Physical activity and sedentary behavior patterns of Singaporean Adolescents

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Abstract

Background: Adolescents require at least 60 minutes of daily moderate to vigorous intensity physical activity (PA) for optimum health benefits. Reduced active and increased sedentary time can adversely affect health independently. This study investigated the sedentary behavior and physical activity patterns of Singaporean adolescents.

Methods: 233 adolescents aged 13-15 years participated in the study. Accelerometery was used to assess the daily PA patterns for three weekdays and two weekend days consecutively. Height, weight, BMI, waist circumference and waist-hip ratio were determined as surrogate measures of health.

Results: None of the participants achieved the recommended 60 minutes of daily MVPA on all five days. Significantly more time was spent engaging in sedentary activity compared to MVPA on both weekdays and weekends. MVPA and sedentary time were positively associated on weekdays after controlling for gender ($p < .001$). Weekday MVPA was positively associated with waist circumference ($p < .001$) and waist-hip ratio ($p < .001$).

Conclusion: Singaporean adolescents fall substantially short of meeting the daily PA recommendations. Separate strategies to promote PA may be necessary for adolescents of differing weight status and gender. Pragmatic rather than idealistic targets to promote PA need to be set based on population-specific baseline data.

Introduction

The World Health Organization (WHO) estimates that 1.9 million deaths worldwide are attributable to physical inactivity.[1] Insufficient physical activity is one of the known lifestyle risk factors for obesity, the other being excessive energy intake.[2-3] In adolescents, strict dietary restrictions are often not recommended lest they affect the growth in their pubertal years.[4] Hence, physical activity becomes the primary modifiable and preventive lifestyle factor in adolescents. The critical need to encourage physical activity and decrease sedentary behavior in adolescents is heightened by two reasons. Firstly, adolescence marks the period of decline in physical activity [5-6] and secondly, physical activity has been shown to "track" from youth into adulthood.[6-7] Particularly, this "tracking" may hasten an early onset of chronic metabolic disorders, cardiovascular diseases, musculoskeletal disorders, vascular diseases, psychological disorders and some cancers.[8-9] Therefore, the importance of physical activity promotion in adolescents cannot be over-emphasized and strategies to increase regular physical activity and reduce sedentary behaviours should commence in early childhood through adolescence.

Current guidelines recommend at least 60 minutes of accumulated moderate-to-vigorous physical activity (5-8 METs) (MVPA) and less than 2 hours of sedentary behaviour per day for optimum health benefits in adolescents.[10] Physical inactivity is defined as the insufficient engagement in physical activity, below the age-specific recommendations while sedentary behavior refers to the engagement of activity ≤ 1.5 METs (metabolic equivalents) while in sitting or reclining posture.[11] While both of these terms are often used interchangeably, they represent distinct paradigms with sedentary behavior affecting health independent of physical activity. This therefore suggests that they are not opposite sides of the same coin and should be investigated and elucidated as separate behavioural attributes.[12]

The current prevalence rates of obesity in Singaporean school-age children have been reported to be stable at about 11% for the past three years[13]. However the global trends of rise in physical inactivity and sedentary behaviour in the adolescent population does not allow any room for laxity in physical activity promotion in this age group. Moreover, studies have reported a rising trend of increased sedentariness and insufficient physical activity amongst Singaporean children and adolescents.[14] The concern is further compounded by studies showing Singaporean adolescents being exposed to cyber sports before they experience physical sport at a young age,[15] potentially decreasing their preference for physically active play.

Singapore is a highly urbanized tropical country with little natural vegetation and open space, thus potentially limiting physical activity and play to organized sports and man-made facilities like playgrounds and sports-specific arenas. In terms of ethnic distribution, Chinese form the majority (74.2%) of the population followed by the Malays (13.3%) and Indians (9.2%). While the trend of increasing physical inactivity and sedentary behaviour amongst adolescents has been widely reported in many countries, the population-specific race/ethnic profile, social patterns, environmental and lifestyle characteristics may limit the transferability of data and strategies between different countries and populations. The unique physical, racial and sociocultural profile of Singapore makes it imperative to investigate the physical activity and sedentary behavioural patterns in this population to develop feasible physical activity promotion strategies.

There is seemingly a dearth of studies with objective evidence on physical activity and sedentary behavioral patterns in the Singapore adolescent population. Accelerometry is an objective method of physical activity assessment, which has been shown to highly correlate with doubly-labeled water, the "gold" standard of measuring energy expenditure.[16] In addition, accelerometers provide deeper insights into frequency, intensity and duration of physical activity, which are critical domains when exploring relations to health and public health guidelines.[17-18] However, apparently none of the previous studies have used accelerometry-based methods to determine the distribution of intensities within the daily physical activity of the Singaporean youths.

Therefore, the primary objective of the present study was to investigate the sedentary behavior and physical activity patterns of Singaporean adolescents. The additional aims were to determine gender differences in physical activity patterns and sedentary behavior and to elucidate the relationships between physical activity and surrogate measures of health in Singaporean adolescents.

Methods

This study was conducted in 2009-10. A stratified random sampling approach was adopted to include schools from each zone across Singapore. 233 students (122 boys and 111 girls), aged 13-15 years old, were recruited from seven secondary schools across Singapore. These being neighbourhood schools were representative of the ethnic distribution in Singapore population. Ethical approval was obtained from the University Institutional Review Board and school Principal's approval, parental consent and student assent were obtained prior to participation.

The key objective of the study was to describe physical activity patterns of Singaporean adolescents, specifically the average daily MVPA in minutes. Therefore, the study was essentially descriptive in nature involving continuous variables. In such study designs, there are no predictor or outcome variables, nor are different groups compared. However, sample size is important in descriptive studies because it affects how precise the observed means are expected to be. In such studies, the minimum expected difference reflects the difference between the upper and lower limit of an expected confidence interval (CI) that represents a range of values about the sample mean.[19]

As the variable of interest was continuous, the sample size was based on the confidence interval around the mean value of that variable. To estimate the sample size in our study, the following were required[20]:

(i) The standard deviation (σ) of the variable of interest

(ii) Specify the desired precision or width (D) of the confidence interval

(iii) Select the confidence level for the confidence interval

The sample size was then estimated using the equation:

$$N = 4z_{\alpha}^{2}\sigma^{2} \div D^{2}$$

The z_{α} is the standard normal deviate for α (the probability of type-1 error).

If the alternate hypothesis is two-sided, z_{α} is 2.58 when $\alpha = 0.01$ and z_{α} is 1.96 when $\alpha = 0.05$

The standardized width is calculated as $D \div \sigma$

Using the above concept of sample size estimation, it was found that a sample size of 217 would be required to state with 99% confidence that the population MVPA mean would be ± 2.5 minutes of the observed mean.

Physical activity was assessed with the triaxial accelerometer (Actitrainer, Actigraph Manufacturing Technology Inc, Fort Walton Beach, FL., USA). The students were instructed to wear the accelerometer over the right hip during waking hours, for a period of five consecutive days (three weekdays and two weekend days). They were only allowed to remove the accelerometer during bathing, water activities and contact sports. Students were also given a daily log sheet to record the time at which the accelerometer was taken off and the reason(s) for which it was removed and the time when they strapped it back again. The following strategies were used to encourage compliance – 1) research team demonstrated the ideal way to wear the accelerometer; 2) written and verbal instructions as well as daily text messages were sent to the students; and 3) regular reminders by given to the students by their school teachers.

Non-wear time was determined to be 10 consecutive minutes of 0 count with allowance of 1-2 mins of counts between 0-100, similar to that outlined by Andersen et al[21]. Minimal wear time requirement for a valid day was set at 8 h based on the 70/80 rule, and 5 valid days of data were needed to compute the outcome variables. Minute-by-minute data were stored as counts in memory and subsequently downloaded to a computer. Counts per minute for each participant were extracted from the accelerometer using ActiLife Data Analysis Software (ActiGraph Manufacturing Technology Inc, Fort Walton Beach, FL., USA). Daily time spent in various METs (sedentary behaviour, light activity and MVPA) was summed up and categorized based on previously recommended criteria by Evenson et al[22-23]. Time spent in various METs on weekdays was further divided into three monitoring periods – 1) overall (7am – 11pm), 2) in-school hours (7am – 3pm) and 3) after-school hours (3.01pm – 11pm). Due to the difference in wear time between the adolescents, minutes spent in the various METs were also expressed as proportion of total wear time of each participant during the different monitoring periods.

Anthropometric Measurements

Standing height was measured without shoes to the nearest 0.1cm with a Charder HM200p portable stadiometer. Body mass was measured without shoes with an Omron body composition monitor (Karada Scan Model HBF-362). Body-Mass-Index (BMI) was calculated as follows, BMI = (body weight in kg)÷(height in metres^2). BMI percentile was estimated using BMI-for-age percentile charts developed for the Singapore population.[24] Waist circumference was measured with a Seca (201cm) measuring tape at the narrowest point between the lower rib margin and the iliac crest at the end of a gentle expiration. The hip circumference was measured around the widest portion of the buttocks. For both an average of two measures was used for analysis.

Statistical Analyses

All statistical analyses were performed using IBM®SPSS® Statistics Version 21 (New York, USA. IBM Corporation; 2012). Mean difference between weekday and weekend physical activity patterns was evaluated using the paired *t*-tests. The independent Student's *t*-test was used to evaluate between-gender comparisons. The *a priori* significant alpha level chosen for all statistical tests was $P < .05$, unless otherwise stated. Linear associations were measured using the Pearson's correlation coefficient.

Results

Participants

Descriptive characteristics of the participants are presented in Table 1. Of the 233 participants, 225 met the requirements of participation. In terms of BMI, majority of the participants were in the healthy weight category. Thirty-three participants (14.9%) were underweight, 20 (9.0%) were overweight and 10 (4.5%) were obese.

Table 1.
Anthropometrical statistics by gender

Parameter	All (n=225)	Male (n=118)	Female (n=107)	*p*-value[a]
Height, mean (SD), cm	1.59 (0.08)	1.61 (0.09)	1.55 (0.06)	< .001
Mass, mean (SD), (kg)	50.22 (11.49)	52.09 (12.04)	48.21 (10.55)	.02
Body Mass Index (kg/m2)	19.89 (4.00)	19.92 (4.10)	19.87 (3.89)	.869
Waist Circumference, mean (SD), (cm)	67.09 (11.03)	69.41 (9.89)	64.53 (11.68)	.002
Waist-to-Hip Ratio, mean (SD)	0.79 (0.10)	0.83 (0.05)	0.75 (0.11)	< .001

[a] Gender differences were determined using a two-tailed Independent Student's *t*-test

Physical Activity

225 participants provided complete and valid accelerometry data on weekdays, with the mean wear time being 10.02 ± 3.16 hours. Of these, only 122 provided valid accelerometry data on weekends, with a mean wear time of 8.38 ± 3.09 hours. The remaining participants had a wear time of less than 8 hours on weekends, and were excluded from the analysis of weekend physical activity patterns. As both weekday and weekend physical activity patterns often offer unique and mutually exclusive information, they will be reported and discussed separately. Accelerometer-derived physical activity and step count data for both weekdays and weekend days are presented in Table 2 and 3 respectively.

Table 2.

Weekday Accelerometer-derived Physical Activity and Step Count Data[a]

	All	**Male**	**Female**	**Gender differences[a]**		
	(n=225)	**(n = 118)**	**(n =107)**	***df***	**95% CI**	***p*-value**
Accelerometry, average minutes per day (SD)						
- Sedentary time	369.61 (133.57)	328.31 (138.12)	402.73 (131.51)	223	-109.62, -39.21	< .001
- In-school hours	218.41 (72.52)	202.05 (72.21)	236.45 (68.78)	223	-52.98, -15.83	< .001
- After-school hours	151.20 (76.37)	131.83 (76.92)	172.56 (70.12)	223	-60.13, -21.32	< .001
- Time spent in light activity	207.57 (74.29)	199.16 (78.28)	216.84 (68.81)	223	-37.12, 1.77	.08
- In-school hours	114.63 (39.39)	116.14 (42.50)	112.97 (35.77)	223	-7.20, 13.55	.55
- After-school hours	151.20 (76.37)	83.02 (43.92)	103.87 (43.03)	223	-32.29, -9.41	< .001
- Time spent in moderate to vigorous activity	24.06 (14.02)	28.30 (14.61)	19.38 (11.73)	223	5.41, 12.42	< .001
- In-school hours	14.4 (9.95)	17.13 (10.86)	11.41 (7.86)	223	3.21, 8.23	< .001
- After-school hours	9.65 (7.00)	11.17 (7.58)	7.97 (5.90)	223	1.40, 5.00	0.001
Step count, average steps per day (SD)						
- Overall	6889.29 (2719.40)	6980.93 (2662.38)	7045.77 (2501.51)	223	-745.44, 615.78	.851
- In-school hours	4074.68 (1634.86)	4177.58 (1703.44)	3961.19 (1555.80)	223	-213.70, 646.49	.323
- After-school hours	2937.09 (1445.16)	2803.35 (1491.23)	3084.58 (1384.57)	223	-660.45, 97.99	.145

[a] Gender differences were determined using a two-tailed Independent Student's *t*-test

None of the participants achieved the recommended 60 minutes of daily MVPA on all five days. Four of the participants (1.78%) achieved the criterion during weekdays, while only two achieved it during weekends (0.89%). Significantly more time was spent engaging in sedentary behaviour compared to MVPA on both weekdays and weekends. On weekdays, time spent in sedentary behaviour was approximately 15 times that of time spent in MVPA across all three monitoring periods (Figure 1). On weekends this proportion doubled, with time spent in sedentary behaviour approximately 30 times the time spent in MVPA (t_{121}= -28.71, 95% CI -327.38 to -285.18, $P < .001$).

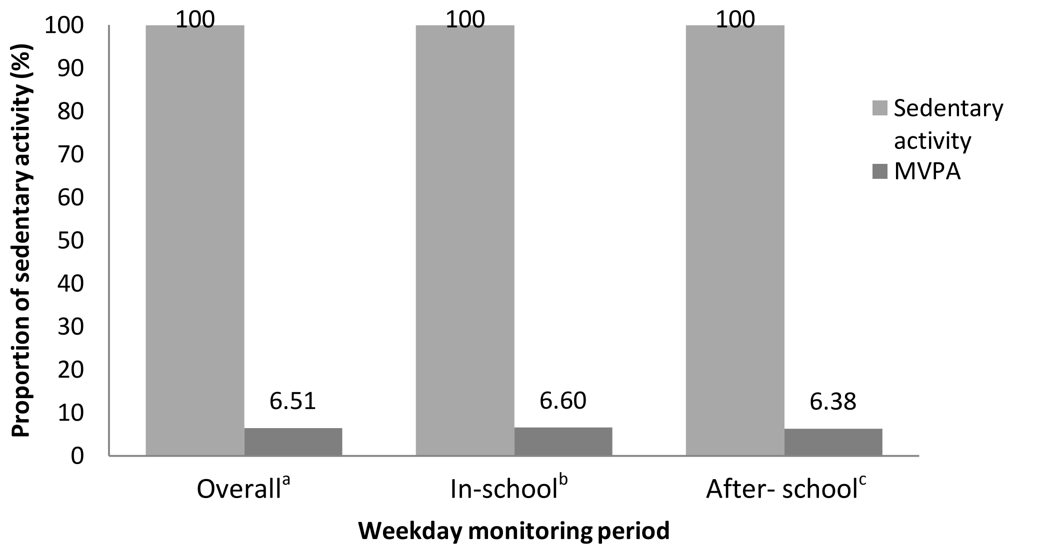

Figure 1. Time spent in moderate-vigorous physical activity (MVPA) expressed as a proportion of time spent in sedentary behaviour on weekdays. Difference between sedentary behaviour and MVPA was determined by a two-tailed test for paired samples.
[a] Overall; t_{225} = 39.00, 95% CI [332.51 – 367.36], $P < .001$
[b] In-school hours; t_{225} = 42.54, 95% CI [194.55 – 213.45], $P < .001$
[c] After-school hours; t_{225} = 27.84, 95% CI [131.53 – 151.57], $P < .001$

Sedentary time during in-school hours was approximately 1.4 times more than that during after-school hours (t_{225} = 15.3, 95% CI [58.56 – 75.86], $P < .001$). Similar difference was also observed between MVPA during in-school hours and after-school hours (t_{225} = 7.15, 95% CI [3.45 – 6.07], $P < .001$)

A positive moderate association was observed between time spent in sedentary pursuits and MVPA on weekdays after controlling for gender (Pearson *r* = .346, *P* < .001). The strength of association between sedentary behaviour and MVPA on weekends also increased after controlling for gender (Pearson *r* = .236, *P* = .009 versus Pearson *r* = .319, *P* = .002). Mean step count for weekdays was positively associated with both sedentary behaviour (Pearson *r* = .450, *P* < .001) and MVPA (Pearson *r* =.711, *P* < .001). A positive association was also observed between mean step-count and sedentary behaviour (Pearson *r* = .407, *P* < .001), as well as MVPA (Pearson *r* = .236, *P* < .001) on weekends.

Table 3.
Weekend Accelerometer-derived Physical Activity and Step Count Data

	All (n=122)	**Male (n = 43)**	**Female (n =79)**
Accelerometry, average minutes per day (SD)			
- Sedentary time	313.36 (121.47)	292.41 (109.07)	327.87 (124.29)
- Time spent in light activities	177.99 (86.31)	157.34 (75.40)	190.08 (90.29)
- Moderate and Vigorous activity time	8.49 (15.07)	11.89 (16.34)	7.57 (7.59)
Step count, average steps per day (SD)	4310.62 (2570.16)	4159.5349 (2424.24)	4447.4241 (2626.36)

When compared to boys, the girls had significantly more sedentary time on both weekdays and weekends, and significantly less time engaging in MVPA on weekdays. This was regardless of whether it was as a full day, during in-school hours or after-school hours. On weekdays, the proportion of wear time spent in sedentary behaviour and MVPA was overall similar during in-school hours for both boys and girls. However, the proportion of total wear time spent in sedentary activities decreased slightly during after-school hours for both girls (t_{106} = 6.48, 95% CI [3.40 – 6.40], *P* < .001) and boys (t_{117} = 3.46, 95% CI [1.73 – 6.37], *P* < .001) (Figure 2).

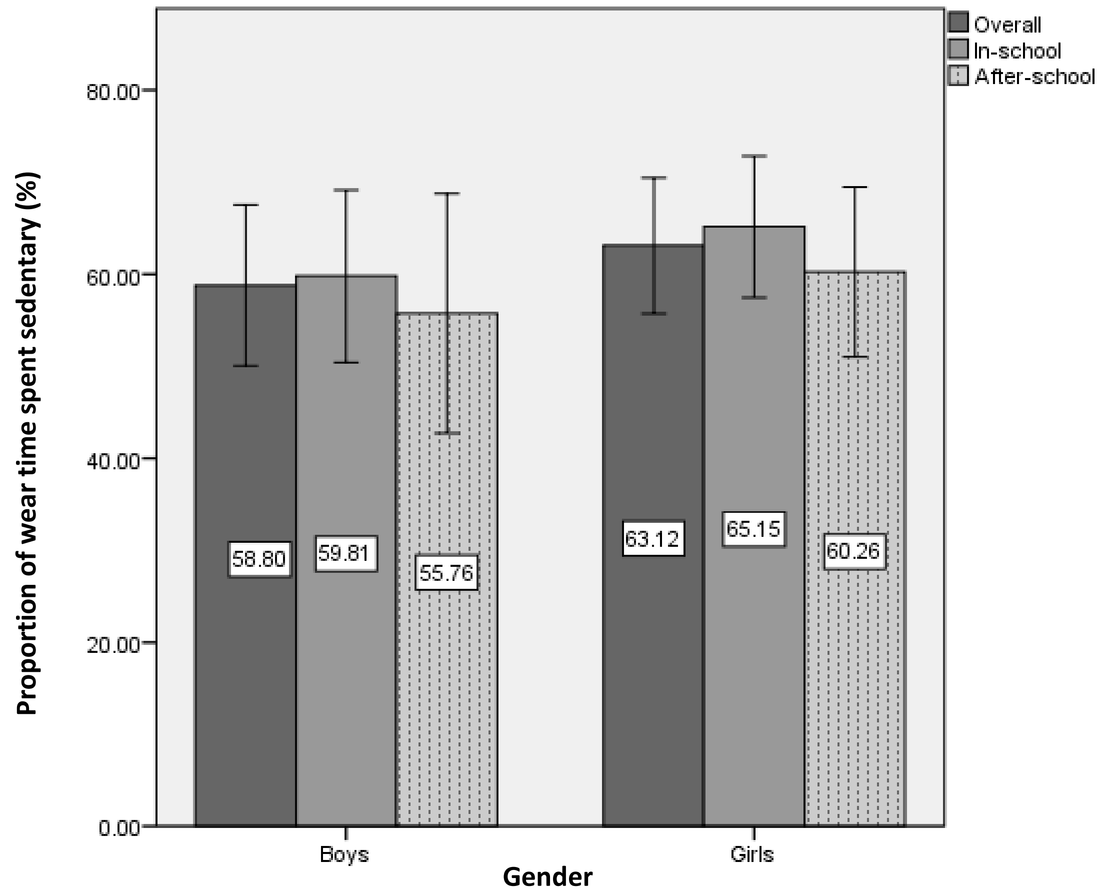

Figure 2. Proportion of wear time spent sedentary across different monitoring periods on weekdays according to gender

The proportion of total wear time spent in MVPA during after-school hours increased for boys (t_{117} = -2.27, 95% CI [-2.67 to – 1.85], *P* = .03) but no significant difference was observed between proportion of total wear time spent in MVPA during in-school and after-school hours for girls (t_{106} = 0.74, 95% CI [-2.76 to 0.60], *P* = .462)(Figure 3).

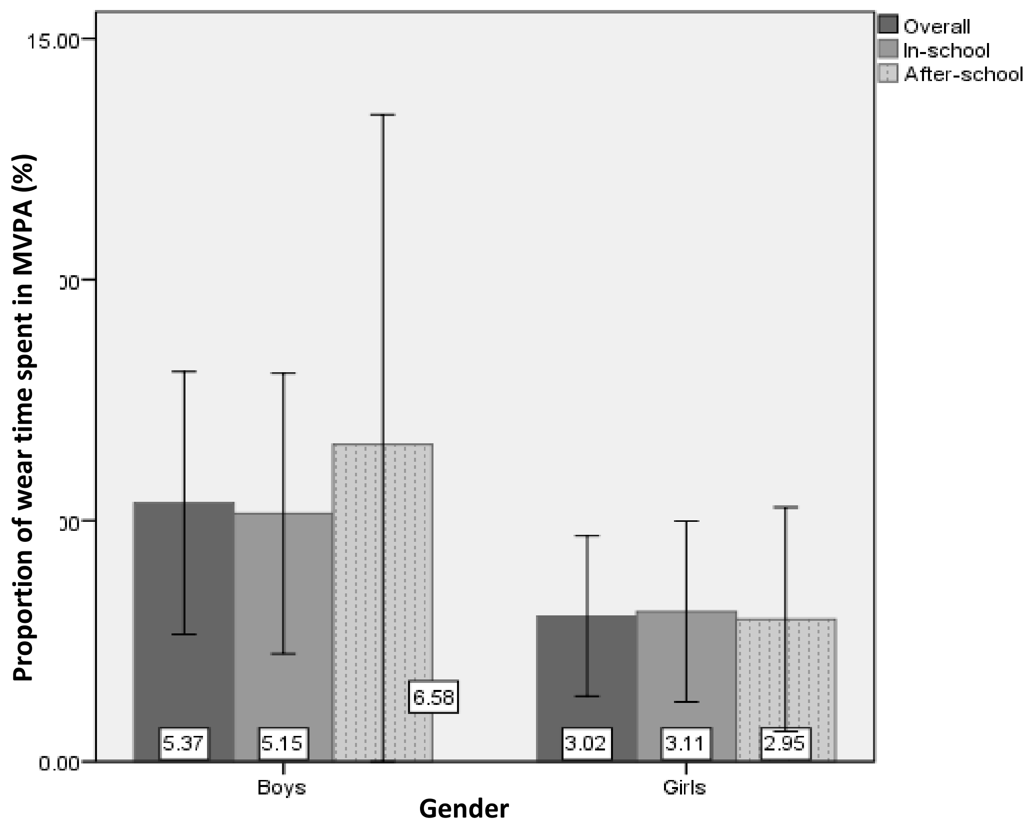

Figure 3. Proportion of wear time spent in MVPA across different monitoring periods on weekdays according to gender

The proportion of time spent in light activity increased after-school hours for both boys (32.9 % versus 36.4%, t_{117} = 5.08, 95% CI [2.48 – 5.64], *P* < .001) and girls (34.0% versus 38.0%, t_{117} = 4.18, 95% CI [1.83 – 5.13], *P* < .001). However, no gender difference was observed for step-count.

Correlation between physical activity and anthropometrical parameters

Weekday MVPA was positively associated with waist circumference (Pearson *r* = .234, *P* < .001) and waist-hip ratio (r =.262, *P* < .001). However, no significant association was observed between sedentary time and the anthropometric parameters, physical activity parameters and BMI.

Weekday MVPA was compared between the lowest and highest quartile of waist circumference and waist-hip ratio. Those in the highest quartile of waist circumference engaged in significantly more MVPA than those in the lowest quartile (20.05 min versus 26.25 min, $t_{109} = -2.49$, 95% CI [-11.13 to -1.26], $P < .05$). However, no significant differences were observed in sedentary behaviour between the first and last quartile of waist circumference. Similarly, no significant difference was observed in sedentary time and MVPA between the first and last quartile of BMI and waist-hip ratio quartiles.

Discussion

The key finding of this study was that Singaporean adolescents are not engaging in sufficient physical activity and tend to engage in excessive sedentary behaviour. None of the participants met the recommended criterion of daily physical activity and greatly exceeded the recommendations for sedentary behaviour. This raises an alarming concern that makes it imperative to address the situation as a priority, despite the stable prevalence of childhood obesity in Singapore. It is also noteworthy that these findings were independent of body weight suggesting that the normal weight adolescents may be undermining or ignoring the significance of being physically active. Collectively the findings of the study indicate that adolescents of different weight status may require specific health promotion strategies.

Low levels of physical activity and sedentary behavior have been reported in other populations but with at least 5% of the sample population meeting the physical activity recommendations.[25-26] Therefore, the apparent physical “inactivity-ness” and “sedentariness” of Singaporean adolescents is a serious cause for concern. When compared to the recommended criterion of 60 minutes of daily MVPA, the participants in this study could achieve only 40% (24 minutes) on weekdays and less than 15% on weekends. Concomitantly, the mean daily sedentary behaviour was more than twice the recommended limit on both weekdays and weekends. In addition, the positive relationships observed between sedentary behaviour and MVPA on both weekdays and weekend days after controlling for gender further strengthens the notion that these two behaviours are not opposite side of the same coin.[12] These results are in also accordance with a previous study by Wang et al[14] on 10-14 years old Singaporean adolescents (n=1935). The authors reported that participants spent a substantial amount of time engaging in sedentary behaviours and there was no inverse relationship between sedentary behaviour and MVPA. These results suggest a rooted trend and places Singaporean adolescents at a risk of negative health outcomes related to insufficient physical activity and excessive sedentary behavior.

The logical assumption of overweight and/or obese adolescents being more physically inactive was showed otherwise in the results of this study. Interestingly, the results showed that the normal weight and overweight/obese adolescents appear to have similar physical activity patterns, with no significant correlations observed between physical activity, as well as sedentary behavior patterns, with BMI, unlike other studies.[27-30] This supports our premise that there are population-specific characteristics related to physical activity and sedentary behaviours in adolescents. In other words, it can be inferred that normal weight adolescents are no less sedentary or more active than their overweight/obese peers, especially in the Singapore context. This observation supports a previous study done by Chia[31] using heart rate monitors in Singapore. The author showed that older children and young adolescents of normal body weight in Singapore (n=520; aged 9-15 years) spent 86% and 94% of time over a 10-hour monitoring period being sedentary on weekdays, and this increased to 96% and 99% on weekends.[31] Together, it this is suggestive that Singaporean adolescents are not engaging in sufficient physical activity, regardless of body weight status. This implies that normal weight adolescents may be neglecting the importance of physical activity, which might have serious implications for health when one considers the shifting demographics of weight status.

Currently, in most countries including Singapore, a large proportion of the adolescent population remains to be of normal weight status. Assuming population growth remains constant, the increase in prevalence of overweight/obesity means that more healthy weight individuals gain weight and move up into the overweight/obese category. Hence, it is critical that healthy weight individuals also become active targets when encouraging physical activity. In other words, it is important to consider that physical activity may not be of a high priority to normal weight adolescents and different health promotion strategies may be necessary for them, as compared to their overweight/obese peers.

The lack of observed differences in sedentary behaviour and MVPA between adolescents of differing weight status also suggests that while overweight/obese adolescents may be performing more MVPA, perhaps as part of a deliberate lifestyle modification, they are not making comparable efforts to decrease the sedentary time. This further emphasises that different strategies may be needed for adolescents of different weight status, with no weight status being of a lower priority.

BMI remains to be currently the most common measure of obesity, despite its limitations.[30] Three surrogate indicators of body fatness/obesity were used in this study – body mass index, waist circumference and waist-hip ratio. While waist circumference and waist-hip ratio showed a significant relationship with the physical activity parameters, no significant association was observed between BMI and sedentary or physical activity measures. These results provide corroborative evidence that waist circumference may be a better predictor of health risks related to inadequate physical activity, especially in adolescents.[30] Moreover, waist circumference has also been showed to be a strong predictor of cardiovascular and metabolic health risks like insulin resistance in adolescents.[32-33] However, the translation of waist circumference into meaningful clinical application in adolescents requires population-specific percentile cut-off points. This remains to be developed in the Singapore context.

Physical activity is a multi-dimensional behaviour and this underpins the inherent challenges in promoting physical activity and decreasing sedentary behaviour. Besides body mass and obesity, other known correlates of physical activity and inactivity include gender, in-school/after-school hours and weekends.

Similar to that reported in previous studies,[6-7, 34-35] Singaporean adolescent boys performed more MVPA compared to their female counterparts reflecting common trends between different populations. However, our finding that girls decreased their MVPA while boys increase their MVPA during after-school hours suggests a gender preference for leisure activities. The increase in strength of association between sedentary behaviour and MVPA on both weekday and weekends, after adjusting for gender, further supports this notion. In relation to physical activity, Wu et al[36] reported differences in self-efficacy, perceived benefits and barriers and sources of social support and role models between Taiwanese male and female adolescents. Gender differences in preferences have also been previously reported[37-38] and the results of our study further strengthen the understanding that these differences should be considered when developing strategies and programmes to promote physical activity.

Both in-school hours and after-school hours have been suggested as potential vehicles to encourage physical activity and decrease sedentary behaviour.[7, 39] Adolescents spent 8-10 hours of their waking time in the school, with much of these hours spent sitting due to the curriculum requirements. On the other hand, after-school hours present the window of time where most adolescents are able to exert greater autonomy over their behaviours.[40] Despite this, no significant difference was observed in the proportion of time spent in MVPA between in-school and after-school hours, irrespective of gender. This strengthens our notion that different strategies may be needed to modify the physical activity behaviour during these two windows of time.

Schools have a strong potential to encourage physical activity as they play a leadership role in inculcating healthy habits in terms of activity and also for alternative choices for sedentary behaviours.[41] In addition, schools offer good access, often with the necessary facilities for physical activity interventions.[42] Particularly, long-term whole-school approaches, which included environmental, curriculum and policy strategies appeared to be most effective.[39] However, due to curriculum commitments, it may be more pragmatic to target an increase in MVPA rather than decrease sedentary behaviour. In Singapore, PRIDE for PLAY™, a two-year school-based intervention programme by Chia[43], involved these strategies. It extracted 3-minutes from each time-tabled period for academic subject and collectively pooled it into a period of extended play for the children.[43] Results from the implementation in primary schools showed an increase in step-counts by 10%, which accomplished 39-42% and 31-33% of the recommended step count for girls and boys respectively.[43] This provides additional support to suggest that schools are important platforms to promote physical activity, even in the local context.

During after-school hours, also known as the "critical hours/period", sedentary pursuits have been highlighted as a competitor for adolescents' times.[44] Interventions to decrease sedentary time have resulted in increased activity during after-school hours,[38] suggesting that it may be more effective to focus on decreasing sedentary behaviour during the "critical hours". The authors reported a substantial decrease in proportion of time spent in sedentary behaviour during after-school hours, but it appeared to have contributed to the increase in proportion of time spent in light activity during the same window of time, rather than MVPA. Therefore in addition to sedentary behaviour, light activities may also be a strong competitor for MVPA, especially in girls. In other words, when encouraging adolescents to "sit less" and "move more", it may also be beneficial to highlight the transition of light activities into more meaningful moderate-vigorous intensity activities.

The results of this study highlight a substantial gap between the physical activity patterns of Singaporean adolescents and the current recommendations (24 minutes versus the recommended 60 minutes of MVPA). For this reason, in the Singapore context it may be more realistic to encourage an increase in physical activity and decrease in sedentary behaviour by a pragmatic proportion as a short-term objective (for example, 5% in 6 months), and have the recommended guidelines as an ideal target to achieve in long-term. Considering the current physical activity habits of Singaporean adolescents, even modest changes in physical activity may still contribute significant benefits to health in long term. This is in line with the "some physical activity is better than none at all" notion of the US physical activity guidelines, which is supported by findings of Sattelmair et al[45].

While this is apparently the first study to report objectively measured physical activity data in a representative sample of Singaporean adolescents using accelerometry, it is not without its limitations. As previously mentioned, physical activity is a multi-dimensional behaviour and many factors like the pubertal status and maturation, socioeconomic status and other psychological determinants were not considered in this study. Future studies on physical activity and sedentary behaviour patterns in Singaporean adolescents should account for these variables. Despite strategies to encourage compliance with wearing the accelerometers, it was low during after-school hours and on weekends, especially so in boys. This limits the strength of evidence related to weekend physical activity behaviour of Singaporean adolescents, and in turn, may have contributed to the lack of association between weekend physical activity and anthropometrical parameters. Compliance in adolescents is a widely-acknowledged issue and may result in incomplete data sets and data interpretation issues.[46] This highlights the need for more research into compliance strategies tailored for the adolescent population.

In light of the findings of this study, several future recommendations can be made. Firstly, it is important to obtain population-based baseline data prior to the formulation and implementation of physical activity intervention strategies and programs. Secondly, despite being of a similar biological age, adolescents of different weight status, as well as gender, may require different approaches to increase physical activity and decrease sedentary behaviour. Lastly, based on population-specific data, having pragmatic rather than idealistic targets with respect to increasing physical activity might be of a greater consequence. Considering the differing physical activity patterns within the same adolescent population, achieving small but gradual and progressive increase in physical activity might be a more sustainable approach to achieve long-term goals and health benefits.

Conclusion

The major finding in this study was that Singaporean adolescents fall substantially short of meeting the daily physical activity recommendations and that the normal weight adolescents in Singapore are not physically more active and less sedentary than their overweight/obese peers. This presents a major public health concern for Singapore. The results also suggest variability in preferences of sedentary and active pursuits between boys and girls. Collectively, the evidence from the study presents a strong premise to investigate the effect of specific strategies to promote physical activity in adolescents of differing weight status and gender. Schools present a vital platform to increase physical activity during in-school hours and it may be necessary to view the decrease of sedentary behaviour as an independent strategy, particularly for after-school hours. When developing strategies to promote physical activity, pragmatic rather than idealistic targets need to be set based on population-specific baseline data.

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References

1 World Health Organisation. Unhealthy Diets and Physical Inactivity Factsheet. Published 2009. http://www.who.int/nmh/publications/fact_sheet_diet_en.pdf. Accessed June 21, 2013.

2 Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. Lancet. 2002;360(9331):473-482.

3 Must A, Strauss RS. Risks and consequences of childhood and adolescent obesity. Int J Obes Relat Metab Disord. 1999;23:S2-11.

4 Caballero B. Obesity prevention in children: opportunities and challenges. Int J Obes Relat Metab Disord. 2004;28(suppl 3):S90-95.

5 Dumith SC, Gigante DP, Domingues MR, Kohl HW, 3rd. Physical activity change during adolescence: a systematic review and a pooled analysis. Int J Epidemiol. 2011;40(3):685-698.

6 Caspersen CJ, Pereira MA, Curran KM. Changes in physical activity patterns in the United States, by sex and cross-sectional age. Med Sci Sports Exerc. 2000;32(9):1601-1609.

7 Biddle SJ, Gorely T, Stensel DJ. Health-enhancing physical activity and sedentary behaviour in children and adolescents. J Sports Sci. 2004;22(8):679-701.

8 Pietilainen KH, Kaprio J, Borg P, et al. Physical inactivity and obesity: a vicious circle. Obesity (Silver Spring).2008;16(2):409-414.

9 Yang X, Telama R, Leskinen E, Mansikkaniemi K, Viikari J, Raitakari OT. Testing a model of physical activity and obesity tracking from youth to adulthood: the cardiovascular risk in young Finns study. Int J Obes (Lond). 2007;31(3):521-527.

10 Strong WB, Malina RM, Blimkie CJR, et al. Evidence based physical activity for school-age youth. J Pediatr. 2005;146(6):732-737.

11 Sedentary Behaviour Research Network. Letter to the Editor: Standardized use of the terms “sedentary” and “sedentary behaviours”. Appl Physiol Nutr Metab. 2012;37(3):540-542.

12 Yates T, Wilmot EG, Khunti K, Biddle S, Gorely T, Davies MJ. Stand up for your health: Is it time to rethink the physical activity paradigm? Diabetes Res Clin Pract. 2011;93(2):292-294.

13 Wang CKJ, Chia YHM, Quek JJ, Liu WC. Patterns of physical activity, sedentary behaviors, and psychological determinants of physical activity among Singaporean school children. Int Rev Sport Exerc Psychol. 2006;4(3):227-249.

14 Chia M. Beyond fitness and fatness in Singaporean youths. In: Wang P, Kuo CH, Takeda N, Singal PK, eds. Adaptation Biology and Medicine, (Cell Adaptation and Challenges). Volume 6. New Delhi, India: Narosa Publishers; 2011:471-479.

15 Ong TK. Obesity and health promotion amongst students. Ministry of Education Parliamentary replies. http://www.moe.gov.sg/media/parliamentary-replies/2012/08/obesity-and-health-promotion-a.php , 2012. Accessed April 17, 2014.

16 Plasqui G, Westerterp KR. Physical activity assessment with accelerometers: an evaluation against doubly labeled water. Obesity (Silver Spring). 2007;15(10):2371-2379.

17 McClain JJ, Tudor-Locke C. Objective monitoring of physical activity in children: considerations for instrument selection. J Sci Med Sport. 2009;12(5):526-533.

18 Troiano RP. A timely meeting: objective measurement of physical activity. Med Sci Sports Exerc. 2005;37(11)(suppl):S487-489.

19 Eng J. Sample size estimation: how many individuals should be studied? *Radiology.* 2003;227(2):309-313.

20 Browner W, Newman T, Hulley S. Estimating sample size and power: Applications and Examples. In: Hulley S, Cummings S, Browner W, Grady D, Newman T, eds. *Designing Clinical Research*. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2007:73-75.

21 Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). Lancet. 2006;368(9532):299-304.

22 Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. Med Sci Sports Exerc. 2011;43(7):1360.

23 Evenson K, Catellier D, Gill K, Ondrak K, McMurray R. Calibration of two objective measures of physical activity for children. J Sports Sci. 2008;26(14):1557-1565.

24 Health Promotion Board. Growth and Development Assessment. Health Screening for Primary School. https://www.hpb.gov.sg/HOPPortal/health-article/632. Updated 2012. Accessed Nov 1, 2013.

25 Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc. 2008;40(1):181.

26 Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. Health Rep. 2011;22(1):15-23.

27 Janssen I, Katzmarzyk P, Boyce W, et al. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. Obes Rev. 2005;6(2):123-132.

28 Gordon-Larsen P, Adair LS, Popkin BM. Ethnic differences in physical activity and inactivity patterns and overweight status. Obes Res. 2002;10(3):141-149.

29 Patrick K, Norman GJ, Calfas KJ, et al. Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. Arch Pediatr Adolesc Med. 2004;158(4):385.

30 Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. Pediatrics. 2007;120(suppl 4):S193-S228.

31 Chia M. Physical inactivity among children and adolescents in Singapore-a paradoxical issue. Acta Kinesiologica. 2008;2(2):7-15.

32 Lee S, Bacha F, Gungor N, Arslanian SA. Waist circumference is an independent predictor of insulin resistance in black and white youths. J Pediatr. 2006;148(2):188-194.

33 Maffeis C, Corciulo N, Livieri C, et al. Waist circumference as a predictor of cardiovascular and metabolic risk factors in obese girls. Eur J Clin Nutr. 2003;57(4):566-572.

34 Trost SG, Pate RR, Sallis JF, et al. Age and gender differences in objectively measured physical activity in youth. Med Sci Sports Exerc. 2002;34(2):350-355.

35 Jago R, Anderson CB, Baranowski T, Watson K. Adolescent Patterns of Physical Activity: Differences by Gender, Day, and Time of Day. Am J Prev Med. 2005;28(5):447-452.

36 Wu T-Y, Pender N, Noureddine S. Gender differences in the psychosocial and cognitive correlates of physical activity among taiwanese adolescents: A structural equation modeling approach. Int J Behav Med. 2003;10(2):93-105.

37 Garcia AW, Broda MAN, Frenn M, Coviak C, Pender NJ, Ronis DL. Gender and developmental differences in exercise beliefs among youth and prediction of their exercise behavior. J Sch Health. 1995;65(6):213-219.

38 Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc. 2000;32(5):963-975.

39 Dobbins M, Husson H, DeCorby K, LaRocca RL. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. Cochrane Database Syst Rev. 2013;2.

40 Hohepa M, Scragg R, Schofield G, Kolt GS, Schaaf D. Associations between after-school physical activity, television use, and parental strategies in a sample of New Zealand adolescents. J Phys Act Health. 2009;6(3):299-305.

41 Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting physical activity in children and youth: a leadership role for schools: a scientific statement from the

American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. Circulation. 2006;114(11):1214-1224.

42 Story M. School-based approaches for preventing and treating obesity. Int J Obes Relat Metab Disord. Mar 1999;23(suppl 2):S43-51.

43 Chia M. Play reconsidered, resurrected and repositioned in children: case study results from Singapore. Sport Science. 2009;2(1).

44 Atkin AJ, Gorely T, Biddle SJ, Marshall SJ, Cameron N. Critical hours: physical activity and sedentary behavior of adolescents after school. Pediatr Exerc Sci. Nov 2008;20(4):446-456.

45 Sattelmair J, Pertman J, Ding EL, Kohl HW, 3rd, Haskell W, Lee IM. Dose response between physical activity and risk of coronary heart disease: a meta-analysis. Circulation. 2011;124(7):789-795.

46 Rowlands AV. Accelerometer assessment of physical activity in children: an update. Pediatr Exerc Sci. 2007;19(3):252.