1.14**	**0.10, 2.18**	−0.03	−0.52, 0.45	−0.39	−2.59, 1.82
ST	0.22	−2.07, 2.50	−4.33	−8.82, 0.16	0.92	−1.17, 3.01	−2.95	−12.45, 6.54
Weekend days								
Light PA	−1.40	−3.74, 0.94	3.11	−1.43, 7.65	−0.66	−2.86, 1.54	−0.05	−10.85, 10.75
MVPA	**1.33**	**0.15, 2.51**	0.23	−2.06, 2.52	0.09	−1.02, 1.20	−3.23	−8.68, 2.23
ST	−2.14	−5.23, 0.96	0.74	−5.28, 6.75	−0.06	−2.98, 2.85	−3.13	−17.43, 11.18

Linear mixed models adjusted for children's age, sex, and body weight status, sibling, parents' age, sex, BMI, maternal education, accelerometer wear time, and type of TPU (random effect). IM, independent mobility; MVPA, moderate-to-vigorous physical activity; ST, sedentary time.

of IM (for non-school destinations) than girls, whereas those who were underweight had less IM for home-school trips compared with those being normal weight (Table 2). Compared with students attending schools in urban/high SES areas, those in the other three types demonstrated higher parents' license and IM-school. Furthermore, children in schools in sprawl/low SES areas perceived higher level of IM-non-school and IM outdoor than those in urban/high SES areas.

The relationships of IM with weekday and weekend PA and sedentary behavior are presented in Table 3. Parents' license was positively associated with time spent in MVPA on weekend days (b=1.33, 95% CI: 0.15–2.51), while IM-school was positively associated with time spent in MVPA on weekdays (b=1.14, 95% CI: 0.10–2.18).

Discussion

This study examined children's IM by using explicit measures including both 'licenses' given by parents to travel to different destinations or roam in the neighborhoods independently and 'actual mobility' perceived by children themselves. Sociodemographic factors, such as children's age, sex, body weight status, and maternal education, were associated with children's IM. Children living in urban/high SES areas had a lower level of IM compared to those in other types of areas. Children with greater parents' license were more physically active on weekend days, while those who were allowed to travel independently to and from school accumulated more MVPA minutes on school days.

Similar to the findings in an international survey on IM for 7 to 15-year-olds across 16 other countries [28], the degree of IM was generally low for children in Hong Kong. We found that over one third children were not allowed to travel to and from school independently, while nearly 40 % of them did not possess the freedom to go outdoor without adults' supervision. It indicates that children's independence during home-school trips did not change dramatically over the last two decades in Hong Kong [16]. Furthermore, several sociodemographic factors were associated with the level of IM. Parents of older children, of children being overweight and obese, with medium education level, and being older were more likely to grant license to their children. Although the increased parents' license observed in older children concurs with the findings in other countries [29, 30], the associations between other sociodemographic factors (e.g., body weight status, parental education) and IM have either seldom been reported or been equivocal in the literature [12, 31–33]. Due to a cross-sectional design in this study, the observed relationships did not indicate any causality. It is possible that parents with lower education levels perceive higher safety level of their children's home-school routine [34], and therefore, grant more freedom for their children to travel independently [30, 35]. Alternatively, greater parents' license may be indicative of a parenting style characterized by low behavioral control and low support, which has been found to be related to a higher children's BMI [36, 37].

We found that children residing in sprawl and rural low SES areas enjoyed more freedom than their counterparts living in urban and high SES areas. Previous studies examining the associations of area-level SES and urbanization with IM had mixed findings. A multi-site study in Canada found that area-level SES was not associated with IM, however, children living in low SES neighborhoods had decreased odds of spending more than 2 h outdoor [38]. Another study conducted in Australia indicated that area-level SES had no influence on the distance adults would permit for children's independent travel or outdoor play [39]. For children in Canada and Australia, neither parents' license nor children's self-reported IM differed across type of urbanization [38, 40]. However, in Japan, children living in small town and rural areas enjoyed less freedom to engage in IM than those from capital city [40]. On the contrary, urbanization degree was negatively associated with children's IM in Portugal, which was due to parental perception of stranger danger more frequent in highly-urbanized environment than in moderately- and non-urbanized environment [32]. It is worth noting that comparisons of our findings with previous studies should be cautious because there is only one high SES category with the highest level of urbanization, and no data were available for lower levels of urbanization (sprawl and rural). The discrepancy in these studies is largely attributable to the remarkable differences in classifications of urban, sprawl, and rural areas across countries, though most of them replied on population density mostly. In an ultra-dense metropolis like Hong Kong, population density in the 'sub-urban' or 'rural' areas in this study is over 30,000 and 4,000 people per km^2, respectively, which would be considered highly-urbanized in most of the western countries [40]. In addition, the sprawl areas selected in this study are government-planned new towns which experienced rapid population growth over the past 30 years [16]. It may explain why we did not find a linear, negative relationship between urbanization and IM, as Lam & Loo did two decades ago [16]. It is plausible that compared with sprawl and rural areas, urban areas in Hong Kong had higher road density, wider vehicular street, and more dangerous crossing, which increase parents' safety concerns and thus negatively affect the license they grant for their children to move around in their neighborhoods without adults' supervision [29, 41]. A child-friendly environment, i.e., protective and walkable, is particularly needed for children residing in inner-city in Hong Kong.

A systematic review has shown that children who perceived greater IM had higher PA in general [42]. Although it is anticipated that children's IM may be more influential to PA during discretionary time, the findings have been inconsistent. A study conducted in Australia found no relationships between self-reported IM during walking/cycling to local destinations and MVPA on weekday or weekends [43]. However, in Canada, children with higher IM had more total PA and MVPA, while less sedentary behavior, both after-school and on weekends [7]. With reference to parents' license, Larouche et al. found a positive relationship between the degree of license and number of active transportation, volume and distance of active transportation, and total steps accumulated a day [12]. In our study, parents' license only influenced children's MVPA on weekend days, while having more IM during home-school trips was related to more PA on weekdays. There are several possible reasons for this finding. The higher pressure of academic performance and school obligations on weekdays in Hong Kong mean that children's routines are largely determined by schools and dominated by academic-related activities [44]. Nevertheless, children who are allowed to travel independently to and from school may have more opportunity to be physically active on the way back home, thus accumulated more MVPA on school days [45]. During non-school hours (e.g., weekends), more parental restrictions were associated with less MVPA for children as shown in a previous study [46]. These findings suggest that parents should be encouraged to allow their children to travel independently and play outdoor, given that active commuting was not only an important resource of PA [47], but also creates other opportunities for being physical active.

Strengths of this study include assessment of both parents' license and children's actual mobility, and the objective measures of PA. This study also had several limitations. A convenience sample was recruited based on school location rather than the residence address. We acknowledge the potential discrepancy in neighborhood characteristics between school location and children's residence. However, based on the previous experience in Hong Kong, it is almost impossible to recruit potentially eligible participants directly from residential address [48]. Since most districts in Hong Kong are highly self-contained with schooling facilities provided to residents [49], children are likely to live within the same neighborhoods as their schools. In addition, the current sample did not include all types of neighborhoods in Hong Kong; the findings may not be generalized to those residing in sprawl/rural and high SES areas. Furthermore, the cross-sectional design of this study precludes the inference of cause-and-effect relationships. Although children who can move around independently are more likely to engage in PA, a converse relationship is also possible, that is, children who are more physically active may in turn make parents more comfortable with granting them IM.

Conclusions

In densely populated metropolis, children living in highly urbanized areas with higher SES experienced reduced parental license and actual mobility compared to their peers in less affluent neighborhoods, irrespective of the level of urbanization. Given the positive associations between IM and children's PA, it is plausible that promoting IM may be a viable intervention approach to enhance children's PA. Better understanding of social and environmental correlates of parents' license could be helpful to inform the interventions.

Acknowledgments: We would like to express our great appreciation to all participating children, parents, and teachers. We also thank Mr Lai Ka Ho for his help in data collection.

Research ethics: This study was approved by the University Research Ethics Committee (HASC/16-17/0072).

Informed consent: Parents provided written consent forms.

Author contributions: Wendy Huang: conceptualization, methodology, formal analysis, writing – original draft preparation. Jie Feng: validation, writing – review & editing. Stephen Wong: conceptualization, methodology, writing – review & editing. The authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Competing interests: The authors state no conflict of interest.

Research funding: This work was supported by the General Research Fund of the Research Grants Council, the Hong Kong Special Administrative Region [#12601017].

Data availability: The raw data can be obtained on request from the corresponding author.

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Supplementary Material: This article contains supplementary material (https://doi.org/10.1515/teb-2024-0006).