Relative contribution and interactive effects of psychological, social, and environmental correlates of physical activity, sedentary behaviour, and dietary behaviours in Hong Kong adolescents

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KEY MESSAGES

1. Multilevel psychological, social, and environmental factors, and their interactions were all important correlates of obesity-related behaviours (physical activity, sedentary behaviour, and dietary behaviours) and body mass index in Hong Kong adolescents.
2. Parents may influence adolescents' obesity-related behaviours by being good role models, establishing appropriate rules about eating and providing material and emotional support for obesity-preventive behaviours.
3. Schools and communities may provide opportunities for engagement in physical activity and healthy eating, as well as for reducing sedentary behaviour and intake of unhealthy foods.
4. Environmental correlates of adolescents' obesity-related behaviours somewhat varied by sex, age, and level of enjoyment of specific behaviours.

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Introduction

Adolescence is a critical period for predicting adult obesity, which is a major contributor to chronic non-communicable diseases.[1] The prevalence of overweight/obesity in Hong Kong adolescents has been increasing, owing to insufficient physical activity, excessive sedentary behaviour, and unhealthy dietary behaviours.[2] It is important to identify modifiable factors to improve these obesity-related behaviours (ORBs).

Socio-ecological models posit that behaviours are affected by multilevel individual, social, and environmental factors, and their interactions.[1] Factors associated with adolescents' ORBs have been examined in Western countries,[1] but such data on Hong Kong adolescents are rare.[2] In the West, self-efficacy was reported to positively relate to physical activity and healthy dietary behaviours, and negatively relate to sedentary behaviour.[2] Social factors including sources of social support, parental modelling, and parenting practices are significant for all ORBs, as are environmental factors with respect to physical activity and sedentary behaviour.[2] The evidence on dietary behaviours highlights the importance of social factors and the home environment (parental modelling, parenting styles/rules, availability of foods), whereas findings about the school and neighbourhood environments are sparse.[3] In Hong Kong, research on the correlates of adolescents' physical activity is limited and inconsistent, as is that on correlates of dietary behaviours and sedentary behaviour.[2]

Using a social-ecological framework, this study investigated the effects of individual, social, and environmental factors, and their interaction, on ORBs and body mass index (BMI) in Hong Kong adolescents.

Methods

This study was approved by the Human Research Ethics Committee for Non-Clinical Faculties of The University of Hong Kong (EA351010). We recruited adolescents and one of their parents/primary caregivers ('dyads') residing in tertiary planning units stratified by transport-related walkability (based on characteristics of the environment [residential density, street intersection density, and mixed land use] that facilitate walking for transportation

purposes), determined by Geographic Information Systems data and Census-based median household income.

Eligible participants were healthy adolescents (aged 11 to 18 years) attending one of 20 participating secondary schools and one of their parents/primary caregivers. They had lived in the selected area for ≥6 months and were planning to reside there in the following 8 months. The overall response rate was 48%. Of 1363 dyads, 1299 (43% boys; mean±standard deviation [SD] age, 14.7±1.6 years; mean±SD BMI, 19.8±3.0) provided valid survey data. Incentives were provided to minimise attrition and boost the response rate.

The study included two surveys 6 months apart (retention rate, 96%) completed by the adolescents, a parental survey, objective assessment of adolescents' height and weight, objective assessment of adolescents' physical activity and sedentary behaviour for 7 days using accelerometers, and objective assessment of participants' neighbourhoods.

The first adolescent survey used validated scales adapted for Hong Kong adolescents[4] to measure ORBs and physical activity–related environmental and psychosocial correlates. The second adolescent survey added items to gauge environmental and psychosocial correlates of sedentary behaviour and dietary behaviours. The parental survey assessed household and adolescent socio-demographics, parental ORBs, neighbourhood and household environment, and parental practices and rules related to ORBs.

Physical activity and sedentary behaviour were objectively assessed for a week in ~40% (n=552) of randomly selected adolescents using an accelerometer (ActiGraph). Adolescents re-wore the accelerometer if they did not have enough valid hours (<10 hours per weekday; <8 hours per weekend) for ≥4 weekdays and 1 weekend day. A valid hour was an hour with no >30 consecutive minutes of '0' activity counts. Data were scored as minutes spent in sedentary and moderate-to-vigorous physical activity using Freedson's thresholds developed for adolescents.[2] Time being sedentary used a cut-off of <100 counts per minute.

Neighbourhood was defined as an 800-m crow-fly radial buffer area. Environmental audits of 50% street segments within the buffer areas were conducted using the Environment in Asia Scan Tool – Hong Kong version and the Public Open Space Tool, and integrated into a Geographic Information Systems database containing other data (eg, walkability). Environmental audits assessed the number of publicly accessible parks, public transit points, food outlets, and public recreational facilities.

Generalised linear mixed models and zero-inflated negative binomial models with robust standard errors (accounting for clustering at the tertiary planning unit level and school level) were used to address all research questions. A significance level of P<0.05 was used.

Results

Table 1 shows descriptive statistics of adolescents (n=1299) and those who participated in accelerometer monitoring of physical activity and sedentary behaviour (n=552). On average, both boys and girls accumulated the recommended amount of physical activity of ≥60 minutes of moderate-to-vigorous physical activity per day. However, both girls and boys did not meet the recommended daily intake of fruit (≥2 servings) and vegetables (≥3 servings).

Individual-level psychological, social, and environmental factors were all independent correlates of self-reported adolescents' physical activity and sedentary behaviour, except for active transport (ie, cycling or walking) to/from school (Table 2). Environmental factors were the strongest correlates of physical activity and sedentary behaviour, with physical activity unexpectedly negatively associated with neighbourhood walkability and aesthetics. Availability of certain foods at home and self-efficacy for eating or avoiding certain foods were the strongest correlates of adolescents' dietary behaviours (Table 3). The home social environment (parental modelling and rules) also played an important role. Eating disinhibition was predictive of unhealthy dietary behaviours.

The associations of environmental correlates with ORBs sometimes depended on adolescents' sex, age, and level of enjoyment of a specific ORB. For example, traffic safety as perceived by parents was positively related to active transport to destinations other than school only in older adolescents (P<0.01) and access to services only in boys (P<0.01). An unhealthy school food environment was predictive of lower vegetable intake in those with low enjoyment eating fruits and vegetables only (P<0.05) and was predictive of higher sugar-sweetened drink consumption in younger adolescents (P<0.001).

BMI was negatively related to physical activity equipment in home (b= −0.12, 95% confidence interval [CI]= −0.19 to −0.04, P<0.01), transport-related walkability (b= −0.11, 95% CI= −0.19 to −0.03, P<0.01), and fresh vegetable intake (b= −0.03, 95% CI= −0.03 to −0.01, P<0.05). An unhealthy school food environment predicted a higher BMI (b=0.17, 95% CI=0.02-0.35, P<0.05), as did parental (b=0.08, 95% CI=0.02-0.14, P<0.01) and adolescent (b=0.06, 95% CI=0.01-0.11, P<0.05) amount of sedentary behaviour. In the accelerometry subsample, moderate-to-vigorous physical activity (b=0.01, 95% CI=0.00-0.02, P<0.05) and neighbourhood aesthetics (b=0.50, 95% CI=0.20-0.79, P<0.001) were unexpectedly positively related to BMI, whereas the

TABLE. 1 Physical activity, sedentary behaviour, dietary behaviours, and body mass index of adolescents

Variable	Boys (n=558)	Girls (n=741)	P value
Physical activity			
Physical activity at school, min/week	169±84	158±70	<0.001
Physical activity outside school, days/week with ≥60 min	2.4±1.9	1.7±1.6	<0.001
Active transport to/from school, times/week	5.0±4.6	4.3±4.5	>0.05
Active transport to other destinations, times/week	7.6±5.7	7.8±5.8	>0.05
Sedentary behaviour out of school, hours/day	6.1±3.1	6.2±3.0	>0.05
Dietary behaviours			
Fresh fruit consumption, times/week	6.5±5.6	7.3±5.7	>0.05
Fresh fruit consumption, servings/day	1.6±1.2	1.8±1.2	<0.05
Fresh vegetable consumption, times/week	9.2±6.0	9.9±6.0	>0.05
Cooked vegetable consumption, servings/week	1.8±1.1	1.8±1.1	>0.05
Deep fried or fatty food consumption, times/week	4.4±4.9	3.5±3.5	<0.001
Consumption of any snacks, times/week	4.0±4.7	4.7±4.8	<0.05
Sugar-sweetened drink consumption, times/week	5.5±5.2	4.7±4.8	<0.05
Body mass index, kg/m^2	20.2±3.2	19.6±2.8	<0.01
Accelerometer monitoring	**Boys (n=253)**	**Girls (n=299)**	
Average daily monitor wear time, min/day	779±89	794±84	<0.05
Average valid days of wear	7.5±1.9	7.3±1.7	>0.05
Accelerometer-assessed moderate-to-vigorous physical activity, min/day	108±36	100±33	<0.01
Accelerometer-assessed sedentary time, min/day	574±151	604±114	>0.05

* Data are presented as mean±standard deviation

associations with proximity to commercial facilities (b= –0.42, 95% CI= –0.75 to –0.09, P<0.05) and frequency of family meals (b= –0.29, 95% CI= –0.56 to –0.02, P<0.05) were in the expected direction.

Discussion

This study identified individual-level psychological, social, and environmental factors independently associated with ORBs and BMI in Hong Kong adolescents. In line with socio-ecological models of health,[2] all categories of factors contributed to ORBs. This confirms the need to consider multilevel influences on adolescents' ORBs and obesity. Individual-level psychological constructs (self-efficacy and enjoyment) and social factors (parental modelling, social support, and/or parental rules) were consistent predictors of ORBs. Environmental characteristics associated with neighbourhood safety and/or access to public transport, destinations/facilities and/or physical activity equipment were associated with higher levels of activity.

Of particular relevance to Hong Kong are the negative associations of transport-related walkability (defined as high residential and intersection density) and aesthetics (defined as green, well-maintained, usually hilly areas), and the positive association of access to public transport with moderate-to-vigorous physical activity. In Hong Kong, lower-density, lower-traffic, not-too-steep areas, with good access to public transport may be more physical activity–friendly environments for adolescents than high-density areas surrounded by green steep slopes. Low-density locations with good public transport may provide more open space for active play and opportunities for accrual of amounts of active transport similar to those living in high-density areas owing to a high level of regional accessibility. It is important to note that neighbourhood walkability was negatively related to not only physical activity but also BMI.[5] Reasons underlying these associations are yet to be established; it is possible that high-density walkable areas in Hong Kong do not provide suitable places for engagement in higher-intensity physical activity. Assuming similar levels of adiposity across Hong Kong, this would result in adolescents from high-density walkable areas having lower BMI. Alternatively, it is also plausible to assume that adolescents living in high-density walkable areas may regularly engage in large amounts of low-intensity physical activity (eg, walking for different purposes) that can contribute to lower levels of adiposity and hence lower BMI.

The availability of foods at home, parental dietary behaviours, and rules about eating were consistent correlates of adolescents' dietary behaviours. These findings suggest that the home

TABLE 2. Individual-level psychological, social, and environmental correlates of physical activity and sedentary behaviour

Variable	e^b (95% CI)	P value
Physical activity at school, min/week		
Physical activity–friendly school policy	1.04 (1.01-1.06)	<0.01
Parental leisure-time physical activity	1.01 (1.00-1.02)	<0.05
Self-efficacy for physical activity	1.08 (1.05-1.12)	<0.001
Physical activity outside school, days/week with ≥60 min		
Physical activity equipment at home	1.03 (1.01-1.05)	<0.01
Street connectivity	0.88 (0.82-0.95)	<0.01
Neighbourhood aesthetics	1.10 (1.02-1.17)	<0.01
Social support for physical activity from adults	1.07 (1.02-1.12)	<0.01
Social support for physical activity from siblings and friends	1.06 (1.02-1.11)	<0.01
Self-efficacy for physical activity	1.37 (1.31-1.44)	<0.001
Enjoyment of physical activity	1.12 (1.05-1.20)	<0.001
Odds of any active transport to/from school		
Proximity to school	2.04 (1.69-2.46)	<0.001
Social support for physical activity from siblings and friends	1.24 (1.08-1.43)	<0.01
Social support for physical activity from adults	0.78 (0.67-0.91)	<0.01
Parental rules about physical activity	0.95 (0.91-0.99)	<0.01
Non-zero weekly frequency of active transport to/from school		
Proximity of child's school	1.08 (1.05-1.11)	<0.001
Active transport to other destinations, times/week		
Traffic safety	1.12 (1.01-1.24)	<0.05
Proximity to commercial facilities	1.11 (1.06-1.17)	<0.001
Social support for physical activity from siblings and friends	1.07 (1.03-1.11)	<0.001
Self-efficacy for physical activity	1.15 (1.09-1.21)	<0.001
Enjoyment of physical activity	1.08 (1.02-1.13)	<0.01
Accelerometry-assessed moderate-to-vigorous physical activity, min/day		
Transport-related walkability	0.98 (0.98-0.99)	<0.05
Neighbourhood aesthetics	0.93 (0.91-0.96)	<0.001
Proximity to transit points	1.03 (1.02-1.04)	<0.05
Attitude towards physical activity	1.09 (1.02-1.16)	<0.01
Self-efficacy for physical activity	1.04 (1.01-1.07)	<0.01
Sedentary behaviour (out of school), hours/day		
Screen media in the bedroom	1.03 (1.02-1.05)	<0.001
Proximity to commercial facilities	0.95 (0.92-0.98)	<0.001
Parental sedentary behaviour	1.02 (1.01-1,03)	<0.001
Self-efficacy for reducing sedentary time	0.94 (0.92-0.97)	<0.001
Enjoyment of sedentary behaviour	1.06 (1.01-1.11)	<0.01
Accelerometry-assessed sedentary behaviour, min/week		
Neighbourhood-level income (ref: low)	1.11 (1.05-1.18)	<0.001
Safety from crime	0.95 (0.90-0.99)	<0.05
Proximity to public transit points	0.98 (0.96-0.99)	<0.05

Abbreviation: e^b = antilogarithm of regression coefficient denoting proportional difference in outcome associated with 1 unit increase in the correlate

TABLE 3. Correlates of dietary behaviours

Variable	e^b (95% CI)	P value
Fresh fruit consumption, times/week		
# of food outlets (objective measure)	1.00 (1.00-1.01)	<0.05
Availability of fresh fruits and vegetables at home	1.22 (1.14-1.30)	<0.001
Parental rules about eating	1.02 (1.00-1.03)	<0.05
Parental consumption of fruits	1.15 (1.09-1.22)	<0.001
Self-efficacy for eating fruits and vegetables	1.17 (1.10-1.25)	<0.001
Enjoyment of fruits and vegetables	1.06 (1.00-1.12)	<0.05
Fresh vegetable consumption, times/week		
Availability of fresh fruits and vegetables at home	1.18 (1.12-1.24)	<0.001
Parental rules about eating	1.01 (1.00-1.02)	<0.05
Self-efficacy for eating fruits and vegetables	1.17 (1.12-1.22)	<0.001
Deep fried or fatty food consumption, times/week		
Availability of unhealthy snacks at home	1.20 (1.09-1.32)	<0.001
Self-efficacy for eating low-fat foods	0.85 (0.80-0.91)	<0.001
Eating disinhibition	1.02 (1.01-1.02)	<0.001
Consumption of any snacks, times/week		
Availability of unhealthy snacks at home	1.29 (1.17-1.43)	<0.001
Availability of healthy snacks at home	1.14 (1.04-1.24)	<0.01
Attitude towards eating high-fat foods	1.20 (1.04-1.38)	<0.05
Self-efficacy for eating low-fat foods	0.91 (0.84-0.98)	<0.05
Eating disinhibition	1.03 (1.02-1.04)	<0.001
Sugar-sweetened drink consumption, times/week		
Availability of sugar-sweetened beverages at home	1.14 (1.05-1.23)	<0.001
Attitude towards drinking sugar-sweetened beverages	1.22 (1.07-1.38)	
Self-efficacy for reducing sugar-sweetened beverages	0.85 (0.80-0.90)	
Eating disinhibition	1.02 (1.01-1.02)	

Abbreviation: e^b = antilogarithm of regression coefficient denoting proportional difference in outcome associated with 1 unit increase in the correlate

environment is an important determinant of dietary behaviours. Schools were also identified as potentially important environments for establishment of a healthy lifestyle. In fact, the availability of snack and drink vending machines and fast food at school were associated with higher BMI.

Behavioural factors contributing to BMI were sedentary behaviour, fresh vegetable consumption, and physical activity. Physical activity is associated with lower adiposity and accumulation of more (lean) muscle mass.[2] The relatively low average BMI of the sample would explain the unexpected finding. It is also possible that heavier adolescents engaged in more physical activity to lose or control weight.

Environmental correlates of adolescents' ORBs varied by sex, age, and level of enjoyment of a specific behaviour. Interventions should target those who are less intrinsically motivated to engage in obesity preventive behaviours. For example, unhealthy school food environments may have a particularly negative impact on the dietary behaviours of younger adolescents and those who do not enjoy eating fruit and vegetables. Hence, school-based interventions supportive of healthier food options may be effective in developing healthy dietary behaviours in these adolescents. Residential density and traffic safety emerged as possible facilitators of physical activity in older adolescents and those who did not enjoy physical activity. This indicates that promotion of walking programmes in environments that facilitate walking for transport (ie, areas with good traffic safety and high residential density) may be effective in increasing physical activity in these adolescents.

Conclusion

Intervention strategies to promote a healthy and active lifestyle in Hong Kong adolescents should

involve communities, schools, and families. It is important for schools to provide access to physical activity and to set policies that limit the availability of unhealthy food options (eg, vending machines selling sugar-sweetened beverages). Communities and policy-makers should provide convenient and safe opportunities for obesity-preventive physical activity and dietary behaviours to adolescents and their families. Families would benefit from interventions aimed at developing parenting practices and behaviours promoting healthy eating and physical activity in their adolescent children.

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