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Faculdade de Desporto

Centro de Investigação em Actividade Física, Saúde e Lazer (CIAFEL)

Accelerometer-Based Physical Activity Levels and Sedentary Behavior under Free-Living Conditions in Thai Adolescents

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Dissertation submitted with the purpose of obtaining a doctoral degree in Physical Activity and Health, organized by the Research Centre in Physical Activity, Health, and Leisure (CIAFEL), Faculty of Sport, University of Porto, under the Law 74/2006 from March 24th.

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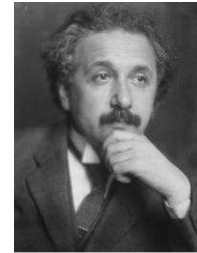
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KEY WORDS: ACCELEROMETER, ADOLESCENT, BODY COMPOSITION, GUIDELINES AND RECOMMENDATIONS, OBESITY, PHYSICAL ACTIVITY

“Imagination is more important than knowledge”



Albert Einstein, 1879-1955

A German-born theoretical physicist who developed the theory of general relativity effecting a revolution in physics.

“All truths are easy to understand once they are discovered; the point is to discover them”



Galileo Galilei, 1564-1642

An Italian physicist, mathematician, astronomer and philosopher who played a major role in the Scientific Revolution.

“When you can measure what you are speaking about, and express it in numbers, you know something about it; when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be”



William Thomson (Lord Kelvin), 1824-1907

A British mathematical physicist and engineer who did important work in the mathematical analysis of electricity and formulation of the first and second laws of thermodynamics, and did much to unify the emerging discipline of physics in its modern form; the temperature unit “Kelvin” is named in his honor.

This thesis is dedicated to the Konharn family

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Abstract

The prevalence of childhood overweight/obesity (OW/OB) is increasing rapidly in most parts of the world, including in Thailand. More investigations are required to help improve our understanding of the links between physical activity (PA) and health. Unfortunately, the relationship between habitual PA and health for Thai adolescents is still less understood. Moreover, the assessment of PA needs to be accurately quantified using appropriate methods. Accelerometers provide an objective measure of habitual activity which is valid, reliable, and feasible in children and adolescents. The purpose of this cross-sectional study was to characterize levels of objectively measured PA and sedentary behavior (SED) in adolescents from northeast Thailand. Among 186 samples (92 boys and 94 girls) of 13- to 18-year-old adolescents with randomly selected sampling included an equal proportion of main characteristics distribution. Objective activity was measured using ActiGraph accelerometers (GT1M) that were worn for 7 consecutive days during all waking hours. The mean daily PA levels were expressed in minute of time engaging, and were calculated by using age-specific cut-off points. The results showed that, according to IOTF classification of BMI categories, the prevalence of OW/OB in Thai adolescents was 23.1%. At all ages, boys were significantly more active than girls ($p < 0.01$). Moderate-to-vigorous PA (MVPA) levels were greater during weekdays compared to weekends. SED time was significantly higher in urban adolescents ($p < 0.01$). Regardless of their OW/OB group, rural adolescents had significantly more minutes of MVPA compared to adolescents from urban ($p < 0.05$). However, the daily compliance with PA guidelines was also similar between urban and rural areas. Adolescents who walked or bicycled to school had higher in MVPA than those who traveled by motorized transport particularly girls and rural adolescents ($p < 0.01$). According to socioeconomic status (SES), adolescents of low-income families accumulated more minutes of daily MVPA ($p < 0.01$) and less of SED ($p < 0.05$) than those of high-income families. Moreover, low-SES girls achieved the PA guidelines more than those in the other two groups ($p < 0.01$). This thesis has increased the

knowledge about adopting PA habits in routine daily life, informing an effort to halt or reverse trends in OW/OB among adolescents, and PA promotion has been identified as a key focus of efforts to promote health, therefore, potentially effective strategies to increase adolescents' PA in school, family, and community settings adolescents are urgently needed.

Key words: ACCELEROMETER, ADOLESCENT, BODY COMPOSITION, GUIDELINES AND RECOMMENDATIONS, OBESITY, PHYSICAL ACTIVITY

Resumo

A prevalência do excesso de peso/obesidade (SP/O) está a aumentar rapidamente na maior parte do mundo, incluindo a Tailândia. São necessárias mais investigações que ajudem a melhorar ou entender as relações entre atividade física (AF) e a saúde. Infelizmente, a relação entre a AF habitual e saúde em adolescentes tailandeses ainda é menos compreendida. Além disso, a avaliação da AF precisa ser quantificada com precisão através de métodos apropriados. Os acelerómetros fornecem uma medida objetiva da atividade habitual, é um instrumento válido, fiável e viável em crianças e adolescentes. O objetivo deste estudo transversal foi caracterizar os níveis de AF avaliados de forma objetiva e o tempo de atividades sedentárias (SED) em adolescentes do nordeste da Tailândia. A amostra compreendeu 186 crianças (92 rapazes e 94 raparigas) de 13 a 18 anos de idade e foi selecionada aleatoriamente de forma a incluir uma igual proporção de distribuição das características principais. A atividade foi medida objetivamente usando acelerómetros ActiGraph (GT1M) que foram colocados durante 7 dias consecutivos durante o dia e retirados durante o sono. Os níveis médios da AF diária foram expressos em minutos e foram calculados utilizando pontos de corte específicos à idade. Os resultados mostraram que, de acordo com a classificação da IOTF para as categorias de IMC, a prevalência de SP/O em adolescentes tailandesa foi de 23,1%. Em todas as idades, os rapazes foram significativamente mais ativos que as raparigas ($p < 0,01$). As atividades de intensidades moderadas a vigorosas (AFMV) foram mais elevadas durante a semana em comparação com fins de semana. O tempo em SED foi significativamente maior em adolescentes da zona urbana ($p < 0,01$). Independentemente do grupo SP/O, os adolescentes da zona rural apresentaram significativamente mais minutos de APMV quando comparados com os adolescentes da zona urbana ($p < 0,05$). No entanto, o cumprimento diário das recomendações internacionais da AF para a saúde foi semelhante entre as áreas urbana e rural. Os adolescentes que faziam o seu trajeto para a escola de bicicleta apresentaram níveis mais elevados de APMV em relação aos seus pares que viajavam de transporte motorizado, em

particular para as raparigas e adolescentes da zona rural ($p < 0,01$). De acordo com o estatuto socioeconómico (ESE), os adolescentes de famílias de baixo rendimento, acumularam mais minutos diários AFMV ($p < 0,01$) e menos de SED ($p < 0,05$) do que as de famílias de rendimento mais elevado, além disso, um maior número de raparigas de baixo ESE alcançaram os níveis recomendados de PA comparativamente aos outros dois grupos ($p < 0,01$). Esta tese contribuiu para o conhecimento sobre a adoção de hábitos da AF na rotina do dia a dia, a promoção da AF foi identificada como um dos principais focos de interesse para promover a saúde e para parar ou inverter as tendências de aumento do SP/O entre os adolescentes. É portanto necessário e urgente criar estratégias potencialmente eficazes que incluam a escola, a família ou o envolvimento da comunidade para aumentar a AF de adolescentes.

Palavras chave: ACELEROMETRO, ADOLESCENTE, COMPOSIÇÃO CORPORAL, DIRETRIZES E RECOMENDAÇÕES, OBESIDADE, ATIVIDADE FÍSICA

บทคัดย่อ

อุบัติการณ์ของภาวะน้ำหนักเกินและโรคอ้วนในเด็กและวัยรุ่นกำลังเพิ่มสูงขึ้นอย่างรวดเร็วทั่วโลก และถือเป็นปัญหาที่สำคัญระดับต้นๆของระบบสาธารณสุขไทย ด้วยเหตุนี้จึงมีความจำเป็นอย่างยิ่งที่จะต้องดำเนินการเพื่อศึกษาให้เกิดความเข้าใจถึงปัจจัยและสาเหตุที่เกี่ยวข้องระหว่างกิจกรรมทางกายและสุขภาพให้มากขึ้น แต่ในปัจจุบันการศึกษาและความรู้ด้านนี้กลับยังมีอยู่อย่างจำกัด อีกทั้งยังต้องการวิธีการประเมินกิจกรรมทางกายในชีวิตประจำวันที่มีประสิทธิภาพและเที่ยงตรง เครื่องวัดความเคลื่อนไหวร่างกายแบบพกพา (Accelerometers) ถือเป็นเครื่องมือที่ใช้วัดค่ากิจกรรมทางกายที่ได้รับการตรวจสอบและยอมรับในระดับนานาชาติแล้วว่ามีความเที่ยงตรงและเชื่อถือได้สูงสำหรับกลุ่มเด็กและวัยรุ่น การศึกษาภาคตัดขวาง (Cross-sectional study) ในครั้งนี้จึงมีวัตถุประสงค์เพื่ออธิบายลักษณะของค่ากิจกรรมทางกายในชีวิตประจำวันกับปัจจัยทางกายภาพต่างๆ ของวัยรุ่นไทยที่กำลังศึกษาอยู่ในระดับมัธยมศึกษาชั้นปีที่ 1-6 ในภาคตะวันออกเฉียงเหนือ โดยสุ่มตัวอย่างจากวัยรุ่นไทยที่มีอายุ 13-18 ปีมาจำนวน 186 คน แบ่งเป็นเพศชาย 92 คนและเพศหญิง 94 คน ผู้เข้าร่วมศึกษาทุกคนจะต้องทำการติดเครื่องวัดความเคลื่อนไหวร่างกายแบบพกพารุ่นจีทีหนึ่งเอ็ม (GT1M) ตั้งแต่ตื่นนอนไปจนถึงก่อนเข้านอนเป็นระยะเวลาติดต่อกัน 7 วัน โดยค่ากิจกรรมทางกายในระดับต่างๆ ที่วัดได้จากผู้เข้าร่วมศึกษาทุกคนจะถูกคำนวณออกมาเป็นนาฬิกาตามวิธีการของฟรีดสันและคณะที่สัมพันธ์กับอายุด้วยโปรแกรมเฉพาะทาง ผลการศึกษาค้นพบว่า อุตบัติการณ์ของภาวะน้ำหนักเกินและโรคอ้วนในวัยรุ่นไทยจากการใช้เกณฑ์มาตรฐานสากลเท่ากับร้อยละ 23.1 เพศชายมีกิจกรรมทางกายสูงกว่าเพศหญิงอย่างมีนัยสำคัญในทุกกลุ่มอายุ ($p < 0.01$) โดยวัยรุ่นจะมีระดับกิจกรรมทางกายระดับปานกลางถึงหนัก (MVPA) ในช่วงวันธรรมดา (Weekdays) มากกว่าวันหยุดสุดสัปดาห์ (Weekends) ในขณะที่กลุ่มวัยรุ่นในเมืองใช้เวลาไปกับกิจกรรมทางกายที่มีการเคลื่อนไหวต่ำ (Sedentary behavior) มากกว่ากลุ่มวัยรุ่นที่อาศัยในเขตชนบทอย่างมีนัยสำคัญทางสถิติ ($p < 0.01$) และเมื่อไม่คำนึงถึงกลุ่มที่มีภาวะน้ำหนักเกินและโรคอ้วนจะพบว่า วัยรุ่นที่อาศัยในเขตเมืองก็ยังคงใช้เวลาไปกับกิจกรรมทางกายในระดับปานกลางถึงหนักต่ำกว่าวัยรุ่นในเขตชนบทอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) อย่างไรก็ตามทั้งสองกลุ่มนี้มีอัตราการผ่านเกณฑ์ตามแนวปฏิบัติและข้อเสนอแนะการมีกิจกรรมทางกายสำหรับเด็กและวัยรุ่น (Physical activity guidelines) ไม่แตกต่างกัน ผลการศึกษาในครั้งนี้ยังพบอีกว่า วัยรุ่นที่เดินทางไปโรงเรียนด้วยการเดินเท้าหรือปั่นจักรยานจะมีค่ากิจกรรมทางกายในระดับปานกลางถึงหนักสูงกว่ากลุ่มที่รายงานว่าการเดินทางโดยพาหนะต่างๆที่ใช้เครื่องยนต์ โดยเฉพาะในวัยรุ่นหญิงและวัยรุ่นที่อาศัยในเขตชนบท ($p < 0.01$) เมื่อพิจารณาถึงปัจจัยด้านสถานภาพทางเศรษฐกิจสังคม (Socioeconomic status) ของครอบครัวพบว่า วัยรุ่นที่อยู่ในกลุ่มครอบครัวที่มีรายได้ต่ำมีค่ากิจกรรมทางกายสูงกว่าวัยรุ่นในครอบครัวที่มีรายได้สูง ($p < 0.01$) โดยเฉพาะในกลุ่มวัยรุ่นเพศหญิงพบว่า กลุ่มที่ครอบครัวมีรายได้สูงจะผ่านเกณฑ์แนวปฏิบัติและข้อเสนอแนะการมีกิจกรรมทางกายสำหรับเด็กและวัยรุ่นน้อยกว่ากลุ่มที่มาจากครอบครัวที่มีรายได้ต่ำ

กว่าอย่างมีนัยสำคัญทางสถิติ ($p < 0.01$) การศึกษาครั้งนี้จึงช่วยเพิ่มองค์ความรู้ด้านลักษณะของกิจกรรมทางกายในชีวิตประจำวันกับปัจจัยทางกายภาพต่างๆที่เกี่ยวข้องในวัยรุ่นไทย และแสดงให้เห็นว่าการสนับสนุนให้มีกิจกรรมทางกายที่เพิ่มขึ้นโดยอ้างอิงกับผลการศึกษาข้างต้นนั้น ถือเป็นสิ่งสำคัญเร่งด่วนที่จะช่วยในการส่งเสริมเพื่อลดหรือชะลออุบัติการณ์ภาวะน้ำหนักเกินและโรคอ้วนในวัยรุ่นไทยได้ต่อไป แต่อย่างไรก็ตามการสร้างแบบแผนหรือยุทธวิธีเหล่านี้ให้ตรงจุดและมีประสิทธิภาพนั้น มีความจำเป็นอย่างยิ่งที่ต้องพิจารณาปัจจัยจำเพาะระหว่างนักเรียน โรงเรียน ครอบครัว และชุมชนควบคู่กันไปอย่างเป็นบูรณาการ

คำสำคัญ: เครื่องวัดความเคลื่อนไหวร่างกายแบบพกพา, วัยรุ่น, องค์ประกอบของร่างกาย, แนวปฏิบัติ และข้อเสนอแนะ, โรคอ้วน, กิจกรรมทางกาย

List of abbreviations

ANOVA	: Analysis of variance
AOR	: Adjusted odds ratio
BF	: Body fat
BIA	: Bioelectrical impedance analysis
BMI	: Body mass index
BMR	: Basal metabolic rate
CDC	: Centers for disease control and prevention
CHD	: Coronary heart disease
CSEP	: The Canadian Society for Exercise Physiology
CVD	: Cardiovascular disease
cm	: Centimeter
cpm	: Counts per minute
CVD	: Cardiovascular diseases
DEXA	: Dual energy x-ray absorptiometry
DLW	: Doubly labeled water
EE	: Energy expenditure
HDL	: High-density lipoprotein
IASO	: The International association for the study of obesity
IOTF	: The international obesity task force
kg/m²	: Kilogram per square meter
LDL	: Low-density lipoprotein
METs	: Metabolic equivalents
MVPA	: Moderate-to-vigorous physical activity
n	: Frequency of sample
NSO	: National statistical office (of Thailand)
OR	: Odds ratio
OW/OB	: Overweight/obesity <i>or</i> Overweight and obesity
p	: p-value
PA	: Physical activity
PAEE	: Physical activity energy expenditure

PAG	: Physical activity guidelines (recommendations)
PALs	: Physical activity levels
PAP	: Physical activity patterns
PASW	: The Predictive Analytics Software
r	: Reliability or correlation coefficient
RMR	: Resting metabolic rate
SED	: Sedentary behavior
SEE	: Standard error of estimate
SES	: Socioeconomic status
SPSS	: Statistical package for the social sciences
SD	: Standard deviation
TEE	: Total energy expenditure
TFM	: Total fat mass
UK	: The United Kingdom
US	: The United States (of America)
VPA	: Vigorous physical activity
WC	: Waist circumference
WHO	: World health organization
%BF	: Percentage of body fat
χ^2	: Chi-square test
V	: Cramer's V coefficient

CHAPTER I

INTRODUCTION AND BACKGROUND

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The prevalence of childhood obesity is high and still increasing at an alarming rate throughout the world, in almost all developed countries for which data are available; additionally, evidence suggests that the prevalence of overweight and obesity (OW/OB) has increased to relatively high levels in many developing countries (Wang & Lobstein, 2006; WHO, 1998). A growing number of studies worldwide (Janssen et al., 2005; Wang & Lobstein, 2006) help to shed light on the patterns and time trends of OW/OB in children and adolescents. Currently, our understanding of the global circumstances surrounding obesity in children and adolescents is still limited due to the lack of comparable representative data from different countries, and varying criteria for defining overweight and obesity. This methodological problem of consistency between classifications of childhood obesity is the major obstacle in studying global secular trends for younger age groups (Lobstein, Baur, & Uauy, 2004; Wang & Lobstein, 2006).

Almost all researchers in this field agree that prevention of OW/OB in children and adolescents could be the key strategy for controlling the current epidemic of OW/OB, a good understanding of the global situation can provide useful insights on the causes of the current OW/OB epidemic and will assist the planning and development of international collaborations and programs to address this growing public health crisis (Wang & Lobstein, 2006). Insufficient PA and prolonged sedentary behavior (SED) are widely acknowledged as the primary mechanisms underlying the rise in excess body weight, and is associated with a range of poor health outcomes (Dietz, 1996; Jirapinyo, Densupsoontorn, Chinrungrueng, Wongarn, & Thamonsiri, 2005). While regular PA is widely recognized as a mean of preventing the occurrence of many chronic diseases and reduced risk of all-cause mortality (Hallal, Victora, Azevedo, & Wells, 2006). Childhood and adolescence are crucial times for public health, while the decline in PA during adolescence is a key public health concern (Allison, Adlaf, Dwyer, Lysy, & Irving, 2007) and the increasing

prevalence of OW/OB is also noticeable in this age-period (Telama & Yang, 2000). Furthermore, it has been well documented that the highest risk for childhood obesity that persists into adulthood occurs among overweight adolescents (Dietz, 1996; Dietz & Robinson, 1998). There is a critical need for a better understanding of adolescents' PA patterns (PAP) and the trends in childhood OW/OB to shape their physical health status, and it can contribute towards improving quality of life for many people of all age groups in later adolescence. In addition, an understanding of how SED and PA relates to health status may provide new avenues for clinical and public health approaches in disease prevention and control.

Consequently, PA is now included in most global health promotion recommendations. Attempts to reduce the decline in PA in adolescence have been the focus of many public health interventions in recent years. For example, in Canada, the national approach has shifted from assessing physical fitness in youth to assessing and promoting PA, and aimed at positively influencing knowledge, belief, and attitudes about PA and health lifestyles (Morrow, Jackson, Disch, & Mood, 2000). Prevention of declines in PA in adolescent is also a Scottish public health priority (Group, 2010).

1. Prevalence and trends in overweight and obesity among children and adolescents

1.1 Worldwide trends in childhood overweight and obesity

The increasing prevalence of OW/OB is clearly visible throughout the world, and an epidemic of OW/OB affected children and adolescents across the developed and developing countries (Bertoncello, Cazzaro, Ferraresso, Mazzer, & Moretti, 2008; Bundred, Kitchiner, & Buchan, 2001; de Onis & Blossner, 2000; Martorell, Kettel Khan, Hughes, & Grummer-Strawn, 2000; Ogden et al., 2006; Ramachandran et al., 2002). However, it should be noted that direct comparison of those prevalence rates with reports from country to country and from age to age, should be made with caution as each report had used different

criteria for classifying OW/OB (Tee, 2002). Nevertheless, the lack of data for certain age groups such as adolescents need to be addressed.

In most of the currently available data, the prevalence of childhood OW/OB in developed countries is higher than that in developing countries, but the vast majority of affected children live in developing countries (de Onis, Blossner, & Borghi, 2010). Additionally, the relative increase in the last two decades has been higher in developing countries (+65%) than in developed countries (+48%). Asia has the highest number of overweight and obese children, because more than half (18 million in 2010) of the affected children from developing countries live in this region (de Onis, et al., 2010).

Recently, a total of 450 nationally representative cross-sectional surveys from 144 countries showed that, in 2010, 43 million children (81.4% or 35 million in developing countries) were estimated to be overweight and obese whereas 92 million are estimated to be at risk of overweight (de Onis, et al., 2010). Meanwhile, another study published in the same year reported by The International Association for the Study of Obesity/The International Obesity Task Force (IASO/IOTF) estimated that approximately 1 billion adults are currently overweight [Body mass index (BMI) = 25-29.9 kg/m²], and a further 475 million are obese (BMI > 30 kg/m²). When Asian-specific cut-off points for the definition of obesity (BMI > 28 kg/m²) are taken into account, the number of adults considered obese globally is over 600 million (IOTF, 2010). World Health Organization (WHO) further projects that by 2015, approximately 2.3 billion adults will be overweight and more than 700 million will be obese. Globally, IASO/IOTF also estimate that up to 200 million school aged children are either overweight or obese, of those 40-50 million are classified as obese (IOTF, 2010). These findings confirm the need for effective interventions and programs to reverse anticipated trends starting from childhood.

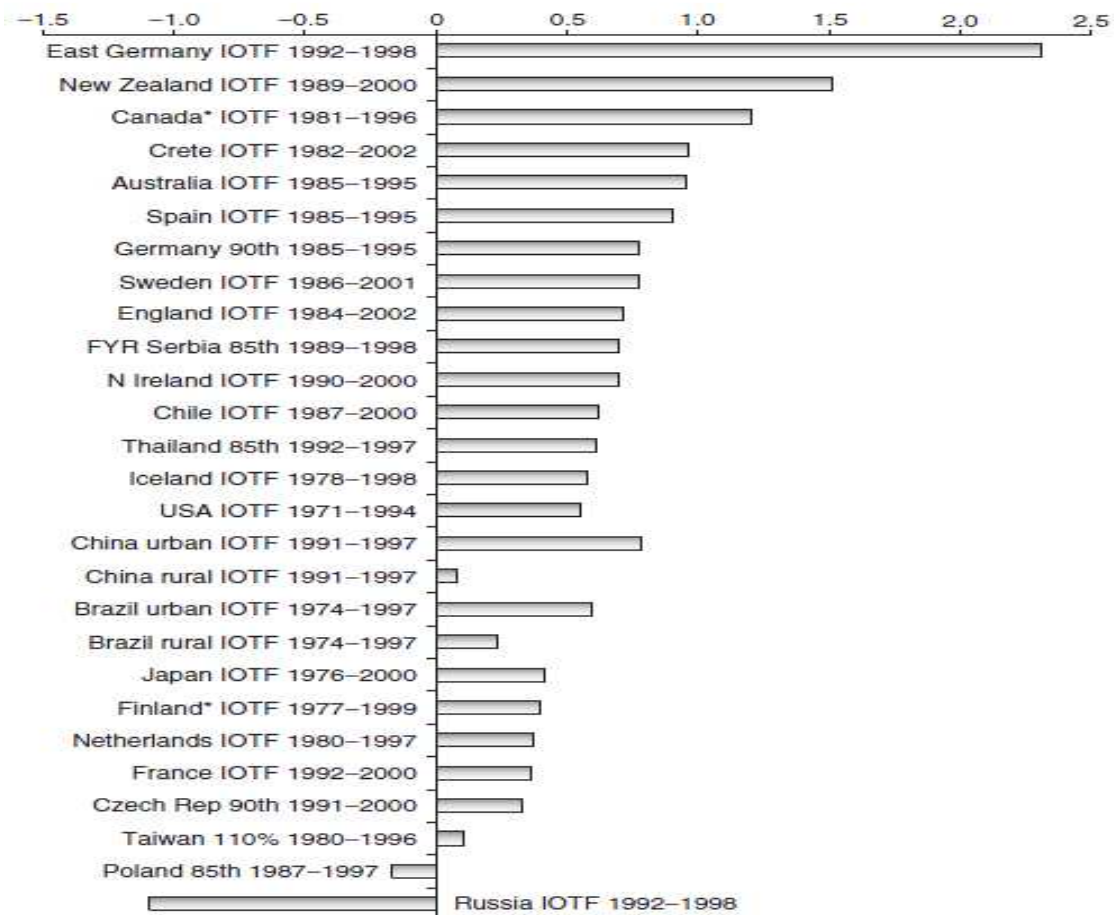


Figure 1. Change in the combined prevalence of overweight and obesity among school-age children in surveys since 1970. The chart shows country, method of measurement, and period of assessment for prevalence change. Methods of IOTF cut-point for overweight and obesity: 85th and 90th = percentiles for local or WHO Body Mass Index reference charts, 110% = percent of ideal body weight (locally defined). *Self-reported data.

[Adapted from Wang, Y., & Lobstein, T. (2006). Worldwide trends in childhood overweight and obesity. *Int J Pediatr Obes*, 1(1), 11-25.) (Wang & Lobstein, 2006)]

1.2 The prevalence of childhood overweight and obesity in Asia

The sustained economic growth, the increasing political stability, the improving health facilities, as well as the transition from a rural to an urban lifestyle (e.g., increased consumption of high energy dense foods and decrease in PA) is associated with increased levels of obesity in many Asian populations. However, countries and regions in Asia are at different phases of development. Some like Vietnam and Indonesia are in the early stages of development whereas others like Japan, Singapore, Malaysia, and Hong Kong are at more

advanced stages. Nevertheless, childhood OW/OB has also reached epidemic proportions and is major public health problems in many Asian countries. Similar trends can also be seen in Thailand. In 1995, an estimated 17.6 million children were overweight in the developing countries. Of this total, 61% or 10.6 million were in Asia (de Onis & Blossner, 2000; Tee, 2002). Interestingly, the highest rate of OW/OB in Asia is in Thailand (overweight 28.3% and obesity 6.8%) (Aekplakorn et al., 2004; Ramachandran & Snehalatha, 2010).

A 1997 national survey of children under 5 years of age in Brunei Darussalam showed a high prevalence of overweight ranging from 7.7% to 10.2% in different parts of the country, and averaging 9.1% for the whole country. In Kuala Lumpur, Malaysia, the prevalence of overweight in primary school children was observed to be 8.4% (Tee, 2002), boys were almost 1.4 times more likely to be overweight than girls. In a nationally representative cross-sectional data from the 2002 China National Nutrition and Health Survey, OW/OB percentage of Chinese children aged 7-17 years was 4.5 and 2.2, respectively (Y. Li et al., 2007). For the same period (2002), a study conducted among urban Indian adolescents aged 13-18 years have also demonstrated that the prevalence of overweight was 17.8% for boys and 15.8% for girls, while obesity was reported in 3.6% boys and 2.7% girls (Ramachandran, et al., 2002). A more recent study (2010) in India also revealed that, school children of 12-18 years of age, from different areas, found a prevalence of overweight of 14.3% among boys and 9.3% among girls, with an obesity prevalence of 1.5%-2.9% (Goyal et al., 2010). A six-year longitudinal study in Japanese primary school children, conducted between 2001 and 2007, showed that the prevalence of overweight in boys has changed over the 6 years: from 15%-18.3% in 2001 to 16.5%-21.7% in 2007, and obesity prevalence has also increased, from 4.9%-5.9% in 2001 to 3.6%-5.4% in 2007. During the same period, in girls, there has changed from 15.2%-17.1% to 14.7%-15.5% for overweight, and 4.0%-4.1% to 2.0%-2.1% for obesity (Nakano et al., 2010).

1.3 Prevalence and determinants of childhood overweight and obesity in Thailand

There is no doubt that the prevalence of childhood OW/OB is also rapidly increasing at an alarming rates in Thailand – directly parallels that which is occurring in the West or other developed countries. Furthermore, the impact of engulfment of western culture due to globalization has resulted in attenuation of Thai traditional practices and behaviors, like eating (Mo-suwan & Geater, 1996), and the living standard in Thailand has been much improved. A previous study performed by Mo-suwan and colleague reported that the prevalence of obesity (weight-for-height > 120% of the Bangkok reference) in 6- to 12-year-old children rose from 12.2% in 1991 to 13.5% in 1992 and 15.6% in 1993 (Mo-suwan & Geater, 1996). In the 4th National Nutrition Survey 1995 of Thailand, the prevalence of overweight among children 0-5 years of age was reported to be 17.6%, whereas 5.4% of the children were reported to be obese (Department of Health, 1995). The study conducted in 1997 in *Saraburi* Province where is located in the Central Region of Thailand, which is approximately 100 km northeast of Bangkok. Three districts were randomly selected from the 13 districts in the province for representatives of children in rural areas, and the *Saraburi* municipality was chosen for representatives of children in urban areas, the prevalence of childhood obesity over 97th percentile for weight-for-height ($>p_{97}$) was 22.7% in urban and 7.4% in rural areas whereas the prevalence of overweight (p_{90-97}) was 16.1% in urban group, and 8.7% in rural group (Sakamoto, Wansorn, Tontisirin, & Marui, 2001). A 6-year longitudinal study published in 2005 found that, during adolescence (grades 7-12), the rates of OW/OB increased with age. The prevalence of overweight in boys and girls at grade 7 were 13.6% and 9.9%, and at grade 12 were 14% and 10.5%, respectively. In addition, the prevalence of obesity in boys and girls at grade 7 were 26.8% and 13.5%, and at grade 12 were 15% and 10.8%, respectively (Jirapinyo, Densupsoontorn, Chinrungrueng, et al., 2005). A 6-year retrospective study of body weights of primary-school children from grade 1 to grade 6 in three cities with different urbanization levels showed that the prevalence of obesity increased at quite dramatic rates during the primary school period: the prevalence of obesity in children in grade 1 from schools in *Bangkok*, *Saraburi* (100-km northeast from Bangkok) and *Sakolnakorn* (600-km

northeast from Bangkok) was 16%, 23% and 4% respectively, and this increased to 31%, 30% and 9%, respectively, by 6th grade (Jirapinyo, Densupsoontorn, Kongtragoolpitak, Wong-Arn, & Thamonsiri, 2005). In 2008, prevalence of obesity among students grade 7-12 in *Nakhon Pathom* province (56-km northwest from Bangkok), a rural-urban area, was 8.7%, and this prevalence was higher in boys (10.89%) than in girls (6.98%). Additionally, father's occupation and family income had a significant association with obesity status in children (Nguyen, Kamsrichan, & Chompikul, 2008).

Although comparison is difficult because those surveys use a variety of definitions of OW/OB and employ a range of different measures, all the studies mentioned above show that the prevalence of childhood obesity in Thailand has increased dramatically over the last decade. Therefore, if those trends of OW/OB are allowed to go on as mentioned above, the prevalence of obesity in the Thai population in the near future will be much higher than the current figure, and the magnitude of the public health problem caused by obesity in the next decade will also be much higher (Jirapinyo, Densupsoontorn, Kongtragoolpitak, et al., 2005). In addition, the international age- and gender-specific cut-off points should be used in future research in order to eliminate inconsistencies in choice of measurements, cut-points, and also to facilitate international comparisons.

2. Potential determinants of childhood obesity and overweight prevalence trends

A number of factors have been linked to OW/OB, including age, gender socioeconomic status, racial/ethnic groups, and geographic location.

2.1 Differences in prevalence associated with age and gender

Although OW/OB seems to be growing in children and adolescents regardless of gender, previous studies suggested that the prevalence of OW/OB are different between genders. Reilly has suggested that gender differences in prevalence are also possible for any population and may emerge

in future, though not present now, so prevalence estimates should always consider the genders separately, at least initially (Reilly, 2005), and age-related differences in the prevalence should also be considered.

In one study, the secular trends in obesity in the United States (US) suggest that gender differences may become more marked over time, as increases in prevalence during the period 1986-1998 were much greater in boys than in girls (Strauss & Pollack, 2001) whereas in the United Kingdom (UK), the apparent gender difference is an artifact of the IOTF definition, which has much lower sensitivity in boys than girls (Reilly, Dorosty, & Emmett, 2000). A six-year longitudinal study published in 2010 on the prevalence of OW/OB in Japanese children, showed that boys (15-23% for overweight, and 4-7% for obesity) are fatter than girls (15-18% for overweight, and 2-4% for obesity), while up to 70% of OW/OB Japanese primary school children track into junior high school OW/OB adolescents. The tracking of OW/OB status is higher among boys than girls (Nakano, et al., 2010). In India, the prevalence of overweight in urban adolescents aged 13-18 years was 17.8% for boys and 15.8% for girls; obesity was seen in 3.6% of boys and 2.9% of girls, additionally its prevalence was found to be significantly associated with age (Ramachandran, et al., 2002). In developed countries such as the UK, the prevalence of childhood obesity also increased with age; moreover, an association between socioeconomic deprivation and childhood obesity was strong, especially in girls (Kinra, Nelder, & Lewendon, 2000).

2.2 Differences in prevalence associated with socioeconomic status

The pandemic of obesity has been restricted to developed and high-income countries until few decades ago, but recently, it has penetrated even the developing and poor countries. Asia has undergone considerable socioeconomic transition in the past few decades which has resulted in increased availability of food, better transport facilities, and better health care facilities. In general, the prevalence of OW/OB is associated with higher socioeconomic status (SES) in both children and adults (Powell, Hoffman, & Shahabi, 2001; Ramachandran & Snehalatha, 2010; Wardle & Griffith, 2001).

In developing nations child obesity is most prevalent in wealthier sections of the population (Danielzik, Czerwinski-Mast, Langnase, Dilba, & Muller, 2004; Lobstein, et al., 2004). On the other hand, the major causative factors are related to the lifestyle changes occurring due to rapid socioeconomic transition, increasing economic development tends to be associated with increases in prevalence of childhood obesity in developing countries (Martorell, et al., 2000). Adolescents from socially advantaged backgrounds also tend to be heavier than those from disadvantaged backgrounds (Nunez-Rivas, Monge-Rojas, Leon, & Rosello, 2003; Wang, 2001). In China, the OW/OB prevalence increased with the family's income level and the mother's educational level (Y. Li, et al., 2007).

However, the reasons for the differences in prevalence of childhood obesity among groups are complex and not entirely clear, likely involving country, age, gender, culture, ethnicity, environment, and interactions among these variables and SES on childhood obesity not fully recognized. Importantly, understanding the influence of those variables on the patterns of PA that lead to OW/OB will be critical to developing public policies and effective clinical interventions to prevent and treat childhood obesity. Thus, the magnitude of SES differences in obesity risk is worth considering.

2.3 Differences in prevalence associated with racial or ethnicity

Although racial or ethnic differences in obesity risk may be explained in part by socioeconomic factors in developed countries (i.e., the US), racial/ethnic differences in obesity risk are not merely the result of differences in income and education, whereas in developed countries with smaller and more geographically diffuse populations of ethnic minorities than the US, the extent of ethnic differences in the prevalence of obesity is less clear (Reilly, 2005; Reilly, Wilson, Summerbell, & Wilson, 2002), there appears to be a cultural component to lifestyle which is responsible for the high obesity risk in some minority groups (Gordon-Larsen, Adair, & Popkin, 2003). Asian populations show several differences in genetic factors when compared with the Western population. Thus, future research should continue to explore racial/ethnic differences in

OW/OB prevalence in an effort to identify policies and interventions that are more effective in Asian population.

2.4 Differences in prevalence associated with geographical areas

Rural and urban residents are known for having different lifestyles (Arambepola, Allender, Ekanayake, & Fernando, 2008). Rural communities are culturally more homogeneous than urban communities, and they have less exposure to different lifestyles. Generally, lifestyle and diet were the most important risk factors to explain the differences between urban and rural residents; these lifestyles create their own patterns of food demand and time allocation. The consequences for diets, PA, and health have been enormous (Gao et al., 2011). Additionally, people's lifestyles have changed rapidly over the last decade and were found to be a contributory factor for the rising rates of obesity (Ramachandran et al., 2004); in other words, a urban-rural setting is associated with increases in OW/OB (Davison & Lawson, 2006).

Most western countries show a greater regional distribution of obesity in rural areas (Borders, Rohrer, & Cardarelli, 2006; Jackson, Doescher, Jerant, & Hart, 2005; Peytremann-Bridevaux, Faeh, & Santos-Eggimann, 2007). In Costa Rica, one of Central America's countries, 7-12-year-old children from urban areas had a higher prevalence of overweight than those living in rural areas (36.7% vs. 30.0%, respectively), whereas the obesity prevalence was 28.4% in urban and 21.5% in rural areas (Nunez-Rivas, et al., 2003). But a study using the adult samples of 10 European countries found no differences in the prevalence of OW/OB between rural and urban areas (Peytremann-Bridevaux, et al., 2007). While one study in Southern European country, such as Italy shows that school-aged children residents in rural areas have a higher risk of OW/OB compared with children residents in urban areas (Bertoncello, et al., 2008).

However, in developing countries, there is a clear difference with respect to the geographical areas. A higher prevalence of OW/OB occurring in urban areas as compared to rural areas, because urbanization is associated with a variety of lifestyles and behavioral changes, including physical inactivity and

high-fat, energy-rich diets, which influence body weight (Gao, et al., 2011). In Malaysia, the OW/OB prevalence in primary school children was about 4 times higher in urban areas than in rural areas (Tee, 2002). One study in India also highlighted a high prevalence of overweight in urban adolescents (Ramachandran, et al., 2002). A more recent study (Gao, et al., 2011) conducted in Chinese adult sample confirmed that urban residents have a much higher prevalence of OW/OB than that in rural counterparts. The prevalence of OW/OB in urban residents was 3 times as much as that in rural residents (42.6% vs. 14.1%).

However, it is important to note that most previous studies on the influence of a rural/urban setting on OW/OB prevalence in children and adolescents were not sufficiently controlled for race, gender, age, grade level, school location, and perhaps, may not have included a representative sample of rural and urban children/adolescents. Consequently, our understanding of how OW/OB rates vary depending on the level of urbanization may help health professionals to either tailor programs to the needs of the individuals living in these different areas or to target existing programs to the contexts where they are most likely to have an impact.

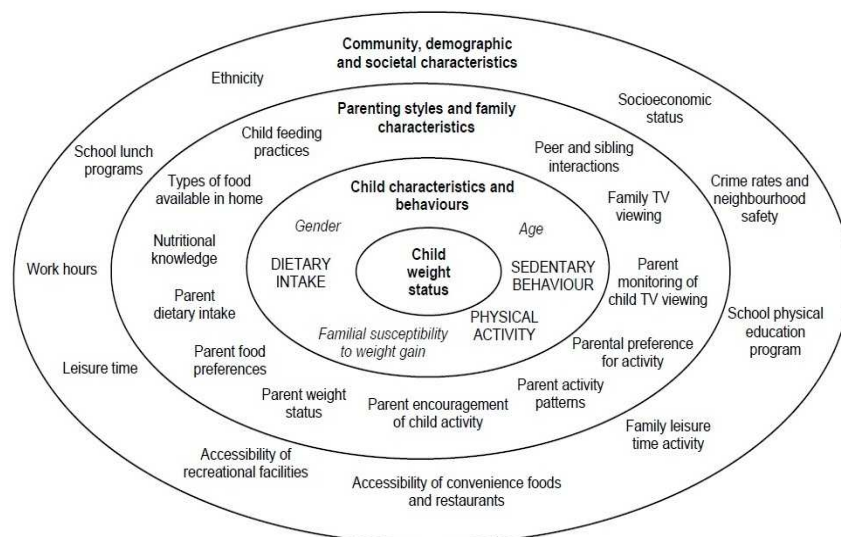


Figure 2. Framework for factors associated with childhood overweight and obesity (Adapted from Davison, K. K., & Birch, L. L. (2001). Childhood overweight: a contextual model and recommendations for future research. *Obes Rev*, 2(3), 159-171.) (Davison & Birch, 2001)

3. Standard definition of child overweight and obesity worldwide

For medical purposes, overweight or obesity refers to excess body fat (BF); however, it is difficult to measure BF percentage (%BF) without special equipment, and is impracticable for epidemiological use. Generally, for clinical practice and epidemiologic studies, child OW/OB are assessed by means of indicators based on weight and height measurements, such as weight-for-height measures or BMI [weight/height² (kg/m²)].

BMI does not measure BF directly but it is strongly correlated with %BF (Mei et al., 2002; Pandit, Chiplonkar, Khadilkar, Khadilkar, & Ekbote, 2009; R. W. Taylor, Jones, Williams, & Goulding, 2002); additionally, BMI is an inexpensive and easy-to-perform method of screening for weight categories that may lead to health problems, and therefore has become the standard indicator to describe the degree of excess weight, and it is a reasonable indicator of body fatness for most children and adolescents.

Different international and national reference systems based on BMI have been proposed to define OW/OB in childhood, and the dispersion in systems mentioned before, turns it difficult to establish comparisons between different methods. An international reference will be useful for making appropriate comparisons across studies and monitoring the global epidemic of OW/OB. To meet such demands, the Childhood Obesity Working Group of the IOTF proposed the international age- and gender-specific BMI cut-off points to define OW/OB for 2- to 18-year-old children (see Table 1). In this definition, used data from 6 national studies conducted in different countries (Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the US) and provided centile curves that linked to the widely accepted cut-off points of a BMI of 25 kg/m² and 30 kg/m² for adult OW/OB (Cole, Bellizzi, Flegal, & Dietz, 2000). This BMI definition provides a useful practical reference for surveys aimed at estimating the prevalence of OW/OB among adolescents (Al-Sendi, Shetty, & Musaiger, 2003; Y. Li, et al., 2007).

Table 1. International body mass index cut-offs for overweight and obesity by sex between 2 and 18 years old, defined to pass through body mass index 25 and 30 kg/m² at age 18 years old.

(Adapted from Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*, 320(7244), 1240-1243.) (Cole, et al., 2000)

Age (years)	Body Mass Index 25 kg/m ²		Body Mass Index 30 kg/m ²	
	Boys	Girls	Boys	Girls
2	18.4	18.0	20.1	19.8
2.5	18.1	17.8	19.8	19.5
3	17.9	17.6	19.6	19.4
3.5	17.7	17.4	19.4	19.2
4	17.6	17.3	19.3	19.1
4.5	17.5	17.2	19.3	19.1
5	17.4	17.1	19.3	19.2
5.5	17.5	17.2	19.5	19.3
6	17.6	17.3	19.8	19.7
6.5	17.7	17.5	20.2	20.1
7	17.9	17.8	20.6	20.5
7.5	18.2	18.0	21.1	21.0
8	18.4	18.3	21.6	21.6
8.5	18.8	18.7	22.2	22.2
9	19.1	19.1	22.8	22.8
9.5	19.5	19.5	23.4	23.5
10	19.8	19.9	24.0	24.1
10.5	20.2	20.3	24.6	24.8
11	20.6	20.7	25.1	25.4
11.5	20.9	21.2	25.6	26.1
12	21.2	21.7	26.0	26.7
12.5	21.6	21.1	26.4	27.2
13	21.9	22.6	26.8	27.8
13.5	22.3	23.0	27.2	28.2
14	22.6	23.3	27.6	28.6
14.5	23.0	23.7	28.0	28.9
15	23.3	23.9	28.3	29.1
16	23.9	24.4	28.9	29.4

Table 1 (continued). International body mass index cut-offs for overweight and obesity by sex between 2 and 18 years old, defined to pass though body mass index 25 and 30 kg/m² at age 18 years old.

Age (years)	Body Mass Index 25 kg/m ²		Body Mass Index 30 kg/m ²	
	Boys	Girls	Boys	Girls
16.5	24.2	24.5	29.1	29.6
17	24.5	24.7	29.4	29.7
17.5	24.7	24.8	29.7	29.8
18	25	25	30	30

4. Prevention of overweight and obesity

OW/OB are associated with significant health problems in the pediatric age group and is an important early risk factor for much of adult morbidity and mortality (Dietz, 1996; Ippisch & Daniels, 2008; Reilly, 2005; Rowell, Evans, Quarry-Horn, & Kerrigan, 2002; Williams et al., 2002). In order to prevent childhood obesity and its health consequences, population-based strategies improve social and physical environmental contexts for healthful eating and PA are essential (Kumanyika et al., 2008) (see Figure 3). Population-based approaches to OW/OB prevention are complementary to clinical preventive strategies and also to treatment programs for those who are already overweight or obese. Engaging in regular PA is widely accepted as an effective preventative measure, therefore, over the last decade, several experts have developed and provided the health-benefit PA guidelines (PAG) for children and adolescents (Cavill, Biddle, & Sallis, 2001; Martinez-Gomez et al., 2010; Strong et al., 2005; Tremblay, Warburton, et al., 2011). They suggest that the guideline of 60 minutes of moderate-to-vigorous PA (MVPA) per day is associated with further health benefits.

In contrast, SED such as watching television, playing on the computer and with video games have been associated with potentially adverse health conditions such as child OW/OB (Gortmaker et al., 1996), reducing sedentary time can also help prevent childhood obesity (Robinson, 1999). Therefore, a

major challenge in public health is to develop efficacious and effective health promotion strategies targeting children and adolescents in the population to alleviate the potential future burden of preventable lifestyle diseases; in other words, interventions aimed at increase PA and reduce SED among children and adolescents should be considered.

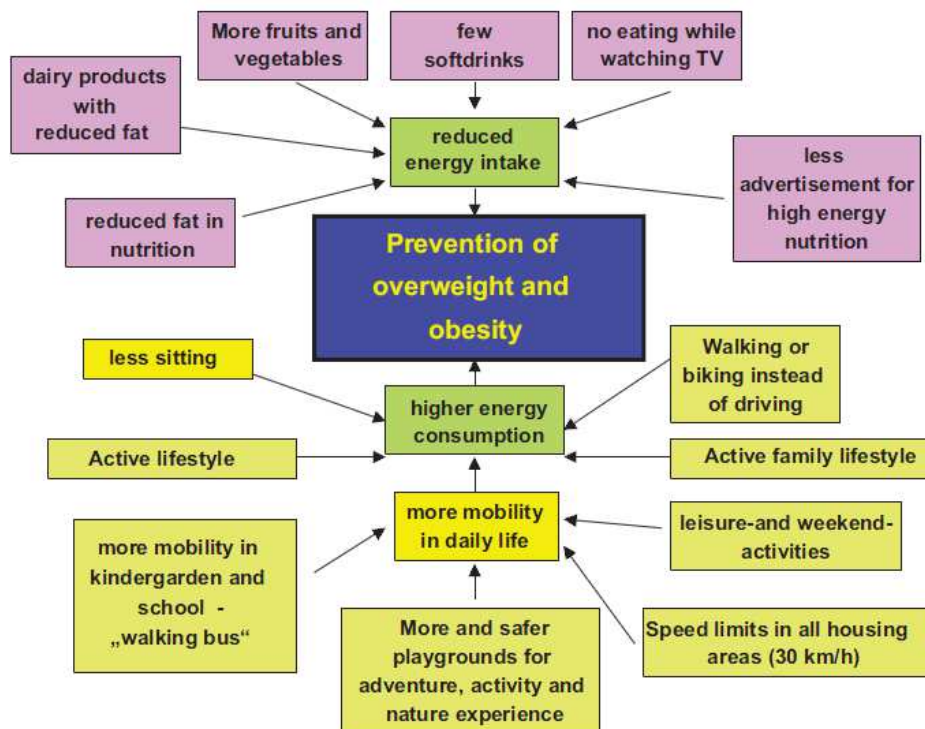


Figure 3. Interacting factors those are responsible for the development of overweight and obesity

(Adapted from Lob-Corzilius, T. (2007). Overweight and obesity in childhood--a special challenge for public health. *Int J Hyg Environ Health*, 210(5), 585-589.) (Lob-Corzilius, 2007)

5. Definition, dimension, and classification of physical activity

5.1 Definition of physical activity

PA is defined as “*any bodily movement produced by skeletal muscles that requires energy expenditure*”; it includes occupational work, chores, leisure activity, playing sports, and exercise that is planned for fitness or health purposes (Caspersen, Powell, & Christenson, 1985). A daily life PA is “*a behavior that involves all large muscle movements for various purposes and*

carried out throughout the day and the different types and amounts of physical activity are required for different health outcomes” (Dishman, Washburn, & Heath, 2004).

PA is not a single behavior but it is a complex set of distinct acts that include, for example, planning for participation, initial adaptation PA, continued participation or maintenance, and overall periodicity of participation (e.g., release, resumption of activity, and seasonal variation) (Dishman, et al., 2004). PA includes sports as well as non-sports activities. Sports and exercise are connected, “*Sports*” are often planned, structured, and repetitive, with the objective of improving or maintaining physical fitness (Caspersen, et al., 1985), whereas non-sports activities can be subdivided into different categories such as occupational, household activities, transportation activities, personal care and leisure-time (including, recreational activities, competitive sports, and exercise/exercise training). “*Exercise*” is a subset of PA that involves purposive, structure, and repetitive movements with the aim of improving or maintaining one or more components of physical fitness (i.e., cardio-respiratory and muscular fitness). It is carried out in a more structured manner, often performed at a greater intensity (more vigorous) (Dishman, et al., 2004; WHO, 1995).

It is clear from these definitions that PA has an impact on EE, and the extent to which body movement leads to EE is dependent on body size and body composition (Plasqui & Westerterp, 2007). Experts recommend all children and youth should be physically active daily as part of play, games, sports, work, transportation, recreation, physical education, or planned exercise in the context of family, school, and community (e.g., volunteer, employment) activities (Tremblay, Warburton, et al., 2011).

5.2 Dimension of physical activity

Assessing PA is fraught with difficulties as it is multidimensional, and no single method can capture all subcomponents and domains in the activity of interest. In general, PA is commonly described as having the following 4 main dimensions (Dishman, et al., 2004; Harro & Riddoch, 2004):

Duration: refers to a time of participation in a single bout of PA (Caspersen, et al., 1985). *Intensity*: refers to a physiological effort associated with participating in a special type of PA (Caspersen, et al., 1985). According to health benefits, higher-intensity activities require less time spent participating in that activity, whereas lower-intensity activities require more time spent participating in the activity (see Figure 4). In general, EE is commonly used to determine PA intensity, while quantitative information on total daily EE (TEE) expressed as units of EE (i.e., kcal or kj). There are three principal components of human TEE: basal metabolic rate (BMR or resting EE), diet-induced thermogenesis, and PA (the most variable component of TEE). The metabolic equivalent (MET) is a widely used physiological concept that represents a simple procedure for expressing energy cost of physical activities as multiples of resting metabolic rate (RMR). MET is the ratio of a person's working metabolic rate relative to their RMR. One MET is defined as the EE for sitting quietly and is equivalent to a caloric consumption of 1 kcal/kg/hour. For the average adult, approximates 3.5 ml of oxygen uptake per kilogram of body weight per minute ($\text{ml.kg}^{-1}.\text{min}^{-1}$) or $4.184 \text{ kJ.kg}^{-1}.\text{h}^{-1}$ (Ainsworth et al., 2000; Burniat, Cole, Lissau , & Poskitt, 2002; G.J. Welk, 2002). A comprehensive listing of the MET levels for various form of PA known as the compendium of physical activities was published to provide some consistency with the way that physical activities are quantified (Ainsworth et al., 1993; Ainsworth, et al., 2000). *Frequency*: is the number of events of PA during a specific time period (Caspersen, et al., 1985). *The type or mode*: refers to the form of the activity, its rate or pace, and its continuity (Dishman, et al., 2004).

The amount of energy expended in PA can be expressed as total energy (kJ) or work performed (watts), however MET is commonly used for the estimating EE under free-living PA. Levels of habitual PA in human are generally classified into three categories, and example of activities by specific intensity relative to the definition of a MET in the compendium of physical activities (Ainsworth, et al., 2000) are shown as below:

1. Light-intensity activities: (< 3 METs), for example:
 - walking from house to car or bus

- printing (standing)
- playing guitar, classical, or folk (sitting)
- ironing
- fishing from boat, sitting

2. Moderate-intensity activities: (3-6 METs), for example:

- walking briskly
- swimming, leisurely, not lap swimming, general
- bicycling < 19.3 km/h
- sweeping garage, sidewalk or outside of house

3. Vigorous-Intensity Activities (including to very vigorous): (≥ 6 METs), for example:

- walking 8 km/h, jogging, general
- running, stairs up
- stair-treadmill, ergometer, general
- bicycling, 19.3-22.4 km/h, leisure, moderate effort
- swimming, butterfly, general

5.3 Sedentary behaviors

Sedentary behavior refers to activities that do not increase EE substantially above the resting level (RMR) and includes activities such as sleeping, sitting, lying down, and watching television, and other forms of screen-based entertainment. Operationally, SED includes activities that involve EE at the level of 1.0-1.5 METs (Ainsworth, et al., 2000; Dietz, 1996; Pate, O'Neill, & Lobelo, 2008). Recently, the development of accelerometry as an objective measure of PA has opened up new possibilities for studying the health effects of all intensity levels of PA, including a very low level of EE such as SED. Researchers now can measure the entire range of human activity, from completely sedentary to very vigorous, in free-living subjects over a number of days (Pate, et al., 2008).

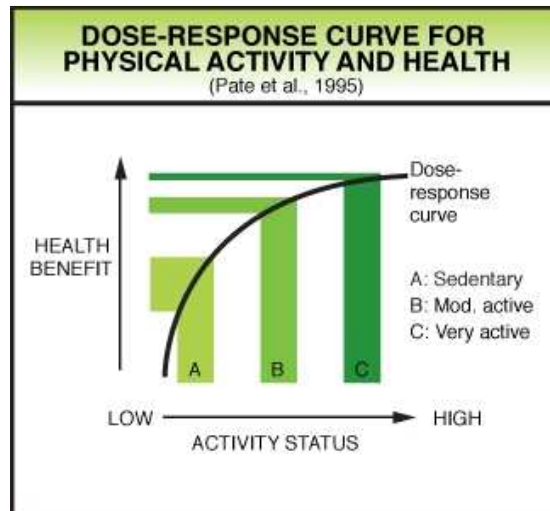


Figure 4. The benefits of changing sedentary people to exercising people have the greatest potential for public health benefit.

(Adapted from Pate, R. R., Pratt, M., Blair, S. N., Haskell, W. L., Macera, C. A., Bouchard, C., et al. (1995). Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*, 273(5), 402-407.)
(Pate et al., 1995)

6. Health benefits of physical activity in children and adolescents

Regular PA has been shown to have many health benefits in all age groups. Some of the benefits to young people include develop healthy musculoskeletal tissues (i.e., bones, muscles and joints) (D. A. Bailey & Martin, 1994), develop a healthy cardiovascular system (i.e., heart and lungs), develop neuromuscular awareness (i.e., coordination and movement control) and maintain a healthy body weight (Dietz, 1996; Hallal, et al., 2006; Hill & Wyatt, 2005). PA has also been associated with psychological benefits in young people by improving their control over symptoms of anxiety and depression. Similarly, participation in PA can assist in the social development of young people by providing opportunities for self-expression, building self-confidence, social interaction and integration. Additionally, it has also been suggested that physically active young people more readily adopt other healthy behaviors (e.g., avoidance of tobacco, alcohol and drug use) and demonstrate higher academic performance at school (Burniat, et al., 2002; G.J. Welk, 2002; WHO, 2012).

Excess weight has both immediate and long-term consequences and the current issue demands serious attention. According to the relationship between PA and OW/OB, both cross-sectional and longitudinal studies show that weight gain occurs as a result of energy imbalance, specifically when a child consumes more calories than the child uses (Ravussin et al., 1988; WHO, 2000). Several behaviors can contribute to weight gain including nutrition, PA (L. Li, Li, & Ushijima, 2007; Ruiz et al., 2011), and SED (Must & Tybor, 2005). Habitual PA also prevents the development of coronary artery disease (CHD) and reduces symptoms in patients with established CVD (Berlin & Colditz, 1990; Lakka & Salonen, 1992), and some of the beneficial role of PA may result from its effects on the improvement in endothelial function, inhibition of platelet aggregation and improved insulin sensitivity (Helmrich, Ragland, & Paffenbarger, 1994).

7. Physical activity and health-related physical fitness in children and adolescents

Physical fitness is an attribute that has a genetic basis but is also sensitive to changes in type and amount of PA, especially as people age (Dishman, et al., 2004). Physical fitness refers to the full range of physical qualities (cardio-respiratory fitness, muscular strength, speed of movement, agility, coordination, and flexibility). It can be understood as an integrated measurement of all functions (skeleton-muscular, cardio-respiratory, hemato-circulatory, psycho-neurological and endocrine-metabolic) and structures involved in the performance of PA and/or physical exercise (Castillo Garzon, Ortega Porcel, & Ruiz Ruiz, 2005).

Health-related physical fitness includes the five major components of fitness directly related to improvement of health: cardio-respiratory fitness, muscular strength, muscular endurance, flexibility, and body composition and there is increasing evidence that high levels of fitness during childhood and adolescence have a positive influence on adult health status (Malina, 2001; Ruiz et al., 2009). Body composition is a health-related physical fitness component that relates to the relative amounts of muscle, fat, bone, and other

vital parts of the body (Corbin & Lindsey, 1994). In order to achieve the objectives of this thesis, body composition was the only factor taken to determine the health-related physical fitness in adolescents.

7.1 Body mass index

Body Mass Index (BMI) is a weight-to-height ratio which is calculated by dividing the body weight in kilograms by the height in meters squared (kg/m^2). BMI does not measure body fat directly, but it is a reasonable indicator of body fatness for most children and adolescents. Importantly, BMI is strongly associated with measures of adiposity derived from dual energy x-ray absorptiometry (DEXA) in children and adolescents (Lindsay et al., 2001; Mei, et al., 2002; Pandit, et al., 2009; R. W. Taylor, et al., 2002) to both percent fat ($r = 0.83\text{--}0.94$; $p < 0.0001$) and fat mass ($r = 0.96\text{--}0.98$; $p < 0.0001$) (Lindsay, et al., 2001). Measurement of BMI is cheaper, technically far easier and, given that variability on repeated measurements of height and weight should be low, likely to be more precise than either BF or fat mass. The results of a previous study also support the use of BMI as a fatness measure in groups of children and adolescents (Pietrobelli et al., 1998). Therefore, BMI is the one most commonly recommended and widely used for classifying OW/OB in children and adolescents (Dietz & Robinson, 1998; Pietrobelli, et al., 1998).

7.2 Body fat percentages

Body fat (BF) is a compound comprised of glycerol – a substance formed in fatty acids – and fatty acids which is required as a concentrated energy source for our muscles. Fat is a storage substance for the body's extra calories and it fills fat cells (adipose tissue) that help insulate the body. Obesity is defined as excessive fat accumulation to the extent that health may be impaired (WHO, 2000). Declines in PA are associated with increases in BF and BF tends to accumulate during adolescence (Dencker et al., 2006; L. Li, et al., 2007). BMI is strongly correlated with %BF in both boys and girls ($r = 0.89$, $p < 0.01$) (Pandit, et al., 2009).

Recently, McCarthy et al. have developed age- and gender-specific cut-offs for %BF in 5- to 18-year-old children to define regions of '*underfat*', '*normal*', '*overfat*' and '*obese*' are set at the 2nd, 85th and 95th centiles (McCarthy, Cole, Fry, Jebb, & Prentice, 2006). These cut-points have been designed to yield similar proportions of overweight/overfat and obese children to the IOTF BMI cut-off points (Cole, et al., 2000).

7.3 Waist circumference

The BMI is used as an indicator of overall adiposity, whereas waist circumference (WC) has been advocated as an indicator of central obesity because it is a good predictor of abdominal fat (Pouliot et al., 1994). The interest in WC stems from research linking accumulated visceral adipose tissue to increased health risks and metabolic disorders in children and adults, and the use of BMI and WC for the prediction of risk factor clustering among children and adolescents has significant clinical utility (Katzmarzyk et al., 2004; Reilly, 2005). The optimal WC and BMI thresholds for predicting risk factor clustering among 5-18 years old children also does exist (Katzmarzyk, et al., 2004).

8. Physical activity guidelines for children and adolescents

The lack of PA can lead to obesity and many other health problems as mentioned before. Some daily physical activities, such as walking, running, bicycling, household chores, gardening, and many others are free or low-cost and do not require special equipment, and can be done almost anywhere; additionally, emerging scientific evidence suggests that routine PA has been shown to significantly improve the health outcomes for children and adolescents (Hallal, et al., 2006). MVPA (≥ 3 METs) is deemed to be the minimum intensity required to produce health benefits. Moderate-intensity activity is generally equivalent to a brisk walk and noticeably accelerates the heart rate, whereas vigorous-intensity activity is exemplified by jogging (see Topic 7.3 *physical activity levels*), and causes rapid breathing and a substantial increase in heart rate (Ainsworth, et al., 2000; Armstrong & Bray, 1991; Haskell et al., 2007).

In the last decade, therefore, much effort has been put into the development of PA guidelines (PAG) for children and adolescents (Cavill, et al., 2001; Martinez-Gomez, et al., 2010; Strong, et al., 2005; Tremblay, Leblanc, et al., 2011). These guidelines refer to the minimum levels of PA required for positive health benefits. New science was added to our understanding of the biological mechanisms by which PA provides health benefits and the PA profile (type, intensity, and amount) that is associated with enhanced health and quality of life. The intent of the original recommendation has not been fully realized whereas physical inactivity and SED remain a pressing public health issue (Haskell, et al., 2007).

In 2011, therefore the Canadian Society for Exercise Physiology (CSEP) has developed the new Canadian PAG for children and youth. This new guidelines recommend children (age 5-11 years) and youth (age 12-17 years) should accumulate at least 60 minutes of MVPA daily, this should include vigorous-intensity activities at least 3 days per week and activities that strengthen muscle and bone at least 3 days per week (Tremblay, Warburton, et al., 2011). Furthermore, to limit time spent in sedentary activities, the SED guidelines published in the same year (Tremblay, Leblanc, et al., 2011), state that children and youth should limit the time they spend being sedentary each day (to no more than 2 hours per day); for instance, limiting recreational screen time, sedentary (motorized) transport, extended sitting time, and time spent indoors such as watching TV, playing video/computer games (Tremblay, Leblanc, et al., 2011). These recommendations can provide young people with important physical, mental and social health beneficial outcomes. Importantly, we have limited research to date that really shows the practical information on the compliance with this new guidelines among children and adolescents, in particular, the rates of compliance between specific socio-demographic characteristics.

9. Socio-demographic characteristics and physical activity in children and adolescents

PA is one of the major lifestyle-related health determinants, and it has been shown to be influenced by the interaction among several factors (Gordon-Larsen, McMurray, & Popkin, 2000; Y. Li, et al., 2007; Sallis et al., 1992; W. C. Taylor & Sallis, 1997). Identifying determinants that are associated with levels of PA and with changes in PA levels (PALs) will help to develop specific prevention strategies. However, researchers usually focus on univariate relationships between single determinants and PA (Kohl & Hobbs, 1998), little empirical research has been done to determine the relationship between multivariate socio-demographic characteristics and behavioral characteristics and PA in child and adolescent populations.

Recently, a systematic review of the literature (Park & Kim, 2008) that addresses factors associated with adolescents' PA, which undertaken using a reference period between 1998 and 2008, found some evidence of associations between PA and the following variables: age, gender, parental education level, SES, self-efficacy, perceived benefits, perceived barriers, perceived behavior control, parental support, parent modeling, peer support, past PA, depressive symptoms, smoking, alcohol consumption, and environmental determinants. However, in this study (Park & Kim, 2008), some of the determinants are still difficult to conclude due to its limited studies and inconsistency. In addition most of all relevant studies relied on self-reported data, cross-sectional study designs with descriptive statistics, and they did not examine the interaction effects among variables or pathways of their effects. To achieve such limitations, Park et al. also have suggested that future studies should assess not only the relationships between the potential determinants and the behavior but also the relationships among the determinants as well as a multivariate approach to build the most useful prediction models, additionally, they should adopt a measurement approach that uses both self-report and objective measurements to measure predictive factors and determinants of PA (Park & Kim, 2008).

Some potential determinants of differences in PA among children and adolescents are shown as below:

9.1 Gender and age

Age and gender continued to be the two most consistent demographic correlates of PA behavior in children and adolescents (Dumith, Gigante, Domingues, & Kohl, 2011; Park & Kim, 2008). Adolescence is known to be a critical phase in life regarding PA change (Dumith, et al., 2011; Telama & Yang, 2000; Trost et al., 2002), while the timing and stage of puberty may also influence the prevalence of OW/OB. Moreover, there is evidence that the benefit of being active at an early age can carry over into adulthood as active children are more likely to become active adults (Strong, et al., 2005).

Generally, PALs is consistently higher in boys than in girls, and is inversely associated with age (Ammouri, Kaur, Neuberger, Gajewski, & Choi, 2007; Hallal, et al., 2006; Ruiz, et al., 2011; Trost, et al., 2002). However, there have also been inconsistent findings concerning the relationship between age and PA (Santos, Guerra, Ribeiro, Duarte, & Mota, 2003; Shi, Lien, Kumar, & Holmboe-Ottesen, 2006). For example, Santos and co-authors found an increase in MVPA time as age increases (Santos, et al., 2003).

Although differences between boys and girls on PA and the decline in PALs seems to be consistent in previous literature, it is not clear yet what are the factors related to this change. Furthermore, there may be an interaction between PA decline and gender with year of study and age at baseline (Dumith, et al., 2011). It is difficult to state if the PA decline is actually becoming greater in girls or in boys, or if this trend is an effect of the instruments used in the studies. This is important to explore in future studies.

Correlates of specific PA intensity are another inherent component that deserves further investigation, because its definition and instrument varied widely across studies (Dumith, et al., 2011). Again, urbanization and new technology are rapidly changing global lifestyles patterns, differences between boys and girls in the pattern of PA therefore may change over time, as well as an interaction with age. Based on all above mentioned findings, some limitations are pointed out for future research and investigations.

9.2 Race and ethnicity

In terms of PA, among boys, the proportion of adolescents to participate in MVPA varied little by ethnicity, a greater percentage of non-Hispanic white and Asian girls participated in MVPA, whereas the proportion is smaller for non-Hispanic blacks and Hispanics. However, results for physical inactivity (TV/video viewing and video/computer game use) show greater ethnic variability than for activity. The proportion of inactive adolescents is greatest for non-Hispanic black males and females and Hispanic males and females, and is lowest for Asian and non-Hispanic white females (Gordon-Larsen, et al., 2000).

9.3 Family socioeconomic status and background

It is often concluded that differences in SES are the cause of differences in health status and outcomes between population groups (Adler et al., 1994; Adler & Newman, 2002; Powell, et al., 2001). SES underlies three major determinants of health: health care, environmental exposure, and health behavior. Reducing SES disparities in health therefore will require policy initiatives addressing the components of SES (income, education, and occupation) as well as the pathways by which these affect health (Adler & Newman, 2002).

Mueller and Parcel states that SES is composed of two associated concepts (social stratification and social inequality) (Mueller & Parcel, 1981). The term "*social stratification*" refers to the process of organization of social systems (i.e., societies) where individuals, families, and groups are classified into hierarchies (i.e., social classes) according to for example their access to or control of education, wealth, prestige, power and the like. "*Social inequality*" refers to the fact that, in virtually all societies, critical social values (i.e., education, occupation, economic resources, prestige, power, information) are not uniformly distributed. Social inequality is a result of complex processes of social stratification that hierarchically distribute people according to their access to these values and resources. The relative position of individuals, families, and groups in a given hierarchy is frequently converted into a score produced by a scale, and SES is normally indexed by one or a combination of the following

prominent indicators: occupation, education, and income (Adler & Newman, 2002; Miech & Hauser, 2001; Mueller & Parcel, 1981).

SES has long been a prime predictive variable in epidemiological studies, including PA research, it is associated with mortality/morbidity rate and life expectancy, interestingly, this relationship is not limited to adults but also to young people. In many developed countries, among children and adolescents, low SES has been associated with increased morbidity and mortality for various health conditions, including OW/OB (Gissler et al., 2010; Wang et al., 2007; Wardle & Griffith, 2001). In terms of PA, Drenowatz et al. revealed that American children from families with lower SES are likely to spend less time participating in PA, engaged in more sedentary activities, and have a higher BMI than those from higher-SES families (Drenowatz et al., 2010). Another study of US sample has also reported that high family income was associated with increased MVPA [adjusted odds ratio (AOR): 1.43; CI: 1.22–1.67] and decreased inactivity (AOR: 0.70; CI: .59 –.82) among adolescents (Gordon-Larsen, et al., 2000). Also, in the findings of one study from Iceland, children of lower SES were found to have worse health and well-being than those of higher SES (Halldorsson, Cavelaars, Kunst, & Mackenbach, 1999). In contrast, one study conducted in Turkey – a Eurasian country located in Western Asia and in Southeastern Europe – reported that children and adolescents of low-SES families participated in more PA than their more economically advantaged counterparts (Kocak, Harris, Isler, & Cicek, 2002).

Interestingly, although health effects of relative SES occur across the whole range of the SES hierarchy, the burden is particularly great for those in poverty (Adler & Newman, 2002); unfortunately, there is limited empirical evidence investigate these relationships based on Asian data. In addition, choosing the best variables or approach for measuring SES should be dependent on consideration of the likely causal pathways and relevance of the indicator for the populations and outcomes under study. SES has traditionally been defined by education, income, and occupation in epidemiologic research. Bringing together with this 3 determinants are associated with an estimated 80

of premature mortality whereas the largest contribution is from behavior and lifestyle (Adler & Newman, 2002).

More information on the impact of SES on PALs/SED and health outcome may inform social policy and program design to effectively reduce health disparities in a socially and economically diverse society (Shavers, 2007), and future research on the effects of SES disadvantage and adolescents' status on their health for policy makers in developing countries, where limited resources make it crucial to use existing health care resources to the best advantage. Consequently, it is important to understand to what degree SES may affect an objective measure of PALs/SED, as well as its association with BMI.

9.4 Geographic location and neighborhood built environment

As mentioned above (See Topic 2.4 *"Differences in prevalence associated with geographical areas"*), childhood obesity prevalence also varies by geographic location (Borders, et al., 2006; Davison & Lawson, 2006; Jackson, et al., 2005; Nunez-Rivas, et al., 2003; Peytremann-Bridevaux, et al., 2007). In Thailand, levels of childhood obesity were about 3 times higher in urban areas (22.7%) than in rural areas (7.4%) (Sakamoto, et al., 2001). A number of previous studies have examined the influence of geographic location or neighborhood built environment on PALs of children and adolescents, and found that physical environments variables play an especially important role in their level of PA (Gordon-Larsen, et al., 2000; Loucaides, Chedzoy, & Bennett, 2004; J. Mota, Almeida, Santos, & Ribeiro, 2005; Shi, et al., 2006). More active children were reported to more significantly agree with the importance of the accessibility of shops, the social environment, neighbors with recreational facilities, and aesthetics (J. Mota, et al., 2005). Several previous studies showed that urban-rural difference is associated with children's PALs (L. J. Chen, Haase, & Fox, 2007; Davison & Lawson, 2006; Loucaides, et al., 2004), and geographic region also associated with the achievement of sufficient levels of PA (Butcher, Sallis, Mayer, & Woodruff, 2008).

In most of the developed countries, urban-rural areas demonstrated the strong and most consistent associations with PA behavior. Urban children are more active than rural children. One of the studies conducted in Cyprus reported that children in rural schools tended to have more space available in the garden and in the neighborhoods and safer neighborhoods than those in urban schools, whereas children in urban schools had more exercise equipment available at home and were transported more frequently to places where they could be physically active (Loucaides, et al., 2004). On the other hand, In China, urban boys spent significantly more time watching TV/video and/or playing PC games than rural boys, there was a similar but not significant trend among girls (Shi, et al., 2006).

Despite recognition of the important influence of environmental determinants on PAP, minimal empirical research has been done to assess the impact of environmental/contextual determinants of PA. There remains a need to better understand environmental influences and the factors that influence different levels of PA. Moreover, few studies have examined the association between environmental variables and level of PA in adolescent population.

9.5 School travel modes

Previous studies have found that active transportation to school (walking and bicycling) is associated with higher levels of PA (Cooper, Page, Foster, & Qahwaji, 2003; Tudor-Locke, Ainsworth, & Popkin, 2001) and is inversely related to obesity (Bassett, Pucher, Buehler, Thompson, & Crouter, 2008). While a growing urbanization, as well as the increased use of cars for private transportation, has had a great impact on modern life. At the same time, a safe use of bicycles as well as spaces for running is limited due to major streets and highways, therefore the opportunities to participate in regular PA tend to be more restricted (Gordon-Larsen, et al., 2000; Lob-Corzilius, 2007). People of all ages, including children and adolescents, are expending less energy on traditional forms of transportation such as walking and bicycling, and the popularity of cars, buses, and motorcycles is increasing (Wu, 2006). Moreover, children spent less time on active transport and also performed less total

moderate/vigorous activities, but they spent longer time on low-intensity activities and SED, including reading, computer use, video games, study, and inactive transport (Y. Li, et al., 2007).

Although there have been several recent studies of active school travel and PA (Cooper, Andersen, Wedderkopp, Page, & Froberg, 2005; Cooper, et al., 2003; Morency & Demers, 2010; Sirard, Alhassan, Spencer, & Robinson, 2008), but none has focused on adolescents and differences in school travel modes by specific group of demographic characteristics [i.e., school location (urban vs. rural), weight status (normal weight vs. OW/OB), SES (low, middle, high), age group (younger vs. older age groups) etc.]. Therefore it is important to consider how PALs and SED differ across school travel modes.

10. Surveys and surveillance of physical activity and sedentary behavior in children and adolescents

The increase in childhood OW/OB has led to the issue being labeled as a public health threat of the 21st century. Childhood overweight is influenced by a variety of factors on multiple levels (Burniat, et al., 2002; Sidik & Ahmad, 2004; Singh et al., 2007), and a number of OW/OB-related factors may change from year to year to account for this rise in childhood overweight. Survey and surveillance of PA behavior are essential components of the public health approach to promoting activity and helping to reduce obesity. OW/OB and PA are two health issues affecting young people. Data on the prevalence and distribution of PA (and SED) in the population, helps us to understand how to target interventions appropriately, and trend data can increase our understanding of the collective impact of interventions over time. The combination of epidemiologic, surveillance, and market data increases the capacity for achieving greater effectiveness in PA research and programs (Fridinger, Macera, & Cordell, 2002).

10.1 Global and Western prevalence

Globally, PA participation tends to decline with increasing age during adolescence, especially among girls (Kann et al., 2000; Pratt, Macera, & Blanton, 1999). This decline of PA is largely due to increasingly common sedentary ways of life (Ammouri, et al., 2007; Dumith, et al., 2011; Gordon-Larsen, et al., 2000; J. Mota, et al., 2005; Shi, et al., 2006).

Unfortunately, PALs are decreasing among young people in countries around the world, including those in developing countries. However, there are substantial variations across countries. Recently, across all 34 countries that participated in the Global School-based Student Health Survey (GSHS), most adolescents in developing countries do not meet the recommended 60 minutes or more of MVPA per day on at least 5 days per week. Only 23.8% of boys and 15.4% of girls met these recommendations, whereas the prevalence of sedentary lifestyle (excluding the time spent sitting at school and doing homework) is differed between countries and regions (Guthold, Cowan, Autenrieth, Kann, & Riley, 2010).

Across 9 European countries (Greece, Germany, Belgium, France, Hungary, Italy, Sweden, Austria, and Spain) participating in the HELENA cross-sectional study (Ruiz, et al., 2011) found a higher proportion of boys (56.8% of boys vs. 27.5% of girls) met these PA recommendations , whereas adolescents spent most of the registered time in SED [9 hours/day or 71% of the average registered time (12.8 hours/day)], and the trend in boys was similar to those in girls. Nevertheless, the prevalence of PA and SED varied significantly between countries and regions. The comparison between Southern and Central-Northern European regions revealed that adolescents from Central- Northern Europe were more active than their peers from Southern Europe; these differences seemed less pronounced in boys than in girls. While another study based on accelerometer measurements collected from defined areas in 4 European countries (Denmark, Portugal, Estonia, and Norway) has showed that boys tended to be more active than girls, and there is a marked reduction in activity over the adolescent years (between age 9 and age 15). The great majority of younger children (97.4%-97.6%) achieved those recommendations, whereas

fewer older children do so (62%-81.9%), particularly in older girls (Riddoch et al., 2004).

A cross-sectional phone survey of adolescents (aged 14-17 years) conducted in the 100 largest cities in the US in 2005 (Butcher, et al., 2008) showed that a majority of the girls and a large portion of the boys failed to meet the current guidelines – approximately 40% of girls (37%-42.3%) and 57% of boys (55.2%-57.9%) complied with those PAG. Interestingly, however, they did not find any significant differences between geographic regions (Northeast, Midwest, South, and West) whereas they did in European (Riddoch, et al., 2004) and developing countries (Guthold, et al., 2010) as mentioned above. In the 2000-2001 Canadian Community Health Survey (CCHS), based on the level of leisure-time PA measured by the questionnaire, a substantial proportion (50.3%-67.8%) of adolescents aged 12-19 years had classified as inactive group. In addition, 15.8% of all respondents watched TV more than 20 hours/week, and 13.3% reported using computer more than 15 hours/week (Koezuka et al., 2006).

10.2 Prevalence in Asia and Oceania

Data from the 2001 National Health Interview Survey (L. J. Chen, et al., 2007) showed that the percentage of Taiwanese adolescents (aged 12-18 years) in the sample met recommended amounts of PA for health (≥ 30 minutes/day and ≥ 3 times/week of PA that made adolescents breathe hard) is low (28.4%), particularly in girls and late adolescents (age 15-18). 36.9% of early adolescent (age 12-14) boys reached these recommendations, whereas less than 30% of late adolescents did so. In girls, 28.4% of early adolescents and only 21.8% of late adolescents met these recommendations. The majority of respondents (76.7%) reported sitting more than 8 hours each day and the proportion sitting more than 12 hours was over 30% (L. J. Chen, et al., 2007). Based on the 2001 international PA recommendations for youth established by Cavill et al. (Cavill, et al., 2001), in China, 44% of the 11- to 17-year-old Chinese youths failed to meet with these recommendations. There were no differences in the percentage active for other socio-demographic factors.(M. Li, Dibley, Sibbritt, Zhou, & Yan, 2007).

In Australia, using the 2004-national PAG that recommended all children and young people should participate in a minimum of 60 minutes of MVPA every day and should spend less than 2 hour per day using electronic media for entertainment (2-h EE). The results showed that 13.8%-15.7% of children failed to comply with the 60-minute guideline and 23.7%-36.5% of the sample spent longer than the 2-h EE, with respect to gender; whereas 7% of all respondents failed to comply with both recommendations. Prevalence of non-compliance with 2-h EE recommendations was significantly higher in older children (43.8%) than younger (24.8%-25.9%), boys compared with girls (36.5% vs. 23.7%, respectively), and low level maternal education (42.2%) compared with higher levels (27.2%-30.6%) (Spinks, Macpherson, Bain, & McClure, 2007). A similar study in China (M. Li, et al., 2007) mentioned that non-compliance with the 60-minute MVPA recommendation is not significantly associated with any socio-demographic variables. However, it is important to note that non-compliance with this guideline was associated with a 28% increase in overweight status.

10.3 Prevalence in Thailand

To date, very few studies have been conducted addressing prevalence of PA in Thailand, particularly in adolescent population; and most of them used subjective methods of measurement. To the best of our knowledge, there is no internationally published data on the prevalence of PA among Thai children and/or adolescents, and little is known about the socio-demographic and/or behavioral factors associated with PALs and SED. Moreover it is not clear whether the same determinants of PA for adolescents in most Western countries and other Asian countries would be relevant, given those reported-findings. Consequently, there is an urgent need for baseline data on the PAP of adolescents in Thailand in order to provide guidance for more effective nation's health promotion policies and programs, and for further international comparisons.

The only one published study (Nguyen, et al., 2008) showed that approximately 35.2% of the Thai children aged 12-18 years reported playing sports [i.e., football, running, badminton, swimming; range of 4.5-8 METs

(Ainsworth, et al., 2000)] more than 3 times per week, and 71.8% played sport more than 20 minutes each times. While approximately 42.2% of the sample reported participating in moderate-intensity PA (i.e., walking, bicycling, housework, and gardening) more than 5 times per week and 38.1% spent more than 30 minutes each time. Most of them have joined in SED (i.e., surfing the internet, online chatting, playing computer game, and watching TV); moreover, 45% of them reported do it every day. Interestingly, additionally, they spent an average of 5.5 hours a day on sedentary activities, while they should be limited to no more than 2 hours/day (Tremblay, Leblanc, et al., 2011). Furthermore, 81.3% of Thai children in the sample reported using their leisure time for SED, only 18.7% of them spent their leisure time for active activities such as sport and other moderate physical activities(Nguyen, et al., 2008).

In summary, prevalence of regular PA is influenced by a variety of factors on multiple levels. Using various types of data sources for assessing and monitoring PA behaviors on a population level adds to our ability to explain the relationships between individuals and their surrounding social and physical environments. Therefore, to reverse this OW/OB trend, it is reasonable that the childhood overweight epidemic will be most influenced by PA-related policies and educational programs that impact a variety of areas on multiple levels. However, it is widely thought that a greater understanding and surveillance of PAP in children and adolescents using a standardized protocol is needed (Biddle, Gorely, Marshall, Murdey, & Cameron, 2004).

11. Physical activity assessment in children and adolescents

As mentioned above, PA is very difficult to measure precisely under free-living conditions because it is complex and multi-dimensional behavior (Dishman, et al., 2004; Harro & Riddoch, 2004; G.J. Welk, 2002). Although a variety of methods exist to quantify levels of habitual PA during daily life, including objective and subjective measures (G.J. Welk, 2002); however, there exists no single assessment method for measuring PA which reflects all, or

even most, of its dimensions (G.J. Welk, 2002). PA has traditionally been measured with surveys and recall instruments; however, these techniques must be used cautiously in a pediatric population that has difficulty recalling such information (Sirard & Pate, 2001). Crude measures of PA may have led to inconsistent and false-negative results for the association of PA (or SED) and the variables of interest. The ability to accurately and reliably quantify the amount of PA and EE therefore has emerged as a critical component to weight management and the prevention of lifestyle related health problems. During the past 20 years, improved awareness of the health benefits of PA has pressured development, validation, and application of new tools to objectively monitor this behavior for the purpose of surveillance, intervention, or program evaluation (Pate, et al., 1995).

Objective PA measures have gained much attention lately to overcome limitations of self-report measures, especially in children and adolescents (Slootmaker, Schuit, Chinapaw, Seidell, & van Mechelen, 2009), up to date, however there is no single objective PA assessable instrument that is appropriate for all situations, populations, and research questions (McClain & Tudor-Locke, 2009). Instrument selection also is further complicated for those who study children's PA due to: (1) the challenge associated with detecting the typically short and sporadic nature of children's PAP, and short bursts of vigorous activity is believed to be the common pattern in children; this may become obscured by alternating periods of rest when the total value for the minute is calculated (R. C. Bailey et al., 1995; McClain & Tudor-Locke, 2009; G. J. Welk, Corbin, & Dale, 2000); (2) the diversity of developmental maturity/age among potential participants (i.e., from infants and toddlers to adolescents); and, (3) children's inherent curiosity regarding wearable technologies and the associated potential for reactivity to monitoring (McClain & Tudor-Locke, 2009).

Consequently, when selecting a measurement tool to assess children's PALs and sedentary time, researchers and practitioners must be aware of the strengths and limitations of each measurement and related-methodology across an array of environmental settings, because each of the measures has its own specific advantages and disadvantages. In some way, the combination of

methods might provide the best possible information. However, there has been little research concerning the use of multiple measures; this may be because administration of many methods can be burdensome to the participants, costly, and possibly more difficult to interpret (G.J. Welk, 2002). Therefore, an understanding of the strengths and limitations of each technique is required before choosing the appropriate assessment method for a specific research question.

In general, the selection of wearable monitors to measure human PA will depend on the study objectives, characteristics of the target population, and study feasibility in terms of cost and logistics. The desired outcome measure will also determine the specific instrument category, options, and features from which the ultimate instrument choice is made (McClain & Tudor-Locke, 2009). The basic advantages and disadvantages of the different techniques have been fairly well described and are summarized in Table 2. It provides a useful summary of the various methods used to assess human PA and EE.

Table 2. Advantage and disadvantages of various assessment methods

(Adapt from Welk, G. J. (2002). *Physical activity assessments for health-related research*. New York, USA: Human Kinetics Publisher, Inc.) (G.J. Welk, 2002)

Measurement methods	Advantages	Disadvantages
Self-report	- Captures quantitative and qualitative information - Inexpensive, allowing large sample size - Usually low participant burden - Can be administered quickly - Information available to estimate energy expenditure from daily living (i.e., Compendium of physical activities)	- Reliability and validity problems associated with recall of activity - Potential content validity problems associated with misinterpretation of physical activity in different populations
Pedometers	- Inexpensive, noninvasive - Potential for use in a variety of setting including workplace and schools - Easy to administer to large group - Potential to promote behavior change - Objective measure of common activity behavior (i.e., walking)	- Loss of accuracy when jogging or running is being assessed - Possibility of participant tamping - Are specifically designed to assess walking only

Table 2 (continued). Advantage and disadvantages of various assessment methods

Measurement methods	Advantages	Disadvantages
Activity monitor	- Objective indicator of body movement (acceleration) - useful in laboratory and field settings - Provides indicator of intensity, frequency, and duration - Noninvasive - Ease of data collection and analyses - provides minute-by-minute information - Allow for extended periods of recording (week)	- Financial cost may prohibit assessment of large numbers of participants - Inaccurate assessment of large of activities (e.g., upper-body movement, incline walking, water-base activities) - Lack of field-based equations to accurately estimate energy expenditure un specific populations - Cannot guarantee accurate monitor placement on participants during long, unobserved periods data collection
Heart rate monitor	- Physiological parameter - Good association with energy expenditure - Valid in laboratory and field settings - Low participant burden for limited record periods (30 minutes to 6 hours) - Describes intensity, frequency, and duration well (adults)	- Financial cost may prohibit assessment of large numbers of participants - Some discomfort for participants. Especially over extended recording periods - Useful only for aerobic activities
Direct observation	- Provides excellent quantitative and qualitative information - Physical activity categories established a priori, allowing specific targeting of physically activity behaviors - Software programs now available to enhance data collection and recording	- Time-intensive training needed to establish between-observer and within-observer agreement - Labor-intensive and time-intensive data collection, which limits the number of study participants - Observer presence may artificially alter normal physical activity patterns - Limited research reporting on validation of direct observation coding systems against physiological criteria
Indirect calorimetry and doubly labeled water	- Precision of measure - Ability to assess energy expenditure	- Invasive - Challenges associated with assessing patterns of physical activity - High relative cost

12. Rationale for consideration using accelerometers to measure physical activity and sedentary behavior in children and adolescents

Although there has been a rapid recent increase in both the number and type of objective PA assessment instruments which are commercially available to researchers, practitioners, and consumers. PA describes any body movement that substantially increases EE as mentioned before; motion sensors (i.e., pedometers and accelerometers) can be used to detect body movement and provide accurate estimates of PA and are probably the oldest tools available to measure body movement or PA; moreover, advancements in technology also have increased the sophistication, sensitivity and accuracy of these instruments (Sirard & Pate, 2001). The accurate measurement of PA is still critical for determining levels of PA; intensity, frequency and duration of daily PA are of particular interest within surveillance research due to their relationship to current PAG (Tremblay, Warburton, et al., 2011).

Accelerometers are sensors which measure the accelerations of body movements along reference axes (see Figure 5). They are widely accepted as useful and practical wearable devices capable of measuring and assessing PA. Most commercially available accelerometers are small, lightweight, portable, noninvasive, and nonintrusive devices that record motion in one or more planes and provide objective record and express considerable amounts of PA data (including frequency, intensity, and duration) over an extended period of time (K. Y. Chen & Bassett, 2005; Yang & Hsu, 2010). Accordingly, due to the above-mentioned its benefits, accelerometry-based activity monitors have become one of the most commonly used methods for assessing PA in either clinical/laboratory settings as well as under free-living conditions (P. Freedson, Pober, & Janz, 2005; Kelly et al., 2004; Murray et al., 2004; Nilsson, Ekelund, Yngve, & Sjostrom, 2002; Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004; Rowlands, 2007; Sirard & Pate, 2001; Trost, Loprinzi, Moore, & Pfeiffer, 2011).

A number of accelerometers, varying in size, shape, cost, sensitivity, and weight are commercially available such as, the Caltrac, MTI/CSA/GT1M (uniaxial), Actiwatch and Actical (biaxial), Tritrac, RT3, GT3X (triaxial). Typically,

accelerometers range in price from \$50 to over \$400 per unit. The large discrepancy in costs between brands, models and/or axial sensitivities of accelerometers are primarily associated with differences in features such as personal computer (PC) interface and download options, memory capacity, and data aggregation and storage methods. A principle difference between many accelerometers is their ability to download data and their mode of interface with a PC (McClain & Tudor-Locke, 2009). A principle difference between many accelerometers is their ability to download data and their mode of interface with a PC. However, there is relatively little functional difference between models, especially between the ActiGraph and the Actical, in terms of their internal piezoelectric sensors' ability to quantify accelerations associated with children's PA.

12.1 Function of the accelerometer

Accelerometers included for kinematic studies include piezoelectric, piezoresistive, differential capacitor, all of which implement the same basic principle of the spring mass system (K. Y. Chen & Bassett, 2005; Godfrey, Conway, Meagher, & G, 2008). Among all the types of commercially available accelerometers the most common one are piezoelectric accelerometers. They have a wide range of applications because they can provide high precision measurement for both low and high frequencies (K. Y. Chen & Bassett, 2005; Yang & Hsu, 2010). Piezoelectric accelerometers consist of a piezoelectric element with a seismic mass. A more detailed discussion of instrumentation and mechanical properties of accelerometer sensors is provided by Chen and Bassett (K. Y. Chen & Bassett, 2005) and Godfrey et al. (Godfrey, et al., 2008).

In brief, based on the Piezoelectric accelerometers, when the sensor is exposed to an acceleration, the seismic mass (which places force on the element) causes the piezoelectric element to deform (i.e., bend or compress depending on the structure of the particular sensor). This deformation produces a displaced and detectable electrical charge (positive or negative) to build up on one side of the sensor, generating a variable output voltage signal that is proportional to the applied acceleration (K. Y. Chen & Bassett, 2005; McClain &

Tudor-Locke, 2009). Voltage outputs are then converted into unit less numerical values typically called counts. “Counts” are a linear reflection of the sum of the voltage amplitude (i.e., a scalar measure of a wave signal's magnitude of oscillation) detected. Counts are summed and stored (i.e., for most instruments) over a relatively brief length of time (typically ranging from 1 second up to 60 seconds) which is known as an “epoch” or sampling interval (Bouten, Koekkoek, Verduin, Kodde, & Janssen, 1997; K. Y. Chen & Bassett, 2005; Godfrey, et al., 2008). However, it is also important to note that Piezoelectric accelerometers do not respond to the constant component of accelerations (Yang & Hsu, 2010).

A technical specification relating to the commercially available accelerometers are summarized in Table 3.

Table 3. Comparison of technical specifications for each type of commercially available accelerometers

(Adapted from Yang, C. C., & Hsu, Y. L. (2010). A Review of Accelerometry-Based Wearable Motion Detectors for Physical Activity Monitoring. *Sensors*, 10(8), 7772-7788.) (Yang & Hsu, 2010)

Function/ Model	SenseWear	CT1/RT3	AMP331	GT3X/ GT1M	StepWatch	activPAL	IDEEA
Size (mm)	88.4x56.4 x24.1	71x56 x 28	71.3x24 x37.5	38x37x18	75x5x20	53x35x7	720x54x17
Weight (g)	82.2	71.5	50	27	38	20	59
Accelerometer type	n/a	Piezoelectric	n/a	n/a	n/a	piezoresistive	piezoelectric
Number of accelerometer	1	1	2	1	1	1	5
Number of accelerometer axis	2	1/3	1 uni-axis and 1 dual-axis	3/1	2	1	2
Sensor placement	upper arm	waist	ankle	waist or wrist	ankle	thigh	chest, thigh, feet
Sampling rate	32 Hz	0.017 -1 Hz	n/a	30 Hz (12 bit)	128 Hz	10 Hz (8 bit)	32 Hz
Sensitivity rate	2g	n/a	n/a	0.05-2.5g	n/a	2g	5g
Battery type	1.5V AAx1	1.5V AAx1	n/a	3.7V Lithium ion/ Lithium polymer	750 mAh Lithium	3V li-polymer rechargeable	1.5V AA
Battery life	3 days	30 days	n/a	20 days	n/a	7-10 days	60 hours
Data transmission	RF/USB	USB (docking station)	916 MHz RF (USB wireless adapter)	USB	USB (docking station)	USB (docking station)	USB
Data storage capacity	n/a	up to 21 days	n/a	up to 40 days	up to 60 days	n/a	7 days
Reported parameters	EE estimation, activity duration, sleep duration	Activity intensity, EE, MET	Steps, cadence, walking speed, stride length, distance, EE	Activity counts, steps, MET, activity intensity level	Step gait characteristics	Sedentary and upright time, steps, stepping time, cadence, sit-to-stand activities, MET, PAL, kCal	Activity types, gait type, EE

In addition, descriptive characteristics, technical specifications and manufacturer details of 14 accelerometers used in published pediatric studies have also been outlined in the review provided by Reilly and colleagues (Reilly et al., 2008).

12.2 Feasibility and validity of accelerometer measurements to assess physical activity in children and adolescents

An inverse association between accelerometry-derived PA and clustering of metabolic risk factors has recently been observed in children (Brage et al., 2004). Importantly, therefore one of the challenges faced by researchers trying to promote PA is having access to accurate and practical instruments to measure PA. Valid measurement of PA in children and adolescents is challenging, largely due to the sporadic and intermittent nature of their activity behavior (R. C. Bailey, et al., 1995; McClain & Tudor-Locke, 2009; G. J. Welk, et al., 2000).

The ActiGraph, formally known as the CSA and MTI (LLC, Pensacola, FL, USA), is one of the most widely used accelerometers in PA research. It has been extensively and successfully used to assess PA in children and adolescents in both small and large scale epidemiological studies (de Vries, Bakker, Hopman-Rock, Hirasings, & van Mechelen, 2006; Eisenmann et al., 2004; Ekelund et al., 2001; P. Freedson, et al., 2005; Martinez-Gomez, Welk, Calle, Marcos, & Veiga, 2009; Puyau, Adolph, Vohra, & Butte, 2002; van Cauwenberghe, Labarque, Trost, de Bourdeaudhuij, & Cardon, 2011) due to its good reproducibility, validity and feasibility within these groups (de Vries, et al., 2006).

Many studies have developed and validated models with various accelerometers to predict activity EE during both structured, continuous PA and free play activity in different intensity levels among children and adolescents (Eisenmann, et al., 2004; Ekelund, et al., 2001; Evenson, Catellier, Gill, Ondrak, & McMurray, 2008; Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006; Plasqui & Westerterp, 2007; Puyau, et al., 2002; van Cauwenberghe, et al., 2011), the results showed that total EE estimated from some of the most widely accepted

methods of assessing PA [i.e., doubly labeled water (DLW), respiration calorimetry, a portable gas analyzer (Cosmed K4b²), indirect calorimetry] have been strongly correlated with uni-axial accelerometer data: Actiwatch ($r = 0.78-0.80$) (Puyau, et al., 2002), CSA ($r = 0.66-0.73$) (Puyau, et al., 2002), CSA ($r = 0.66-0.82$) (Pate, et al., 2006), Caltrac ($r = 0.22-0.82$) (Eisenmann, et al., 2004), MTI ($r = 0.50-0.78$) (Eisenmann, et al., 2004), CSA ($r = 0.39-0.58$) (Ekelund, et al., 2001).

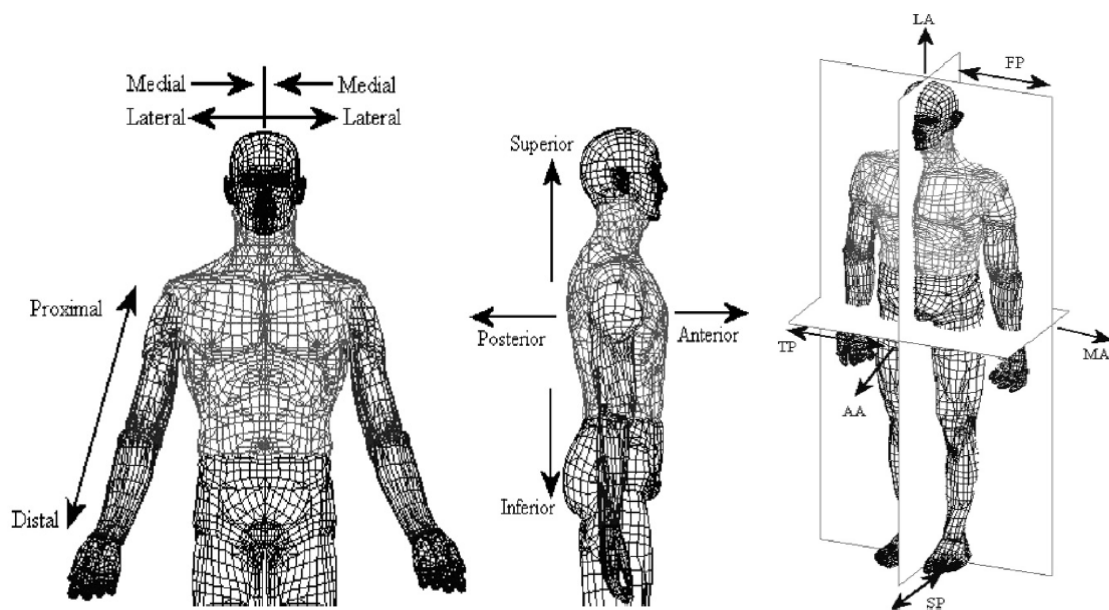


Figure 5. Anatomical terms used to describe position/direction and planes/axis.

(Adapted from Godfrey, A., Conway, R., Meagher, D., & G, O. L. (2008). Direct measurement of human movement by accelerometry. *Med Eng Phys*, 30(10), 1364-1386. (Godfrey, et al., 2008)

In addition, in 2011, van Cauwenberghe et al. have examined the feasibility and validity of the GT1M ActiGraph accelerometer during performed 11 structured activities (i.e., standing, slow walking, brisk walking, or jogging) and one free play session in preschool children. Receiver Operating Characteristic (ROC) curve analyses were used to determine the accelerometer cut points. Cut points were identified at 373 counts/15 seconds for light (sensitivity: 85.9%; specificity: 91.2%; Area under ROC curve: 0.95), 585 counts/15 seconds for moderate (87.2%; 82.2%; 0.91) and 881 counts/15 seconds for vigorous PA (87.5%; 91.3%; 0.94) (van Cauwenberghe, et al., 2011).

In summary, the above-mentioned studies suggest that the accelerometer is a currently valid tool for measuring PA in young people. They has been proven to correlate reasonably with most widely accepted standardized methods-derived EE, and notably the avoidance of bias, greater confidence in the amount of PA and SED measured. In addition, those studies also certify that ActiGraph accelerometer measurements are feasible and valid for quantifying PAP in children and adolescents.

12.3 Accelerometer cut-off points for predicting time spent in children's physical activity

The resulting epoch-by-epoch outputs of accelerometer counts can be utilized in their raw form as a measure of activity volume (i.e., total counts) or activity rate [i.e., counts/minute (cpm)]. Accelerometer counts can also be transformed and/or re-coded to derive frequency, intensity and duration of PA, or PA energy expenditure (PAEE) estimates based on validated prediction models or count cut-points (P. Freedson, et al., 2005; McClain & Tudor-Locke, 2009; G. J. Welk, 2005). Certainly, the use of wearable monitors to partition total activity into sedentary, light, moderate, and vigorous levels of PA has many useful applications in research, public health, and policy (Butte, Ekelund, & Westerterp, 2012).

With numerous accelerometer devices available on the market and multiple regression equations developed for each device, it is often difficult to select the device and regression equation that will be most appropriate for a specific study (K. Y. Chen & Bassett, 2005). In addition, the findings reported by Mota et al. (J. Mota et al., 2007) have clearly shown that compliance with a specific PAG (Cavill, et al., 2001) will depend on the cut-points used for interpreting PA data. In the last decade, several age-specific activity thresholds have been suggested for children and adolescents with different accelerometer cut-points proposed (P. Freedson, et al., 2005; Hoos, Plasqui, Gerver, & Westerterp, 2003; Puyau, et al., 2002; Schmitz et al., 2005; Sun, Schmidt, & Teo-Koh, 2008; Treuth et al., 2004; Trost, et al., 2002). Although a number of different EE prediction equations for both METs and gross EE exist in these

studies using minute-by-minute accelerometer output, however choosing an appropriate cut-point to define PA intensity levels, researchers and practitioners must be aware of the strengths and limitations of each methods and related methodology across an array of environmental settings.

In 2006, Guinhouya et al. have examined the discrepancies in accelerometry cut-off points of MVPA levels between the use of the 2 methods (the 2002-Puyau's method vs. the 2002-Trost's method) in 8- to 11-year-old children, using the Actigraph (model 7164) to measure daily time spent (in minutes) in specific intensity of PA (MVPA). In both boys and girls, the results indicate a high difference in the time spent engaged in MVPA (Trost's method displays significantly higher MVPA time than Puyau's method, with a mean error or bias of 113 minutes/day $p < 0.0001$) and a low relationship [$r^2 = 0.49$, (Standard Error of Estimate; SEE = 0.71; $p < 0.0001$]; in other words, it is apparent that there was considerable lack of agreement between this two methods (Guinhouya et al., 2006). In 2007, additionally, Mota et al. (J. Mota, et al., 2007) have also examined the effects of 2 different cut-off points (the 1997-Freedson's method and the 2002-Puyau's method) on school-time spent in MVPA among children aged 8-16 years, based on the ActiGraph (model 7164) accelerometer data. The data analysis from Freedson's cut points clearly show that both genders engaged in significantly more MVPA when compared with Puyau's cut points, with a mean error or bias of 83.6-113.8 minutes/day ($p \leq 0.01$). Additionally, although the Freedson's cut-point tends to give higher prevalence estimates for compliance with the specific PAG (at least 60 minutes of MVPA/day) than do definitions based on the Puyau's cut-points, with a mean error or bias of 78.3%-82.1% ($p < 0.000$), probably because cut-offs are derived from a laboratory setting, while the Puyau's cut-points was originated in daily routine activities with target on sedentary activities rather than MVPA, which may lead to an under-estimation of moderate activities (J. Mota, et al., 2007). The comparison study published in 2011 has also supported those previous findings that there has been statistically and biologically significant differences in the amounts of SED and PA when various accelerometer cut points were

applied to the same data (based on GT1M ActiGraph data) (van Cauwenberghe, et al., 2011).

A more recent study performed by Rothney et al. (Rothney, Schaefer, Neumann, Choi, & Chen, 2008) have compared three commercially available accelerometry-based activity monitors (ActiGraph, Actical, and RT3) and 7 EE prediction equations (including the Freedson's method) with measured values using a room indirect calorimeter in specific PA intensity categories among a heterogeneous group of healthy men and women (adult sample). They found that most existing EE prediction equations showed differences of less than 2% in the MVPA intensity categories; however, they also have suggested that though the differences in magnitude between these methods is small, may limit the ability of these regressions to accurately characterize whether specific PA goals have been met in the field setting (Rothney, et al., 2008). It is therefore important to note that the prediction errors of PA thresholds should be fully disclosed in future publications and documents.

For estimating the specific activity thresholds, the most common approach has been developed a regression equation that defines the linear or nonlinear relationship between accelerometer counts and EE. The brief descriptions of these references are listed in Table 4.

Table 4. Comparison of validation criteria from various calibration studies in children and adolescents.

[Adapt from (P. S. Freedson et al., 1997; Hoos, et al., 2003; Puyau, et al., 2002; Schmitz, et al., 2005; Sun, et al., 2008; Treuth, et al., 2004)]

Reference	Monitor	Subject	Equation for estimation EE
Freedson , Sirard, Debold, Pate, Dowda, Trost and Sallis (1997)	CSA	Children and Adolescents	EE (METs) = $2.757 + 0.0015 \times \text{counts per minute} - 0.08957 \times \text{age (yr)} - 0.000038 (\text{cpm}) \times \text{age (yr)}$;(SEE = 1.1 METs, $r^2 = 0.74$)
Puyau , Adolph, Vohra and Butte (2002)	CSA	Children	EE (kcal/kg/min) = $0.0183 + 0.000010(\text{counts})$;(SEE = 0.0172, $r^2 = 75\%$)
Puyau , Adolph, Vohra and Butte (2002)	Actiwatch	Children	EE (kcal/kg/min) = $0.0144 + 0.000038(\text{counts})$;(SEE = 0.0147, $r^2 = 81\%$)
Hoos , Plasqui Gerver and Westerterp (2003)	Tracmor2	Children	Physical activity level = $1.156 \times 10^{-5} \cdot \text{Tracmor2 average counts day}^{-1} + 0.978$;(r = 0.79, P < 0.01)
Treuth , Schmitz, Catellier, McMurray, Murray, Almeida, Going, Norman and Pate (2004)	CSA	Adolescents	EE (METs) = $2.01 + 0.000856 \times (\text{cpm})$;(SEE = 1.36 METs, $r^2 = 0.84$)

Table 4 (continued). Comparison of validation criteria from various calibration studies in children and adolescents.

Reference	Monitor	Subject	Equation for estimation EE
Schmitz, Treuth, Hannan, McMurray, Ring, Catellier, Pate (2005)	CSA	Adolescents	$EE (kJ \times min^{-1}) = 7.6628 + 0.1462 [(counts \text{ per minute} - 3000)/100] + 0.2371 (body \text{ weight (kg)}) - 0.00216 [(counts \text{ per minute} - 3000)/100]^2 + 0.004077 [((counts \text{ per minute} - 3000)/100 \times (body \text{ weight (kg)}))] ; (SEE = 5.61 kJ \cdot min^{-1}, r^2 = 0.85)$
Sun, Schmidt, Teo-Koh (2005)	RT3	Children and adolescents	$EE (kcal \cdot min^{-1}) = 0.00030397 (counts \cdot min^{-1}) + 0.00586272 (body \text{ weight}) + 0.58 ; (SEE = 0.38, r^2 = 0.58)$

13. Background of Thailand in brief

Thailand, officially the Kingdom of Thailand, formerly known as “*Siam*”, is a country located at the center of the Indochina peninsula and Southeast Asia – to its east lie Laos and Cambodia; to its south, the Gulf of Thailand and Malaysia; and to its west, the Andaman Sea and Burma. Its capital and largest population city is “*Bangkok*”. Thailand has 513,120 square kilometers or 198,115 square miles of surface area. It is similar in land size to France, Spain, Sweden and California State in the US. Thailand is the world’s 51st largest country in land mass, while is the world’s 20th largest country in terms of population (65.4 millions in 2011; approximately 32.1 million of male and 33.3 million of female). It is comparable in population to countries such as France and the UK. About 75% of the population is ethnically Thai, 14% is of Chinese origin, and 3% is ethnically Malay; the rest belong to minority groups including Mons, Khmers and various hill tribes. The country’s official language is Thai. The primary religion is Buddhism, which is practiced by around 95% of the population. Thailand experienced rapid economic growth between 1985 and 1995, and is presently a newly industrialized country and a major exporter. Tourism also contributes significantly to the Thai economy, as the country is home to a number of well-known tourist destinations.

In 2010, Thailand is divided into 77 provinces (“*changwat*”) which are gathered into 5 groups of provinces by location and geography, partly corresponding to the provincial groups (North, East, Northeast, Central, and West and South). The Northeast is the largest region in term of its population

(21.6 million or 33.9%) and surface area (168,854 km² or 33.17%). Approximately 6 million children and adolescents (5-19 years old) are living in the Northeastern region. Each province is divided into districts (“*amphoe*”) and the districts are further divided into sub-districts [“*tambon(s)*”] (NSO, 2010; Wikipedia, 2012).



Figure 6. Map of Thailand: divided by provinces.

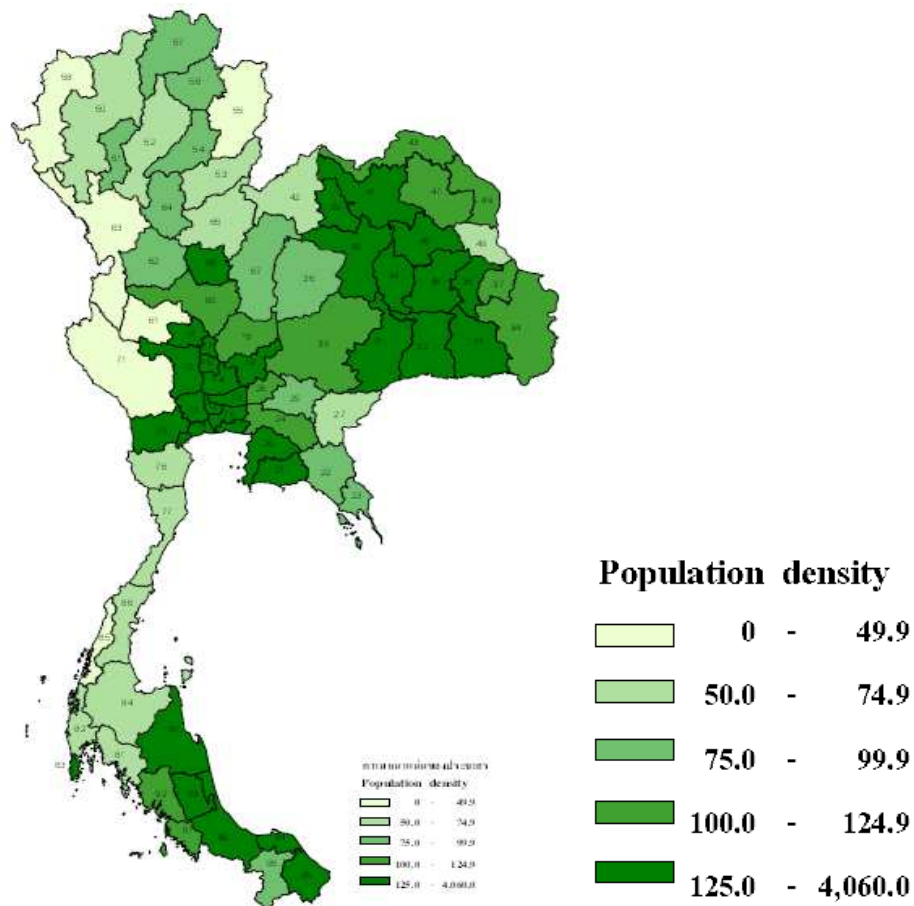


Figure 7. Population density by provinces (per square kilometer) in Thailand, 2000.

(Adapted from The 2000 population and housing census, National Statistical Office, Office of the Prime Minister, Thailand (NSO. (2010). A survey of the population. from <http://www.nso.go.th/>) (NSO, 2010)

14. Rationale and Significance of the Study

As all the above-mentioned studies, during the past decade, the prevalence of childhood obesity is increasing rapidly worldwide, especially in developing countries and countries undergoing rapid industrialization. Interestingly, the highest rate of OW/OB in Asia is in Thailand. A strong body of evidence exists to support the importance of PA in promoting health and preventing and treating diseases, particularly to obesity. However, there are many factors that may influence PA and therefore can be identified as contributors to childhood obesity. While the public health burden of sedentary

behaviors is huge and it is important to target the right population when planning interventions.

OW/OB are shown to track from childhood to adulthood, thereby influencing not only the current health but also long-term health. To date, there are relatively limited data evaluating which PA intervention is most effective in child obesity treatment. Unfortunately, the exposure assessments in PA epidemiology are often crude which can contribute to inconsistent results among studies due to a complexity and multi-dimension of PA. Accurate measurements of PA are crucial to our understanding of the activity-health relationship, estimating population prevalence, identifying correlates, detecting trends, and evaluating the efficacy of interventions.

Epidemiological data suggest that activity levels generally increase from middle childhood into early adolescence, and then they tend to decline; in other words, adolescence is a critical period in which initiation and formation of health behaviors occur, which can continue into adulthood. Consequently, the results of this thesis might contribute to knowledge which may help to change the quality of life for many people of all age groups in later adolescence. In order to further understand the relation between health and PA it is of great importance to have valid methods for measuring PA. Additionally, periodical screening of the prevalence of OW/OB among adolescents is required in order to monitor patterns and trends. Also, a large scale study that establishes age- and gender-specific BMI cut-off points internationally in children and adolescents is highly recommended. Such a study would enable us to estimate OW/OB with more accuracy.

As mentioned before, despite the existence of international guidelines for health-enhancing PA, no study to date has used accelerometers to assess the PA level and patterns of adolescent population, including in Thai sample; whereas the resources to promote more health-enhancing PA in this age period are also limited, and must be utilized effectively. To enable the government authorities involvement to plan new development or improve existing health interventions in a manner most conducive to healthy living, to be able to follow trends and evaluate interventions, valid and feasible instruments that can

measure most types and dimensions of human PA such as accelerometers are needed to assess the levels and patterns of health-enhancing PA in adolescents.

With using accelerometer-based activity, the findings of this thesis may contribute towards a better understanding of adolescents' PAP and compliance with the current guidelines and their related determinants. Potential subgroups of adolescent sample that exist according to their activities and the factors that influence these behaviors is also critical in order to develop interventions and messages that might reverse the increasing trend of childhood obesity in Thailand, it can provide an insight into government authority involvement in adolescent issue. In addition, this comprehensive study investigates inter-relationships between different health behaviors and obesity, including the relationships between PA and SED, as well as interaction effects between PA and SED on OW/OB. Therefore, the studies in this thesis will add knowledge about complicated relationships between obesity and obesity related-health risk factors and provide some implications for future interventions for obesity. Furthermore, the findings of this thesis provide various opportunities for future research into OW/OB and PA among adolescents in both Thailand and other developing nations, particularly those in the Asia-Pacific region. More importantly, the findings of 4 studies in this thesis were significant in that they attempted to answer some of the questions which have been overlooked or avoided in the research literature regarding adolescents' socio-demographic characteristics and their patterns of PA and SED. To the best of my knowledge, it is also important to note that this may be the first study in Thailand using an accelerometer to measure PAP in adolescents.

15. Objectives of the Study

Based on all of the above-described background, the main objectives of this thesis were to examine the association between objectively measured PALs and patterns according to socio-demographic characteristics in Thai 13- to 18-

year-old adolescents. The titles and specific objectives of each paper are presented in Table 5.

Table 5. The titles, specific objectives, and status of each paper included in the thesis.

Paper I	Title: Differences between weekday and weekend levels of moderate-to-vigorous physical activity in Thai adolescents. Authors: Kurusart Konharn K, Maria Paula Santos, José Carlos Ribeiro. Aims: 1) to determine differences in time spent in objectively assessed moderate-to-vigorous physical activity (MVPA) levels by gender and age, of adolescents during weekdays and weekends; and, 2) to use objective monitoring of MVPA to determine the non-compliance and compliance of adolescents with physical activity guidelines. Status: Submitted in Asia-Pacific Journal of Public Health (<i>Status: Under Revision</i>).
Paper II	Title: Differences in physical activity levels between urban and rural school adolescents in Thailand. Authors: Kurusart Konharn, Maria Paula Santos, Christopher Young, and José Carlos Ribeiro. Aims: To examine the differences in objectively measured physical activity levels between urban and rural adolescents, and to determine the percentages of a sample that complied with recommended physical activity guidelines. Status: Submitted in Journal of School Health (<i>Status: Awaiting Reviewer Scores</i>).
Paper III	Title: Associations between school travel modes and objectively measured physical activity levels in Thai adolescents. Authors: Kurusart Konharn K, Maria Paula Santos, Christopher Young, José Carlos Ribeiro. Aim: To determine the association between school travel modes and objectively measured PA of adolescents. Status: Submitted in Asian Journal of Sports Medicine (<i>Status: Under Review</i>).
Paper IV	Title: Socioeconomic Status and Objectively Measured Physical Activity in Thai Adolescents. Authors: Kurusart Konharn K, Maria Paula Santos, José Carlos Ribeiro. Aim: To evaluate the association between socioeconomic status and objectively measured physical activity in Thai adolescents. Status: Submitted in Journal of Physical Activity and Health (<i>Status: Under Revision</i>).

16. Structure of the thesis

This thesis is a collection of papers under editorial review or submitted to peer-reviewed scientific journals for publication. All 4 papers were written to stand alone, and each of them proceeded from a specific research question. Consequently, this may lead to some discontinuity or repetition in the manuscripts.

This thesis is divided into 5 main chapters, which are further subdivided into different chapters as follow:

Chapter I reviews the rationale and background of the theme and presents the significance and main objectives of the study.

Chapter II describes the adopted research methodology and procedure.

Chapter III provides four original papers, each presented in standard format respecting to the “*Normas e orientações para a redacção e apresentação de dissertações e relatórios (3ª Edição; Junho 2009)*” provided by The Scientific Council Board (Conselho Científico), Faculty of Sports, University of Porto

Chapter IV reports the general discussion where all main findings will be introduced and summarized.

Chapter V presents a summary of the findings and main conclusions and presents suggestions for areas for further research in regards to all of studies presented in this thesis. The final conclusion will be explained and some suggestions about future research will be proposed.

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CHAPTER II

METHODOLOGY AND PROCEDURE

CHAPTER II

METHODOLOGY AND PROCEDURE

1. Study design

This thesis was based on a cross-sectional study of Thai secondary-school adolescents and data collection took place between November 2008 and March 2009.

2. Theoretical and Conceptual framework

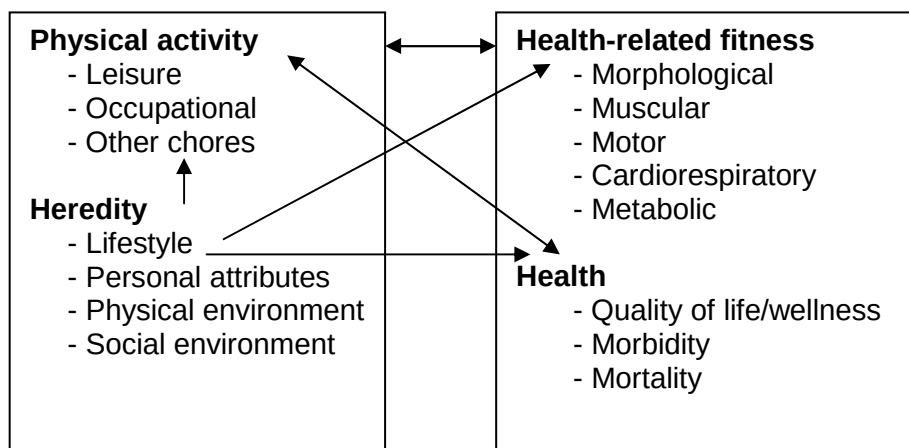


Figure 1. Plausible causal paths for physical activity, fitness, and health.

(Adapt from Dishman, R. K., Washburn, R. A., & Heath, G. W. (2004). *Physical activity epidemiology* (1 ed.). IL, USA: Sheridan Books. (Dishman, Washburn, & Heath, 2004)

3. Participants

3.1 Sites and recruitment of participants

A total of two hundred (100 boys and 100 girls) randomly selected adolescents (aged 13-18: grades 7-12) participated in the study, they were recruited from 8 randomly selected public secondary schools in the northeastern region of Thailand during the 2008/2009 school year. The schools were divided by their geographic location, that is urban and rural areas, and the participants were almost equally divided by gender, grade level, and age.

3.2 Eligibility Criteria

In order to achieve study objectives, the general inclusion criteria for the study population was the school-going adolescents who did not have any diagnosed movement or mental disability over the particular period the study was carried out. Any participants who were unable to participate in this study and/or had been told by a physician to avoid PA, or had some other medical contraindications were considered ineligible: such students being replaced with another eligible adolescent in the school with the same gender, age, and in the same grade level. A simple questionnaire was used to collect information on their socio-demographic characteristics.

Fourteen adolescents were excluded from further analysis regarding their inability to have the minimal wearing time which constitutes a valid day in PA assessment. Finally therefore, a total of 186 adolescents (93.0% of original) had been taken for analysis.

Table 1. Sample size and study variables.

	Recruited sample	Included to analysis sample	Study variables
Paper I	n = 200 (96 boys and 104 girls)	n = 186 (94 boys and 96 girls)	Weekday, Weekend, and Weekly and MVPA time
Paper II	n = 200 (96 boys and 104 girls)	n = 186 (94 boys and 96 girls)	School locations (urban vs. rural) and MVPA/Sedentary time
Paper III	n = 200 (96 boys and 104 girls)	n = 186 (94 boys and 96 girls)	School travel modes and MVPA time
Paper IV	n = 200 (96 boys and 104 girls)	n = 177 (89 boys and 88 girls)	Socioeconomic status and MVPA/Sedentary time

3.3 Research ethics

The study protocol received approval from the Ethical Committee of the Faculty of Sports, University of Porto. Prior to the measurement phase each participant's parent or guardian has provided written consent (written in Thai) and all participants gave verbal assent to participation. Well-trained research assistants explained the study procedures and measurements to the participants.

4. Participant's characteristic measurements

4.1 Adolescents

All participating adolescents reported their own socio-demographic characteristics in a simple questionnaire at school during class time under the supervision of researcher assistants, and information on their family background variables and parental characteristics were completed by one of their parents when participants took the questionnaire home.

For the purpose of this study, we used the number of inhabitants of the population area and national administrative areas to define urban and rural areas, which are determined by the National Statistical Office (NSO) in Thailand based on the Statistical Geographic Information System (SGIS) (Office, 2008) and on the definitions for administrative boundaries (Thailand, 2003). An area with a population of more than 10,000 registered residents with a density of more than 3,000 persons/km² is the cut-off value in the definition of urban area, and rural areas are defined as having a total of population of less than 10,000. These national administrative areas are the ones used in virtually all government activities, and for the collection and presentation of national statistical data.

Furthermore, it is important to note that Thailand is divided into 77 provinces (*changwat*), most of the provinces contain just one significant city or town (*amphoe muang*), which is the capital and officially declared as an urban area. Each province is subdivided into an average of about seven districts (*amphoe*), which are further subdivided into several sub-districts or group of rural villages (*tambon*) and municipalities used in local government. In this thesis therefore, all schools were selected based on this standard: the urban schools are located in the central part of the province (*amphoe mueang*) with at least 130,000 inhabitants living therein, and the rural schools are located in the rural villages (*tambon*) with less than 4,000 inhabitants living there. In addition, urban and rural schools in this study are located at least 50 km from each other.

In order to determine adolescents' PA of different modes for school travel, a brief questionnaire was used to assess socio-demographic

characteristics and specifically mode of transport to school (then, they were divided into 3 groups as; walking, bicycling, and motorized transport). Also, age was divided into 3 groups: 13-14 years, 15-16 year, and 17-18 years.

4.2 Parent or Guardians

A “parent” was defined as either the biological father and mother or legal guardian with whom the participant lived. Parents reported their SES and family characteristics (occupation to main annual household income, annual household income, number of siblings, and birth order of participant) into the questionnaire (written in Thai). Parental occupations were determined based on reported data in this study and categorized into 6 groups as follows: 1) agriculturist, 2) manual worker, 3) government official and retired, 4) unemployed and housewife, 5) merchant/business man and 6) national enterprise officer.

In general, indicators of SES are meant to provide information about an individual's access to social and economic resources. Among the most frequently used socioeconomic indicators are education and occupation. Economic indicators such as household income and wealth are used less frequently but are potentially as important as or more important than education and occupation. In a previous study we found that wealth and family income are the indicators that are most strongly associated with subsequent mortality, and economic components of SES should be a standard feature of the measurement system for monitoring links between SES and health (Daly, Duncan, McDonough, & Williams, 2002). Additionally, many previous research studies (Drenowatz et al., 2010; Raudsepp & Viira, 2000) have suggested that an income is the most influential economic factor of the family.

Thus, in our protocol, we did not classify the parental education and occupation based on SES, the annual household income [measured in Thai currency (Baht; THB)] was the only factor taken to determine the family SES. We divided SES into 3 groups based on the actual value of annual household income obtained from the parents: low (< 25,000 THB), middle (25,000-45,000 THB) and high (> 45,000 THB) or approximated < 800 USD, 800-1,500 USD

and > 1,500 USD, respectively (For rough calculation: 1 USD equals 30 THB). These 3 SES groups were determined by taking the mean annual household income at 33rd and 66th percentile – less than 33rd percentile belonged to the low-SES group, while at percentile of 33rd-66th was classified as middle-SES group, and above 66th percentile categorized as high-SES group.

Birth order was categorized into the first, the second or the third, and greater than or equal the fourth as in a previous study (Hallal, Wells, Reichert, Anselmi, & Victora, 2006), while the number of siblings was separated in 3 categories: one or none, two or three, four or more.

5. Anthropometric measures and Health-related physical fitness test

The research assistants were trained by the study's principal investigator and consultants to administer the measurements and collect the data in a standardized manner according to written protocols.

All anthropometric measurements were made twice and the means of paired values were used in the analyses.

5.1 Weight, Height and BMI

Body weight (kg) was determined with subjects wearing light clothes and no shoes or socks, using an analog scale (SECA 750; Hamburg, Germany), and height was measured using a portable stadiometer (SECA 242; Hamburg, Germany). All anthropometric measurements were taken during school hours in the morning between 8:00 and 9:00 AM, before the first day of PA data collection. Then, these parameters were used to calculate the BMI, using the formula: weight/height^2 (kg/m²). Because of the variability of BMI levels with age among young people, the IOTF international age- and gender-specific BMI cut-off points for children and adolescents developed by Cole et al. (Cole, Bellizzi, Flegal, & Dietz, 2000) were used as a definition of overweight and obese in the sample of this thesis. In addition, we have used BMI as the main outcome for assessing total overweight and obesity, participants were assigned for analysis

purposes to one of two BMI classified groups: normal weight group and overweight/obesity group (OW/OB).

5.2 Body fat percent

Body fat percent (%BF) was determined using bioelectrical impedance analysis (BIA). Whole-body BIA measurements were performed using a bioelectrical impedance analysis (Body Fat Analyse (BF-906); Maltron international Ltd, Essex, UK) with tetra-polar method in supine position with hands and legs slightly apart. Then it was decided, using the age-and gender-specific cut-off points for body fat (McCarthy, Cole, Fry, Jebb, & Prentice, 2006) , whether an adolescent was in the normal fat group or overly fat/obese group.

5.3 Waist circumferences

In this thesis, comprehensive insights are needed on the associations between objectively measured PA variables and OW/OB and central adiposity. While commonly used markers for overweight and adiposity are BMI and waist circumference (WC). Body mass index is a reasonable proxy for total obesity when used with IOTF cut-off values adapted to each age and gender, while WC is used to express central adiposity (McCarthy, Ellis, & Cole, 2003) and the use of tape to measure WC is reliable, consistent, and acceptable for data collection during clinical trials.

To determine adolescents' WC, therefore, the well-trained research assistants positioned the tape around the waist on bare skin immediately at a level of umbilicus in the horizontal plane of the participant. The tape was inspected to ensure it was not twisted, slacking, binding, or compressing the waist tissue. Each participant was instructed to inhale, exhale, and hold his or her breath at the end of the exhalation, and the measurement was made during normal expiration (Yamborisut, Kijboonchoo, Wimonpeerapattana, Srichan, & Thasanasuwan, 2008). With the tension release button of the tape measure depressed, the WC measurement was recorded (nearest 0.1 cm).

6. Physical activity assessment and Data reduction

6.1 Physical activity assessment using accelerometer

6.1.1 Instrument

To better address the impact of PA on health, valid and reliable instruments for its measurement are essential. Because of its dimensionality, a large number of methods exist for the assessment of various aspects of PA. Although the instruments such as doubly-labeled water (DLW) method and direct and indirect calorimetry are very precise in measuring TEE, but they tend to be impractical on a population basis. Moreover, one of the most important measuring limitations is that PA is difficult to assess under free-living conditions. Objective PA measures have gained much attention lately to overcome limitations of those techniques. Accelerometers, in particular, are currently used mainly in a research setting as well as in providing information on the amount, frequency, duration, and intensity of PA for an extended period of time. This may be the most appropriate PA assessment technique to use in a field setting. Consequently, the ActiGraph GT1M accelerometers (ActiGraph LLC, Pensacola, FL, USA) were used in this thesis to measure adolescents' PA and sedentary time.



Figure 2. The uni-axial ActiGraph accelerometer (GT1M).

6.1.2 What is the most appropriate epoch length on the measurement of adolescents' physical activity?

Accelerometer counts are summed and stored over a relatively brief length of time (typically ranging from 1 second up to 1 minute) called '*an epoch*' or '*sampling interval*' (Chen & Bassett, 2005). Instrument epoch lengths are either manufacturer-determined (i.e., unmodifiable) or researcher-selected (i.e., from a range of available epoch lengths), while the ActiGraph has a minimum

epoch length of 1 second (from 1 second to 240 seconds) (Trost, McIver, & Pate, 2005). Several studies have looked at what the most “ideal” epoch length is to use in children and adolescents, while respecting to technical tool limitations, some studies have used the 60-s epoch to record the habitual PA among children (Ortega, Ruiz, & Sjostrom, 2007; Riddoch et al., 2007). But, children and adolescents have specific movement patterns and tend to perform PA in short bursts rather than in prolonged bouts, and such bouts occur frequently (Bailey et al., 1995); in other words, one minute epochs are effectively too long to capture the majority of these bouts (Nilsson, Ekelund, Yngve, & Sjostrom, 2002). It is therefore recommended to use the epochs shorter than 1 minute for assessing PA in children and adolescents (Kelly et al., 2004; Nilsson, et al., 2002; Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006; Reilly et al., 2008; Trost, et al., 2005). Additionally, a recent study has indicated that different epoch times might affect prevalence rates of the time spent in MVPA among children and adolescents, and they strongly recommended that using a shorter epoch might be better adapted to the children/adolescents PAP than a higher epoch time (60-s) did (Edwardson & Gorely, 2010; Vale, Santos, Silva, Soares-Miranda, & Mota, 2009). In this thesis, all accelerometers were programmed and initialized to collect PA at a 30-second epoch setting.

6.1.3 How many days of monitoring are required to characterize adolescents' usual physical activity behavior?

A minimum number of days of monitoring are needed in order to produce an accurate assessment of the PA patterns. Up to the present there is limited evidence documenting recommended measurement periods for assessing PA in free-living conditions for children and adolescents. Moreover, there is still no consensus on how many days are acceptable to gain representative measures of daily life PA; however, in the previous literature, a 3 day range (Reilly et al., 2003), or 4 days (including 1 weekend day) to 7 days (Janz, Witt, & Mahoney, 1995; Ortega, et al., 2007), and up to 2 weeks (Montgomery et al., 2004; Riddoch et al., 2004) of monitoring period has been shown to produce reliable estimates of usual PA in children and adolescents. Whilst Trost and colleagues (Trost, Pate, Freedson, Sallis, & Taylor, 2000) have suggested that 7 days of

activity monitoring is a suitable duration for accurately and reliably estimating usual PA behavior in children and adolescents and accounts for potentially important differences in weekend versus weekday activity behavior as well as differences in activity patterns within a given day. Between 3 and 5 days of monitoring are required to achieve a reliability of 0.70, whereas between 5 and 9 days of monitoring would be necessary to achieve a reliability of 0.80, depending on the age groups. Within all grade levels (7-12), the 7-day monitoring protocol produced acceptable estimates of daily participation in MVPA [$r = 0.76$ (0.71-0.81) to 0.87 (0.84-0.90)]. On this matter, additionally, it has recently been suggested that as a minimum, studies in both children and adolescents aim for at least 4 valid days of monitoring including one weekend day (Corder, Ekelund, Steele, Wareham, & Brage, 2008).

At the time of data collection, 7 days of consecutive PA monitoring was regarded as standard practice in this thesis. After the testing period, the accelerometers were collected by the researchers and data (.DAT files) were uploaded onto the same computer used to initialize them: using Actilife Data Analysis Software (version 3.6 for Windows, ActiGraph, Pensacola, FL) that accompanied the accelerometers. The accelerometer data were then used for further analyses.

6.1.4 How many hours in the minimum accelerometer wear time requirement for a valid day?

Although the number of days is more important to reliability than the number of hours, recent research shows that reliability increased as the number of days and hours of monitoring increased. A monitoring period of 7 days for 10 hours per day produced the highest reliability [$r = 0.80$; 95% CI (70-86%)]. While the inclusion or exclusion of weekend days made relatively little difference (Penpraze et al., 2006)

Consequently, our participants were asked to wear the ActiGraph GT1M accelerometer for 7 consecutive days during all waking hours, and to only remove it during periods of bathing, showering, or other water-based activities.

6.1.5 Where should the accelerometer be placed for recording physical activity?

Accelerometers can be placed at various sites on the body, including the wrist, ankle, thigh, lower back, hip, waist, and umbilicus in order to assess human body movement (Cliff, Reilly, & Okely, 2009). Accelerometers record acceleration in different axes or planes of human movement. A single sensor is typically positioned in line with the vertical axis of the body (Chen & Bassett, 2005; G.J. Welk, 2002) and the relative position of the accelerometer on the body is another important consideration, given that the output from an accelerometer is dependent on the positioning on the body (G. J. Welk, 2005) and its orientation (Mathie, Coster, Lovell, & Celler, 2004). Hence selecting the appropriate location of the accelerometer becomes critical in PA recognition studies. To date, a small number of studies have specifically addressed the issue of monitor placement. Little evidence suggests that one position is better than another. So, it is still not clear where the accelerometer should be placed to produce an accurate recording of the activity level of the whole body. In many cases, the sensors are commonly placed on the sternum, lower back, and waist (Bouten, Koekkoek, Verduin, Kodde, & Janssen, 1997).

However, with regard to the wearing issues, most studies adopted waist-placement for motion sensors (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008; Puyau, Adolph, Vohra, & Butte, 2002; Sekine, Tamura, Togawa, & Fukui, 2000; Trost, Loprinzi, Moore, & Pfeiffer, 2011; Trost, et al., 2005), because of the fact that the waist is close to the center of mass of a whole human body, and the torso occupies the most mass of a human body. In addition, waist-placement causes less constraint in body movement and discomfort can be minimized as well.

Even though most waist-mounted accelerometers have pre-molded or manufactured plastic or metal belt clips which allow them to be easily attached to the waist line of clothing or to a belt, some accelerometers require the use of an additional elastic belt to properly fit the instrument to the wearer. Furthermore, although use of a separate elastic belt (in contrast to a manufactured on-instrument clip) may be considered as an additional burden to

some children (i.e., due to comfort, inconvenience, or fashion), both an instrument and elastic belt could easily be hidden from view of peers by simply wearing it under an un-tucked shirt, or other outer layers of clothing in most cases (McClain & Tudor-Locke, 2009). Affixing instruments to elastic belts may also actually allow children to more quickly and independently prepare, attach, and wear the instrument (e.g., in settings such a relatively brief physical education class); and may reduce the chance of a child inadvertently losing the accelerometer.

In this thesis, therefore, accelerometers were attached to an elastic belt that was securely fitted around the waist, with monitor positioned above the right iliac crest of participants.

6.2 Accelerometer data reduction

6.2.1 Data downloading and Analysis

In this thesis, data from the accelerometers were processed in ActiLife Data Analysis Software (version 3.6 for Windows, ActiGraph, Pensacola, FL) and data reduction, cleaning, and analyses of the raw accelerometer data were performed using a specially written program (MAHUFFe; MRC Epidemiology Unit, Institute of Metabolic Science, Cambridge, UK; available at http://www.mrc-epid.cam.ac.uk/Research/Programmes/Programme_5/InDepth/Programme%205_Downloads.html).

6.2.2 The minimum number of days and daily wearing time required for analysis

Although population-level surveillance studies typically ask participants to wear an accelerometer for 7 consecutive days (including necessarily both weekdays and weekend days), because of non-compliance the number of valid days varies among participants. Therefore the minimum daily wear time is another critical data reduction issue, because it affects the proportion of files that can be included in analyses (Colley, Gorber, & Tremblay, 2010). To date, unfortunately, no consensus has been reached on the minimum number of days

required to gain representative measures of habitual PA in children and adolescents, because the minimum must be high enough to eliminate days when the monitor was clearly not worn long enough to accurately depict PA, but low enough to prevent too many days from being eliminated, which would bias the sample and reduce sample size and statistical power (Colley, et al., 2010).

Consequently, to achieve some consistency, researchers have used various minimums for the number of valid days recommended for inclusion in analyses, ranging from fewer than 4 up to 7 full days. Previous research studies show this criteria is the most reliable ($r = 0.80$) measure of total PA as well as MVPA and SED among children and adolescents (Colley, et al., 2010; Penpraze et al., 2003; Trost, et al., 2000). Additionally, times where the accelerometer was removed were identified from the data by periods of ≥ 10 minutes of consecutive zero counts, making it unlikely that the monitor was worn (Masse et al., 2005).

At the end of the PA measurement process therefore data from an accelerometer was considered for further analyses if the participant wore it for at least 4 of the 7 days (comprised of at least 3 weekdays and 1 weekend day), and data for a given day was considered valid if the accelerometer was worn for ≥ 10 hours on that day, which is consistent with those previously published recommendations (Penpraze, et al., 2003; Trost, et al., 2000). Finally, a total of 186 adolescents (93% of the original participants; 92 boys and 94 girls) who provided the study with adequate amount of PA data - in accordance with the minimum daily wearing time and number of required days - were included in the further data analysis.

6.2.3 Accelerometer cut points for predicting activity intensity

The resulting epoch-by-epoch outputs of counts can be utilized in their raw form as a measure of activity volume (i.e., total counts) or activity rate (i.e., counts/minute). They can also be transformed and/or re-coded to derive frequency, intensity and duration of PA, or PAEE estimates based on validated prediction models or count cut-off points. Therefore, most accelerometer researchers have used count cut-points based on validation research to derive

time in intensity variables from raw count data (P. Freedson, Pober, & Janz, 2005; Matthew, 2005).

The most widely used and extensively validated accelerometer for assessment of PA among children is the ActiGraph (P. Freedson, et al., 2005). Many published pediatric studies have been developed for addressing specific accelerometer activity count cut-points (P. Freedson, et al., 2005; Puyau, et al., 2002; Reilly, et al., 2003; Treuth et al., 2004; Trost et al., 1998). Additionally, previous ActiGraph-based studies provided age-specific cut-points for children and adolescents (P. Freedson, et al., 2005; P. S. Freedson et al., 1997), whereas in the other two studies, the validation of the MTI/CSA certifies this monitor as a valid, reliable and useful device for the assessment of PA in children (Puyau, et al., 2002; Reilly, et al., 2003; Trost, et al., 1998). Freedson et al. (P. Freedson, et al., 2005; P. S. Freedson, et al., 1997) developed a regression equation to estimate EE (in METs) from the MTI/CSA (presently known as the ActiGraph) accelerometer counts and age where 6- to 18-year-old children used a treadmill at two different walking paces and one running pace. Others derived a cut point of different ages (Puyau, et al., 2002; Reilly, et al., 2003; Treuth, et al., 2004; Trost, et al., 1998) and respiratory gas exchange was measured using indirect calorimetry with ActiGraph worn on the hip and programmed to collect minute-by-minute activity counts. Resting EE was estimated from age-specific prediction equations to derive the metabolic equivalent of MET intensity levels.

Consequently in the present thesis, the following age-specific MET prediction equation developed by Freedson et al. (P. Freedson, et al., 2005; P. S. Freedson, et al., 1997) was used to determine cut-off points for estimating time spent in different intensities of PA, and SED:

Equation 1 :

$$\begin{aligned} \text{"METs"} = & 2.757 + (0.0015 \times \text{counts per minute}) - (0.08957 \times \text{age (year)}) \\ & - (0.000038 \times \text{counts per minute} \times \text{age (year)}) \\ & R^2 = 0.74, SEE = 1.1 \text{ METs} \end{aligned}$$

The amount of time spent (minutes/day) at each PA intensity level was calculated and presented as an average time per day during the complete registration. SED (< 1.5 METs), light PA (1.5-2.9 METs), moderate PA (3-6 METs), vigorous PA (> 6 METs) and very vigorous PA (> 9 METs) intensities were defined upon cut-off limits published elsewhere (Troost et al., 2002). Also, time spent in at least moderate intensity level (≥ 3 METs) was calculated to be the sum of time spent in MVPA. These cut-off points for defining the intensity categories are similar to those used in previous study (Ortega, et al., 2007). The proportion of adolescents who complied or did not comply with the current PAG of accumulating at least 60 minutes of MVPA per day [published by The Canadian Society for Exercise Physiology (CSEP) in cooperation with the ParticipACTION and other stakeholders (Tremblay et al., 2011)] was also estimated.

Table 2. Age-specific count per minute (cpm) cut-points adapted by Freedson et al's method.

(1.) Freedson, P., Pober, D., & Janz, K. F. (2005). Calibration of accelerometer output for children. *Med Sci Sports Exerc*, 37(11 Suppl), S523-530. 2.) Freedson, P. S., Sirard, J., Debold, E. P., Dowda, M., Trost, S., & Sallis, J. F. (1997). Calibration of the Computer Science and Applications, Inc. (CSA) accelerometer. *Med Sci Sports Exerc*, 29(5), 45.) (P. Freedson, et al., 2005; P. S. Freedson, et al., 1997)

Age		CPM		CPM		CPM		CPM	
13	Sedentary	100	Light	1399	Moderate	4381	Vigorous	7363	Very Vigorous
14		100		1547		4646		7745	
15		100		1706		4932		8158	
16		100		1879		5242		8606	
17		100		2068		5581		9093	
18		100		2274		5950		9627	

7. Statistical Analysis

All statistical analyses were carried out using SPSS Predictive Analytics Software (PASW) version 18.0 (SPSS Inc., Chicago, Illinois). The level of statistical significance was set at $p < 0.05$ (two-tailed testing) for all comparisons. Descriptive statistics were performed for all study variables. Discrete variables were expressed as percentages and continuous variables as mean ($\bar{x}$) $\pm$ standard deviation (S.D.). Different statistical tests were used with respect to the aim of each specific study. A summary of the statistical tests used in each paper in the present thesis is shown in Table 3.

Table 3. Statistical tests applied in the different papers.

Tests/Paper	Paper I	Paper II	Paper III	Paper IV
1.) Independent samples <i>t</i> -test	x	x	x	x
2.) Paired Samples <i>t</i> -test	x			
3.) One-way analysis of variance (1-way ANOVA) with Bonferroni post hoc test		x	x	x
4.) Chi-square test	x	x	x	x
5.) Two-way analysis of variance (2-Way ANOVA) with pairwise comparisons using independent samples <i>t</i> -test		x		
6.) Pearson product-moment correlation coefficient	x			x
7.) Point-biserial correlation coefficient				x
8.) Cramer's V coefficient test			x	x
9.) Partial eta-squared		x		
10.) Multinomial logistic regression			x	
11.) Two-way analysis of variance (2-Way ANOVA) with Bonferroni post hoc tests		x		

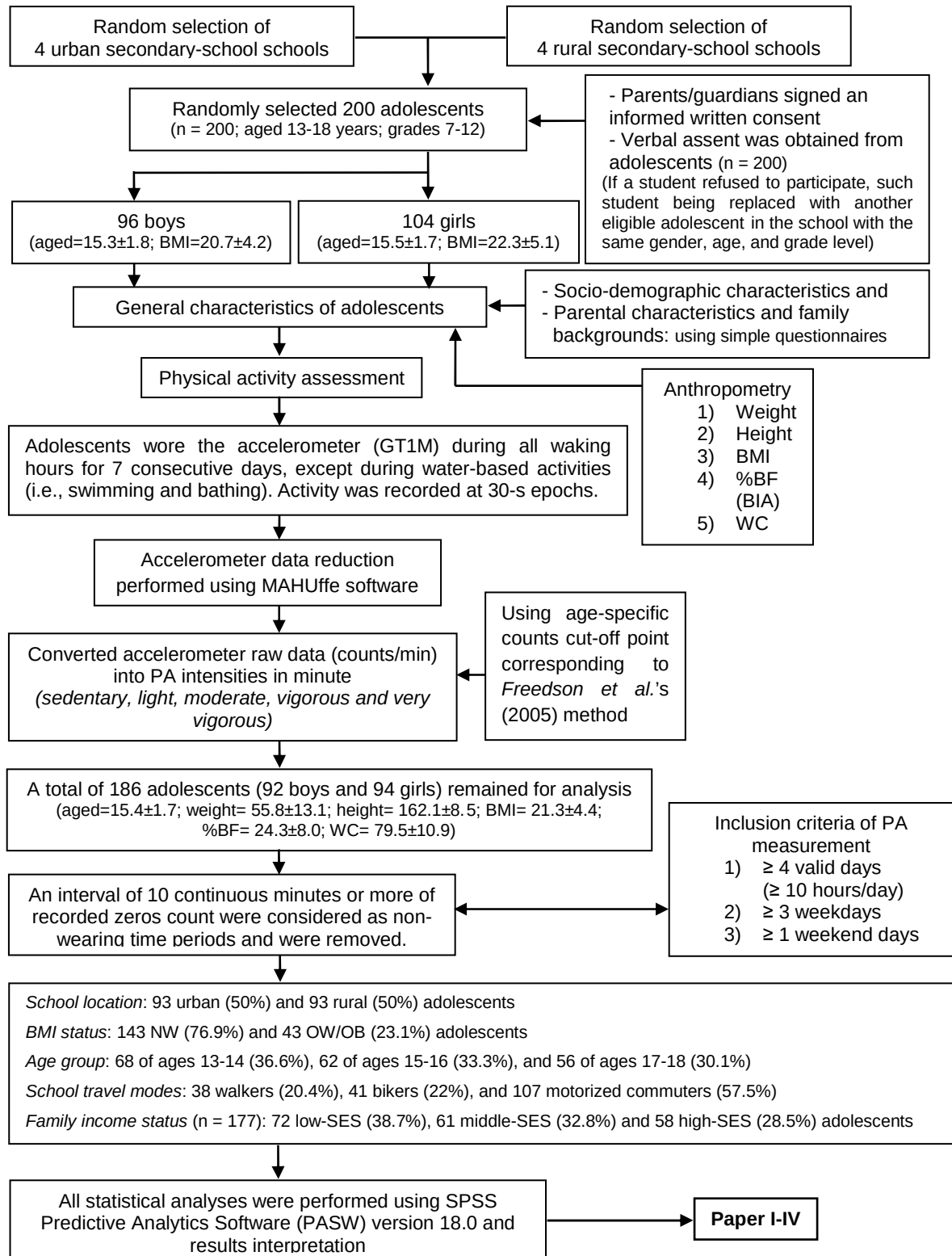


Figure 3. Study methodology from eligible participants to those who agreed to include in the analysis flow chart.

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CHAPTER III
RESEARCH PAPERS
: Paper I-IV

PAPER I

Differences between Weekday and Weekend Levels of Moderate-to-Vigorous Physical Activity in Thai Adolescents

Kurusart Konharn, Maria Paula Santos, and José Carlos Ribeiro

ABSTRACT

Background: It is generally accepted that the promotion of physical activity (PA) is a key strategy for reducing the risk of childhood obesity. However, the relationship between weekday-weekend difference and adolescents' PA levels measured objectively is poorly documented.

Aim: 1) to determine differences in time spent in objectively assessed moderate-to-vigorous physical activity (MVPA) levels by gender and age, of adolescents during weekdays and weekends; and, 2) to use objective monitoring of MVPA to determine the non-compliance and compliance of adolescents with current PA guidelines (PAG).

Subjects and methods: This was a cross-sectional study of 186 Thai adolescents aged 13-18 years (92 boys and 94 girls) in Northeast Thailand. Participants were asked to wear an ActiGraph (GT1M) accelerometer for 7 consecutive days, during all waking hours. Mean daily minutes of MVPA were obtained by applying accelerometer count thresholds corresponding to MVPA.

Results: The results showed MVPA levels were significantly higher in boys than girls, on both weekdays ($p < 0.01$) and weekends ($p < 0.05$). MVPA was higher during weekdays compared with weekend days. Additionally MVPA levels tend to decline with increasing age during adolescence. The results also showed statistically significant differences between genders in the proportion of compliance with PAG.

Conclusions: This study will add to public knowledge about adopting PA habits in routine daily life, starting at adolescence. Specifically, it highlights the need to take weekend-weekday differences into account when developing PA interventions for adolescents.

Keywords: Accelerometer, adolescent, evaluation, epidemiology, guidelines, recommendations, physical activity.

INTRODUCTION

Physical activity (PA) is associated with lower childhood overweight/obesity (OW/OB) prevalence, chronic disease and more health benefits (Centers for Disease Control and Prevention, 1996; Daniels et al., 2005). Furthermore OW/OB during adolescence is positively correlated with adult obesity (Sidik & Ahmad, 2004). Prevalence of childhood OW/OB is increasing rapidly worldwide (WHO, 1998), including in Thailand. From 1995 to 2004, prevalence of childhood obesity in Thailand has increased from 15.6% to 22.0% (Ministry of public health, 1997). Thus, it is important to understand the related factors that may help to explain the association between PA and OW/OB that are not fully understood, even though there were well-documented cases in the West (Daniels, et al., 2005; Grize, Bringolf-Isler, Martin, & Braun-Fahrlander, 2010; Sidik & Ahmad, 2004; Trost et al., 2002).

The accurate and reliable assessment of PA is necessary for any research study to develop more effective approaches to PA promotion, but the processes may differ in relation to different cultural and social backgrounds (Grize, et al., 2010). PA questionnaires remain the most widely used self-report instrument to assess PA and have been used extensively in research, however it has been shown that using a single self-report/questionnaire may not respect the broad range of total PA levels (PALs) in which children and adolescent might participate (Welk, Corbin, & Dale, 2000). Furthermore it is also difficult to obtain a precise description of the activity pattern during the day-to-day or between weekday and the weekend using existing questionnaires in terms of amount and intensity. The feasibility of using objective PA measures for national surveillance studies therefore should be considered. Fortunately, motion sensors such as accelerometers have been widely used as objective measures of PA (in all activity levels) to overcome the limitations related to self-report methods (Trost, et al., 2002; Welk, et al., 2000), particularly in children and adolescents (Cooper, Page, Fox, & Misson, 2000; P. S. Freedson, Melanson, &

Sirard, 1998; Hendelman, Miller, Baggett, Debold, & Freedson, 2000; Rowlands, Pilgrim, & Eston, 2008; Trost et al., 1998; Welk, et al., 2000). In addition accelerometers provide data to further investigate the relationship between activity patterns and PA recommendations. To our knowledge accelerometers have not been used to examine PALs among Thai adolescents. The latest recommendations for an adequate level of PA have been proposed by the Canadian Society for Exercise Physiology (CSEP) that children and youths need to accumulate at least 60 minutes of moderate-to-vigorous physical activity (MVPA) per day (Tremblay, Warburton, et al., 2011). Up to the present, there is very sparse objective research with regard to the percentage of adolescents who accomplish these PA guidelines (PAG) with respect to weekend-weekday differences.

The purposes of this study were to compare the objectively assessed MVPA levels by chronological age and gender, of 13- to 18-year-old Thai secondary-school adolescents, during weekdays, and weekends (and all the week); additionally to examine the compliance between genders in a sample of randomly selected Thai adolescents with PAG – using objective assessments of PA.

METHODS

Participants

In this cross-sectional study, 200 secondary-school adolescents were recruited equally in the distribution between urban and rural schools (urban = 4, rural = 4) in Northeast Thailand. The healthy students were invited to participate in this study by random selection, with the number of (all) represented school grades (7th to 12nd) equal. Any participants who were unable to participate in this study and/or had been told by a physician to avoid PA, or had some other medical contraindications being considered ineligible: such students being replaced with another eligible adolescent in the school with the same gender, age, and in the same grade level. Questionnaires were used to determine socio-demographic characteristics by all participants under supervision.

A total of 186 adolescents (92 boys, 94 girls) provided the study with enough PA data in both weekdays and weekends. Body weight (to 0.5 kg; SECA 750, Hamburg, Germany) and height (to 0.5 cm; SECA 242, Hamburg, Germany) were determined by standard anthropometric methods. Body mass index (BMI) was defined as weight/height^2 (kg/m^2). The research committee of the Research Centre of Physical Activity, Health, and Leisure, Faculty of Sports, University of Porto, approved the study. Each participant's parent or guardian provided written informed consent, and all participants assented to participation.

Physical Activity Assessment

The ActiGraph GT1M (Pensacola, FL, USA) accelerometers were used in this study. These monitors offer objective measures of PA, they provide quantification of the intensity and duration of body movement over periods of several days, or even weeks, enabling patterns of movement or inactivity to be assessed (Cooper, et al., 2000; Hendelman, et al., 2000; Rowlands, et al., 2008; Trost, et al., 1998). This ActiGraph model is a uniaxial accelerometer that collects and stores vertical accelerations in the magnitude of 0.05-2.13 Gs with a frequency response of 0.25-2.50 Hz. It is small ($4.5 \times 3.5 \times 1.0$ cm) and lightweight (43 g).

All accelerometers were initialized to collect simultaneous acceleration counts using 30-second increments storing (Epoch) and set to begin collecting data at 6:00 AM on the first day. All participants were instructed to wear the accelerometers on their right hip, attached to a belt whilst carrying out their normal daily activities during all waking hours and were asked to take it off only when sleeping, bathing or swimming, for 7 consecutive days to obtain PA data for the entire week. Parents and teachers were also informed about the procedure and asked to remind the adolescents to wear the devices every day. At the end of our monitoring period (8 days later), all accelerometers were collected by the researchers. Downloading the data from accelerometers was done immediately and on the same computer where they were initialized; to prevent disturbances that can be caused by the time offset between computers. Actilife software (Manufacturing Technologies Inc. Health Systems, Shalimar,

FL; version 3.6 for Windows) which accompanied the accelerometers was used to download the data (.DAT files) to a computer for further subsequent data reduction and analysis.

Data Reduction

The MAHUFFe software (www.mrc-epid.cam.ac.uk, Cambridge, UK) was used to create an Excel file that contained minutes of each participant's PALs for each hour and the monitored time from minute-by-minute activity counts (counts/min). The primary data used is the amount of time spent (minutes) in MVPA (≥ 3 METs; summing of the minutes of moderate activity and greater), which was calculated using Freedson et al. (P. Freedson, Pober, & Janz, 2005; P. S. Freedson, et al., 1998) age-specific cut points for children and adolescents, according to count thresholds. Data from an accelerometer was only considered in our analyses if it was worn for at least 4 of the 7 days (with at least 3 weekdays and should have one weekend day) and for at least 10 hours each day (P. Freedson, et al., 2005; Trost, Pate, Freedson, Sallis, & Taylor, 2000). Sustained 10 minutes periods of zero counts-per-minute was taken as proof that the monitor had been removed (Masse et al., 2005). Because our study was also designed to examine compliance with the current PAG (Tremblay, Warburton, et al., 2011), the daily time spent in MVPA was used to determine the percentage of adolescents who met the PAG.

Data Analysis

Means, frequency (n) and standard deviations (SD) of the main variables, and the time spent in MVPA were calculated for these analyses. All statistical analyses were performed using the Predictive Analytics Software (PASW) version 18.0 for Windows (SPSS Inc, Chicago, IL, USA). Differences in mean values of the measured variables of sample descriptive characteristics between genders (boy vs. girl) were analyzed using independent sample *t*-tests. Differences in MVPA between genders respecting age and weekend-weekdays were tested by independent sample *t*-tests. The Pearson product-moment correlation coefficient was used to test associations between MVPA and BMI.

All primary variables approximated Normal distribution. Statistical significance was accepted at $p < 0.05$ and for a 95% CI. All hypotheses were tested using 2-tailed tests.

For descriptive analysis (percentage), by gender, minutes of MVPA over weekend-weekdays were categorized into 2 groups that related to PAG as follows: 1) less than 60 minutes and 2) equal or/and greater to 60 minutes. This permitted us to recognize the percentage of adolescent meeting the PAG. A Chi-square test was used to determine differences in the prevalence of adolescents who meet the PAG, split by weekday-weekends.

RESULTS

Descriptive characteristics (expressed as mean $\pm$ SD) of participants according to age and gender are shown in Table 1. Of the 186 adolescents (93% of original participants) who provided applicable data (age: 15.4 ± 1.7 years; BMI: 21.3 ± 4.4 kg/m²), there were 92 boys (age: 15.3 ± 1.8 years; BMI: 20.7 ± 4.0 kg/m²) and 94 girls (age: 15.5 ± 1.7 years; BMI: 22.0 ± 4.7 kg/m²).

Mean BMI was statistically higher among girls than among boys ($p < 0.05$), but not in every age group. BMI of boys slightly increased with age (exception at 16-year-old) whereas in girls, although the same pattern exists, a slight variation is also observed at 17-18-years-old. The Pearson product-moment correlation coefficient test showed an inverse correlation between levels of MVPA and BMI ($r = -0.17$, $p < 0.05$).

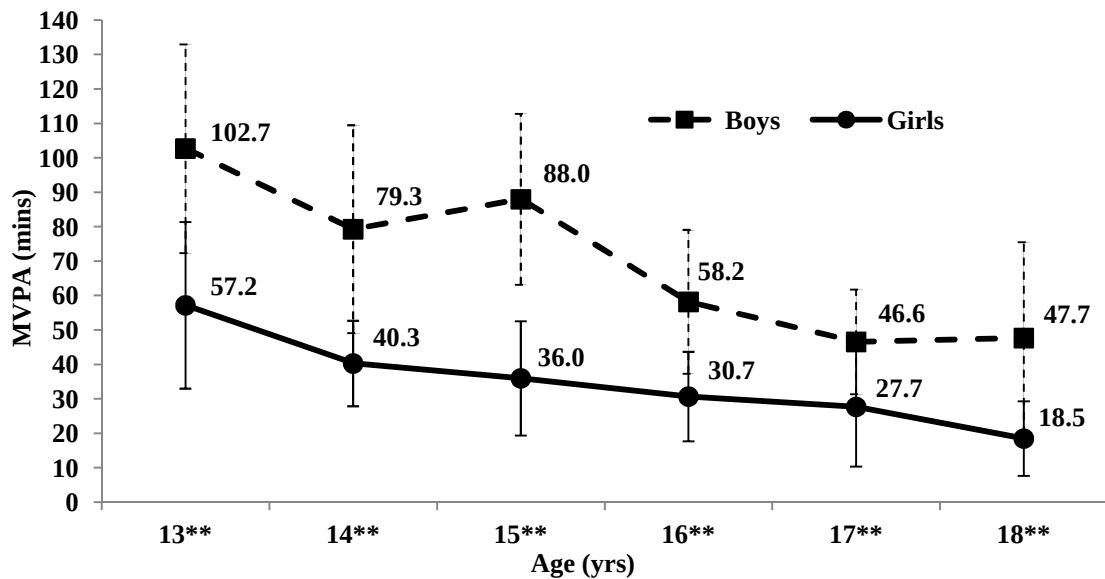
Results from Figure 1 to Figure 3 show that boys spent the majority of their MVPA time with higher levels than girls on weekdays ($p < 0.01$), weekend days ($p < 0.05$) and the entire week ($p < 0.01$). The key question of interest in this study was whether MVPA levels would differ between older and younger adolescents. Age has a significant inverse correlation with MVPA. On weekdays, younger boys spent more MVPA than their older counterpart; with similar patterns in girls.

Table 1. Descriptive of Participant's Characteristics (n = 186).

Age (years)	Boys							Girls							Both gender						
	n	Weight (kg)		Height (cm)		BMI (kg/m ²)		n	Weight		Height		BMI		n	Weight		Height		BMI	
		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD
13	22	52.0	16.5	157.0	11.1	20.6	5.1	16	52.2	11.7	157.3	6.8	20.9	3.1	38	52.0	14.5	157.1	9.5	20.7	4.3
14 †‡	15	58.6	14.3	166.2	7.3	20.7	4.5	15	50.1	7.2	156.3	6.9	20.6	2.7	30	54.4	11.9	161.3	8.6	20.6	3.7
15 ‡	10	58.3	11.6	169.4	5.9	20.8	3.7	17	56.9	13.0	156.5	7.3	23.1	5.0	27	57.2	12.3	161.3	9.2	22.2	4.6
16 ‡ ¶	18	54.6	9.6	169.9	6.1	20.1	3.5	17	60.1	16.3	159.8	5.3	24.2	7.1	35	57.2	13.4	165.0	7.6	22.1	5.9
17 ‡	15	59.5	13.7	170.0	6.7	21.0	3.5	12	54.8	17.1	158.8	7.4	21.5	5.5	27	57.4	15.2	165.0	8.9	21.2	4.4
18 ‡	12	61.9	9.6	170.0	5.2	21.4	3.1	17	54.9	9.1	159.9	6.5	21.1	2.7	29	57.8	9.8	164.1	7.8	21.2	2.8
Total ‡ ¶	92	56.8	13.3	166.2	9.3	20.7	4.0	94	54.9	12.8	158.1	6.7	22.0	4.7	186	55.8	13.1	162.1	9.0	21.3	4.4

Note: † = Statistical significant differences between genders on weight (p < 0.05)
‡ = Statistical significant differences between genders on height (p < 0.05)
¶ = Statistical significant differences between genders on BMI (p < 0.05)

Figure 1. Distribution of mean minutes and standard deviations of MVPA for monitored physical activity during the weekday by age and gender (92 boys, 94 girls).



Note: **Significant differences between genders ($p < 0.01$)

Between 13 and 18 year-old boys, the youngest ones' time in MVPA was more than double that of the 18 year olds (102.7 ± 30.3 and 47.7 ± 28.2 , respectively), and these differences were greater (3.1 times) in the girls (57.2 ± 25.0 and 18.5 ± 10.6 , respectively) compared to boys', and with a steeper decline the same pattern also can be seen on weekends. For the entire week, 13-years-old boys were engaged in more than 90 minutes daily of MVPA, whilst 13 year old girls were only engaged in 53.5 minutes of the same intensity. Apart from of ages 16 and 17 MVPA (by percentage) has increased with age, from 13 to 18 years old (44.6%-63.6%).

Table 2 show that all participants spent significantly ($p < 0.01$) more time in MVPA during weekdays (72.3 vs. 35.0, boys and girls respectively) when compared to weekends (56.4 vs. 23.4, boys and girls respectively). The differences in MVPA between weekdays and weekend days (for ages 13-18) are for boys 24.6%-35.2% and for girls 21.7%-54.1%.

Figure 2. Distribution of mean minutes and standard deviations of MVPA for monitored physical activity during the weekend by age and gender (80 boys, 81girls).

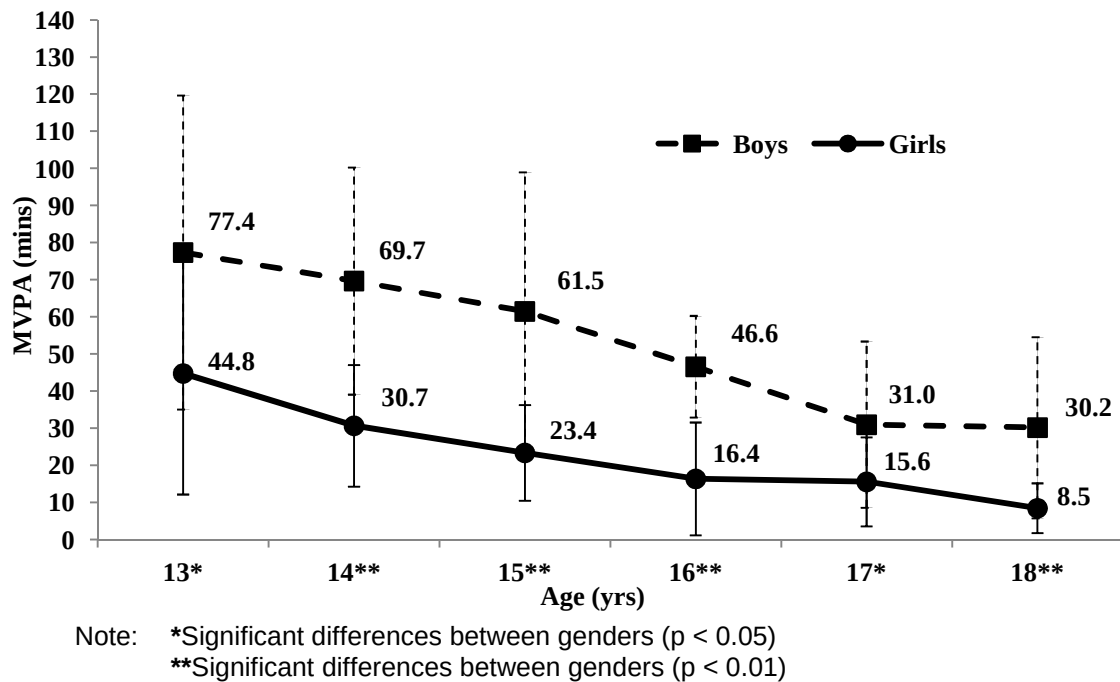


Figure 3. Distribution of mean minutes and standard deviations of MVPA for monitored physical activity over whole week by age and gender (92 boys, 94 girls).

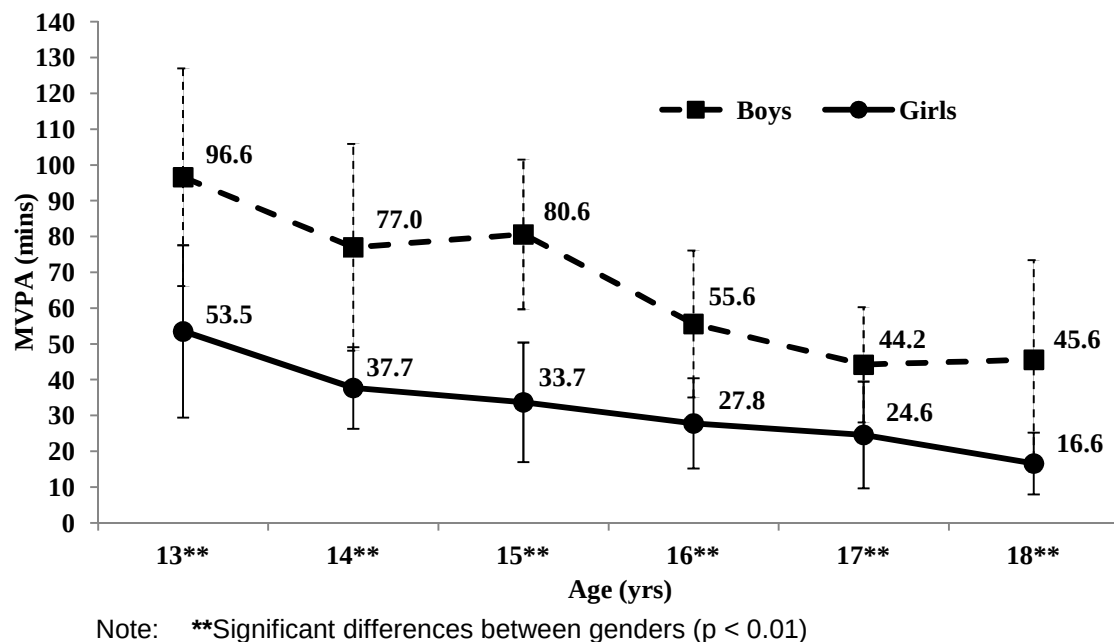


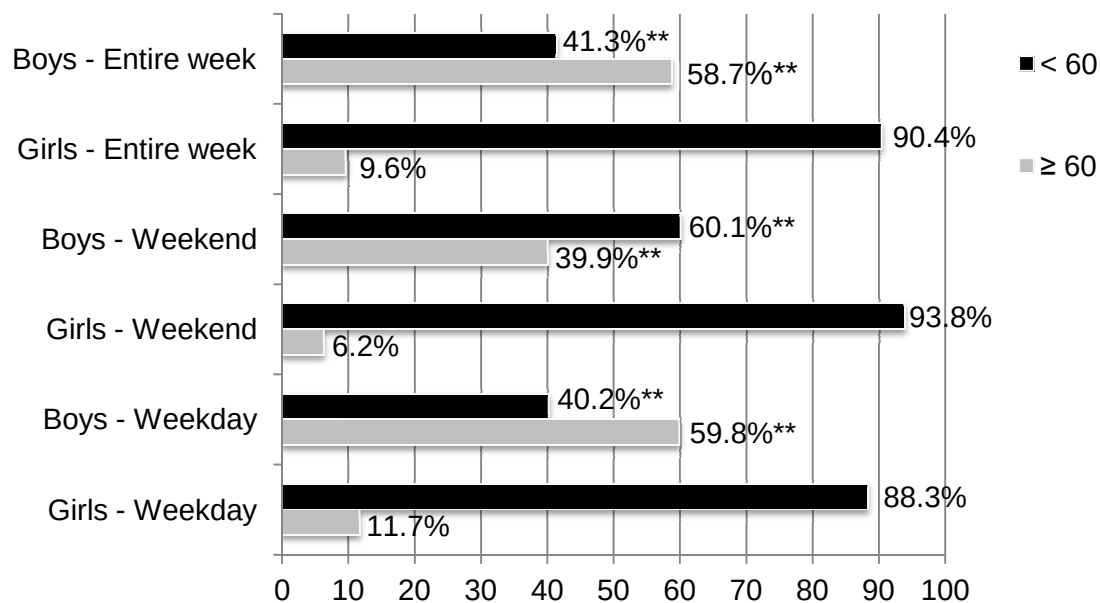
Table 2. Differences in time spent (minutes) in MVPA levels between genders, during weekdays, weekend days, and entire week, and its correlation with BMI (92 boys, 94 girls).

Gender of subject	Time spent in MVPA (minutes)		
	Weekdays	Weekends	Entire week
Boys #	72.3±33.3**	56.4±37.8**	68.5±31.9**
Girls #	35.0±20.2	23.4±21.2	32.1±19.1
Total #	53.5±33.2	39.8±34.7	50.2±31.8
Correlation with BMI (<i>r</i>)			-0.17 (<i>p</i> < 0.05)

Note: ** = statistically significant differences between genders on weekdays/weekend days/entire week (*p* < 0.01)
 # = statistically significant differences between weekdays and weekend days (*p* < 0.01)

On average at least 58.7% of boys and only 9.6% of girls meet the PAG (*p* < 0.01). Similarly if we only consider the adherence to the PAG on weekdays, 59.8% of boys met the PAG, while only 11.7% of girls met the PAG (Figure 4). The weekend patterns were no different, with 39.9% of boys meeting PAG and only 6.2% girls doing it.

Figure 4. Percentage of participants who meet the recommended activity guidelines of 60 minutes of MVPA per day on weekdays, weekends and entire week by gender.



Note: **Significant differences between genders (*p* < 0.01)

DISCUSSION

Our findings confirmed other studies (Aires et al., 2007; Armstrong & Welsman, 2006; Rowlands, et al., 2008; P. Santos, Guerra, Ribeiro, Duarte, & Mota, 2003) that boys were significantly more active during both weekdays and weekends than girls over all ages, and all adolescents were less active at weekends than on weekdays, with a tendency for girls' MVPA to drop off more steeply at the weekend compared to the weekday. The prevalence estimates of compliance to PAG ranged from 6.2%-11.7% (for girls) and 39.9%-59.8% (for boys), depending on the week periods analyzed. Adolescent girls were 2 times less likely to meet the PAG on weekends (6.2%) than on weekdays (11.7%). Therefore, future research should explore whether gender differences in MVPA on the weekdays and weekends may be related to gender factors [e.g., PA behavior and structure (both structured and unstructured PA)]. Other objectively measured PA results were observed by Ribeiro et al. (Ribeiro et al., 2009), in Portuguese adolescents, where they found compliance to PAG (when extrapolating over a 5-day period) of 24.6% (for girls) and 53.7% for boys; while with Norwegians, approximately 62% boys and 50% girls met the PAG (Klasson-Heggebo & Anderssen, 2003). This study has shown that Thai girls were less active than certain European girls, in particular to Portuguese, but results from Thai boys were similar, in comparison with some European boys. Conversely, Australian boys (13%) have achieved less PAG than girls (24%) (Olds & Esterman, 2009). These findings show that PA patterns could significantly differ with cultural differences and social backgrounds, within the same method, as supported by Yan and McCullagh (Yan & McCullagh, 2004). Whereas Ribeiro et al. evaluated the compliance with the PAG based on each day of the week (Ribeiro, et al., 2009), our study analyzed minutes during a week. Therefore it is crucial to compare the percentage of adolescents who meet PAG with the results of several surveillance studies for validation. Moreover it is important to provide a more precise estimate of children and adolescents who are meeting the PAG – according to recent data (Klasson-Heggebo & Anderssen, 2003; Li et al., 2010; Martinez-Gomez et al., 2010; Olds & Esterman, 2009; Ribeiro, et al., 2009). Additionally it would be of fundamental

importance to establish international agreed methods about the aspects of compliance with PAG regarding the number of days needed during a week (regarding periods of week), with 60 minutes of MVPA. Future researches must address MVPA levels that are most closely associated with BMI in adolescents; additionally, further studies are required to compare the PAG accomplishment based on BMI status using the internationally-agreed BMI cut-points for children and adolescent (Cole, Bellizzi, Flegal, & Dietz, 2000).

Estimation of MVPA levels versus age show that a significant declined was observed between boys and girls aged 13 to 18, which is consistent with other findings (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008; Wickel, Eisenmann, & Welk, 2009). Thus PA interventions are needed to reduce the age-related decline in PA. However, the validity of the empirical knowledge used in formulating the PAG for children and adolescent are still unclear, due to the fact that achieving the recommendations is the most challenging task worldwide. Although there were limitations to the use of accelerometers to evaluate PA in our study (swimming activity is not measured for example), these devices still continue to be used frequently in determining PA. Another possible limitation of this study is that cut-off points (P. Freedson, et al., 2005; P. S. Freedson, et al., 1998) in determining the average amount of time spent in MVPA have been established under laboratory conditions using just a few example activity protocols and may not be representative of all movements performed by adolescents during the course of a day. There may even be activities characteristic in Asians/Thais that could influence this aspect. However it should be highlighted that this is one of the primary studies related with objectively measured MVPA levels (with extensive one-week data collection), to evaluate compliance with the latest PAG (Tremblay, Warburton, et al., 2011) that has been carried-out so far in an adolescent population-based sample in Thailand.

Our study provided only cross-sectional data and does not allow us to examine individuals as they progress through older age. This study site also was selected only in the Northeastern region; a national representative sample is needed in order to establish several public health strategies aiming at

increasing the PAG compliance. In addition, this is also the first study to report objectively measured PA in the largest sample of native Thai adolescents up to the present, as well as representing equally the urban-rural people. The prevalence of Thai adolescents meeting the PAG of a week is too small, especially in girls. As others had previously suggested (Treuth et al., 2007), middle school girls spent the majority of their days in sedentary behavior and light PA. With these results almost all MVPA in the whole week was made up of weekday MVPA, and adolescents spent less MVPA on weekends compared to the weekday. It is possible that removal of the structured school environment at weekends is disadvantageous to some adolescents' activity levels, with this effect being particularly noticeable in girls (Rowlands, et al., 2008). Moreover interventions to increase PA and specifically MVPA needs to be weekday-centric or school-centric. This suggests that interventions designed to increase MVPA on weekdays could make a huge impact on total MVPA among adolescents. In the present study, differences in MVPA between weekdays and weekend days were clear and comparable with other studies (Aires, et al., 2007; Klasson-Heggebo & Anderssen, 2003; Rowlands, et al., 2008; Treuth, et al., 2007). The school PA involvements may affect these findings more than home or community participation in MVPA during weekend. Furthermore periods of time after school are potentially the primary moments of extra-curricular MVPA in children (Baranowski & de Moor, 2000; Mota et al., 2008). Thus we suggest to start intervention strategies to improve recommended PA level for school-age adolescents on school-period is urgently needed, particularly for girls and late adolescence. Despite weekend activity being less influential these days still had significance for adolescent health, and need to be acknowledged as crucial PA opportunities that are associated with their overall PA (Ferreira et al., 2007).

CONCLUSIONS

Boys spent significantly more time engaged in MVPA than girls, in both weekdays and weekends. Adolescents spent statistically significant more MVPA on weekdays than on weekend days. MVPA is mainly linked to school periods

(weekdays); in other words, schools may play a major role in adolescents' PA participation. Furthermore our results showed that MVPA levels might decline with increasing age, and appear more pronounced in girls. Therefore particular attention should be addressed regarding the PA promotion that encourages the increase in the levels of MVPA, particular to girls, late adolescent, and for the entire week with special attention to weekend days.

Conflict of interest

No conflicts of interest are declared.

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PAPER II

Differences in Physical Activity Levels between Urban and Rural School Adolescents in Thailand

Kurusart Konharn, Maria Paula Santos, Christopher Young, and José Carlos Ribeiro

ABSTRACT

Background: The relationship between geographical location and adolescents' physical activity (PA) levels (PALs) measured objectively is poorly documented.

Aim: To examine the differences in objectively measured PALs between urban and rural adolescents, and to determine the percentages of a sample that complied with recommended PA guidelines (PAG).

Subjects and methods: A cross-sectional study was conducted involving 93 urban and 93 rural adolescents. In order to obtain PA data, each participant wore the ActiGraph GT1M accelerometer for 7 consecutive days during all waking hours. Mean activity time (in minutes) at various intensities were created and used for further analysis.

Results: Boys were more physically active than girls ($p < .05$). Urban adolescents presented significantly higher levels of sedentary behavior (SED) ($p < .01$) than those in the rural group. However there was no significant difference in either moderate-to-vigorous PA (MVPA) or compliance with PAG between the two groups. Despite their overweight/obese group, rural adolescents had significantly more minutes of MVPA compared to adolescents from urban ($p < .05$).

Conclusions: The differences in PALs and SED vary with urban/rural school location, and indeed with gender and weight status. Urban/Rural placement is an important factor for interventions to promote PA among adolescents.

Keywords: accelerometer, high school students, overweight, obesity, Thailand.

INTRODUCTION

It is a well-known fact that regular physical activity (PA) helps improve health and well-being. However, in order to see health benefits and to avoid becoming overweight/obesity (OW/OB), children and youths should accumulate an average of at least 60 minutes of moderate-to-vigorous physical activity (MVPA) every day (Tremblay, Warburton, et al., 2011). Insufficient PA or prolonged sedentary behavior (SED) during childhood has been positively associated with an increased risk of becoming overweight and obese (Must & Tybor, 2005; Pietilainen et al., 2008), and being susceptible to many chronic diseases (Berlin & Colditz, 1990; Helmrigh, Ragland, & Paffenbarger, 1994). These trends continue in the transitional period from adolescence to adulthood, a time critical for the development of obesity (Gordon-Larsen, Adair, Nelson, & Popkin, 2004). Moreover, the prevalence of OW/OB children and adolescents has increased sharply in both the developed and developing countries (de Onis & Blossner, 2000; Wang & Lobstein, 2006). In Thailand alone (Mo-suwan & Geater, 1996) the prevalence of obesity among school children increased from 12.2% in 1991 to 15.6% in 1993. Interestingly, the recent national study (Jirapinyo, Densupsoontorn, Chinrungrueng, Wongarn, & Thamonsiri, 2005) highlighted that obesity levels (26.8% for boys, 15% for girls) was higher than overweight levels (13.5% for boys and 10.8% for girls). A recent longitudinal study also showed that the prevalence of overweight and obesity in Thai adolescents increased from grade 7 to grade 12 (Jirapinyo, et al., 2005), and levels of obesity were about 3 times higher in urban areas than in rural areas (22.7% vs. 7.4%, respectively) (Sakamoto, Wansorn, Tontisirin, & Marui, 2001). Consequently, differences between urban and rural adolescents in PA participation may therefore be expected and it is important to examine this factor influencing the development of childhood obesity. Schools are ideal settings for population-based interventions to address being overweight and obese because school-age children spend most of their waking hours at school (Story, 1999), additionally, severely overweight children and adolescents are four times more likely than their healthy-weight peers to report impaired school

functioning related to health issues (Story, Kaphingst, & French, 2006). Hence, it is during this window of opportunity that PA could be influenced the most.

To the best of our knowledge, little is known about the impact of school location in relation to a youth's PA levels (PALs), although some previous studies have examined PA differences among children and adolescents with respect to geographical location. Huang et al. (Huang, Hung, Sharpe, & Wai, 2010) revealed that Taiwanese urban children had greater total amount of PA after school and on weekends than those dwelling in rural areas. In contrast, a study conducted in the United States (Joens-Matre et al., 2008; Liu, Bennett, Harun, & Probst, 2008) has suggested that being a rural youth is synonymous with a lower rate of physical inactivity (Liu, et al., 2008), and furthermore that urban American children in grades 4-6 have less activity after school and in the evening than children from rural areas and small cities (Joens-Matre, et al., 2008). The latter is the key issue, but a clear association is not available, and strategies for promoting regular PA have been limited in their effectiveness. The reason there is not a clear association might be due to imprecise measurement of PA, while the challenge remains to find ways to take children and adolescents away from SED to more physically active pursuits. To properly measure PA, accurate and reliable instruments are essential. Motion-sensing devices such as accelerometers have become objective PA monitors that can record PA under free-living conditions, during unorganized sports and unstructured activities. Additionally, it has become feasible to measure children and adolescents' PA patterns (e.g., frequency, intensity, and duration) over several days, and several studies have demonstrated that energy expenditure predicted by accelerometry yields relatively high correlations when compared to criterion methods in a controlled laboratory setting accelerometers (P. Freedson, et al., 2005; Trost, et al., 1998). Furthermore, a number of calibration studies (P. Freedson, et al., 2005; Treuth et al., 2004) have also been conducted to delineate accelerometer thresholds for their PALs.

To date, quantification of SED and PALs among urban and rural adolescents measured by accelerometers is poorly documented and there is still no evidence which shows differences in the proportion of urban-rural

adolescents meeting the current PAG. To illustrate the significance of accelerometry derived data therefore it would be interesting to compare the MVPA of adolescents with PAG, and implementation of such techniques would also facilitate the establishment of more specific PAG for adolescents. The purposes of this study were: 1) to examine the effects of differences in school location (urban schools vs. rural schools) on the objectively measured PA or sedentary time (using accelerometer) in 13-18 year-old secondary-school adolescents, and 2) to determine the percentages of adolescents in this sample that met PAG.

METHODS

Study design

This cross-sectional study was performed among Thai adolescents who were recruited from eight secondary schools in Northeast Thailand, with random selection of students, and school locations (urban and rural schools) equally represented. The data was collected during the 2008/09 school year. Due to the lack of an agreed definition of urban/rural areas, there are no specific universally accepted operational definitions of what constitutes an urban and rural area, the parameters and the degrees used and other details can vary greatly (Tacoli, 1998) and the definition is depending on national standards in each country. For the purpose of this study, the number of inhabitants of the population area and national administrative areas defined the urban and rural areas, which are determined by the National Statistical Office (NSO) in Thailand based on the Statistical Geographic Information System (SGIS) (N. S. O. o. Thailand) and of the definitions for administrative boundaries (O. o. t. C. o. S. o. Thailand, 1953). These national administrative areas are the ones used in virtually all government activities, and for the collection and presentation of national statistical data. Furthermore, it is important to note that Thailand is divided into 76 provinces (*changwat*), most of the provinces contain just one significant city or town (*amphoe muang*), which is the capital and officially declared as an urban area. Each province is subdivided into an average of about seven districts (*amphoe*), which are further subdivided into several sub-

districts or group of rural villages (*tambon*) and municipalities used in local government. All schools in this study were selected based on this standard: the urban schools are located in the central part of the province (amphoe mueang) with at least 130000 inhabitants living therein, and the rural schools are located in the rural villages with less than 4000 inhabitants living therein. In addition, urban and rural schools in this study are located at least 50 km from each other.

Participants

A total of two hundred school-going adolescents aged 13-18 years (grades 7-12) were almost equally divided by gender and age. All 200 participants completed a simple questionnaire to collect their general data (i.e., gender, age, or grade level) but 14 adolescents (7% of original) were excluded were excluded from further analysis regarding the minimal wearing time to constitute a valid day in PA assessment (P. Freedson, et al., 2005; Rowlands, et al., 2008), and finally 186 participants were included in the analysis. The study protocol received approval from the Ethical Committee of the research committee of the Research Centre of Physical Activity, Health, and Leisure, Faculty of Sports, University of Porto. Prior to the measurement phase, each participant's parent or guardian provided written informed consent and all participants gave verbal assent to participation. If a student refused to participate, a replacement was randomly selected from the same grade and gender.

Anthropometry

All anthropometric measurements were taken during school hours in the morning, well-trained staffs measured height and weight following standardized procedures. Body weight was measured using a weighing balance (SECA 750, Hamburg, Germany) and height was measured using a portable stadiometer (SECA 242; Hamburg, Germany). Body Mass Index (BMI) was calculated as the ratio of body weight to body height squared expressed as kg/m^2 . In accordance with generally accepted international classification of BMI, normal weight, overweight, and obesity were defined using the international age- and

gender-specific (International Obesity Task Force; IOTF) child BMI cut-off points (Cole, et al., 2000). Participants were assigned for analysis purposes to one of two BMI classified groups: normal weight group and OW/OB group.

Body fat percent (%BF) was determined using bioelectrical impedance analysis (BIA). Whole-body BIA measurements were performed using a Body Fat Analyse (BF-906; Maltron international Ltd, Essex, UK) with tetra-polar method in supine position with hands and legs slightly apart. A tape was used to measure waist circumference (nearest 0.1 cm) at a level of umbilicus in the horizontal plane of the participant and the measurement was made during normal expiration (Yamborisut, Kijboonchoo, Wimonpeerapattana, Srichan, & Thasanasuwan, 2008).

All anthropometric measurements were made twice and the means of paired values were used in the analyses.

Physical activity assessment

After anthropometric measurements were made, participants were instructed by the researchers about the wearing and removing of the ActiGraph GT1M (Pensacola, FL, USA) accelerometers before the first day of actual assessment. Accelerometers are portable monitors that measure movement in terms of acceleration, which can then be used to record body movements to estimate PA patterns (frequency, intensity, and duration) over an extended period. Computer software was used to initialize all accelerometers to record activity counts every 30 seconds (Epochs) for 7 consecutive days. Each participant was instructed to wear the single accelerometer over the right hip attached with an elastic belt while carrying out their habitual daily activities under free-living conditions during all waking hours, except during water-based activities or when sleeping. The accelerometers were returned after 7 days, and the data was downloaded onto the same computer used to initialize the accelerometers; using ActiLife Data Analysis Software (version 3.6 for Windows, ActiGraph, Pensacola, FL). The cleared accelerometer data for the physical activities were then used for further analyses.

Accelerometer-data reduction

In accordance with the previous suggestions (P. Freedson, et al., 2005; Rowlands, et al., 2008; Trost, Pate, et al., 2000), data from an accelerometer was considered for further analyses if the participant wore it for at least 4 of the 7 days (comprised of at least 3 weekdays and 1 weekend day), with at least 10 hours per day. The amount of time spent (in minutes) at different PA-intensity categories (sedentary, light, moderate, vigorous and very vigorous) was estimated from minute-by-minute accelerometer counts (cpm) on MAHUFFE 1903 software (www.mrc-epid.cam.ac.uk, Cambridge, UK). Activity intensity levels were determined by applying the age-specific energy expenditure prediction formula by Freedson et al (P. Freedson, et al., 2005) with: Metabolic equivalent (MET) = $2.757 + (0.0015 \times \text{counts per minute}) - [0.08957 \times \text{age (in year)}] - [0.000038 \times \text{counts per minute} \times \text{age (in year)}]$. Each minute over a specific cutoff was allotted to the corresponding intensity level group (sedentary, light, etc). Time spent in MVPA was calculated by summing minutes of moderate and vigorous intensity PA (≥ 3 METs) on each eligible day and dividing the total by the number of days eligible. Times where the accelerometer was removed were identified from the data by periods of ≥ 10 minutes of consecutive zero counts, making it unlikely that the monitor was worn (Masse, et al., 2005; Riddoch et al., 2004).

The associations between school location and the adolescents engaged in sedentary time and other activity levels were analyzed for gender, BMI classification, and age group. The proportion of adolescents who complied or did not with the current PAG (Tremblay, Warburton, et al., 2011) was also estimated.

Statistical Analysis

Descriptive statistics were performed for all study variables. Discrete variables were expressed as percentage and continuous variables as mean $\pm$ standard deviation (SD). Independent sample *t*-tests were used to explore differences in participant characteristics across school location (urban vs. rural) by specific group – between genders (boys vs. girls) and BMI classification

(normal weight vs. overweight/obesity). Since participants were categorized by 3 age groups: 13-14 years, 15-16 year, and 17-18 years, one-way ANOVA was used to test the differences in participants' characteristics per age group.

To examine PA level differences respecting adolescents' characteristics, a 2 x 2 analysis of variance (2-way ANOVA) was performed on school location with gender, and on school location with BMI classification, and significant associations were spotted by pairwise comparisons using independent-samples *t*-test. A 3x2 two-way ANOVA was conducted with school locations and age groups, Bonferroni post hoc tests were performed where significant differences in PA levels existed. The effect sizes were estimated using partial eta-squared (η_p^2).

Chi-square tests were used to examine differences between school locations in their proportions of meeting PAG according to gender, BMI classification, and age groups. All statistical tests were two-tailed and a value of $p < 0.05$ was considered statistically significant. All statistical analyses were performed using the Predictive Analytics Software (PASW, Chicago, IL, USA) version 18.0. All authors had full access to the data and take full responsibility for their integrity.

RESULTS

Participants' characteristics

Descriptive data for the physical characteristics of the participants are presented in Table 1. Overall 186 adolescents (mean age: 15.4 ± 1.7 years; height: 162.1 ± 9.0 cm; weight: 55.8 ± 13.1 kg; BMI: 21.3 ± 4.4) took part in this study. There were 93 urban adolescents (age: 15.4 ± 1.8 ; BMI: 22.0 ± 4.3) and 93 rural adolescents (age: 15.4 ± 1.7 ; BMI: 20.6 ± 4.5). In our sample, 32.3% of urban and 14% of rural adolescents were classified as overweight or obese (23.1% for both areas). BMI ($p < 0.05$) and %BF ($p < 0.01$) of urban adolescents was significantly higher than that of their rural counterparts. Girls had significantly higher BMI ($p < 0.05$) and %BF ($p < 0.01$) than boys, particularly in rural areas.

Time Spent in PA between school locations – related to gender

According to the results, which were analyzed by 2-way ANOVA (Table 2), gender ($F_{(1,182)} = 18.150$, $p < 0.001$, $\eta_p^2 = 0.09$) and school location ($F_{(1,182)} = 23.730$, $p < 0.001$, $\eta_p^2 = 0.12$) had a significant main effect on SED. MVPA was significantly affected by genders ($F_{(1,182)} = 87.953$, $p < 0.001$, $\eta_p^2 = 0.326$) but the school location was not found to significantly affect MVPA ($F_{(1,182)} = 1.966$, $p < .163$, $\eta_p^2 = 0.011$). The independent-samples *t*-test also indicated that boys had significantly higher PALs in minutes compared to girls ($p < 0.05$), in both areas. Urban adolescents spent significantly more time in SED than those from rural areas ($p < 0.01$). There was no significant interaction between the effects of gender and school location (gender x school location; $p > 0.05$) on PALs.

Time Spent in PA between school locations – related to BMI classification

Two-way ANOVA was also used to compute the differences in PALs by BMI classification and school location (Table 3). There was no significant main effect in any of the PALs or SED from BMI classifications ($p > 0.05$). SED and most of the PALs showed no significant relation to the product BMI classification x school location, indeed a significant interaction was observed only for moderate PA (MPA) ($F_{(1,182)} = 4.228$, $p = 0.04$, $\eta_p^2 = 0.023$). In rural areas, normal-weight adolescents performed significantly more MPA (52.7 vs. 36.7 minutes, respectively) and MVPA (55.3 vs. 38.3 minutes, respectively) than those classified as overweight/obese ($p < 0.05$). This indicates that the differences in MPA vary with combined school location and BMI group.

Table 1. Demographic characteristics of the study participants.

Variables	n (%)	Age (years)		Weight (kg)		Height (cm)		BMI (kg/m ²)		WC (cm)		BF (%)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Urban (n = 93)													
Based on gender ^{**HF}													
Boys	46 (49.5)	15.2	1.7	59.9	12.7	168.5	7.1	21.7	4.3	82.2	11.1	20.6	6.5
Girls	47 (50.5)	15.6	1.8	56.1	11.0	159.1	7.0	22.4	4.2	79.6	11.6	30.9	4.3
Based on BMI classification ^{**WBCF}													
Normal weight	63 (67.7)	15.6	1.7	52.3	7.5	163.8	8.5	19.7	2.0	75.7	7.6	23.6	7.0
Overweight/Obesity	30 (32.3)	14.9	1.8	69.9	10.6	163.7	8.4	26.9	3.6	91.2	11.1	30.5	6.6
Based on age groups ^{*C, **A}													
13-14 years old	33 (35.5)	13.4 ^{‡abc}	0.5	59.4	12.0	162.3	7.4	22.4	4.1	85.1 ^{‡c}	10.2	26.7	7.6
15-16 years old	33 (35.5)	15.6	0.5	56.3	11.8	163.2	9.3	22.1	5.0	77.7	11.9	25.0	8.3
17-18 years old	27 (29.0)	17.5	0.5	58.4	12.3	166.1	8.1	21.4	3.6	79.1	11.0	25.8	6.6
Rural (n = 93)													
Based on gender ^{*B, **HF}													
Boys	46 (49.5)	15.4	1.8	53.6	13.3	163.9	10.6	19.7	3.5	77.5	8.9	16.4	5.3
Girls	47 (50.5)	15.4	1.7	53.7	14.3	157.1	6.3	21.6	5.2	79.0	11.4	28.9	5.0
Based on BMI classification ^{**WBCF}													
Normal weight	80 (86.0)	15.4	1.8	50.0	9.4	160.1	9.6	19.2	2.1	75.5	7.0	21.2	7.2
Overweight/Obesity	13 (14.0)	15.3	1.4	76.0	15.4	162.9	7.2	29.2	5.8	94.9	11.3	31.8	7.5
Based on age groups ^{*B, **AWHC}													
13-14 years old	35 (37.6)	13.5 ^{‡abc}	0.5	47.1 ^{‡ab}	11.8	155.8 ^{‡ab}	9.8	19.1 ^{‡a}	3.2	73.5 ^{‡ab}	8.0	22.1	8.1
15-16 years old	29 (31.2)	15.5	0.5	58.3	14.0	163.5	7.5	22.2	5.9	82.1	11.7	23.5	8.6
17-18 years old	29 (31.2)	17.5	0.5	56.9	13.0	163.0	8.3	21.0	3.8	80.1	9.0	22.6	7.8

Table 1. (continued). **Demographic characteristics of the study participants.**

Variables	n (%)	Age (years)		Weight (kg)		Height (cm)		BMI (kg/m ²)		WC (cm)		BF (%)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All participants (n = 186)													
Based on gender ^{*B, **HF}													
Boys	92 (49.5)	15.2	1.8	56.8	13.3	166.2	9.3	20.7	4.0	79.5	10.3	18.5	6.3
Girls	94 (50.5)	15.5	1.7	54.9	12.8	158.1	6.7	22.0	6.7	79.1	11.4	30.0	4.8
Based on place of school ^{*WHB, **F}													
Urban	93 (50.0)	15.4	1.8	58.0	12.0	163.8	8.4	22.0	4.3	80.7	11.4	25.8	7.6
Rural	93 (50.0)	15.4	1.7	53.6	13.8	160.5	9.3	20.6	4.5	78.2	10.2	22.7	8.1
Based on BMI classification ^{**WBCF}													
Normal weight	143 (76.9)	15.5	1.7	51.0	8.7	161.7	9.2	19.4	2.1	75.6	7.2	22.3	7.2
Overweight/Obesity	43 (23.1)	15.0	1.7	71.8	12.4	163.5	8.0	27.6	4.5	92.3	11.2	30.7	6.8
Based on age groups ^{**AH}													
13-14 years old	68 (36.55)	13.4 ^{‡abc}	0.5	53.1	13.4	159.0 ^{‡ab}	9.2	20.7	4.0	79.1	10.8	24.3	8.1
15-16 years old	62 (33.34)	15.6	0.5	57.2	12.8	163.4	8.5	22.1	5.3	79.8	12.0	24.3	7.3
17-18 years old	56 (30.14)	17.5	0.5	57.6	12.6	164.5	8.3	21.2	3.7	79.6	10.0	24.1	7.3
Total	186 (100.0)	15.4	1.7	55.8	13.1	162.1	9.0	21.3	4.4	79.5	10.9	24.3	8.0

Note: 1.) Significant difference, ^{*}at the 0.05 level ($p < 0.05$) or ^{**}at the 0.01 level ($p < 0.01$) between groups, ^Aat age, ^Wat weight, ^Hat height, ^Bat BMI, ^Cat Waist circumference (WC), ^Fat Body fat percent (BF), by either Independent-samples *t*-test or 1-way ANOVA, depending on the size of groups.

2.) Significant difference, [‡]at the 0.05 level ($p < 0.05$) or [‡]at the 0.01 level ($p < 0.01$) between age groups; ^a age 13-14 and age 15-16, ^bage 13-14 and 17-18, ^cage 15-16 and age 17-18, by Bonferroni Post hoc test.

Table 2. Mean minutes per day spent at each activity level between urban and rural school adolescents, divided by gender.

Variables	Boys				Girls				F _{Gender}	F _{Location}	F _{Gender x Location}	All participants				
	Urban		Rural		Urban		Rural					Urban		Rural		t
	Mean	SD	Mean	SD	Mean	SD	Mean	SD				Mean	SD	Mean	SD	
Number of valid days (day)	6.1	0.9	6.0	1.1	6.3	1.1	5.8	1.1	0.005	3.8	.85	6.2	1.0	5.9	1.0	1.965
Average monitor wear time per day (min) ^{#B, ¶G}	729.9	89.7	697.6	55.7	712.0	65.5	673.5	55.6	4.433*	12.591**	.093	720.9	78.5	685.5	56.6	3.528 ^{oo}
Sedentary behavior (min) ^{¶BG}	386.1 [‡]	71.1	340.9 [‡]	58.8	419.4	51.1	380.9	51.4	18.150**	23.730**	0.15	402.9	63.7	361.1	58.5	4.665 ^{oo}
Light PA (min)	278.8 [‡]	53.3	284.8 [‡]	44.5	262.2	42.3	258.3	44.8	10.029**	.026	.527	270.4	48.5	271.4	46.8	-.149
Moderate PA (min)	61.0 [‡]	26.2	67.3 [‡]	31.1	29.8	16.2	33.8	21.2	82.850**	2.10	.105	45.2	26.7	50.4	31.3	-1.20
Vigorous PA (min)	3.7 [‡]	5.2	4.4 [‡]	5.0	0.6	1.4	0.5	1.2	41.080**	.233	.458	2.2	4.1	2.4	4.1	-.431
MVPA (min)	65.0 [‡]	29.4	72.0 [‡]	34.1	30.4	16.6	34.4	21.4	87.953**	1.966	.143	47.6	29.4	52.9	34.0	-1.15

Note: 1.) Significant difference, *at the 0.05 level ($p < 0.05$) or **at the 0.001 level ($p < 0.01$) between factors, by 2-way ANOVA.
2.) Significant difference, [†] at the 0.05 level ($p < 0.05$) or [‡] at the 0.01 level ($p < 0.01$) between genders of urban and rural areas, by Independent-samples *t*-test.
3.) Significant difference, [#] at the .05 level ($p < 0.05$) or [¶] at the 0.01 level ($p < 0.01$) between school locations (urban and rural) of different genders (^Bboys or ^Ggirls), by Independent-samples *t*-test.
4.) Significant difference, ^{oo} at the 0.01 level ($p < 0.01$) between school locations (urban and rural), by Independent-samples *t*-test.

Table 3. Mean minutes per day spent at each activity level between urban and rural school adolescents, divided by BMI classification.

Variables	Normal weight		Overweight/Obesity						F _{BMI}	F _{Location}	F _{BMI x Location}
	Urban	Rural	Urban	Rural	Mean	SD	Mean	SD			
Number of valid days (day) ^{#N}	6.2	0.9	6.0	1.1	6.1	1.2	6.2	1.0	.124	.642	1.601
Average monitor wear time per day (min) ^{#O, †N}	713.0	77.8	688.3	58.5	737.4	78.6	677.7	41.4	.022	13.825**	3.151
Sedentary behavior (min) ^{#O, †N}	398.2	57.0	360.7	60.0	412.8	76.1	363.7	51.9	.590	14.437**	.259
Light PA (min)	267.0	48.0	272.3	45.4	273.4	50.2	265.7	53.4	.015	.057	.383
Moderate PA (min) ^{#N}	43.2	24.8	52.7 [†]	32.1	49.5	30.3	36.7	22.2	.796	.098	4.228*
Vigorous PA (min)	2.4	4.7	2.6	3.9	1.7	2.5	1.5	5.2	1.257	.000	.057
MVPA (min) ^{#N}	45.8	28.2	55.3 [†]	34.6	51.3	32.0	38.3	25.8	.958	.085	3.642

Note: 1.) Significant difference, *at the 0.05 level ($p < 0.05$) or **at 0.01 level ($p < 0.01$) between factors, by 2-way ANOVA.
2.) Significant difference, [†]at the 0.05 level ($p < 0.05$) between BMI classifications of urban and rural area, by Independent-samples *t*-test.
3.) Significant difference, [#]at the 0.05 level ($p < 0.05$) or [†]at the 0.01 level ($p < 0.01$) in BMI classification (^Nnormal weight or ^Ooverweight/obesity) between urban and rural, by Independent-samples *t*-test.

Time Spent in PA between school locations – related to age groups

The use of multiple comparison tests (Bonferroni post hoc test) following two-way ANOVA (Table 4) shows school location did not have a significant main effect on MPA or greater activity levels ($p > 0.05$) in any age group, however MPA or greater activity levels were significantly linked to age group ($p < 0.01$). School location had a significant main effect on SED ($F_{(1,180)} = 21.232$, $p < 0.001$, $\eta_p^2 = 0.106$); but SED was not a statistically significant result of age group. Regarding the differences in daily time spent on PA between age groups, post analyses using Bonferroni indicated that older adolescents were significantly less active in MPA, vigorous PA and MVPA when compared to younger adolescents. There was no significant effect of the school location x age groups on either SED or PALs.

The proportion of adolescents achieving current physical activity guidelines between school locations

Tables 5 and Table 6 show the results of chi-square tests in examining the differences between discernible variables of adolescents related to meeting the 60-minute PAG. Although the level of meeting the PAG in urban adolescents was similar to those of their rural counterparts (33.3% vs. 34.4%, respectively; $p = 0.87$). OW/OB group adolescents living in urban areas were 2.7 times more likely to meet these PAG compared to those living in rural areas. In contrast, rural girls were doubly likely to meet these recommendations percentage-wise than urban girls (12.8% vs. 6.4%, respectively). In both urban and rural locations, boys were more likely than girls to meet the PAG, while PAG accomplishment seemed to decrease sharply with age, even though and there were quite similar levels of PAG accomplishment in urban and rural areas. We did not find any statistically significant differences ($p > 0.05$) in the proportion of adolescents meeting the PAG according to school location and age group.

DISCUSSION

The prevalence of overweight/obesity and General findings

In this sample, 23.1% of adolescents were classified as OW/OB based on the IOTF BMI cut-off (Cole, et al., 2000), prevalence of OW/OB was seen to link with different geographical locations. These findings are very alarming, especially for urban areas. Urban adolescents were 2.3 times more likely to be OW/OB than their rural counterparts. Associations of OW/OB prevalence and geographical areas are consistent with a previous national study (Sakamoto, et al., 2001), but there is an inverse relationship with the prevalence of obesity in American (Davis, Bennett, Befort, & Nollen, 2011), rural children and adolescents were significantly more likely to be obese (21.8%) than those living in urban areas (16.9%).

Table 4. Mean minutes per day spent at each activity level between urban and rural school adolescents, divided by age group.

Variables	13-14 years old				15-16 years old				17-18 years old				F _{Age group}	F _{Location}	F _{Age group x Location}
	Urban		Rural		Urban		Rural		Urban		Rural				
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Number of valid days (day) ^{†C}	6.2	1.0	5.8	1.0	6.2	1.0	6.4	1.0	6.1	1.0	5.5	1.1	4.083*	3.647	2.081
Average monitor wear time per day (min)	742.1	71.4	690.0	63.5	712.4	64.6	688.2	59.0	705.3	97.7	677.2	45.3	2.11	12.017**	.799
Sedentary behavior (min)	395.8	63.0	347.9	67.1	402.2	61.8	372.6	57.7	412.5	67.9	365.6	45.4	1.544	21.232**	.439
Light PA (min)	278.8	50.0	271.3	47.6	266.4	48.4	267.1	50.3	265.0	47.8	275.9	41.9	.487	.038	.573
Moderate PA (min) ^{‡ABC}	63.4	27.5	67.9	34.1	42.1	21.1	45.6	24.3	26.9	16.1	34.1	23.2	30.413**	1.817	.083
Vigorous PA (min) ^{†B}	3.8	5.9	2.8	4.3	1.5	2.3	2.9	5.2	1.0	2.0	1.5	2.0	4.360**	.266	1.385
MVPA (min) ^{†C, ‡AB}	67.4	31.1	70.8	37.0	43.8	22.9	48.6	28.5	27.9	17.3	35.7	24.1	28.210**	1.673	.102

Note: 1.) Significant difference, *at the 0.05 level ($p < 0.05$) or **at the 0.01 level ($p < 0.001$) between factors, by 2-way ANOVA.
2.) Significant difference, [†]at the 0.05 level ($p < 0.05$) or [‡]at the 0.01 level ($p < 0.01$) between age groups; ^Aage 13-14 and age 15-16, ^Bage 13-14 and age 17-18, ^Cage 15-16 and age 17-18, by Bonferroni Post-hoc test.

Table 5. Differences (in %) of adolescents meeting the guidelines (of 60 minutes of MVPA per day) between urban and rural school adolescents, according to gender and BMI classification.

School location/ Variables	Gender						BMI classification					
	Boys			Girls			Normal weight			Overweight/ obesity		
	Missed	Met	p (χ^2 , V)	Missed	Met	p (χ^2 , V)	Missed	Met	p (χ^2 , V)	Missed	Met	p (χ^2 , V)
Urban	39.1%	60.9%	.67	93.6%	6.4%	.29	69.8%	30.2%	.44	60.9%	39.1%	.22
Rural	43.5%	56.5%	(.179, .044)	87.2%	12.8%	(1.106, .108)	63.8%	36.3%	(.586, .064)	85.7%	14.3%	(1.491, .223)
Total	41.3%	58.7%		90.4%	9.6%		66.4%	33.6%		66.7%	33.3%	

Note: p: p-value, χ^2 : Pearson Chi-square test value, V: Cramer's V coefficient value

Table 6. Differences (in %) of adolescents meeting the guidelines (of 60 minutes of MVPA per day) between urban and rural school adolescents, according to age group and for all participants.

School location/ Variables	Age groups (years old)									All participants		
	13-14			15-16			17-18			Total		
	Missed	Met	p (χ^2 , V)	Missed	Met	p (χ^2 , V)	Missed	Met	p (χ^2 , V)	Missed	Met	p (χ^2 , V)
Urban	42.4%	57.6%	.83	69.7%	30.3%	.81	92.6%	7.4%	.70	66.7%	33.3%	.87
Rural	40.0%	60.0%	(.041, .025)	72.4%	27.6%	(.055, .03)	89.7%	10.3%	(.148, .051)	65.6%	34.4%	(.024, .011)
Total	41.2%	58.8%		71.0%	29.0%		91.1%	8.9%		66.1%	33.9%	

Note: p: p-value, χ^2 : Pearson Chi-square test value, V: Cramer's V coefficient value

Importantly, the OW/OB prevalence presented in our current study is higher in both areas than reported in previous national studies (Mo-suwan & Geater, 1996; Sakamoto, et al., 2001), while urban adolescents were not only linked with the higher prevalence of OW/OB but also a higher rate of SED. Therefore this and the previous studies (Marshall, Biddle, Gorely, Cameron, & Murdey, 2004; Strong et al., 2005) supported that time spent on SED is associable with OW/OB rates and a high body fat percentage in children and adolescents. Interestingly, OW/OB in our adolescents is also more prevalent in comparison to other developed countries, for examples, 14.4%-15.8% in Australia (Vincent, Pangrazi, Raustorp, Tomson, & Cuddihy, 2003), 16.6%-16.8% in Sweden (Raustorp, Pangrazi, & Stahle, 2004); but there is less than some US reports (33.1-33.6%) (Davis, et al., 2011; Vincent, et al., 2003). It is important to note that the inconsistent estimates of the prevalence among those latter studies may be related to differing geography, differing samples and a differing method for defining obesity and the overweight. Nevertheless, the high prevalence among our sample urgently calls for the design of OW/OB prevention programs for Thai adolescents, especially those living in urban areas.

Our sample was predominantly sedentary (52.7%-55.9%) or engaged in light activity (37.5%-39.6%), with their MVPA level never accounting for greater than 8% (6.6%-7.7%). An experiment with adolescents of similar samples size, grade level which employed accelerometers (Treuth, Hou, Young, & Maynard, 2005), showed that some American rural youth had SED figures as follows: 51.4% to 56% and 39.4%-43.2% for light PA, while only 4.6-5.4% of time spent in MVPA. In addition, at similar ages American rural youths spent 44.3-51.1 minutes/day in MVPA while Thai rural adolescents spent 52.9 minutes. The latest PAG has recommended that children and youth also need to participate in vigorous activities at least 3 days per week (Tremblay, Warburton, et al., 2011). Interestingly we found that very little time was spent in vigorous activity in either urban or rural adolescents (< 2.5 minutes), thus adolescents generally may not be fit for the guidelines. Participation in more vigorous activity needs to be promoted; additionally, PA interventions targeting inactive or slightly active

adolescents in both urban and rural areas are also clearly needed. However, regarding a large percentage of time spent in SED and light activity, there is a good explanation that this is partly to be expected because the predominant activity at school is sitting in class – an average daily class period is about 7 hours (*data not shown*). Additionally, students in urban schools generally attended more private lessons not involving PA after school than those from rural (Loucaides, Chedzoy, & Bennett, 2004).

The most recent study in the UK (Ogunleye, Voss, Barton, Pretty, & Sandercock, 2011) reported that rural adolescents' PA did not differ from urban dwellers', while another recent study (Dyck, Cardon, Deforche, & De Bourdeaudhuij, 2011) which used pedometers to assess PA in a sample of Belgian adults, urban participants took more steps/day and reported more walking than rural counterparts. In contrast with our Thai sample which demonstrated that rural adolescents were more likely to be physically active than urban adolescents, particular those with a normal weight – supported by studies of Greek-Cypriot children (11-12 years old) (Loucaides, et al., 2004) and some (aged 10-17) in US (Liu, et al., 2008), children in rural schools spend significantly more time on PA than urban children (Loucaides, et al., 2004). Consequently the man-made and social environmental factors are important in developing interventions to halt or decrease the decline in PA in adolescents (M. P. Santos, Page, Cooper, Ribeiro, & Mota, 2009).

Gender and School location

Gender and school location were the main factors affecting SED. This result is consistent with well established evidence indicating that the risk of insufficient PA is greater in girls than in boys, especially during their adolescent years (Sallis, Prochaska, & Taylor, 2000). Previous studies (P. Santos, et al., 2003; Trost, et al., 2002) using objective measures have also demonstrated boys engaged in significantly more MVPA than girls. Moreover, the current findings show that boys had more MVPA than the minimum of the PAG, but girls did not, this finding was consistent in both urban and rural areas. It is possible that the accessibility of PA facilities and current PA promotion may be

particularly beneficial for boys to accumulate more PA, and boys might generally perceive their environment in a more positive way than girls (M. P. Santos, Page, et al., 2009). Our data suggest that adolescent-aged girls are priority group for future PA interventions. Both urban and rural schools should provide appropriate curriculums that meet their needs in the PA domain, for instance providing adequate playground supervision, suitable sport equipment, physical education classes/sports, and other contexts where PA may take place that may promote equal participation for both genders.

BMI classification and School location

It was discovered surprisingly that the effect of time spent in SED and light activity among Thai adolescents was independent of their BMI status by using 2-way ANOVA. But this result is consistent with one prior study (Stone, Rowlands, & Eston, 2009) which reported that PALs of children did not differ with weight status. However, among rural areas, normal-weight adolescents performed 17 additional minutes of MVPA per day compared to the OW/OB adolescents. Interestingly, in the present study collective MVPA between school locations was inconsistent across BMI groups. In rural areas, normal-weight adolescents were significantly more active (for moderate and MVPA) than their matched counterparts. But urban adolescents who classified as overweight or obese were more likely to be active than those of the normal-weight group; though we did not find any significant difference between these two groups. A potential explanation of these findings may relate to the differences in accessibility to places where adolescents can do in urban and rural locations. Urban residents have better accessibility (Huang, et al., 2010) and so it might be appropriate for OW/OB adolescents. In addition, schools and family in urban areas might also effectively provide the specific exercise program for their OW/OB children. Although Treuth et al. (Treuth, et al., 2007) and De Bourdeaudhuij et al. (De Bourdeaudhuij et al., 2005) reported that normal-weight adolescents engaged significantly more in MPA and MVPA than their OW/OB counterparts, those studies did not examine the differences between school locations, whereas we found rural normal-weight subjects were

significantly more active than their urban counterparts. However urban adolescents who were overweight or obese tended to spend more time in MVPA than their rural counterparts. We therefore strongly suggest that further studies should attempt to identify the PA facilities and school programs impact over different BMI groups in both school locations.

In summary and in regards to school location and BMI status, it should be noted that school location differences may reflect differences in activity levels between overweight and non-overweight adolescents. Consequently, taking BMI status and school location together may be important to establish specific intervention for encouraging adolescents to improve their PALs.

Age and School location

We found the associations of PALs between school locations and between age groups were independent of each other; moreover, it is interesting that there was no significant difference in time spent in SED between age groups. However, older adolescents seemed to participate in SED more than their younger counterparts, indeed a decline in PA from childhood through adolescence has been reported. For instance, Trost et al. reported that daily MVPA from the accelerometer data exhibited a significant inverse relationship from grade 1 to 12 (Trost, et al., 2002). Conversely, Santos and colleagues found that time spent in MVPA increased with age for both boys and girls, with the largest differences in MVPA occurring between ages 11-13 and 14-16 among children aged 8-15 years (P. Santos, et al., 2003). However, PA behaviors between children and adolescents might be different, due to prevailing conditions in the wider socioeconomic environment outside the home (Lau, Lee, & Ransdell, 2007). One would expect that the cultural differences would be important in said associations.

Compliance with physical activity guidelines

Regarding the latest PA recommendations for children and youths (Tremblay, Warburton, et al., 2011), the present results show that school location was not statistically significantly associated with meeting PA

recommendations (33.3% for urban and 34.4% for rural adolescents). More than half of the boys were achieving the PAG of ≥ 60 minutes of MVPA per day, while a very small percentage of girls managed the same. Using a similar methodology, Ribeiro et al. reported that the prevalence of compliance with PAG in Portuguese youth (12-18 years old) ranged from 15.4%-17.5% (when extrapolating over a 4-day period) (Ribeiro, et al., 2009). A study from the US (Pate et al., 2002) also revealed that more boys (72.4%) than girls (66.3%) met those guideline, and compliance with PAG declined with ages (100% on ages 1-3 to 29.4% on ages 10-13). Other prevalence studies do exist, but a study using different methods would therefore be incomparable. Importantly, this study provided the extended knowledge that the prevalence of PAG accomplishment is linked to school locations; moreover, meeting the recommendations for PA is accentuated with specific characteristics of the participants.

Girls living in rural areas were found to be positively associated with meeting PAG compared with those living in urban areas, but living in urban areas brought some success for the OW/OB group in meeting PAG. It is possible that OW/OB adolescents living in urban areas and girls living in rural areas may have greater opportunity for active play than their rural and urban counterparts. Further studies are needed to clarify these interesting associations. Furthermore, it is important to note that engaging in high SED and insufficient MVPA has shown to be a risk factor for failing to meet the 60-minutes of PAG and increasing prevalence of OW/OB. We suggest that school locations should not be ignored when considering improving compliance with PAG of secondary-school adolescents, and should be specific to gender and BMI status.

Strengths of the study design

In this study, we used data from a large sample with demographic variables well-distributed, this allowed for tests for interactions across school locations among adolescence period. Pursuing the global interactions conducted in the present study has extended the knowledge of the PA field, and it is also provided very important challenges for researchers due to gaps in

information on adolescents' health between rural and urban areas. The seven days of monitoring using this method are truly representative of PA on both weekdays and weekend days measured with a highly accurate instrument such as an accelerometer; that data might be appropriate for comparing with the latest PAG. Most importantly, it might be the primarily study that examined the PA level differences between geographical locations, and clarified how adolescents succeeded with the PAG. Consequently, the findings of this study are strengthening children and adolescents' health research, as well as the practice, and policy for PA promotion.

Study limitations

Several limitations of the present study should be noted. Firstly, although one recent longitudinal study (Pabayo, Belsky, Gauvin, & Curtis, 2011) has indicated that areas of residence did not predict MVPA over time; nevertheless, the cross-sectional design of this study limits our ability to make causal inferences about the observed relationships. Secondly, the sampling method in this study may not nationally representative; future studies in nationally representative samples would be desirable, as well as more evidences from other cultural contexts being required. Thirdly, we cannot control for socioeconomic status and our participants reside in the poorest and less privileged regions of the country, where socioeconomic status (SES) may exaggerate urban/rural differences, thus it may have affected our current results. Therefore further studies need to clarify the interaction between PALs and SES differences, or the man-made environments in relation to PA regarding urban/rural areas (Davison & Lawson, 2006; Huang, et al., 2010). Finally, although respondent bias is decreased with the use of accelerometers when measuring PA, bias and inaccuracy are not eliminated entirely due to the accelerometer limitations because an accelerometer cannot be worn during water-based activities (i.e., swimming): this may under represent the total amount of PA minutes.

According to main results, the current findings would benefit from additional data and is extending knowledge on how area characteristics relate

to adolescents' PALs. Several key patterns were identified that characterize how PA behaviors are influenced by adolescents' characteristics and thereby provide a basis for developing strategies to promote activity in this population regarding geographical areas. Importantly, these current findings also can help identify subgroups of the population that may need to be targeted for specific intervention programs. More research addressing this topic is strongly required.

CONCLUSION

This study suggests that girls and urban adolescents are an at-risk group for SED and becoming overweight or obese, this is essential for designing effective interventions to target those most at risk. We cannot ignore geographical differences as the dependent factors to public health implications for reducing time spent in SED and increasing PA participation. Addressing such issues might substantially decrease the incidence of overweight and obesity for adolescents. It would be of interest to future investigation as to whether this factor can be manipulated in a specific intervention designed to increase children and adolescents' PA based on school locations.

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Declaration of interest

The authors report no declarations of interest. The authors alone are responsible for the content and writing of the paper.

PAPER III

Associations between School Travel Modes and Objectively Measured Physical Activity Levels in Thai Adolescents

Kurusart Konharn, Maria Paula Santos, Christopher Young, and José Carlos Ribeiro

ABSTRACT

Background: Active commuting to school is an excellent opportunity for increasing children's daily physical activity (PA), but there is little study-based evidence to describe patterns in adolescent population within specific demographic and socioeconomic profiles.

Aim: This study was conducted in order to determine the association between school travel modes and objectively measured PA of adolescents.

Subjects and methods: 186 adolescents (ages 13-18) wore the ActiGraph GT1M accelerometers to obtain objective measurements of PA during all waking hours for 5 consecutive weekdays. Average and total daily moderate-to-vigorous PA (MVPA) minutes were analyzed for 3 categorized travel modes (walking, bicycling, and motorized transport).

Results: Adolescents who walked or bicycled to school had significantly higher daily MVPA than who those traveled by motorized transport, in particular girls and rural dwelling adolescents. Adolescents categorized as moderately active were more likely to walk to school (*OR*: 5.04 - 95% *CI*: 1.04, 24.54) and also in the active group (*OR*: 10.28 - 95% *CI*: 2.13, 49.74) with motorized transport as reference category.

Conclusions: Active commuting to school such as walking and bicycling presented a worthwhile strategy for improving daily PA in adolescents, with a special focus on MVPA levels.

Keywords: Activities of daily living, adolescent behavior, active commuting, physical activity guidelines, Thailand

INTRODUCTION

Physical activity (PA) has positive effects on several health outcomes among children and adolescents, including decreased risk of obesity and excessive weight gain and contributing to higher cardiovascular fitness (Lubans, Boreham, Kelly, & Foster, 2011). According to the most recent PA guidelines (Tremblay, Warburton, et al., 2011) and sedentary behavior (Tremblay, Leblanc, et al., 2011) guidelines, children and youths should accumulate an average of at least 60 minutes of moderate-to-vigorous PA (MVPA) every day (Tremblay, Warburton, et al., 2011) and should limit motorized transport (Tremblay, Leblanc, et al., 2011). Thus an achievement of these PA guidelines could be fulfilled by the journey to school (Cooper, Andersen, Wedderkopp, Page, & Froberg, 2005; Silva et al., 2011; Sirard, Alhassan, Spencer, & Robinson, 2008; Tudor-Locke, Ainsworth, Adair, & Popkin, 2003) and examining the influence of school travel mode on MVPA level could assist public health bodies in developing interventions suited to school-age adolescents. Unfortunately over the last decade a number of social and environmental changes have limited children's access to safe places where they can walk, bike and play, and the percentage of school-age children who actively commute has decreased in many countries (Cooper, et al., 2005; McDonald, 2007) and represent a major challenge for health promotion (Grize, et al., 2010).

Many studies (Landsberg et al., 2008; Morency & Demers, 2010; Robertson-Wilson, Leatherdale, & Wong, 2008; Silva, et al., 2011) that have focused on school transportation in children and adolescents used self-report measures, and suggested that active commuting to school is associated with higher levels of PA among children and adolescents. However, it has been shown that using a single self-report/questionnaire may not respect the broad range of total PA levels (PALs) in which children and adolescent might participate (Welk, et al., 2000). Additional researches to determine the relationship between objectively measured PA and modes of travel to school are needed. The accelerometers are a useful epidemiologic tool to measure PA in free-living conditions, and have been proved to be valid for detecting and assessing PA patterns (intensity, duration, frequency) over extended periods.

This is one important reason why accelerometers are often favored in field-based research with children and adolescents (Puyau, Adolph, Vohra, & Butte, 2002; Trost, et al., 1998). To the best of our knowledge, accelerometers could provide a good opportunity to explore the differences between travel modes on time spent in MVPA during the school days. Accelerometer-based PA assessment has been considered in several previous studies on commuting to school (Cooper, et al., 2005; Cooper, Page, Foster, & Qahwaji, 2003; J. Panter, Jones, Van Sluijs, & Griffin, 2011; J. R. Panter, Jones, Van Sluijs, & Griffin, 2010; Rosenberg, Sallis, Conway, Cain, & McKenzie, 2006; Sirard, Alhassan, et al., 2008; Sirard, Riner, McIver, & Pate, 2005), and suggested that promotion of active commuting to school might be an important way to increase levels of PA in school children, however most of the evidences was collected in children samples and/or in developed countries. Previous research has suggested that the determinants of active travel differ from childhood to adolescence and highlights the need for adolescent-specific research (Nelson, Foley, O'Gorman, Moyna, & Woods, 2008). To our knowledge only one study (Tudor-Locke, et al., 2003) has explored the association of school travel modes (focused on walking and motorized transport) on accelerometry-based PA (Caltrac) in adolescents (ages 14-16). However data was expressed as energy expenditure (kcal/day), this does not provide information on how adolescents achieved the 60 minutes of MVPA, and therefore the contribution of school travel modes to meeting PA guidelines in adolescents is still unknown. Furthermore the study did not study include bicycling (Tudor-Locke, et al., 2003).

Additionally the previous studies (Faulkner, Buliung, Flora, & Fusco, 2009; Landsberg, et al., 2008; Lubans, et al., 2011; Rosenberg, et al., 2006) are also still inconclusive regarding the influence of active transportation to school on gender and BMI in children and adolescents. It seems like there is no absolute agreement yet on active transportation to school as a supplement to the daily PA amount with influence on BMI. Importantly active transport to school also may differ in developing countries, since social and cultural factors might play an important role behind the behavior (Grize, et al., 2010). In addition environmental characteristics were also important, as the school

location is associated with active commuting (Robertson-Wilson, et al., 2008) and little is known respecting the urban-rural and socioeconomic status (SES) differences regarding transport to school and PA.

Therefore it is important to investigate whether there are differences in PALs between adolescents who travel by different transportation modes to school. The aims of this cross-sectional study were: 1) to examine the relationship between school travel modes, objectively measured levels of MVPA and BMI in school-age adolescents; 2) to verify the MVPA level differences in school travel modes and its possible dependence on adolescents' demographic and socioeconomic variables; 3) to explore the prevalence of school travel modes in accordance with adolescents' socio-demographic characteristics; and, 4) to compare the compliance among school travel modes with the latest PA recommendations.

METHODS

Samples

In our cross-sectional study data was collected between November 2008 and March 2009 in Northeastern Thailand. Two-hundred adolescents were randomly selected from eight public secondary schools with equal proportions in urban and rural schools; participants were from between the 7th and 12th grades (aged 13-18 years), and took part in the PA measurement. A total of 186 adolescents (93% of original participants; 92 boys and 94 girls) who were 15.4 ± 1.7 years old and provided the study with adequate amount of PA data - in accordance with the minimum daily wearing time and number of required days - were included in the further data analysis. Questionnaires were used to determine socio-demographic characteristics and specifically modes of transportation to school (then, they were divided into 3 groups; walking, bicycling, and motorized transport).

We divided SES into 3 groups based on the actual value of annual household income obtained from the parents: low (< 25,000 THB), middle (25,000-45,000 THB) and high (> 45,000 THB) or approximated < 800 USD, 800-1,500 USD and > 1,500 USD, respectively (For rough calculation: 1 USD

equals 30 THB). These 3 SES groups were determined by taking the mean annual household income at 33rd and 66th percentile – less than 33rd percentile belonged to the low-SES group, while at percentile of 33rd-66th was classified as middle-SES group, and above 66th percentile categorized as high-SES group. In the present study urban-rural area was defined on the basis of population density and the definition of the National Statistical Office (N. S. O. o. Thailand). The urban schools are located in the central part of the province (amphoe mueang) with at least 130000 inhabitants are living therein and which is officially declared as an urban area. The rural schools are located in the rural villages (*tambon*) with less than 4,000 inhabitants are living there. Age was divided into 3 groups: 13-14 years, 15-16 year, and 17-18 years.

Written consent was obtained from parents or guardians before the subjects entered into the study and participants assented to participation by verbal consent. Any adolescents who were unable to participate in this study and/or had been told by a physician to avoid PA, or had some other medical contraindications rendering them ineligible: such students being replaced with another eligible adolescent in the school with the same gender, age, and in the same grade level. Human subject approval for this study was obtained from the Faculty of Sports Scientific Board at the University of Porto.

Anthropometric Measures

Body weight (to 0.5 kg; SECA 750, Hamburg, Germany) and height (to 0.5 cm; SECA 242, Hamburg, Germany) were determined by standard anthropometric methods. BMI was calculated by dividing weight in kilograms by height in meters squared (kg/m^2).

Body fat percent (%BF) estimates were determined using the Maltron bioelectrical impedance analysis (BIA) system [Body Fat Analyse (BF-906); Maltron international Ltd, Essex, UK]. BIA measurements were carried out using the tetrapolar technique with the subject lying in a supine position with hands and legs slightly apart on a flat, nonconductive bed. A tape was used to measure waist circumference (WC; nearest 0.1 cm) at a level of umbilicus in the horizontal plane of the participants and the measurement was made during

normal expiration (Yamborisut, et al., 2008). Well-trained researchers administered all measurements and all anthropometric measures were collected twice, and the average of the two values was used in analysis.

Physical Activity Assessment

Physical activity was objectively measured for 7 consecutive days using the GT1M accelerometers (ActiGraph LLC, Pensacola, FL, USA), but only 5 school days (Monday to Friday) were selected for analysis. This instrument is an uniaxial activity monitor, small (3.8x3.7x1.8 cm), light weight (27 g), generally used to measure and record acceleration ranging in magnitude from approximately 0.05 to 2.0 G's with frequency response from 0.25 to 2.5 Hz. It provided quantification of the intensity and duration of body movement over periods of several days, or even weeks, enabling patterns of active and inactive activity (Cooper, et al., 2000).

With adults, use of a 1 minute time-sampling interval (known as epoch) is typical for accelerometer assessment of PA, however the use based on 1-minute epoch may be inappropriate for children and may result in underestimation of their total PA (Trost, McIver, & Pate, 2005). Research suggests that due to children's specific movement patterns which tend to consist of shorter and more frequent bouts of PA, the ability to use an epoch shorter than 1 minute is a critical consideration in instrument selection for PA assessment in children (Trost, et al., 2005; Vale, Santos, Silva, Soares-Miranda, & Mota, 2009). In this study therefore the epoch was set at 30 seconds in all accelerometers, and all participants were instructed to wear the accelerometers on their right hip, attached to a belt while carrying out their normal daily activities during all waking hours, and were asked to take it off only when sleeping and aquatic activities (i.e. bathing, swimming). The adolescents returned the accelerometers after seven days of recording, data was then downloaded by the same laptop computer that was used to initialize them via the USB port.

Accelerometer Data Reduction

ActiLife software (Manufacturing Technologies Inc. Health Systems, Shalimar, FL; version 3.6 for Windows) that accompanied the accelerometers was used to download the accelerometer data (.DAT files). After that MAHUFFe software (www.mrc-epid.cam.ac.uk, Cambridge, UK) was used to establish the amount of time participants spent in different activity-intensity categories (light, moderate, vigorous, and vigorous intensity). This time was averaged per day and for all 5 weekdays, based on application of count thresholds corresponding to intensity-specific activity, using the age-specific counts-per-minute cut-off points for children and adolescents established by Freedson et al. (P. Freedson, et al., 2005). The output used for further data analysis was the amount of time spent (minutes) in MVPA (time spent in PA which was at least moderate). Daily average minutes spent in MVPA and total daily MVPA were estimated for all valid days (during weekdays).

Adolescents were considered to have valid data provided the monitor was worn for at least 3 days, and a minimum of 600 minutes of valid data per day were recorded (Masse, et al., 2005; Trost, Pate, et al., 2000; van Sluijs et al., 2009). Sustained 10 minutes periods of zero counts-per-minute was taken as proof that the monitor had been removed (Masse, et al., 2005).

Statistical Analysis

Differences in mean values of the measured variables of our sample and especially in minutes of MVPA between genders and school locations were analyzed using independent sample *t*-tests. Between school travel modes and SES groups we used one-way analysis of variance (1-way ANOVA). Differences in average and total daily MVPA (in minute) between commuting types were tested using 1-way ANOVA. Post-hoc multiple comparisons were performed using the Bonferroni test.

The Chi-square test (χ^2) with Cramer's V coefficient test (V) was used to determine the prevalence of adolescents who meet the PA guidelines and the prevalence of school travel modes based on adolescents' socio-demographic characteristics.

Multinomial logistic regression was performed to analyze the degree to which MVPA in minutes could be predicted by travelled modes to school. To allow meaningful odds ratios, the values for objectively measured MVPA in minutes were converted into 4 categorical variables by quartile (*Inactive, moderately inactive, moderately active and active*), adjusted by age and gender. Adjusted models where the effects of travelled modes to school (*walking, bicycling and motorized transport*) on minutes of MVPA quartile groups were created and are presented in tubular format. Odds ratios, 95% confidence intervals (CI) and Standard Error are provided for all analyses. Reference (*Dummy*) variables were created for these analyses with the aforementioned inactive group as the reference category.

All hypotheses were tested using 2-tailed tests. Statistical significances were considered as $p < 0.05$. All analyses were performed using Predictive Analytics Software version 18.0 (PASW, Chicago, IL).

RESULTS

Participants' Characteristics and Prevalence of School Travel Modes

Descriptive characteristics of the participants are presented in Table 1 and Table 2. One-hundred and eighty-six adolescents (aged = 15.4 years; BMI = 21.3 kg/m^2 ; %BF = 24.3, and WC = 79.5 cm) were evaluated, there were no significant differences in mean age based on school travel mode, school location, gender, and SES group ($p > 0.05$). Approximately 60% of the subject sample reported using an "inactive mode of transportation" (i.e. using a motorcycle, taking a bus, or riding a car; expressed as motorized transport in this study), 22.0% traveled by bicycle, and 20.4% walked to school.

The prevalence of motorized transport was higher in urban adolescents ($p = 0.00$) and those in higher income families ($p = 0.01$) when compared with those who commuted to school by walking and/or by bicycling. Almost 90% of urban adolescents reported using inactive modes of transportation. Additionally, the prevalence of motorized transport in adolescents living in high-SES families was greater than the other two groups ($p = 0.01$). A greater percentage of younger adolescents seemed to be bicycling to school.

Regarding body composition variables, boys had significantly lower %BF than girls ($p < 0.01$), while adolescents who lived in urban areas had a higher %BF than those living in rural areas ($p < 0.01$). Participants who travelled by motorized transport had significantly higher BMI ($p = 0.02$) and %BF ($p = 0.00$) than those who travelled by active transport (walking and bicycling). We found also that adolescents who walked to school had the lowest mean value in either BMI or %BF, compared with the other two groups.

Table 2. Descriptive characteristics of the participants regarding school travel modes.

Variables	School travel modes						p
	Walking		Bicycling		Motorized transport		
	(n=38 or 20.4 %)		(n=41 or 22.0 %)		(n=107 or 57.5 %)		
	Mean	SD	Mean	SD	Mean	SD	
Age (year)	15.6	1.8	14.8	1.7	15.5	1.7	0.07
Weight (kg)	52.1	9.8	54.2	17.5	57.8	11.8	0.05
Height (cm)	162.5	8.8	160.5	11.0	162.6	8.2	0.46
%BF	21.3	7.2	22.0	9.0	26.2	7.3	0.00**
WC (cm)	76.3	6.8	78.9	12.7	80.9	11.1	0.07
BMI (kg/m ²) based on group							
Gender							
Boys	20.1	2.5	19.3	4.3	21.7	4.2	0.03*
Girls	19.5	2.0	22.9	7.2	22.4	4.2	0.04*
School location							
Urban	18.9	1.8	18.0	1.8	22.5	4.3	0.01*
Rural	20.0	2.3	21.2	6.2	20.7	3.9	0.53
SES group							
Low	20.2	2.5	19.6	5.2	23.0	5.8	0.03*
Middle	19.4	2.1	23.3	7.2	21.1	3.1	0.05
High	19.6	2.2	19.2	3.1	22.0	3.2	0.04*
Total	19.8	2.3	20.8	5.9	22.1	4.2	0.02*

Notes: n: frequency, SD: standard deviation, p: p-value

* Significant difference between school travel modes ($p < 0.05$)

** Significant difference between school travel modes ($p < 0.01$)

Table 1. Descriptive characteristics of the participants (n=186).

Variables	Gender				School location				SES group						Total	
	Boy		Girl		Urban		Rural		Low		Middle		High			
	(n=92 or 49.5 %)		(n=94 or 50.5 %)		(n=93 or 50.0 %)		(n=93 or 50.0 %)		(n=72 or 38.7 %)		(n=61 or 32.8 %)		(n=53 or 28.5 %)		(n = 186)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (year)	15.3	1.8	15.5	1.7	15.4	1.8	15.4	1.7	15.0	1.7	15.7	1.8	15.5	1.7	15.4	1.7
Weight (kg)	56.8	13.3	54.9	12.8	58.0*	12.0	53.6	13.8	53.8	14.4	56.7	13.5	57.5	10.2	55.8	13.1
Height (cm)	166.2**	9.3	158.1	6.7	163.8**	8.4	160.5	9.3	160.8	9.9	162.9	8.2	163.1	8.5	162.1	8.5
BMI (kg/m ²)	20.7	4.0	22.0	4.7	22.0*	4.3	20.6	4.5	21.4	5.2	21.2	4.4	21.4	3.2	21.3	4.4
%BF	18.5**	6.3	29.9	4.8	25.8**	7.6	22.7	8.1	22.7	7.7	24.6	8.5	26.0	7.3	24.3	8.0
WC (cm)	78.8	10.3	79.1	11.4	80.7	11.4	78.2	10.2	78.9	12.5	79.4	10.6	80.4	8.8	79.5	10.9

Notes: n: frequency, SD: standard deviation, p: p-value
 * Significant difference between groups (p < 0.05)
 ** Significant difference between groups (p < 0.01)

School Travel Modes and Physical Activity

Mean ($\pm$ SD) for daily MVPA (in minutes) according participants' characteristics and mode of commuting to school are shown in Table 3. Analysis by gender indicated that the differences in MVPA between school travel modes were seen only in girls ($p = 0.01$), but there were no statistically significant differences in daily MVPA between the travel modes among boys ($p = 0.87$).

According to school travel modes, the highest minutes of average daily MVPA were found in adolescents who walked to school (60 ± 27.9) and walkers accumulated 11 more minutes of MVPA than those who reported using motorized transport to school. Girls were less physically active and engaged in less MVPA than boys among all travel modes ($p < 0.05$). However, girls who travelled to school by walking spent 62 more minutes of total daily MVPA than those who travelled by motorized transport, and spent 36 more minutes than those who reported using a bicycle to travel to school, but significant differences were not found ($p = 0.06$). In addition, in total daily MVPA there were significant differences between travel modes and MVPA in the sample in rural areas ($p = 0.01$), and Bonferroni multiple comparisons also showed that adolescents who reported using motorized transport were significantly less active than those who walked or bicycled to school ($p < 0.05$). In contrast with the other two groups of travelers, urban adolescents who traveled to school by motorized transport were significantly more engaged in total daily MVPA than their counterparts living in rural areas ($p < 0.05$).

According to SES group there were no significant differences in the time spent in MVPA between commuting modes in each SES group ($p > 0.05$); however, adolescents living in low-SES families tended to be more active than those living in high-SES group, particularly with bicycling.

After adjustment for potential confounders (age and gender), multinomial logistic regression analyses (Table 4) showed adolescents who were categorized as moderately active were more likely to walk to school (OR: 5.04 - 95% CI: 1.04, 24.54) and the same for those who belonged to the active group

(OR: 10.28 - 95% CI: 2.13, 49.74) with motorized transport as reference category.

Table 3. Time spent in MVPA (*in minutes*) on school travel modes.

Variables	Travel to/from school modes			F	p
	Walking	Bicycling	Motorized transport		
	Mean ±SD	Mean ±SD	Mean ±SD		
Average daily MVPA					
Gender					
Boys	70.3 ± 28.6 †	75 ± 37.1 ‡	72 ± 33.9 ‡	0.136	0.87
Girls	48.1± 22.2 ¶¶	36 ± 24.7	31 ± 16.7	5.126	0.01*
School location					
Urban	56.9 ± 15.0	41.0 ± 29.6	51.0 ± 32.0	0.364	0.69
Rural	61.0 ± 29.9	61.3 ± 38.4	42.3 ± 34.2	2.730	0.07
SES group					
Low	64.9 ± 25.0	70.6 ± 43.8	58.0 ± 37.0	0.783	0.46
Middle	55.1 ± 30.9	45.0 ± 21.0	47.1 ± 27.8	0.608	0.54
High	60.7 ± 31.0	50.1 ± 36.7	42.8 ± 31.3	0.887	0.42
Total	60 ± 27.9	59 ± 37.7	49 ± 32.6	2.396	0.09
Total daily MVPA					
Gender					
Boys	331.5 ± 52.0 ‡	336 ± 90.1 ‡	327 ± 45.8 ‡	0.258	0.77
Girls	208.1± 94.4	172± 27.0	146.1 ± 84.5	2.933	0.06
School location					
Urban	250.3 ± 61.0	205.0 ± 47.9	241.1 ± 51.6†	0.157	0.85
Rural	281.2 ± 52.9¶	289.7 ± 93.0§	174.9 ± 44.9	4.328	0.01*
SES group					
Low	306.2 ± 25.0	339.7 ± 20.9	269.3 ± 62.8	1.080	0.34
Middle	245.7 ± 49.2	203.6 ± 91.8	218.9 ± 28.2	0.420	0.65
High	268.0 ± 77.0	245.2 ± 86.9	194.7 ± 39.0	0.841	0.43
Total	276 ± 42.2	279± 88.7	226 ± 46.1	2.568	0.08

Note: SD: Standard Deviation

* Significant difference between school travel modes by 1-way ANOVA at less than 0.05

† Significant difference between groups ($p < 0.05$)

‡ Significant difference between groups ($p < 0.01$)

§ Significant difference between Bicycling and Motorized transport by Bonferroni post-hoc test ($p < 0.05$)

¶ Significant difference between Walking and Motorized transport by Bonferroni post-hoc test ($p < 0.05$)

¶¶ Significant difference between Walking and Motorized transport by Bonferroni post-hoc test ($p < 0.01$)

Table 4. Result of Multinomial logistic regression analysis predicting active status on average daily MVPA (at 4 quartiles groups) with school travel, adjusted by age and gender.

Groups of average daily MVPA and School travel modes	Std. Error	Adjusted Odds ratio	95% CI
Inactive [#] (Mean MVPA = 29.54±19.81 min)			
Moderately Inactive (Mean daily MVPA = 44.19±24.43 min)			
Walking	0.84	4.62	0.89, 23.96
Bicycling	0.49	1.85	0.70, 4.86
Motorized transport [#]		1.00	
Moderately Active (Mean daily MVPA = 57.27±29.81 min)			
Walking	0.81	5.04	1.04, 24.54*
Bicycling	0.56	0.59	0.20, 1.76
Motorized transport [#]		1.00	
Active (Mean daily MVPA = 79.58±35.15 min)			
Walking	0.80	10.28	2.13, 49.74**
Bicycling	0.56	1.03	0.35, 3.07
Motorized transport [#]		1.00	
All groups (Mean daily MVPA = 53.45±33.16 min)			

Note: CI: Confidence Interval, Std. Error: Standard Error
 * Significant difference between groups (p < 0.05)
 ** Significant difference between groups (p < 0.01)
 # Inactive as the reference group

Compliance with Physical Activity Guidelines and School travel modes

Table 5 shows the results of chi-square tests examining the differences between adolescents' discernible variables and the proportions of adolescents who meet current PA guidelines for children and youths of at least 60 minutes of MVPA per day – respecting school travel modes. In all participants, although there was no exclusive correlation between school travel modes and the compliance with PA recommendations ($\chi^2 = 1.956$, $p = 0.37$) however adolescents who traveled to school by walking and/or bicycling were more likely to meet PA recommendations compared to those who reported using motorized transport (36.8%, 41.5%, and 29.9%, respectively). Additionally, boys met the

guidelines to a higher percentage than girls across all travel modes ($p < 0.05$). The results also showed that there was similar in the compliance of 60-minutes MVPA between girls who traveled to school by walking and those who reported bicycling for transportation, only 5% of girls who reported using motorized transport achieved these recommendations.

Table 5. Compliance of adolescents who meet the physical activity guidelines (≥ 60 -minutes MVPA) between modes of travel to school [presented as percentage (%)].

Divided by groups	School travel modes								
	Walking		p (χ^2 , V)	Bicycling		p (χ^2 , V)	Motorized transport		p (χ^2 , V)
	Missed	Met		Missed	Met		Missed	Met	
Gender									
Boys	47.6%	52.4%	0.02* (4.871, .358)	41.7%	58.3%	0.00** (6.787, .407)	61.7%	38.3%	0.00** (40.422, .615)
Girls	82.4%	17.6%		82.4%	17.6%		95.0%	5.0%	
School location									
Urban	66.7%	33.3%	0.84 (.380, .031)	80.0%	20.0%	0.29 (1.081, .162)	65.9%	34.1%	0.08 (3.010, .168)
Rural	62.5%	37.5%		55.6%	44.4%		84.0%	16.0%	
SES group									
Low	58.8%	41.2%	0.88 (.248, .081)	42.9%	57.1%	0.10 (4.606, .335)	55.9%	44.1%	0.06 (5.437, .225)
Middle	66.7%	33.3%		78.6%	21.4%		71.9%	28.1%	
High	66.7%	33.3%		66.7%	33.3%		80.5%	19.5%	
All participants	63.2%	36.8%		58.5%	41.5%		70.1%	29.9%	0.37 (1.956, .103)

Note: p: p-value, χ^2 : Pearson Chi-square test value, V: Cramer's V coefficient value

* Significant difference between groups ($p < 0.05$; chi-square test)

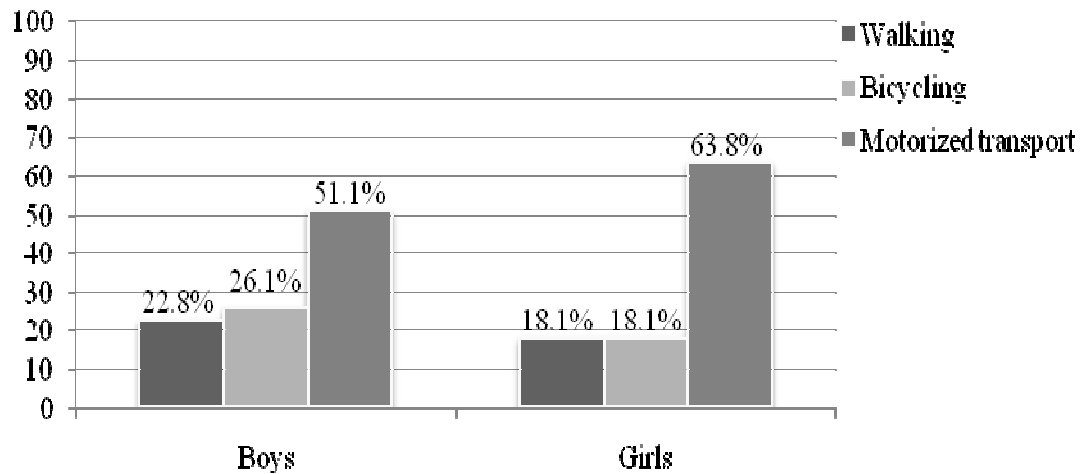
** Significant difference between groups ($p < 0.01$; chi-square test)

Rural adolescents who traveled to school by bicycling were 2.2 times more likely to meet PA recommendations than those bicyclists living in urban areas ($\chi^2 = 1.081$, $p = 0.29$). Regard to SES groups, low-SES adolescents tended to meet these PA guidelines higher than adolescents from higher SES groups in all modes of travel to school.

DISCUSSION

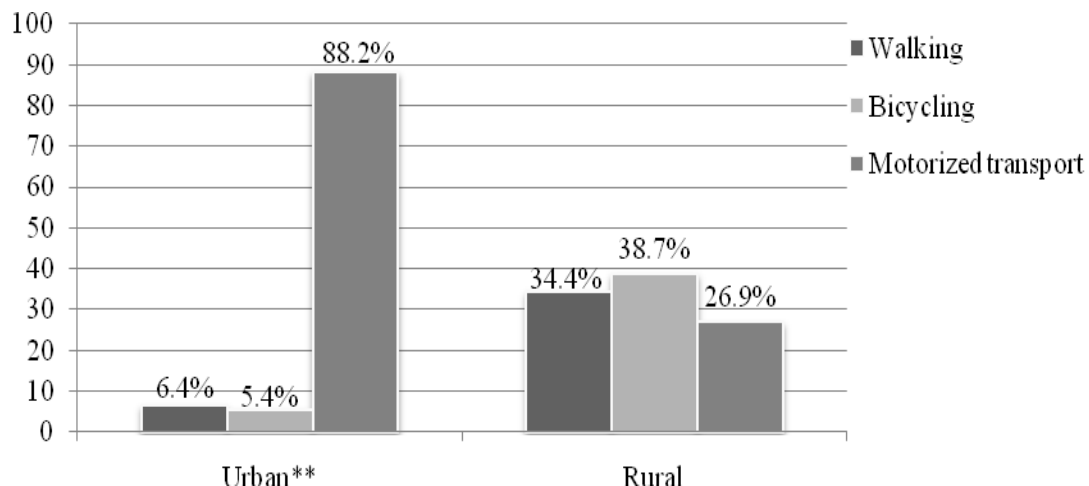
This study investigated the association between objectively measured MVPA levels and modes of commuting to school during five school days among Thai secondary-school adolescents, compared against specific socio-demographic profiles of adolescents.

Figure 1. Prevalence of school travel modes, divided by gender.



Note: No significant difference between genders ($\chi^2 = 3.174$, $df = 1$, $p = 0.20$)

Figure 2. Prevalence of school travel modes, divided by school location.



Note: ** Significant difference between school locations ($\chi^2 = 71.593$, $df = 1$, $p = 0.00$, $V = 0.620$)

In the current study more than half of the adolescents commuted inactively to school. The prevalence of active commuting to school (combining walking and bicycling) in this sample (42.4%) are quite similar in Filipino adolescents (Tudor-Locke, et al., 2003) and British children (J. Panter, et al., 2011), but these percentages are lower than those found in Portugal (M. P. Santos, Oliveira, Ribeiro, & Mota, 2009) and Brazil (Silva, et al., 2011), where respectively 66.3% and 56.7% of 13- to 19-year-old adolescents commuted actively to school. Although Western adolescents reported a much higher prevalence of walking to school than bicycling to school (M. P. Santos, Oliveira, et al., 2009; Silva, et al., 2011), but the present study found that there is a

similar prevalence in walking and bicycling to school. These findings could be explained by environmental factors, possibly caused by differences in climate and in geographical locations between the countries. Research into the reasons for such low levels of walking and bicycling among urban adolescents is urgently needed.

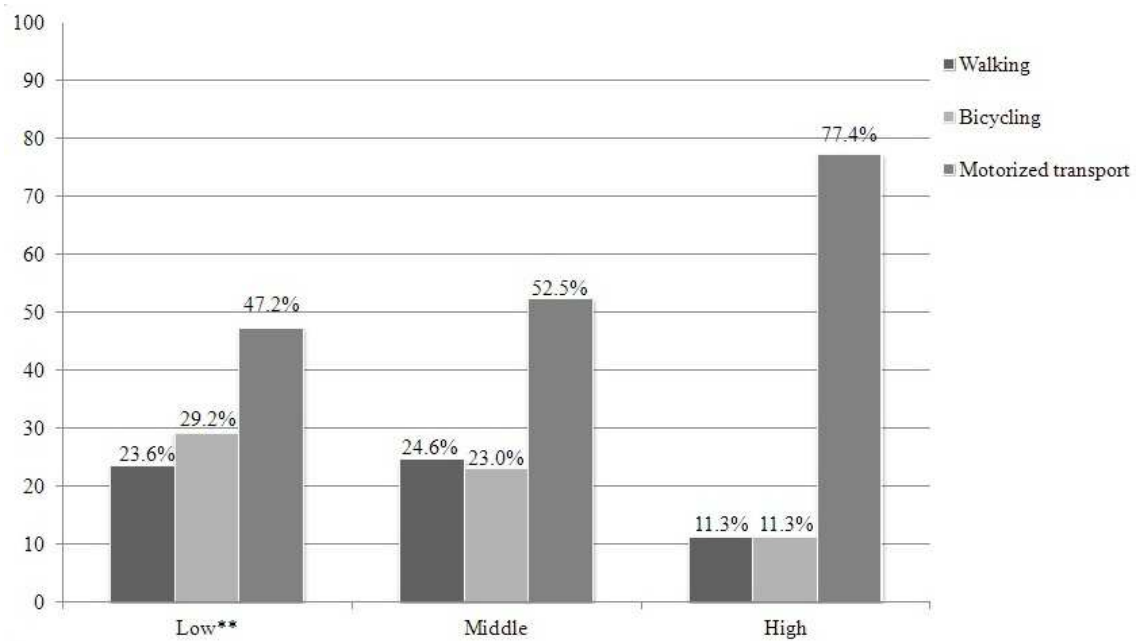
The present results indicate that the prevalence of active commuting to school is varied across school location and is also associated with levels of family income. Adolescents living in rural areas of Thailand were more likely to actively commute than those in urban areas, but, among rural areas there was no extreme prevalence of any one travel mode (that is walking, bicycling or motorized transport). However rural adolescents were still more likely to use active commuting than otherwise. In addition, almost 90% of urban adolescents and almost 80% of all adolescents belonging to high income families traveled to school inactively. This is probably one of the reasons why inactive commuting was most frequent for adolescents in urban areas, where the household income is generally much higher than in rural areas. Additionally higher-income families tend to have more motor vehicles per capita (McDonald, 2008); these factors may increase the likelihood of inactive commuting to school in this group. Our results are in contrast to recent studies (Rosenberg, et al., 2006; Silva, et al., 2011) which say that a greater proportion of inactive commuters are rural. Consequently, the environmental characteristics are the factor influencing adolescents' travel modes choice for school trips (Larsen et al., 2009; Robertson-Wilson, et al., 2008). Additionally, our results also confirmed that passive commuting was positively associated with higher family income, while it was negatively associated with time spent in MVPA. Among bicycle users, rural adolescents spent more additional 20 minutes of average daily MVPA than those from urban areas. Thus it is possible that social and environmental influences of urban-rural area could have contributed to this association, and one of the possible explanations could be that the rural students may be live further away from their school. These findings could potentially inform the development of interventions specific to these different areas.

Interestingly, some potential PA benefits of motorized transport mode should be notice in adolescents who are living in urban areas. The prevalence of adolescents who traveled to school by motorized transport was high in urban areas, they still spent significantly more total daily time in MVPA than those living in rural areas. The reason for these differences is unknown in the present study, but PA of motorized transport users in urban areas could not be accounted for by the reported-journey mode alone. Because public transport travelers are generally also assumed to undertake some walking or bicycling to get to public transport (Besser & Dannenberg, 2005; Morency & Demers, 2010) they may engage in more PA, but the amount of PA undertaken is also unknown. Nevertheless, almost of Thai adolescents who reported using motorized transport to school were motorcycle users and we found a few public transport users (*data not shown*). Furthermore it should to be noted that since the majority of urban adolescents travel to school by motorized transport they are missing out on important additional minutes of PA to reach guidelines figures.

In agreement with other studies (Grize, et al., 2010; Rosenberg, et al., 2006), our results show that the factors influencing PA participation with respect to school travel modes originate from more than one influence and there are different ones in developing countries such as Thailand; wherein there are different cultural and socioeconomic backgrounds. The future interventions therefore targeted at school travel modes should consider SES and school location as the important factors, and more studies are needed.

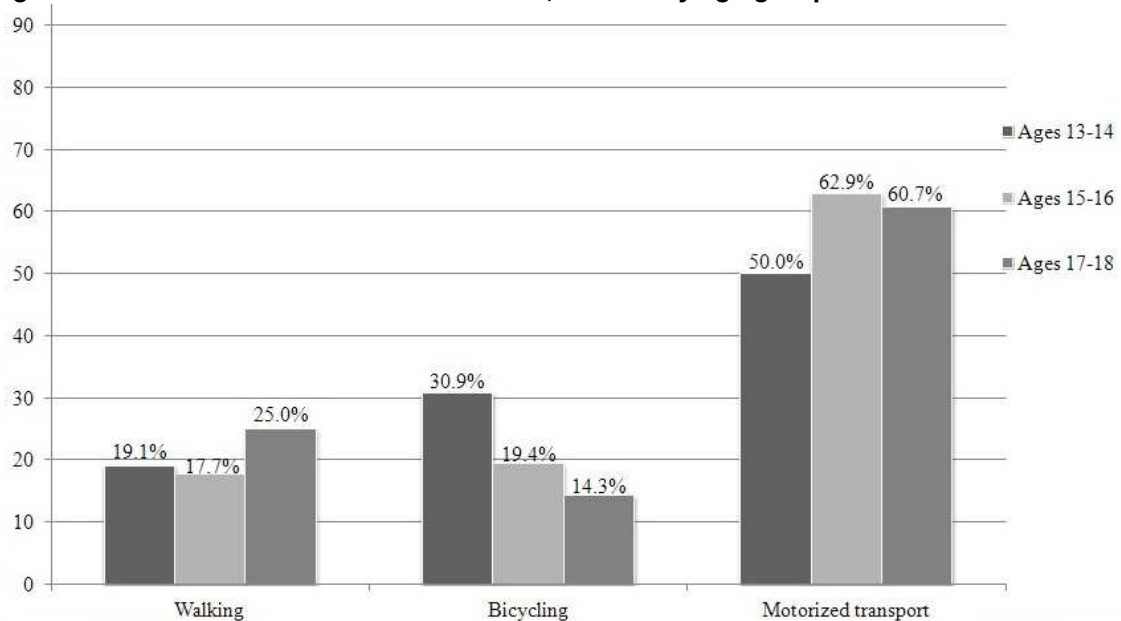
A strong gender difference was seen in activity associated with any given school travel mode. Our results were consistent with earlier findings (Cooper, et al., 2005; Sallis, et al., 2000; Silva, et al., 2011) showing that boys are more likely than girls to actively commute to school. These results may reflect the social tendency of less independent mobility in girls and young adolescents. Age is inversely associated with active commuting such as bicycling to school. According to total weekday MVPA, girls who travelled to school by walking spent an additional 62 minutes of MVPA than those who travelled by motorized transport.

Figure 3. Prevalence of school travel modes, divided by SES.



Note: ** Significant difference between SES groups ($\chi^2 = 12.695$, $df = 2$, $p = 0.01$, $V = 0.1385$)

Figure 4. Prevalence of school travel modes, divided by age groups.



Note: No significant difference between age groups ($\chi^2 = 6.072$, $df = 2$, $p = 0.19$)

Interestingly, in this study school travel mode did not produce statistically significant difference in the time spent in MVPA among boys. Another study using accelerometers showed that Danish children who reported active commuting (walking and bicycling) were significantly more active than those who traveled to school by car or/and bus and this significant difference was

found both boys and girls (Cooper, et al., 2005). The percentage difference in MVPA between passive travelers and walkers during school days is larger for girls than boys in this sample. We suggesting that active commuting may make a larger proportional contribution to girl's total daily MVPA (J. Panter, et al., 2011). However the reason for these gender-specific differences is unknown.

It has been previously shown that active commuting to school is associated with higher overall levels of PA and energy expenditure among children and adolescents (Sirard, Alhassan, et al., 2008; Sirard, et al., 2005; Tudor-Locke, et al., 2003; van Sluijs, et al., 2009). This study also demonstrates that walking and bicycling are associated with higher level of daily health-beneficial PA such as MVPA in secondary school adolescents when compared with those traveled to school by motorized transport. In our Thai sample adolescents who walked had higher daily MVPA than those who bicycled and also greater than adolescents who were driven to school during weekdays, consistent with the objective measurement study from UK (van Sluijs, et al., 2009). This specific study revealed that 11-year-old children who regularly walk to school are more active during the week than those travelling by car. Additionally, in this study adolescents who travelled to school by active transport had 10-11 more minutes of daily MVPA than those who reported using inactive transport; moreover this represents approximately 17% to 18% of the PA guidelines. Furthermore the difference in total daily MVPA between adolescents who walked and who commuted passively to school is 18.1%, it is close to the magnitude of the difference (18.2%) reported in a Danish study using the MTI 7164 accelerometer (Cooper, et al., 2005). Although there are similar patterns of findings in the current study those studies were conducted on children (Cooper, et al., 2005; van Sluijs, et al., 2009).

Previous studies that have found statistically significant correlations between weight-variables and travel mode and yet weak statistical links were found (Gordon-Larsen, Nelson, & Beam, 2005; Sirard, et al., 2005) however they also suggest that children who commuted actively were likely to live too close to realize greater changes in weight and BMI (Cooper, et al., 2003; Gordon-Larsen, et al., 2005; Loucaides & Jago, 2008). We also found that both

male and female adolescents had slightly less BMI and %BF with walking than bicycling, and bicycling versus motorized transport. To best of our knowledge, relatively few studies have examined the prospective effects of active commuting to school on body composition while using objective methods to assess PA and its correlations with transportation. Rosenberg et al. used the Caltrac accelerometers to assess PA among fourth-grader children from seven suburban schools in southern California, USA, they found boys who actively commuted to school had lower BMI ($F = 7.24$, $p < 0.01$) and skinfolds than non-active commuters to school; indeed it was not significantly different for girls ($F = 1.10$, $p = 0.30$) (Rosenberg, et al., 2006). However, it is quite difficult to explain this association, since the accelerometers were worn for only 1 weekday. Although this study was not longitudinal in design, we also found statistically significant differences in either BMI or %BF between school travel modes. Active commuters were significantly leaner than inactive commuters; in other words, leaner adolescents were more likely to commute actively to school. However several existing findings are still inconclusive (Heelan et al., 2005; Landsberg, et al., 2008; Robertson-Wilson, et al., 2008; Rosenberg, et al., 2006; Sirard, Alhassan, et al., 2008; Tudor-Locke, et al., 2003) about the influence of active commuting to school on BMI in children and adolescents, and few of these studies have focused on adolescents; indeed active commuting (walking for example) to school is associated with higher levels of overall PA (Cooper, et al., 2005; Cooper, et al., 2003; Sirard, Alhassan, et al., 2008) and therefore may be associated with weight loss. A systematic review of the most recent research heeds that active travel to school is associated with a healthier body composition and that could be particularly important to halt the prevalence of overweight people and obesity (Lubans, et al., 2011). Additional analysis using age- and gender-adjusted logistic regression confirmed that the chosen mode of transportation was strongly predictive of adolescents' MVPA levels (mainly due to use of walking), while previous results from Denmark found children and adolescents who bicycled to school were significantly more fit (cardiovascular fitness) than those who walked or traveled by motorized

transport (*OR* 4.8; 95% *CI* 2.8-8.4) and were in the top quartile of fitness (Cooper et al., 2006).

In addition to date there is no published study assessing the association of school travel modes and PAG achievement. These findings provide up-to-date evidence that active transportation helps adolescents (proved herein at least for girls and rural) to reach the minimum PAG – and potentially see many health benefits. The chi-square test indicated that high proportions of Thai adolescents did not achieve currently recommended levels of MVPA, particularly girls who inactively commuted to school. In our sample, adolescents who reported traveling to school actively were approximately 6.9 to 11.6% more likely to achieve the PA guidelines compared with inactive commuters. Such information is extremely important to increase the efficacy of intervention strategies to promote active transportation such as walking and bicycling (especially walking), this will not only increase adolescents' daily MVPA but it may also be important to increase PA accomplishment. School days have the potential to influence the habitual PA of adolescents, schools and parents should work together to support and encourage participation in extracurricular active activities, including active commuting to school. Surprisingly, in high-SES adolescents although we observed that there was a 15.7% difference in average daily MVPA between walking and bicycling groups, both were equal in PA achievement. Further investigations are needed to clarify this association. However it is of paramount importance to note that examining socio-demographic variables and PA simultaneously provided information useful for the development of policies specifically useful encouraging active commuting from adolescents.

Strengths and Limitations

This is the first study investigating the relative influence of school travel modes on accelerometry-based PALs in Thai adolescents. It also used data from a large sample with socio-demographic variables well-distributed. Additionally we examined the associations between school travel modes and minutes of average and/or total MVPA from day-to-day data. However it should

be noted that the present study has several limitations. Firstly, a causal relationship cannot be inferred due to the cross-sectional design of the study. Secondly, the sample may not be representative; therefore further studies using a nationally representative sample are needed, including more varied modes of transportation. Thirdly, we should think about, with some caution, the limitations of uniaxial accelerometers in that they can underestimate PA during nonambulatory activities (P. Freedson, et al., 2005; Treuth, et al., 2004). It is important to note that accelerometer-measured total minutes of MVPA time may be underestimated during activities such as bicycling, and cannot be worn during water-based activities. Therefore we strongly recommended further studies should be carried out with accelerometer-based activity monitors and international PA questionnaires in unison to help provide a more accurate gauge of PA. Finally, we were not able to model the effect of distance to school on PALs regarding modes of transportation. Although previous studies have shown that children who walk and bicycle to school accrued more PA during journey times as the distance to school increased (Morency & Demers, 2010; J. Panter, et al., 2011), we suggest new technology in travel monitors (i.e., GPS travel recorder) in accordance with use of a Geographic Information System (GIS) or Global Positioning System (GPS) may provide more precise estimates of distances to school and also may explain more precisely commuting behavior/routes. Additionally the combination of worn accelerometer and GPS sensors might provides insight into where PA is occurring geographically. This linkage of data is allowing us to explore how the performance of PA is distributed in adolescents' daily lives, particularly in commuting data.

Suggestions

The present findings suggest that the active commuting to school would be potentially useful for increasing daily MVPA in adolescents, both educational and environmental strategies are necessary to encourage adolescents to walk or bike. Furthermore to provide safety, stimulation, and pleasant physical environments between communities and schools for school-aged children and adolescents is important. However the reasons underlying the difference in

MVPA among travel modes to school were not investigated in this study and require further evaluation. Future research should also examine factors that encourage or discourage active commuting for particular groups of adolescents' socio-demographic characteristics, to better target PA interventions. For example adolescents' and/or parents' perceptions of the environment as it relates to walking, biking, and motoring to school.

CONCLUSIONS

This study demonstrates important associations between commuting modes and MVPA levels among adolescents. The likelihood of commuting inactively was greater among girls, late adolescence, those in high-income families, and those who lived in urban areas. Adolescents who walked or cycled to school during weekdays had a significantly higher daily and/or total weekday MVPA and lower BMI and/or %BF levels than those who traveled school by motorized transport. Walking to school was found to be a strong predictor of the likelihood of being in the top quartile of the physically active. Active commutes to school not only give a potentially important opportunity for increasing health-benefit via PA participation, but also contribute to adolescents meeting the PA guidelines. This study highlights important implications for school-based programming designed to increase participation in daily and weekly MVPA among adolescents, through the use of active modes of transportation such as walking and bicycling.

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Declaration of interest

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PAPER IV

Socioeconomic Status and Objectively Measured Physical Activity in Thai Adolescents

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ABSTRACT

Background: The impact of socioeconomic status (SES) towards objective measures of physical activity (PA) in adolescence is poorly understood.

Aim: The purpose of this cross-sectional study was to evaluate the association between SES and objectively measured PA in Thai adolescents.

Subjects and methods: 177 secondary-school adolescents aged 13-18 years were classified into 3 SES groups (low, middle and high), PA was objectively measured every 30 seconds for 7 consecutive days using ActiGraph GT1M uniaxial accelerometers. The associations between SES and adolescents' PA were examined using 1-way ANOVA with multiple comparisons and Chi-square test.

Results: Adolescents of low-income families accumulated more minutes of PA and less of sedentary behavior than those of high-income families, Additionally, low-SES adolescents tended to meet the daily PA guidelines more than other groups, particularly in girls ($p < 0.01$).

Conclusions: This study gives a well-documented inverse relationship between SES and PA levels. These findings reinforce the way to encouraging adolescents to be physically active and thus to meet PA guidelines.

Keywords: accelerometer, adolescence, body composition, community-based research, guidelines and recommendations

INTRODUCTION

Physical activity (PA) is an important predictor for health outcomes in children and adolescents (Twisk, 2001). While, current technological advances are reducing the interest in PA and increasing the appeal of sedentary pursuits (Hill & Peters, 1998). During adolescence there reportedly emerges a decline in PA and sport participation (Telama & Yang, 2000). Furthermore, the increasing prevalence of overweight and obesity is also noticeable in this age-period (Janssen et al., 2005). It is essential to encourage adolescents to improve and maintain both structured and unstructured PA (Gordon-Larsen, et al., 2005).

According to the most recent physical activity guidelines (PAG), children and adolescents should accumulate at least 60 minutes of moderate-to-vigorous physical activity (MVPA) per day (Martinez-Gomez, et al., 2010; Tremblay, Warburton, et al., 2011). Although evidences of the children's and adolescents' health benefits and reduced risk of overweight and obesity (OW/OB) from PA participation are continuously cropping up; however, the magnitude of PA levels (PALs) is wide-ranging from country to country (Butcher, Sallis, Mayer, & Woodruff, 2008; Dumith, Hallal, Reis, & Kohl, 2011; Riddoch et al., 2007), several national studies (Butcher, et al., 2008; Riddoch, et al., 2007) revealed that children and adolescents were not achieving the PAG, and 84.2% of Thai adolescents remain inactive (N. S. O. o. Thailand, 2007). In terms of economic development, prevalence of physical inactivity was higher in Pacific Asian (42%) and developing countries (44%) than in developed countries (23-30%) (Huurre, Aro, & Rahkonen, 2003). Varying ethnic lifestyles makes it difficult to draw conclusions about the association between socioeconomic status (SES) and children's PA globally; meanwhile correlations of PA and health outcomes are just beginning to address questions concerning factors that may influence children's and adolescents' PA behavior.

To develop effective interventions to promote PA among adolescents therefore it is necessary to understand the key determinants of PA in this age group. SES and social support have been identified as important factors influencing PA participation and are associated with health risk factors in adolescents (Goodman, McEwen, Huang, Dolan, & Adler, 2005; Huurre, et al.,

2003), that could be targeted in an intervention. However, the characteristics of the parental influences were by far the most explored in the literature (Ferreira, et al., 2007), particularly regarding to PAG – to the best of our knowledge no previous study has explored the association between family SES and daily compliance with PAG in either children or adolescents. Although several studies suggest a significant correlations between parental support/family's SES and child PALs and sedentary behavior (SED) (Bagley, Salmon, & Crawford, 2006; Gustafson & Rhodes, 2006; Kocak, Harris, Isler, & Cicek, 2002; Mo, Turner, Krewski, & Mo, 2005; Wagner et al., 2004), but the evidences are still somewhat inconsistent and results were mostly inconclusive, hence, it is important for further effective PA interventions if we are to try to close this gap.

One possible reason for this lack of consistency may be due to the fact that previous studies have generally adopted questionnaires or self-report to assess PA. Although self-reports/questionnaires have several advantages in measuring PA (Sallis, Buono, Roby, Micale, & Nelson, 1993), but they also have some limitations when used on children and adolescents (Janz, 1994). To reduce these errors, objective measures such as activity monitors have been developed (Ekelund et al., 2001), and which has been proved to be valid for detecting and assessing patterns of PA over an extended periods of the time (Puyau, et al., 2002; Trost, et al., 1998) and it is often used in field-based research with children and adolescents (Puyau, et al., 2002; Trost, et al., 1998). Furthermore, a correlation between parental support/family's SES on children PA mainly was studied in the West and developed countries (Bagley, et al., 2006; Gustafson & Rhodes, 2006; Mo, et al., 2005; Wagner, et al., 2004). No international conclusion can be drawn without further Asian evidences; more precise estimates of relations may emerge if we have further study in Asia and also close the gap between current daily behaviors and SES to be able to develop effective PA interventions for adolescents. In addition to current knowledge, PA differences with respect to the number of family siblings supported per household and with child's birth order are also very limited (Bagley, et al., 2006; Pettit, Keiley, Laird, Bates, & Dodge, 2007), and regarding the idea that family backgrounds influence the amount of objectively measured

PA (Hesketh, Crawford, & Salmon, 2006) that related to the current PAG, bearing in group of ages, BMI status, or body fat percent (%BF), remain uncertain.

The aims of this study were to explore cross-sectional associations between family SES and accelerometry-based PA regarding adolescents' physical characteristics.

METHODS

Study Design

This cross-sectional study collected the data during the winter in Northeastern Thailand. This research protocol was approved by the Faculty of Sports Scientific Board at the University of Porto and performed in accordance with the Helsinki Declaration. A parent consent form was distributed to children to take home. Only those adolescents whose parents or guardians had signed an informed written consent, and they assented to participation verbally took part in the study. All measurements were administered by well-trained research staff.

Participants

Adolescents' characteristic variables and anthropometric measures

Two hundred adolescents, between the ages of 13 and 18 years, were randomly selected from recruited eight public-secondary schools in equal distribution of urban/rural, gender, age, and grade level. They reported their own basically physical characteristics using questionnaire under supervision of the researcher, while the information about parental characteristics and family backgrounds were completed by their parents, when they carried the questionnaire home. Finally, 177 adolescents (88.5% of original participants) were included for further analysis based on the minimal requirements of monitoring data.

Following a standardized protocol, participants were recorded body weight (kilogram; kg) with an analog scales (SECA 750, Hamburg, Germany), body height (centimeter; cm) with a portable standing stadiometer (SECA 242;

Hamburg, Germany). Body Mass Index (BMI) was calculated as the ratio of body weight to height squared (kg/m^2). Participants were classified into two groups based on international gender- and age-specific BMI cut-off points (Cole, et al., 2000): normal weight and OW/OB. Body fat percentage of participants was assessed using standard bioelectrical impedance analysis (Body Fat Analyse (BF-906); Maltron international Ltd, Essex, UK) with tetra-polar method in supine position with hands and legs slightly apart. There was transformed using the age-and gender-specific cut-off points for body fat (McCarthy, Cole, Fry, Jebb, & Prentice, 2006) to defined into normal fat group and over fat/obese group. A tape was used to measure a waist circumference (nearest 0.1 cm) at a level of umbilicus in the horizontal plane of the participants and that the measurement was made during normal expiration (Yamborisut, et al., 2008).

Parental characteristic variables

A “parent” was defined as either the biological father and mother or legal guardian with whom the participant lived. Parents reported their SES and family characteristics (occupation to main annual household income, annual household income, number of siblings, and birth order of participant) into the questionnaire.

Parental occupations were determined based on reported data in this study and categorized them into 6 groups following: 1) agriculturist, 2) manual worker, 3) government official and retired, 4) unemployed and housewife, 5) merchant/business man and 6) national enterprise officer. However, in our protocol, we did not classify the parental occupation based on SES because previous studies (Drenowatz et al., 2010; Raudsepp & Viira, 2000) recommended that an income is the most influential economic factor of their family. Additionally, social status of the parents by occupational ranking could be different on each culture – it could force class division within the same occupation. For this contextual comparison, therefore, the annual household income was the only factor taken as indicators to determine the family SES. It was measured in Thai currency (Baht; THB).

We divided SES into 3 groups based on the actual value of annual household income obtained from the parents: low (< 25,000 THB), middle (25,000-45,000 THB) and high (> 45,000 THB) or approximated < 800 USD, 800-1,500 USD and > 1,500 USD, respectively (For rough calculation: 1 USD equals 30 THB). These 3 SES groups were determined by taking the mean annual household income at 33rd and 66th percentile – less than 33rd percentile belonged to the low-SES group, while at percentile of 33rd-66th was classified as middle-SES group, and above 66th percentile categorized as high-SES group. Birth order was categorized into the first, the second or the third, and greater than or equal the fourth as in the previous study (Hallal, Wells, Reichert, Anselmi, & Victora, 2006) while the number of siblings was separated in 3 categories: one or none, two or three, four or more.

Physical activity measurement

Monitored Physical Activity

Physical activity was measured using the ActiGraph GT1M accelerometer (ActiGraph, LLC, Pensacola, FL), an uniaxial activity monitor. They are designed to record counts within a defined range of movement that is plausible for children (Puyau, et al., 2002; Trost, et al., 1998). Researchers have visited each participating school to contact the adolescents and instruct them in PA measurements before initialization on the beginning of the next day.

In order to assess PA each participant wore a single accelerometer on an elastic belt at the waist laterally above the right iliac crest during all waking hours in at least 10 hours per day for 7 consecutive days, except during water-based activities (i.e., swimming and bathing) which could totally damage the monitor. All accelerometers were set to record activity counts at 30-second intervals (epochs) prior to data collection and set to begin collecting data at 6:00 am on the first day. After seven days of the recording, data were downloaded into the same computer that used to initialize the accelerometers via the USB port. Raw accelerometer count data and custom interval information were exported from the ActiLife Software (version 3.6 for Windows, ActiGraph, LLC, Pensacola, FL).

Physical activity Data Reduction

MAHUffe 1903 software (www.mrc-epid.cam.ac.uk, Cambridge, UK) was used to establish daily minute-by-minute activity counts (cpm) from accelerometer raw data, where the amount of PA is presented as daily total and average counts. Through a sequence of data reduction steps PA variables were created. The range of 3 to 7 days of monitored assessment was considered to give reliable estimates of PA in the previous literatures (Sirard, Pfeiffer, Dowda, & Pate, 2008; Trost, Pate, et al., 2000). To be included in this analysis, individual participant was required to have 4 or more valid days with at least one weekend day with at least 10 hours summing in daily (Sirard, Kubik, Fulkerson, & Arcan, 2008; Trost et al., 2000). An interval of 10 continuous minutes or more of “zeros” count were considering as non-wearing time and were removed (Masse, et al., 2005).

Software provided an indication of PA intensities in minute (sedentary, light, moderate, vigorous and very vigorous) according to count thresholds corresponding to age-specific activity cut point of Freedson et al.'s method (P. Freedson, et al., 2005), and <100 cpm was classified for SED of all ages. Time spent in minutes on SED and intensity-specific activities was averaged over a week periods (weekday, weekend and whole week). Thus, after calculating the average monitoring times and number of minutes spent in activity levels in separately, the minutes of moderate activity and greater intensities were summed to represent the MVPA.

Data Analysis

All statistical analyses in this study were carried out using the Predictive Analytics Software, version 18.0 (SPSS Inc., Chicago, IL). All hypotheses were tested using 2-tailed tests and $p < 0.05$ was considered as the level of statistical significance. Descriptive statistics (frequency and percentages) of the participant's data were provided for each variables of interest for the SES groups. Means ($\bar{x}$) and standard deviations (SD) were calculated for continuous variables and proportions were calculated for categorical variables.

Measured variables of participant's characteristics and genders (boy and girl) were used for independent sample *t*-test, in order to analyze the differences in mean values. Continuous variables of their characteristics between household SES groups were tested using analysis of variance tests (1-way ANOVA). Significant ANOVA results were followed-up using the Bonferroni post hoc test, adjustments for multiple comparisons where appropriate. Discontinuous variables were conducted with Pearson chi-square test (χ^2).

Differences in averaged minutes of SED and PALs in accordance with its periods (weekday, weekend and weekly) between household SES groups were used the 1-way ANOVA with Bonferroni post-hoc test. Pearson product-moment correlation coefficient was used to test the correlation between minutes of PA and participant's continuous variables. Point-biserial correlation coefficient was used to analyze the correlations between dichotomous variables and PA. Pearson Chi-square test with Cramer's V coefficient test (V) was used to analyze the compliance of the daily 60-minutes of PAG among household SES groups.

Table 1. Prevalence of participant characteristics associated to their household socioeconomic status (SES).

Variable	Household SES groups		
	Low	Middle	High
All participants [177, (100.0%)]	67(37.9%)	51(28.8%)	59(33.3%)
Gender:			
Boys [89, (50.3%)]	40(44.9%)	24(27.0%)	25(28.1%)
Girls [88, (49.7%)]	27(30.7%)	27(30.7%)	34(38.6%)
Age (years):			
13-14 [64, (36.2%)]	27(42.2%)	18(28.1%)	19(29.7%)
15-16 [60, (33.9%)]	27(45.0%)	13(21.7%)	20(33.3%)
17-18 [53, (29.9%)]	13(24.6%)	20(37.7%)	20(37.7%)
BMI:			
Normal weight [135, (76.3 %)]	51(37.8%)	42(31.1%)	42(31.1%)
Overweight/Obesity [42, (23.7%)]	16(38.1%)	9(21.4%)	17(40.5%)
School location: †			
Urban [90, (50.8%)]	27(30.0%)	20(22.2%)	43(47.8%)
Rural [87, (49.1%)]	40(46.0%)	31(35.6%)	16(18.4%)

Note: †: Significant different between SES groups ($p < 0.01$)

RESULTS

General participant's characteristics

Descriptive statistics of participant's characteristics are presented in Table 1 and Table 2. One-hundred and seventy-seven adolescents with 89 boys (aged 15.2 ± 1.7) and 88 girls (aged 15.5 ± 1.7) were evaluated. Since the sample was classified into 3 SES groups (37.9% of low, 28.8% of middle and 33.3% of high), there were no frequency differences in gender, age group and BMI group. Most urban adolescents (47.8%) were grouped with high SES and 46.0% of rural adolescents were members of the low SES group. Division by BMI status shows at least two fifths in the normal-weight group (37.8%) was low-SES families and 40.5% of OW/OB groups were grouped in high SES, and 23.7% of all participants belonged in the OW/OB group (Table 1). Waist circumference was similarly observed between SES groups. Reported-household sibling ranged from two to seven members with a mean of 2.2 to 2.5, with these adolescent's, most of them are the first or the second child in birth order.

Table 4 displays that gender, age, %BF ($p < 0.01$), and BMI ($p < 0.05$) were significantly moderate-to-low correlated (Evans, 1996) with SED and MVPA, the strength of this association varied with variables, ranged between 0.17-0.56. Regarding PALs, the correlations were stronger for %BF than for BMI. Parental occupation was not associated with SED ($p = 0.80$) or MVPA ($p = 0.98$) (*data not shown*).

Physical activity patterns in accordance with week periods and the SES groups

The average minutes of objectively measured PA in accordance with week periods between their SES groups, are presented in Table 3. On weekday and weekly period, but not weekend days, family income (expressed as SES) was significantly and inversely associated with time spent in MVPA and SED. Adolescents from high-SES significantly spent more time in daily SED, and lesser in daily MVPA than those from low-SES (Table 3).

Table 2. Mean ($\pm$ Standard Deviations) of participant (n = 177) characteristics in accordance with their gender and household socioeconomic status (SES).

Variable	Gender		Household SES groups		
	Boys	Girls	Low	Middle	High
Age (years)	15.2(1.7)	15.5(1.7)	15.0(1.6)	15.7(1.8)	15.5(1.7)
Weight (Kg)	56.8(13.2)	55.3(12.9)	53.7(14.4)	57.1(13.3)	57.8(10.8)
Height (cm) †	166.3(9.1)	158.2(6.7)	160.6(9.7)	163.6(8.1)	162.9(8.6)
BMI (kg/m ²):					
Normal weight †	19.1(2.1)	19.9(1.9)	19.0(2.1)	19.5(1.8)	19.9(2.1)
Overweight/obesity #	26.8(3.6)	28.4(5.0)	29.3(5.0)	28.9(5.5)	25.6(2.1)
Body fat (%):					
Normal fat (n=113) †	15.2(3.3)	26.8(2.3)	18.9(2.4)	19.4(1.9)	20.0(2.3)
Over fat/obese (n=64) †	26.1(4.9)	34.5(3.4)	25.7(6.2)	25.1(6.0)	24.0(3.2)
Waist circumference (cm)	79.9(10.3)	79.5(11.6)	79.0(12.7)	79.5(10.0)	80.6(9.6)
Number of siblings in family (person)	2.3(1.0)	2.2(0.8)	2.2(0.9)	2.2(0.6)	2.5(1.1)
Number of monitoring day (days)	6.1(1.0)	6.1(1.0)	6.2(1.0)	5.9(1.0)	6.1(1.0)
Daily accelerometer wear time (minutes)	718.6(72.5)	700.8(57.2)	714.9(77.0)	693.5(50.8)	718.0(61.7)
Birth order	1.7(1.1)	1.6(0.9)	1.6(0.9)	1.6(0.7)	1.8(1.3)

Note: 1. †: Significant different between genders ($p < 0.05$), #: Significant different between SES groups ($p < 0.05$)
2. Statistical significant differences between household SES groups were not found by Bonferroni post-hoc testing

Physical activity patterns in accordance with participant's characteristics and SES groups

Table 4 showed that girls from low-income families spent more time in MVPA than those who come from the middle or high-income families ($p < 0.01$). Older adolescents tended to perceived lower levels of MVPA than their younger counterparts; however, these were not statistically significant between SES groups in any given age groups (Table 4). According to SES we did not find any significant differences with time spent in MVPA within the OW/OB group, only within normal-weight group did we find significant differences regarding SED and MVPA ($p < 0.01$). Following for post hoc analyses low-SES group spent more time doing MVPA than the higher income groups ($p < 0.05$).

Table 3. Household socioeconomic status related to their daily objectively measure physical activities in minutes in accordance with its week periods [expressed as means (SD)].

Physical activity levels	Household SES groups			
	Low	Middle	High	p
<i>Weekday</i>				
Sedentary ^c	385.8 (65.3)	386.5 (68.0)	408.5 (68.0)	0.04*
Light	277.1 (47.8)	270.0 (43.1)	260.0 (46.8)	0.10
Moderate ^c	60.2 (33.1)	44.8 (23.4)	46.2 (29.5)	0.00**
Vigorous	2.9 (5.3)	2.3 (4.6)	2.3 (4.2)	0.68
MVPA ^c	63.2 (36.6)	47.3 (26.1)	48.6 (32.2)	0.00**
<i>Weekend</i>				
Sedentary	333.3 (90.1)	351.2 (78.9)	352.2 (85.1)	0.11
Light	309.2 (82.6)	284.2 (73.5)	273.3 (82.3)	0.05
Moderate	45.7 (36.9)	35.1 (28.2)	32.2 (27.6)	0.06
Vigorous	2.2 (4.8)	1.0 (2.6)	1.9 (4.7)	0.34
MVPA	48.2 (39.6)	36.2 (29.8)	34.2 (30.8)	0.06
<i>Weekly</i>				
Sedentary ^c	372.4 (62.8)	383.0 (60.5)	395.7 (63.7)	0.04*
Light	283.5 (47.4)	272.9 (42.5)	263.5 (46.6)	0.05
Moderate ^{ac}	57.1 (32.3)	42.7 (22.6)	42.5 (27.6)	0.00**
Vigorous	2.8 (4.8)	2.1 (3.8)	2.1 (3.6)	0.54
MVPA ^{ac}	60.0 (35.4)	44.9 (24.9)	44.8 (30.2)	0.00**

Note: ** = Significant differences in SES groups at P-value less than 0.01 ($p < 0.01$)
 * = Significant differences in SES groups at P-value less than 0.05 ($p < 0.05$)
^a = Post-hoc (Bonferroni) significant different between low and middle SES ($p < 0.05$)
^b = Post-hoc (Bonferroni) significant different between middle and high SES ($p < 0.05$)
^c = Post-hoc (Bonferroni) significant different between low and high SES ($p < 0.05$)

Minutes of SED in normal-body fat group was different depending on SES, where high-SES adolescents spent more time with SED than the other groups did ($p < 0.05$). Regarding the birth order only the first child of the family showed significant differences in MVPA and SED time with respect to SES groups ($p < 0.05$), while the number of siblings in family or school location did not show any statistically significant variation. Time spend with SED and MVPA of adolescents did not show significant differences with parental occupation ($p = 0.80$ and $p = 0.98$, respectively, *data not shown*).

Table 4. Daily sedentary behavior and moderate-to-vigorous physical activity differences (expressed as means and SD) among household socioeconomic status (SES) and the correlation with participants' measured variables.

Variables	Sedentary behavior (in minute)				Moderate-to-vigorous physical activity (in minutes)							
	Household SES				Correlations (r)		Household SES				Correlations (r)	
	Low	Middle	High	p	r	p	Low	Middle	High	p	r	p
Gender					0.44	0.00					-0.56	0.00
Boys	378.3 (64.9)	365.8 (66.0)	377.5 (75.2)	0.75			72.9 (35.9)	59.6 (24.1)	68.9 (30.0)	0.26		
Girls	378.6 (60.7)	377.4 (55.9)	398.7 (53.3)	0.25			41.0 (25.1) ^{ac}	31.8 (17.3)	27.0 (13.3)	0.00		
Age					0.32	0.00					-0.55	0.00
13-14 years old	361.5 (71.8)	382.9 (66.9)	400.2 (69.2)	0.18			80.8 (37.0)	56.2 (23.1)	68.5 (33.3)	0.05		
15-16 years old	388.8 (56.7)	373.1 (63.9)	384.2 (55.9)	0.72			51.0 (28.4)	46.1 (23.9)	41.2 (23.1)	0.44		
17-18 years old	391.8 (50.0)	361.3 (53.0)	385.1 (67.7)	0.27			35.7 (20.2)	33.9 (23.2)	25.7 (15.4)	0.28		
BMI status					0.17	0.02					-0.17	0.02
Normal weight	371.2 (63.0) ^c	373.5 (60.5)	398.6 (60.7)	0.03			62.4 (36.2) ^c	46.2 (25.3)	43.1 (29.4)	0.00		
Overweight/obesity	401.4 (58.0)	364.7 (63.2)	391.9 (72.7)	0.40			52.3 (32.8)	38.7 (22.8)	48.9 (32.5)	0.56		
Group of body fat percent					0.37	0.00					-0.44	0.00
Normal fat	370.4 (65.3) ^c	369.0 (57.8)	388.8 (63.4)	0.03			63.8 (36.7)	47.8 (25.6)	50.2 (33.7)	0.06		
Over fat/obese	391.6 (57.1)	378.3 (67.6)	402.0 (63.9)	0.50			53.7 (32.9)	38.5 (22.6)	36.2 (21.6)	0.06		
Number of siblings					0.01	0.94					0.06	0.46
≤ 1 (n=21)	379.7 (44.0)	401.1 (43.6)	375.4 (43.7)	0.64			64.4 (35.4)	46.9 (42.7)	28.5 (8.0)	0.14		
2 or 3 (n=146)	380.1 (66.0)	369.9 (62.8)	396.8 (61.4)	0.11			58.5 (34.3)	45.6 (23.6)	45.8 (31.0)	0.05		
≥ 4 (n=10)	342.7 (79.0)	359.1 (30.5)	334.7 (83.5)	0.90			68.4 (65.0)	24.5 (6.1)	50.5 (35.0)	0.57		
Birth order					0.04	0.58					0.01	0.91
1 st (n=97)	360.7 (65.0) ^c	361.3 (50.2)	388.2 (60.1)	0.04			63.0 (33.8) ^c	45.4 (25.5)	45.4 (29.0)	0.02		
2 nd or 3 rd (n=71)	379.1 (59.1)	383.6 (70.2)	405.2 (57.2)	0.33			54.6 (35.2)	45.3 (24.6)	42.5 (32.2)	0.36		
≥ 4 th (n=9)	342.7 (79.2)	362.1 (54.7)	334.2 (83.5)	0.90			68.4 (65.0)	20.2 (42.7)	50.5 (35.0)	0.68		
School location					-0.11	0.37					0.06	0.45
Urban	401.8 (51.3)	393.7 (61.4)	402.7 (63.3)	0.84			57.9 (30.0)	45.2 (20.8)	44.1 (31.6)	0.13		
Rural	362.6 (65.4)	357.9 (56.5)	354.7 (51.8)	0.89			61.4 (39.0)	44.7 (27.5)	46.6 (26.7)	0.08		

Note: ^a = Post-hoc (Bonferroni) significant different between low and middle SES (p < 0.05)
^b = Post-hoc (Bonferroni) significant different between middle and high SES (p < 0.05)
^c = Post-hoc (Bonferroni) significant different between low and high SES (p < 0.05)

Prevalence of meeting the current physical activity guidelines and SES groups

The magnitude of SES groups' differences was calculated using Cramer's V formula (Table 5). Among adolescents SES was significantly related to meeting the PAG ($\chi^2 = 8.491$, $df = 2$, $p < 0.01$). Almost half (47.8%) of the low-SES adolescents and 27.5% of the middle-class adolescents achieved the PAG while only one fourth (25.4%) of the high-SES class approved it. Socioeconomic status had a weak relationship (Cohen, 1988) ($V = 0.219$) with which Thai adolescents met the PAG, but it had a more significant relationship ($V = 0.359$) specifically for girls and weak relationship specifically for boys ($V = 0.106$) but there was no statistical significance for boys ($p = 0.60$).

Table 5. Household socioeconomic status (SES) and compliance of the 60-minutes of physical activity guidelines [presented as frequency (n) and percentage (%), respectively].

Variables	Gender						All participants		
	Boys (n = 89)			Girls (n = 88)			(n = 177)		
	Missed	Met	p (χ^2 , V)	Missed	Met	p (χ^2 , V)	Missed	Met	p (χ^2 , V)
Low SES (n = 67)	15(37.5)	25(62.5)	0.60 (1.000, 0.106)	20(74.1)	7(25.9)	0.01 (11.335, 0.359)	35(52.2)	32(47.8)	0.01 (8.491, 0.219)
Middle SES (n = 51)	12(50)	12(50)		25(92.6)	2(7.4)		37(72.5)	14(27.5)	
High SES (n = 59)	10(40)	15(60)		34(100.0)	0(0)		44(74.6)	15(25.4)	
Total (n = 177)	37(41.6)	52(58.4)		79(89.8)	9(10.2)		116(65.5)	61(34.5)	

Note: p: p-value, χ^2 : Pearson Chi-square test value, V: Cramer's V coefficient value

DISCUSSION

General findings

This study could be one of the primary studies, particularly on an Asian sample, which identified the influence of SES on objectively measured PA in adolescents, so could promote more effective PA participation. This could help adolescents to meet the most recent PAG. Our results show that adolescents' PA was associated with their family's SES. Regarding MVPA, adolescents from

low-income families accumulated more minutes than those from high-income families; however most of this percentage (94.7-95.2%) was of MPA. Although we observed no statistically significant differences between categorized-SES groups in MVPA over the weekend period, the interaction term was borderline significant.

Adolescents' PA did not significantly differ with parental occupation, however, parental occupation is hard to ignore, since it link to household income, and subsequently affects a child's PA (Federico, Falese, & Capelli, 2009). In this study, parental occupation was significantly related to family income, for example parents who belonged to the government officer and retired groups had the highest annual income, and the agriculturist earned the lowest income (*data not shown*).

Previous studies suggested that siblings are influencing with regard to practical aspects, like helping with transportation to sports activities (Hesketh, et al., 2006; Sallis, Taylor, Dowda, Freedson, & Pate, 2002), and the children who have one sibling participate more often in structured PA outside school and less in SED (Wagner, et al., 2004). Interestingly, the number of siblings showed no overall affect in our results, neither in ED nor MVPA. Friends and schoolmates might be factors in PA participation (Raudsepp & Viira, 2000), further studies are needed.

Physical activity patterns Genders, Age and Body composition in accordance with socioeconomic status

These results add support to growing existing evidence (Bagley, et al., 2006; Hesketh, et al., 2006), suggesting that PA differences exist between boys and girls. Boys being more active than girls, this could be suggesting that boys and girls have different influences on PA; for instance, boys participate more in PA outside school than girls (Mota, Ribeiro, Carvalho, & Santos, 2010) and receive more encouragement to be active than girls (Sallis et al., 1992). However gender did not affect SED participation, even with SES differences. It was also furthermore clear that different SES produced similar PALs for both rural and urban schools.

Adding support to the previous findings (Ferreira, et al., 2007; Gustafson & Rhodes, 2006; Sallis, et al., 2000), our study indicated that household family income is important because it determines the practiced activity patterns among adolescents, but an inverse association between SES and PA participation was found in Thai adolescents. Girls whose families had a high income exhibited 14 minutes of MVPA per day less than girls from low-income families, while the SES did not significantly affect MVPA in boys. Supporting others studies, with said that family support/SES was much stronger correlated with PA in girls than boys (Kocak, et al., 2002; McGuire, Hannan, Neumark-Sztainer, Cossrow, & Story, 2002; Telama, Laakso, Nupponen, Rimpela, & Pere, 2009).

According to age, our results have shown that younger adolescents had more MVPA than older adolescents, but SES was not the significant factor of these differences. However adolescence is the last period of living with one's parent(s) and to be influencing by them, and the impact of parents on children tends to wane in this period (Pettit, et al., 2007). Thus an intervention to promote PA related with SES should be started before the adolescence period.

Regard to body composition, one previous study (Gray et al., 2007) showed strongly inverse association between OW/OB development and SES in various ways; while on the other hand, BMI and %BF are influenced by PA. Even though the current findings have shown a large proportion of adolescents classified as overweight or obese, this does not vary with low and high SES group. Among normal-weight group, low-SES adolescents were significantly more engaged in MVPA and less in SED than high-SES adolescents. Contrasting with the previous results (Drenowatz, et al., 2010), low-SES children are likely to display less physically active and have a higher BMI. Interestingly, SED and MVPA of over fat/obese or OW/OB adolescents were not statistically different regarding the SES, %BF is strongly correlated to BMI ($r = 0.59$, $p < 0.01$, *data not shown*). Therefore extensions of these findings require further research.

Physical activity and socioeconomic status

Among the studies conducted with self-reporting or questionnaires and using different variables to define SES, the similar significant findings are given in some Estonians' (Raudsepp & Viira, 2000) and Turkishs' study (Kocak, et al., 2002) showing that children and adolescents from low-SES families participated in more PA than their high SES counterparts. The current findings are inconsistent with most of earlier studies from the West (Gorely, Atkin, Biddle, & Marshall, 2009; Mo, et al., 2005; Wagner, et al., 2004), which have documented a significant positive association between family SES and children's PALs, in other words, adolescents who living in a low-SES families were associated with reduced participation in sports/exercise (Gorely, et al., 2009). Self-administered questionnaire findings from China (Shi, Lien, Kumar, & Holmboe-Ottesen, 2006) – a neighbor country of Thailand, are also consistent with the present study. They have found that household SES was negatively associated with PA but statistically significance occurred only in boys.

There may be several potential reasons why we found an inverse relationship between SES and adolescents' activity participation from the Western findings. A potential explanation is that Western or developed nations' children and adolescents who are living in the low-income families were less likely to have or use the facilities and programs available for them to do sports and participate in PA, and less are likely to have opportunities available that met their needs compared to whose belonging to higher household income families. High income parents may encourage adolescents to be active, being active with their children, provide transportation and funding for activity (i.e., sports involving fees, sport/exercise uniform, or equipment expenses) and by serving as role models for PA (Gorely, et al., 2009; Mo, et al., 2005) – but this conflicts with the finding's in Asian adolescents such as in our Thais, adolescents with low-household incomes tended to be more active than high-household income adolescents. Cultural and lifestyle differentiation between developed and developing countries might help to explain these differences. Thai parents may have similar care for their children in family support like in the West but they may take a different approach to their childrens' PA behavior using different

strategies. Furthermore Thai children and adolescents may use their parent support in different ways, children and adolescents from high-income families, they typically spend their parent's money for pleasure and enjoy more physical inactivity (e.g. play video games at house and/or game shop, using expensive-fashionable mobile phones for chatting, using the personal computer or laptop, eating non-nutritional foods and snacks, using motorized transportation) (Areekul et al., 2005; In-iw, Manaboriboon, & Chomchai, 2010; Mo-suwan et al., 2004). However the low-income families in contrast haven't got in the same financial support, forcing them to participate or play in public sports/exercises outside home, walking or biking to/from school, help their parent(s) in home-based activities, go out to work for extra money, that may contribute a great deal in PA for themselves. Also, it is important to recognize that the differences in family income between social classes are relatively large in Thailand (National Statistical Office and Office of the National Economic and Social Development Board, 2008). Additionally we found a significant association between SES and adolescents' PA only on weekdays, but not on weekend days, therefore the disposable amount of pocket money adolescents have may indicate in additional influence of the relationship between family SES and health-related behaviors, and can be considered as the strong influence on their health (West, Sweeting, & Young, 2007). Interestingly, the PA in middle-SES adolescents were unstable and fluctuated somewhat – their PA behavior seems to integrate between low and high SES actions, therefore, our result is still inapt to conclude much for this SES group.

Regarding the PAG compliances, it is important to note that PAG accomplishment is significantly associated with SES, low-SES adolescents meeting the daily PAG in contrast to other groups, particularly girls – of any division. There is similar to a previous study in the US (Wenthe, Janz, & Levy, 2009), where SES had a significantly moderating effect on the change in the achievement of 60-minutes MVPA for girls, so the magnitude of this association was greater in girls than in boys.

Adding knowledge and suggestion

It is clear that with different SES family and culture backgrounds are the factors that have a definite influence on adolescents' PA patterns (Ferreira, et al., 2007; Gustafson & Rhodes, 2006), additionally the family income is a salient factor influencing adolescents' PA engagement, there was a strong inverse associations between SES and being physically active. SES could be one of the main factors for PA promotion strategies, and it also can identify groups of individuals that will be targeted for intervention. Programs aiming at increasing PA should to encourage PA and provide more options for PA, both during school hours and home-based activity tailored to the different likes of boys and girls. In particular such action should pay more attention to high-SES adolescents. However, easy, safe, convenient and inexpensive facilities are still considered essential for PA participation in adolescents of lower-SES and middle-SES families. Future studies should explore not only the impact of parent's SES, but also the specific parent and their paternal relationship, with the same procedure as this study.

Strengths, limitations and future study

The present study adds a unique point of view and strengthens data to extend research on adolescents. Giving strength to the findings presented here is the fact that it contributes to this research area by focusing on several variables involving objectively measured adolescents' habitual PA across weekdays and weekend days and the family's SES/backgrounds which provide robust detail on PA and have the potential to overcome many difficulties associated with self-reports (Puyau, et al., 2002; Trost, et al., 1998). Additional strengths also include an equal distribution of age groups (aged 13-18 years), gender, grade levels, and school locations among adolescent sample which can bring variability and comprehensiveness to our data set regarding the influence of SES. Therefore, these findings added valuable knowledge and can help inform future efforts to increase PA for adolescences.

However, limitations of the study should be recognized. Firstly, the cross-sectional design, which is of limited value in the search for causal explanation

might favor longitudinal designs that could be useful for future studies. Secondly, although the sample is quite large and diverse, national representative samples would be desirable; it will be important for future studies to apply similar methods across larger national areas. Thirdly, our measured protocol of SES does not represent the totally characteristics of family SES, however, current factors were used effectively as supplementary indicators of family SES and backgrounds in Thai adolescents. Fourthly, although accelerometer use is acceptable to children and adolescents, it may misrepresent their total PA because water-based activities won't be represented by uniaxial accelerometers (Robertson, Stewart-Brown, Wilcock, Oldfield, & Thorogood, 2011). Finally, PALs may vary with the season (M. P. Santos, Matos, & Mota, 2005), and because we were collected the data during the winter, other seasoning periods need exploration. Considerably more work is also required in this field to point out the specific factors within the family environment that facilitate or inhibit both MVPA and SED in secondary-school-aged adolescents.

CONCLUSIONS

This study gives extend information on research in this area indicating not only that potential moderating factors such as household SES and/or family backgrounds should be considered in future studies regarding influences of adolescents' PALs: being somewhat stronger for the girls, but SES was also inversely associated with health-related PA, boys are more independent of their parent(s) respecting the SES than girls. Nonetheless efforts to promote less SED and improve PA during adolescence may be particularly important for girls and high-SES group.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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CHAPTER IV

GENERAL DISCUSSION

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1. Overview of the thesis

This thesis aimed to examine the association between objectively measured PALs and patterns according to socio-demographic characteristics in Thai 13- to 18-year-old adolescents. Therefore, adolescents' PA was objectively measured by the ActiGraph GT1M accelerometer for 7 consecutive days and it was expressed as average amount of time spent engaging in SED and PALs (minutes/day), particularly in MVPA – these activity intensities and duration supports meeting the PAG based on desired health and behavioral outcomes.

Findings from this study indicated that regular PA is associated with numerous socio-demographic factors. Insufficient PA and prolonged SED are associated with risk of OW/OB in children and adolescents. MVPA levels in adolescents seem to have similar patterns as in developed countries regarding differences to age and gender, however, there differ by SES and geographical area. Engaging in high levels of SED and performing insufficient amounts of MVPA has shown to be a risk factor for failing to meet the daily recommended a minimum of 60 minutes of MVPA and produced higher prevalence of OW/OB. Our data also showed that the prevalence of OW/OB was strongly associated with PA participation. Older adolescents were less active when compared with the younger adolescents. Using a similar protocol to measure PA, on both weekdays and weekends, Thai adolescents show to engage in higher levels of MVPA than those in the West in the same age group (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). In addition, younger Western adolescents (aged 11 year) also accumulated less MVPA than older Thai adolescents (aged 13 years) (Nader, et al., 2008; Treuth et al., 2007), and these differences in levels of MVPA were greater in boys but were similar in girls (Nader, et al., 2008). However, estimates for compliance with the PAG among Thai adolescents were lower than those in other Western nations (Klasson-Heggebo & Anderssen,

2003; Ribeiro et al., 2009); we found 58.6% of boys and only 9.6% of girls accomplished in the current PA recommendations.

It was not surprising that Thai adolescents spent most of their waking hours in physical inactivity. They were predominantly sedentary (55.9% vs. 52.7%) or in light activity (37.5% vs. 39.6%), because the predominant activity at school is sitting in class (6-6.7 hours of sedentary time), with adolescents reporting that they have to attend classes 7 hours per day. However, it was interesting that time spent in MVPA never accounted for greater than 8% (6.6% vs. 7.7% for urban and rural, respectively) and most minutes of MVPA (approximately 95%) is moderate PA. Interestingly, we found that very little time was spent in vigorous activity in either urban or rural areas (less than 2.5 minutes) while the latest PAG recommended children and youth should not only accumulate at least 60 minutes of MVPA daily but they also should participate in vigorous-intensity activities at least 3 days per week (Tremblay et al., 2011). Increasing participation in the vigorous activity should be promoted. Generally, it is quite difficult to reduce academic hours or extend school periods. More attention need to be paid to the promotion, maintenance and enhancement of sports and exercise activities during school recess periods and in-school physical education time.

The present work indicates that all presented PA domains and its related factors are important to increase PA participation among adolescents. It is generally accepted that PA is a multidimensional behavior; the opportunity for children to participate in adequate levels of PA may be influenced by a number of variables across several domains..

2. Discussion of main findings

Based on all important variables which were studied in this thesis, the main findings are as follows:

2.1 Overweight and obesity prevalence in Thai adolescents

This thesis provides a prevalence estimate of OW/OB for adolescents using widely accepted gender- and age-specific BMI cut-off points proposed by the IOTF (Cole, Bellizzi, Flegal, & Dietz, 2000), these BMI cut-off points are reported to be more internationally based than other definitions. The prevalence of OW/OB in Thai adolescents was 23.1%. This prevalence was higher in girls than in boys (25.5% vs. 20.7%, respectively), and differences were found between low and high SES group. In addition, there are major differences in OW/OB rates by geographic area, suggesting that social and environmental factors affect the prevalence of OW/OB, there were 2.3 times more in urban areas than in rural areas. Moreover, living in urban areas was not only associated with the higher prevalence of OW/OB but also higher rate of SED than their rural counterparts. Although this is in contrast with findings in the West such as in the US where rural children were more likely to be obese than those in urban (Davis, Bennett, Befort, & Nollen, 2011). Our data shows similar trends to those observed in the previous national studies (Jirapinyo, Densupsoontorn, Kongtragoolpitak, Wong-Arn, & Thamonsiri, 2005; Sakamoto, Wansorn, Tontisirin, & Marui, 2001). The OW/OB among Thai adolescents in this sample showed higher prevalence than that indicated in Chinese national surveys (Y. Li et al., 2007), this OW/OB rate was higher than those of many developed nations, for example in Australia (Vincent, Pangrazi, Raustorp, Tomson, & Cuddihy, 2003) and Sweden (Raustorp, Pangrazi, & Stahle, 2004), however there was lower than those in the US (Davis, et al., 2011; Ogden et al., 2006; Vincent, et al., 2003). It is especially alarming that the incidence of OW/OB among Thai adolescents has increased sharply and substantially in the last decade – the estimated prevalence of OW/OB in this thesis was considerably higher than the any previously national recorded (Jirapinyo, et al., 2005; Sakamoto, et al., 2001). We are aware that the use of different BMI cut-points may lead to a significant inconsistent-estimation of the prevalence of OW/OB, and it may not be adequately justified by existing studies. Future studies aiming to explore the prevalence of OW/OB in children and adolescents using the international standard cut-points are needed.

In summary, the high prevalence of OW/OB among Thai adolescents should give serious cause for public health concern and highlight the need to promote PA and reduce SED.

2.2 Gender differences in physical activity

Adolescence is one of the most fascinating and complex transitions in the life span, and it is also a time of considerable risk. Despite the limitations of available data, a substantial body of evidence suggests that variations in the gender and age along with the onset of puberty may have developmental and behavioral consequences during adolescence; in other words, sexual maturation may play an important role in adolescent behaviors (Bradley, McMurray, Harrell, & Deng, 2000; Janz, Dawson, & Mahoney, 2000; Machado Rodrigues et al., 2010); therefore, age and gender were always included in analyses to minimize these restrictions.

The results of this thesis verified whether differences exist between adolescents' PALs and gender. Consistent with previous studies (Nader, et al., 2008; P. Santos, Guerra, Ribeiro, Duarte, & Mota, 2003), boys achieved significantly more MVPA and significantly less sedentary time than girls either during the week or on the weekend at every age. Our findings added to the growing evidence that girls tend to use motorized transport to/from school more than boys, and a much higher percentage of adolescent boys than girls met the current PA recommendations (more than three-fifths of boys and only one-tenth of girls achieved these guidelines).

According to PA participation, our findings revealed that parental SES (focused mainly on family income) may be more important for girls than for boys. This relationship is more extreme with older adolescents. Some previous studies reported that, by adolescence, boys and girls have different influences on PA (J. Mota, Ribeiro, Carvalho, & Santos, 2010), boys tend to be more active than girls and receive more encouragement from adults and peers to participate in activity (Sallis et al., 1992), and both genders are believed to reflect the types of activities and contexts by which their participation is influenced (Chen, Haase, & Fox, 2007; M. Li, Dibley, Sibbritt, Zhou, & Yan,

2007). It is possible that the accessibility of PA facilities and current PA promotion may be particularly beneficial for boys to accumulate more PA, and boys generally perceive their environment in a more positive way than girls (M. P. Santos, Page, Cooper, Ribeiro, & Mota, 2009). It is important to consider gender differences in PALs among adolescents and it should be noted that these differences offer a potentially useful avenue for interventions designed to increase PALs in adolescents, particularly for girls. It is necessary to provide appropriate curriculums that meet their relevant experiences in the PA domain, for instance, providing adequate supervision, suitable equipment, physical education classes/sports and other contexts where PA may take place that may promote equal participation of both genders.

2.3 Age differences in physical activity

The decline in PA during adolescence is a key public health concern. In addition to gender differences, in this sample, we anticipated that differences might be evident between the younger and older adolescents with respect to PALs. The purposes of this thesis, therefore, were to determine whether there are critical periods of decline and quantify gender differences in the decline.

The present results fully confirmed PALs decreased with age, this pattern may have developed during early adolescence. In both boys and girls, it appears that chronological age might be linked to a steep decline in PA, a significant decline was observed from ages 13 to 18 and more steeply in boys. In addition, advance in age is also a predictor for BMI increasing. Although the decline in PA with age may be the most consistent finding in PA epidemiology it should be noted that this trend cannot fully generalized via a cross-sectional study. Nevertheless, previous longitudinal studies also revealed that children and adolescents tend less to spend their time for being physically active when getting older; interestingly, there still limited of longitudinal studies have used the objective measures, and most of those studies were from Western countries (Klasson-Heggebo & Anderssen, 2003; Nader, et al., 2008).

Effective interventions are needed to design to reduce the age-related decline in adolescents' PA. Furthermore, the decline in PA with age is

antithetical to public health goals, so methods of countering the decline need to be developed based upon an improved understanding of the phenomenon and its causes. Future research should also examine additional factors influencing the decline in activity and the optimal timing of programs to reduce the decline.

2.4 Differences in physical activity between urban and rural school adolescents

Health promotion measures in order to increase PA should include environmental and policy approaches. Up to the present, several previous studies had examined the differences in PALs between urban and rural school children and adolescents, but the results are still inconclusive (Huang, Hung, Sharpe, & Wai, 2010; Liu, Bennett, Harun, & Probst, 2008) while these existing studies are typically based on questionnaires or other subjective assessment methods, little is known about PALs and geographic correlates of meeting current recommendations for PA in children and adolescents. To the best of my knowledge there is limited research comparing objectively measured PALs in adolescents from rural and urban areas. This thesis is one of the first to assess how objectively measured levels of PA are related with urban-rural difference. This may provide a strong and reliable representation of adolescents' PA in the contemporary period.

We found that the prevalence of OW/OB varies among Thai adolescents in different geographic locations. Moreover, it indicates that the urban-rural distinction does make a difference as regards to the levels of PA among Thai adolescents. Both rural and urban adolescents spent more time on SED than on regular PA. In all age groups, urban adolescents were significantly higher than those from rural areas on sedentary time, but there were no significant differences between urban and rural adolescents in either the minutes of time spent in MVPA or the proportions meeting PAG. Regardless of SED, the location of school (urban vs. rural) did not seem to be a significant factor associated with levels of PA. However, these findings may add valuable knowledge to the issue of geographical factors as a means of promoting PA, as it appear that adolescents' compliance with PA recommendations is associated

with school location respecting specific demographic characteristics. Living in rural areas was found to be positively associated with girls meeting the recommendations for PA, but this association was not evident for boys. While living in urban areas brought some benefits to achieve those recommendations for OW/OB adolescents. With regard to the normal-weight group; the finding is consistent with recent study (Liu, et al., 2008), rural adolescents had significantly more minutes of MVPA when compared to those in urban areas, adolescents living in rural areas have more opportunities for active play, and they have greater active travel times than adolescents in urban areas.

Multi-component school-based interventions are needed to provide equal access to PA and promote the involvement of sports/physical education across rural-urban areas. We also strongly suggest that future research should attempt to identify PA facilities and school policy across both locations, with respect to BMI groups.

2.5 BMI, body composition and physical activity

Body mass index or BMI is the most often recommended and frequently used method for classifying overweight and obese children and adolescents (Dietz & Robinson, 1998; Pietrobelli et al., 1998). Several findings are consistent with the present results, high levels of SED are associated with increased levels of BMI and body fatness among children and adolescents (Dencker et al., 2006; L. Li, Li, & Ushijima, 2007; Reilly, Dorosty, & Emmett, 2000). There were significant inverse relationships between the time spent in MVPA and BMI, and having a higher BMI is associated with more time spent in SED.

In this thesis, BMI was highly correlated with %BF in both boys and girls; in addition, girls had higher BMI values compared to the boys at any given age. Although no significant differences between BMI groups (normal weight vs. OW/OB) were found in SED, adolescents classified as OW/OB were significantly less physically active than those of the normal weight group – these differences were greater in rural adolescents than in their urban counterparts. Also, it should be noted that geographic location illustrated the impact of the school on BMI status – adolescents in the urban areas had significantly higher

BMI than their rural counterparts. Moreover, school locations may reflect differences in activity levels across normal weight and OW/OB adolescents. Normal-weight adolescents in the rural areas engaged in 17 additional minutes of MVPA per day, compared to those classified as OW/OB. These findings highlight how the built environment of a school affects adolescents' opportunities for PA. On the flip side the physical environment of a neighborhood and school environments can support opportunities for play, an essential component of physical development, and for healthy behavior that not only reduces risk of excess weight gain but also has many other benefits for overall well-being. Consequently, the combination of PA participation and school location may an important role in the prevention of OW/OB in adolescents. However, intervention studies are needed to confirm the findings from this observational cross-sectional study.

Additionally, previous studies that have found statistically significant correlations between weight-variables and travel modes to school and yet weak statistical links were found (Gordon-Larsen, Nelson, & Beam, 2005; Sirard, Riner, McIver, & Pate, 2005), and some other studies have shown inconclusive evidence (Landsberg et al., 2008; Sirard, Alhassan, Spencer, & Robinson, 2008; Tudor-Locke, Ainsworth, Adair, & Popkin, 2003), however they also suggest that children who commuted actively were likely to live too close to realize greater changes in weight and BMI, and walking to school is associated with higher daily PALs by presenting data from a different population and using a different measure of PA behavior (Cooper, Andersen, Wedderkopp, Page, & Froberg, 2005; Cooper, Page, Foster, & Qahwaji, 2003; Sirard, et al., 2008). Thus, active transportation to school may also be associated with weight loss in children and adolescents.

Among adolescents aged 13-18 years in this sample, both boys and girls had slightly less BMI and %BF with walking than bicycling, and bicycling versus motorized transport; in other words, leaner adolescents were more likely to commute actively to school. The present results are consistent with those from a previous study using an objective measure of PA in fourth-grade children; boys who actively commuted to school had lower BMI than non-active

commuters to school (Rosenberg, Sallis, Conway, Cain, & McKenzie, 2006). Importantly, future research must address the specific levels of PA (MVPA) are closely associated with BMI in adolescents. Factors such as school location have played a significant role in the decreased rates of active commuting to school, and changes in policy may help to increase the number of adolescents who are able to walk or bike to school. Consequently, evidence for impact of active school transport in promoting healthy BMI for adolescents is not compelling, promoting active transport to school may be an important component of potential intervention programs for increasing PA but more accelerometry-based studies are needed to confirm.

Above all in the topic, the findings provide extended insights into activity behaviors and their associated factors related to weight status that are useful for designing intervention strategies for obtaining specific health benefits for adolescents.

2.6 Physical activity differences in accordance with week periods

Assessing patterns of PA between week periods (during weekdays and weekend days) is of interest to improve our understanding of the variation in adolescents' PA and to provide efficient intervention programs. The findings of this thesis showed that MVPA levels were significantly higher in boys than girls, on both weekdays and weekends. The most consistent finding with previous studies from various countries (Klasson-Heggebo & Anderssen, 2003; Rowlands, Pilgrim, & Eston, 2008; Treuth, et al., 2007) was that for adolescents at all ages, MVPA levels were significantly higher on weekdays than weekend days, with a tendency for girls' MVPA to drop off more steeply at the weekend compared to the weekday. It is possible that removal of the structured school environment at weekends is disadvantageous to some adolescents' activity levels (Rowlands, et al., 2008), with this effect being particularly noticeable in girls. Furthermore, adolescent girls were 2 times less likely to meet the PAG on weekends than on weekdays. This suggests that MVPA on weekdays could make a major impact on total MVPA among adolescent girls.

Information regarding the pattern of adolescents' habitual activity on gender differences and weekday-weekend differences can be used to inform activity interventions and assess the aspects of the activity pattern that are related to health. More effort needs to be devoted to promoting appropriate opportunities for girls across the week periods and the promotion of MVPA during the weekend may hold the greatest promise for increasing overall MVPA.

2.7 Influence of family background and socioeconomic status on physical activity

Family income is perhaps the single most important factor in determining the settings in which adolescents spend their lives. This thesis explored how family and socioeconomic factors are related to adolescents' PA. Since the annual household income was the only factor taken as indicators to classify the family SES, we found differences in objectively measured MVPA and SED according to SES. Family income and birth order were relatively more important in determining adolescents' MVPA participation than parental occupations and number of siblings. Neither siblings nor parent occupation were not associated with adolescents' MVPA. Additionally, family income is perhaps the strongest predictor of adolescents participate MVPA and SED.

Importantly, different cultural background and contextual lifestyles can play a major role in encouraging their children/adolescents to become more active (Ferreira et al., 2007; Gustafson & Rhodes, 2006). Current results are inconsistent with most of earlier studies from the West, which have documented a significant positive association between family SES and PALs in children and adolescents (Gorely, Atkin, Biddle, & Marshall, 2009; Kantomaa, Tammelin, Nayha, & Taanila, 2007; Mo, Turner, Krewski, & Mo, 2005; Wagner et al., 2004) but it was consistent with finding from China (Shi, Lien, Kumar, & Holmboe-Ottesen, 2006), Estonia (Raudsepp & Viira, 2000) and Turkey (Kocak, Harris, Isler, & Cicek, 2002), showing that children and adolescents from low-SES families are more likely to be active than their higher SES counterparts. However, all of those studies performed subjective methods of PA measurement.

These findings make an important contribution to a growing body of knowledge about the effect of SES on adolescents' PA showing that SES is significantly associated with the proportion meeting the health-related 60-minutes MVPA guidelines, low-SES adolescents met these guidelines in contrast to other two groups (middle and high SES groups), and SES had a significantly moderating effect on the change in the achievement of the guidelines for girls; in other words, the magnitude of this association was greater in girls than in boys. In addition, SES was inversely and significantly associated with time spent in MVPA, but only on weekdays. This association was independent of weekend days. Therefore, the disposable amount of pocket money adolescents have may indicate an additional influence of the relationship between family SES and health-related behaviors, and can be considered as the strong influence on their health.

This research suggests that the design of PA interventions, which might include working with families, requires tailoring to groups from different socio-economic backgrounds. In Thailand, family-based interventions for increasing levels of PA should target high SES adolescents, particular to girls in the group, and should focus on creating adolescents' socioeconomic environments to motivate everyone equally to adopt a physically active life-style, as well as, to explore whether family income influences the development of OW/OB and PA participation in adolescents. We also would like to understand how SES is associated with the types of activities in which adolescents engage.

2.8 Modes of transportation to school and physical activity

The prevalence of active commuting to school (combining walking and bicycling) in Thai adolescents (42.4%) are quite similar to those found in adolescents in grades 14-16 living in Cebu, the Philippines where 36.6%-46.8% of children reported using active modes of transportation (Tudor-Locke, et al., 2003) and those found in 9- to 10-year-old British children (Panter, Jones, Van Sluijs, & Griffin, 2011), but these percentages are lower than those found in Portugal (66.3%) (M. P. Santos, Oliveira, Ribeiro, & Mota, 2009) and in Brazil (56.7%) (Silva et al., 2011). The prevalence of daily active commuting to school

differed considerably based on school location and SES. Factors such as age groups also have played a significant role in the decreased rates of actively commute to school; bicycling to school seemed to have a greater percentage of users in younger adolescents. Interestingly, more than half of all adolescents in this sample reported inactive commuting to school (motorized transport). Adolescents living in rural areas were more likely to actively commute than those in urban areas, almost 90% of urban adolescents reported using inactive modes of transportation; this may have coincided with a high in prevalence of OW/OB in urban areas.

Results also revealed that modes of commuting to school were associated with PALs. Engagement in active transportation to school such as walking and bicycling are positively associated with time spent in MVPA, but the major differences were seen only on girls. In totally, adolescents who walked to school were 10.28 times more likely to be physically active than those who used motorized modes of transport. Additionally, active commuting to school was independently associated with greater levels of MVPA and lower levels of BMI and %BF. On the other hand, the engagement in active transportation is the one of major achievement of the current PAG. Mean difference in minutes of MVPA between walking and motorized transport groups represents approximately 20% of the recommended 60-minutes of MVPA per day.

To the best of my knowledge, no previous study has assessed the impact on PAG accomplishment with school travel modes using accelerometer-based methods of PA assessment. Importantly, a high proportion of Thai adolescents did not achieve currently recommended levels of MVPA, particularly girls who inactively commuted to school. Furthermore, our results provide up to date practical information that active transport may contribute more to recommended health benefits and a physically active profile, proved herein at least for girls and rural adolescents. These findings demonstrate important associations between active commuting and MVPA levels in adolescents. There is important to increase the efficacy of intervention strategies to promote more active lifestyles such as walking and bicycling to school among children and adolescents, and will be important to enable them to achieve recommended

levels of MVPA. We recommended that educational and environmental strategies are necessary to encourage adolescents to walk or bike school and to provide safety and pleasant physical environments from community to school for adolescents and also for the general population, and changes in policy may help to increase the number of adolescents who are able to walk or bike to school. Future interventional studies should be developed to examine the change in adolescents' PALs which result from incorporating active modes of commuting.

As all mentioned above, this thesis highlights the complexity of relationships between adolescents' socio-demographic characteristics and PA and SED. The findings added valuable knowledge and can help inform future efforts to promote PA and reduce SED for adolescents. Programs promoting PA and reducing sedentary time may therefore need to tailor their approach dependent upon the gender, age, school location, weight status, weekday-weekend, school travel modes, and family SES/background of the target audience.

3. Study limitations and further researches

According to findings derived from all presented papers in this thesis, we have provided unique and valuable information about the associations between adolescents' socio-demographic characteristics and objectively measured PA. However, this is not without limitations. Firstly, the cross-sectional nature of this study design precluded us from inferring causal relationships between the hypothesized determinants and PA behavior might favor longitudinal designs that could be useful for future studies. Secondly, although the randomly selected sample of 200 adolescents was distributed proportionately by school location, gender, age, and grade levels, these are increased the level of precision of the findings obtainable at adolescence period; however this sample may not be nationally representative and furthermore, participants reside in the poorest and less privileged regions of the country. Those findings may not be

generalized to the entire population of Thai adolescents; a nationally representative sample would be desirable. Thirdly, although respondent bias is decreased with the use of accelerometer to measure PA because accelerometers had showed the best correlation with DLW-derived EE (Plasqui & Westerterp, 2007) which is generally considered the best objective measure of PA in children and adolescents (Sirard & Pate, 2001). However the uniaxial accelerometers for assessing PA in the field also have the inherent limitations that they tended to underestimate non-ambulatory activities that do not involve vertical movement of the trunk (when waist mounted) such as bicycling (Treuth et al., 2004), and they do not capture load-bearing activities well (Freedson, Pober, & Janz, 2005). Also, accelerometers cannot capture all water-based activities.(Robertson, Stewart-Brown, Wilcock, Oldfield, & Thorogood, 2011) and do not provide qualitative information on what types of PA are being performed (household, transportation, leisure, etc.), however respondent bias is decreased with the use of accelerometer to measure PA. Thus, for better understanding in habitual PA we need a combination of measurement instruments such as accelerometers with self-reports (i.e., IPAQ or GPAQ) methods to cover all aspects of PA. Finally, there is no definitive consensus regarding the best cut-off point to assess sedentary activities using the ActiGraph accelerometers, while the use of different cut-points can have profound impact on the estimate of the PA (Freedson, et al., 2005). Moreover the compliance with PAG will depend on the cut-points used to interpret the data collected (J. Mota et al., 2007; Reilly et al., 2008). Additionally, a high priority should be given to further researches to develop the standard scoring protocols based on accelerometer data that can be applied across countries.

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CHAPTER V

MAIN CONCLUSIONS AND FUTURE DIRECTIONS

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1. Main conclusions

The aim of this thesis was to examine the use of objective measurement techniques for the assessment and interpretation of adolescents' PA in Thailand. PA was assessed using the ActiGraph GT1M accelerometers during all waking hours for 7 consecutive days. The amount of time participants spent in different activity-intensity categories were used as the main outcomes. Average and total daily minutes spent in PALs were estimated for all valid days respecting standard criteria. Most of the findings of this thesis reinforce the existing evidences and report the interesting knowledge of PA data that taking from the advantages of the methodological measurement is a key element in prevention of OW/OB in adolescents. Moreover, there is now extensive and compelling literature documenting the health benefits and its related factors of regular PA that was using the standard procedures of the objective measurement with one of the most widely use methods on age-specific cut-off points for data reduction, and also applied the international age-and gender-specific cut points which is the most practical and widely accepted method for defining the prevalence of overweight and obesity. Additionally, the prompted concerns about the impact of low and declining levels of PA and increasing SED during adolescence, results obtained in this thesis provided up-to-date, valuable data in association to PA/SED and related factors of school-going adolescents.

Among Thai adolescents, prevalence of OW/OB was higher than in neighboring countries and many developed countries. More importantly, the prevalence of OW/OB was significantly much higher in the sample compared with the recent national evidences, whereas data analysis showed that achievement of the PA recommendations was low and time spent in SED was high. There is an urgent need to initiate effective prevention strategies and treatment of OW/OB in adolescents by encouraging and promoting in active

lifestyles. Of all ages, boys engaged in more MVPA than girls, for both during weekday and weekend. Levels of MVPA decreased with increasing chronological age in both genders, and it began in early adolescence and appeared more pronounced in girls compared with boys. Thai adolescents spent more time in MVPA during weekdays compared with weekend days; moreover, MVPA is mainly linked to school periods (weekdays). Walking and bicycling to school is strongly associated with higher MVPA daily minutes compared to inactive commuting, particular to girls. We also found a strong negative association between SES and adolescents' amount of MVPA and/or meeting PAG.

The findings of this thesis have a number of important implications for future policy and practice in the fields of public health that targeted programs for adolescents. The results also suggested that interventions should be focused on girls more than on boys, on maintaining PA participation as age increases, for urban adolescents more than rural adolescents, for inactive travelers more than walkers and/or bicycle commuters, for adolescents in high-income families more than those living in low-income families, and should be starting during early adolescence. The findings in this thesis also recommended to urgently starting intervention strategies to improve MVPA level for the entire week with special attention to weekend days.

2. Future directions

This thesis describes disparities in free-living PA participation and SED among adolescents in Thailand, provides intervention implications, and offers recommendations for future research focused on reducing disparities related to levels of PA. An improved understanding of correlates may inform the design of interventions to increase PA in targeted subgroups. To eliminate health disparities, therefore changes in policies that have an impact on PA may be necessary to promote PA among high-risk adolescents. The results suggest interventions to create and enhance access to activity-friendly environments for adolescents may be effective in increasing PA.

Importantly, advances in PA assessment technique will make it easier to study the various factors that influence PA behavior. Although accelerometers may provide the most accurate measures of the frequency and duration of activity at various intensities under free-living conditions, they cannot provide some important PA information such as the types, specific forms, or contexts in which activities take place. Identifying correlates of different types of PA is important because young people's PA may take place in different contexts – they perform in both formal and informal settings (Chen, Haase, & Fox, 2007; Li, Dibley, Sibbritt, Zhou, & Yan, 2007; Vilhjalmsson & Kristjansdottir, 2003). The present findings also strongly recommended for future studies that validated self-reports and objective measures such as accelerometer and Global Positioning System (GPS) sensors should be used in combination to optimize and enrich the quality of the data collected from adolescents in daily PA.

Findings from a cross-sectional study might support significant other factors to facilitate adolescents to participate in healthy behavior regarding daily free-living activity, but it is also possible that adolescents who are already active elicit activity support from other significant factors. Therefore, we suggest that further research might examine longitudinal data, because it can clarify dramatically relationships between correlates and PA and also will be necessary to illuminate the association between parental and adolescents' PA in the long-term relationship.

Most importantly, there is a need for studies to further elucidate how PALs and SED are associated among adolescents regarding all important factors in accordance with the findings in this thesis in nationally representative samples; studies on the child and adolescent populations in other countries are also required. Above all, we believe that research in this area should be expanded – searching in the broader context for determinants of adolescents' achieving recommended levels of daily MVPA.

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