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Effects of active video game intervention on promoting physical activity among Hong Kong Chinese children

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Effects of Active Video Game Intervention on Promoting Physical Activity among Hong Kong Chinese Children

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A thesis submitted in partial fulfilment of the requirements

for the degree of

Doctor of Philosophy

Principal Supervisor: Prof. LAU Patrick WC

Hong Kong Baptist University

August 2015

DECLARATION

I hereby declare that this thesis represents my own work which has been done after registration for the degree of PhD at Hong Kong Baptist University, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications.

Signature:_____

Date: August 2015

ABSTRACT

Background: It is widely recommended that children engage in at least 60 minutes of moderate-to-vigorous physical activity (MVPA) per day for health, well-being and development benefits. However, few Hong Kong children are physically active. Environmental factors unique to Hong Kong, such as dense population, highly urbanized, and high level of outdoor air pollution, suggest need to develop indoor PA programs. Active video games (AVGs) may provide an innovative approach to designing such indoor programs.

Aim: This thesis sought to identify opportunities for interventions using AVGs to promote PA among children, and to develop and evaluate the effect of an AVG intervention on PA among Hong Kong Chinese children. We also intended to clarify the mechanisms of the intervention.

Methods: Three studies were undertaken for the aim of the thesis. First, a systematic review was conducted to evaluate the effects of AVGs on PA and PA-related outcomes (i.e. psychosocial factors and fitness) among healthy children. Secondly, a validation study was conducted that examined the validity and reliability of three scales used to measure PA-related self-efficacy, social support, and enjoyment among Hong Kong Chinese children aged 9-12 years (n=273). Third, a quasi-experimental study was conducted that examined the effects of a school-based AVG intervention on PA, sedentary time, body composition, and psychosocial factors (self-efficacy, social support, and enjoyment) among Hong Kong children aged 9-12 years (n=87). Moderation and mediation effects of psychosocial factors on PA were also tested in the study.

Results: In the first study, fifty-four articles were identified in the review. AVG led to light to moderate intensity PA among children. No effect was identified of AVG on PA in the home setting. Structured AVG play (i.e. AVG play of participants organized by teachers or researchers) may improve PA. However, none of the previous school-based AVG interventions have measured habitual PA objectively. In the second study, confirmatory factor analyses supported the one-factor structure of the tested scales. All of the psychosocial factors (self-efficacy, social support from family, social support from friends, and enjoyment) were significantly ($p<0.01$) associated with self-reported PA (r ranged from 0.23-0.40). All of the scales suggested acceptable internal consistency (Cronbach's alpha>0.7) and test-retest reliability (intraclass correlation coefficient>0.7). The third study found that an AVG intervention delivered during after-school hours, approximately twice a week, significantly ($p<0.05$) increased total PA (counts per minute) and reduced sedentary behavior at week 8. However, this treatment effect was not maintained at 15 weeks when the frequency of AVG play decreased to approximately once a week during weeks 9-15. No significant differences were noted on body mass index z score and percentage body fat, and PA related psychosocial factors. The measured psychosocial factors did not act as mediators or moderators in this intervention.

Discussion: AVGs may be useful to promote PA of children when it is structured. Future interventions should consider the frequency of AVG play in order to increase PA. AVG play should occur at least twice a week based on current research. Other components may be necessary to enhance the treatment effects of AVG interventions on PA among children.

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LIST OF SYMBOLS

β	Standardized regression coefficient
B	unstandardized regression coefficient
CI	Confidence Interval
df	Degree of freedom
J	Joule
kcal	Kilocalorie
kg	Kilogram
kJ	Kilojoule
L	Liter
min	minutes
ml	Milliliter
MJ	megajoule
n	number
p	Probability
r	Correlation
®	Registered Trademark
TM	Trademark
χ^2	Chi square

LIST OF ABBREVIATIONS

AVG   Active Video Game
BCa CI   Bias corrected and accelerated bootstrap confidence interval
BMI   Body Mass Index
CFA   Confirmatory Factor Analysis
CFI   Comparative Fit Index
CPM   Counts Per Minute
CT   Controlled Trial
DDR   Dance Dance Revolution
DLW   Doubly Labeled Water
EE   Energy Expenditure
HKSAR   Hong Kong Special Administrative Region
HR   Heart Rate
ICC   Intraclass Correlation Coefficient
LPA   Light Physical Activity
MET   Metabolic Equivalents
MPA   Moderate Physical Activity
MVPA   Moderate-to-vigorous Physical Activity
PA   Physical Activity
PE   Physical Education
RCT   Randomized Controlled Trial
REE   Resting Energy Expenditure
RMSEA   Root Mean Square Error of Approximation
SCT   Social Cognitive Theory
SD   Standard Deviation
SRMR   Standardized Root Mean Square Residual
SSFA   Social Support from Family
SSFR   Social Support from Friends
TV   Television
US   United States
VA   Vertical Axis
VM   Vector Magnitude
VPA   Vigorous Physical Activity
WHO   World Health Organization

CHAPTER 1. INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

The increasing prevalence of childhood overweight and obesity has been declared a global public health burden (Ng et al., 2014). It is associated with decreasing physical activity (PA) and increasing sedentary behavior (World Health Organization [WHO], 2012). In the current research, "children" refers to individuals aged 18 years or less unless specified. "PA" is construed as "any bodily movement produced by skeletal muscles that result in energy expenditure (EE)" (Caspersen, Powell, & Christenson, 1985). The related term "exercise" is a subcategory of PA, which specifically denotes PA that is "planned, structured, repetitive, and purposive" (Caspersen et al., 1985). Meanwhile, "sedentary behavior" is a distinct construct of PA that pertains to any waking behavior that is characterized by an EE ≤ 1.5 metabolic equivalents (METs, which represent the ratio of EE during a specific activity to the energy expended at rest) while in a sitting or reclining posture (Sedentary Behavior Research Network, 2012).

A recent national survey in Mainland China suggested that in 2010, 15% of Chinese school-aged children, representing 30.43 million individuals, were overweight/obese (Ji, Chen, & Working Group on Obesity in China, 2013). The prevalence was most significant among children from large coastal cities aged 7-18 years: 32.6% among males and 19.1% among females. These rates were comparable to the ones obtained in developed countries (Centers for Disease Control and Prevention, 2008; Ng et al., 2014; Reilly, 2006). The prevalence of overweight/obesity among primary school students in Hong Kong Special

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Administrative Region (HKSAR) was similar to that among students from other large coastal cities in China and increased from 15.9% to 22.2% in the period of 1996-2013 (HKSAR Government Department of Health, 2014). Thus, effective strategies must be implemented to prevent and treat obesity in this population.

The lack of PA (or inactivity) has been identified as the fourth leading risk factor for global mortality (WHO, 2009), and it increases the risk of developing several non-communicable diseases, including cardiovascular disease, type 2 diabetes, and breast and colon cancers (Lee et al., 2012). Although the majority of these cases occur in adulthood, activity patterns are reasonably well-tracked from childhood onward (Matton et al., 2006; Raitakari et al., 1994; Telama, 2009). Therefore, the pursuit of an active lifestyle by children is important to promote public health.

By contrast, regular PA contributes positively to many aspects of the health and well-being of children, such as an increased level of cardiorespiratory fitness, decreased body fat, increased muscle strength (United States [US] Department of Health and Human Services, 2008), and increased bone mineral density (Biddle et al., 2004). It can also reduce the symptoms of anxiety and depression (US Department of Health and Human Services, 2008; WHO, 2010). Existing evidence suggests that PA can enhance self-esteem, cognitive function (Stensel, Gorely, & Biddle, 2008, p. 49), and academic achievement (Abadie & Brown, 2010; Sallis et al., 1999a). Socially, children who participate in PA may exhibit reduced disruptive behaviors (Basile, Motta, & Allison, 1995).

A dose-response relationship has been observed in that more PA is associated with greater health benefits (Janssen & LeBlanc, 2010). Various international guidelines have recommended that children should engage in at least 60 min of moderate-to-vigorous PA (MVPA) per day (Marshall & Welk, 2008; WHO, 2010). Moderate PA (MPA) corresponds to an EE of 3-6 METs, and vigorous PA (VPA) is equivalent to an EE > 6 METs (Ainsworth, Montoye, & Leon, 1996).

Many children do not achieve the above recommended PA levels across countries. For instance, 58% of children in the US aged 6-11 years (Troiano et al., 2008) do not engage in MVPA for 60 min or more a day as per objective measures. The same finding was observed among 67% and 79% of English boys and girls (aged 4-15 years), respectively (Townsend et al., 2012). In HKSAR, the results of a recent questionnaire survey revealed that only 9% of primary school children (7-12 years old) met the recommended levels of PA (HKSAR Government Sports Commission, 2012). This finding highlights the importance of developing effective strategies to increase PA levels among Hong Kong children.

Sedentary behavior is also an important target in improving children's health because apart from obesity, it is also associated with other negative health outcomes, such as decreased cardiovascular fitness (Santos et al., 2014) and increased insulin resistance (Sardinha et al., 2008). Existing guidelines suggest that children should minimize the time they spend on sedentary activities. In particular, they should limit the practice of screen-based sedentary behaviors (e.g., watching television, playing video games, and using computers) to no more than two hours per day (Australian Government Department of Health, 2014; Tremblay

et al., 2011).

A recent review determined that children across countries spent approximately 4-8 hours per day on sedentary activities (Pate, Mitchell, Byun, & Dowda, 2011). On the basis of responses to different questionnaires, two studies reported that Hong Kong children spent roughly 2.6 hours (aged 9-13 years; Lam, Sit, & Cerin, 2010) or 4.0 hours (9-12 years old; Huang, Wong, & Salmon, 2009) on sedentary activities daily. Another local survey found that primary school children in Hong Kong (grades 4-6) spent approximately 2.3 hours per day on screen-based activities (Huang, Wong, & Salmon, 2013). All of these data indicate the necessity of reducing the time spent by Hong Kong children on sedentary behaviors.

Identifying and understanding the factors associated with target behaviors are important in developing effective intervention strategies (Sallis & Owen, 1999). Modifiable factors that may influence such behaviors are particularly significant because they may mediate and be the target of interventions (Baranowski, Anderson, & Carmack, 1998). The terms "PA determinant" and "PA correlate" are occasionally used interchangeably to refer to the factors that are associated with PA behavior (Biddle et al., 2004). Nonetheless, many researchers who have adopted the term "determinant" may not indicate the definite causal effect. In the current thesis, however, the term "correlate" is used hereafter because little evidence supports the role of the majority of established PA correlates as true "determinants" among children (Craggs, Corder, van Sluijs, & Griffin, 2011).

Among all of the PA correlates, environmental factors may be especially

important for children, because children have less autonomy in relation to their own behaviors and are more likely to be influenced by the environment than adults (Ding, Sallis, Kerr, Lee, & Rosenberg, 2011). Environmental factors differ under the potential settings in which PA interventions for children can be implemented. Such settings include school, community, home, and healthcare settings (Ward, Saunders, & Pate, 2007). Two review studies (Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007; van Sluijs, McMinn, & Griffin, 2008) concluded that PA interventions with children were most effective in the school setting. Given that few interventions have been designed for Hong Kong children to promote PA (He, Huang, & Wong, 2014), such interventions should be implemented in the school setting.

Time spent outdoors is positively associated with the activity levels of children (Sallis, Prochaska, & Taylor, 2000b). However, the outdoor air pollution level is relatively high in Hong Kong (WHO, 2011). In addition, Hong Kong is one of the most densely populated places in the world (HKSAR Government Information Services Department, 2013) and is 100% urbanized (United Nations, 2012), thereby limiting the availability of outdoor space in which Hong Kong children can engage in PA. In Hong Kong primary schools, the standard outdoor playground provides 2 m^2 of space per student; this dimension is less than those measured in Mainland China, Korea, and Japan (HKSAR Government Education Department, 2000). Given the constraints on outdoor PA programs (e.g., facility accessibility, safety concern, air pollution, and inclement weather), indoor strategies may increase the activity levels of Hong Kong children. The potential components of such programs may include activity breaks, delivery of active

lessons, and changes to the classroom environment; however, these classroom-based strategies may not be sufficiently intense to induce MVPA (Salmon, 2010). The implementation of these strategies also requires considerable resources for training classroom teachers and altering the classroom environment. Therefore, other novel strategies must be developed and enforced.

Active video game (AVG) technology incorporates body movement into video game playing. This technology may be an attractive option that displaces sedentary screen time and increases the PA levels of children. Laboratory studies have demonstrated that certain AVGs can elicit MVPA among children (Foley & Maddison, 2010; Peng, Crouse, & Lin, 2013). Hence, AVGs can be applied in an indoor intervention to increase PA levels.

Researchers are increasingly interested in the use of AVGs to promote PA and to curb childhood obesity. AVGs have been employed in home, school, community, and healthcare settings. The results of many trials that were conducted at home (Baranowski et al., 2012; Graves, Ridgers, Atkinson, & Stratton, 2010a; Maddison et al., 2011; Maloney et al., 2008; Maloney, Threlkeld, & Cook, 2012b; Mhurchu et al., 2008) suggested that AVGs did not change the objectively measured PA and sedentary behavior of children in comparison with a non-AVG control group. A potential explanation may be that the children did not play AVGs at home throughout the entire intervention period, which lasted 10-24 weeks. This occurrence represents low intervention fidelity. In one study (Paw, Jacobs, Vaessen, Titze, & van Mechelen, 2008), the median self-reported total playing time of a dancing game decreased from 228 min in the first 6 weeks to 0 min in

the subsequent weeks (7-12 weeks). By contrast, a recent cluster randomized controlled trial (RCT; Trost, Sundal, Foster, Lent, & Vojta, 2014) reported a positive treatment effect on objectively measured PA when AVGs (children played AVGs at home) were incorporated into a pediatric weight management program (AVG play+ weight management program vs. weight management program). In this particular study, the console used (Xbox $360^{®}$ Kinect^{TM} [Microsoft, Redmond, WA]) allows users to control and interact with AVGs without a game controller or any other peripheral equipment. Because holding a controller may prevent players absorb in the game (Wood, Griffiths, Chappell, & Davies, 2004), the advantage of Xbox may have generated this contradictory result. It seems promising to use this console in further studies to promote PA among children.

Previous free-living studies have focused primarily on individual AVG play. One study (Paw et al., 2008) made an exception, and suggested that an additional multi-player class may maintain or enhance children's motivation to play AVGs in comparison with children who played the games only at home (dropout was lower in the multiplayer group compared to the home group). The additional social influence from peers may generate this difference. AVG classes, which encourage group play, can be implemented in Hong Kong primary schools as an extracurricular activity to promote PA of children.

There have been school-based AVG interventions which compared intervention groups with non-AVG control groups. However, certain studies did not evaluate outcomes of PA (Gao, Hannan, Xiang, Stodden, & Valdez, 2013a; Staiano, Abraham, & Calvert, 2013). The other studies measured PA only during the

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program periods (Duncan & Staples, 2010; Gao & Podlog, 2012), or assessed habitual PA using self-report (Gao, Huang, Liu, & Xiong, 2012; Lwin & Malik). Gao et al. (2012) determined that the intervention children who played "Dance Dance Revolution (DDR)" (Konami, El Segundo, CA) three times a week for nine months during recess engaged in more PA than the controls did with a quasi-experiment design. Lwin and Malik (2012) also reported a positive treatment effect on self-reported PA at the end of a six-week intervention, which incorporated Wii™ (Nintendo, Kyoto, Japan) boxing, Wii tennis and DDR into physical education (PE) lessons compared with a control group engaging in the usual PE lessons with a cluster RCT design. In summary, little evidence confirms whether or not the exposure of children to AVGs within the school setting can increase habitual PA and/or reduce sedentary behaviors.

The potential mediation effects of interventions are recommended to be examined to understand the mechanisms of effective strategies and to provide information for future studies (Baranowski et al., 1998). A recent systematic review (Brown, Hume, Pearson, & Salmon, 2013) identified 31 intervention studies (published from 1985 to April 2012) that reported on the treatment effects on potential PA mediators among primary school children (5-12 years old). None of these studies performed mediating analyses. PA correlates that are commonly examined in previous PA interventions were self-efficacy, social support, knowledge, enjoyment, intention to be physically active, outcome expectancy, and PA preferences. All of these factors are oriented from a social cognitive perspective. Moreover, these preceding intervention studies hinted at the factors that should be examined in PA interventions among Hong Kong children.

Several social cognitive correlates of PA have been examined in previous studies on AVG interventions among children. Certain correlates have been associated with AVG play, including self-efficacy (Gao et al., 2012; Staiano et al., 2013), perceived competence in exercise (Wagener, Fedele, Mignogna, Hester, & Gillaspy, 2012), social support (Gao et al., 2012), attitude toward exercise, and subjective norm (Lwin & Malik, 2012). By contrast, other correlates such as outcome expectancy (Gao et al., 2012), perceived behavior control, and intention (Lwin & Malik, 2012) have not been associated with AVG play. Only one study (Gao et al., 2012) jointly measured PA and PA correlates as outcomes, but it did not conduct mediating analyses.

Numerous social cognitive variables can act as potential mediators of PA interventions. For the purpose of this thesis, however, only self-efficacy, social support, and enjoyment were selected. These variables are the most commonly studied PA correlates among children, and may be associated with AVG play.

Self-efficacy is the most important construct in the social cognitive theory (SCT; Bandura, 1986). Bandura defined self-efficacy as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p.391). Moreover, "self-efficacy is concerned not with the skills one has but with judgments of what one can do with the skills one possesses" (Bandura, 1986, p.391). This variable has been demonstrated associated with the PA levels of children (van der Horst, Paw, Twisk, & van Mechelen, 2007).

Self-efficacy can be enhanced through positive personal experiences as well as by watching others who are succeeding (Biddle & Mutrie, 2008, p.111). A non-threatening atmosphere may enhance self-efficacy (Biddle & Mutrie, 2008, p.111). In this regard, playing AVGs with peers at school may provide children with a comfortable atmosphere in which to experience this novel PA. Within a group setting, children can learn from one another with regard to AVG play. This process may enhance their self-efficacy to regularly play such games and to engage in PA.

Social support refers to activities that help an individual accomplish his/her goals (Caplan, Robinson, French, Caldwell, & Shinn, 1976). For children, this support mainly comes from their family (parents and siblings), teachers, and friends (peers). A previous review study associated parental support with PA engagement by young children (4-12 years old), and associated friend support with PA engagement by adolescents (13-18 years old) (van der Horst et al., 2007).

The existing social network of children may be enhanced by playing AVGs with peers at school. This network may serve to enhance the social support they receive, particularly from friends, for engaging in PA.

Enjoyment refers to a positive affective response to the experience that reflects generalized feelings such as pleasure, liking, and fun (Scanlan & Simons, 1992). This variable may reinforce the intrinsic motivation of children to engage in related behaviors (Ryan, Rigby, & Przybylaki, 2006). Dishman et al. (2005)

reported that the enjoyment of PA mediated the effect of a school-based PA intervention for American adolescent girls in the eighth grade.

The children who participated in an intervention study (Baranowski et al., 2012) and previous laboratory studies (Graves et al., 2010b; Penko & Barkley, 2010) indicated that they enjoyed playing AVGs. However, these studies did not clearly specify whether or not the enjoyable experiences of AVG play can be transferred to the overall enjoyment of PA.

In summary, self-efficacy, social support, and enjoyment may act as potential mediators of school-based PA interventions based on AVGs. The conceptual model of the thesis is presented in Figure 1.
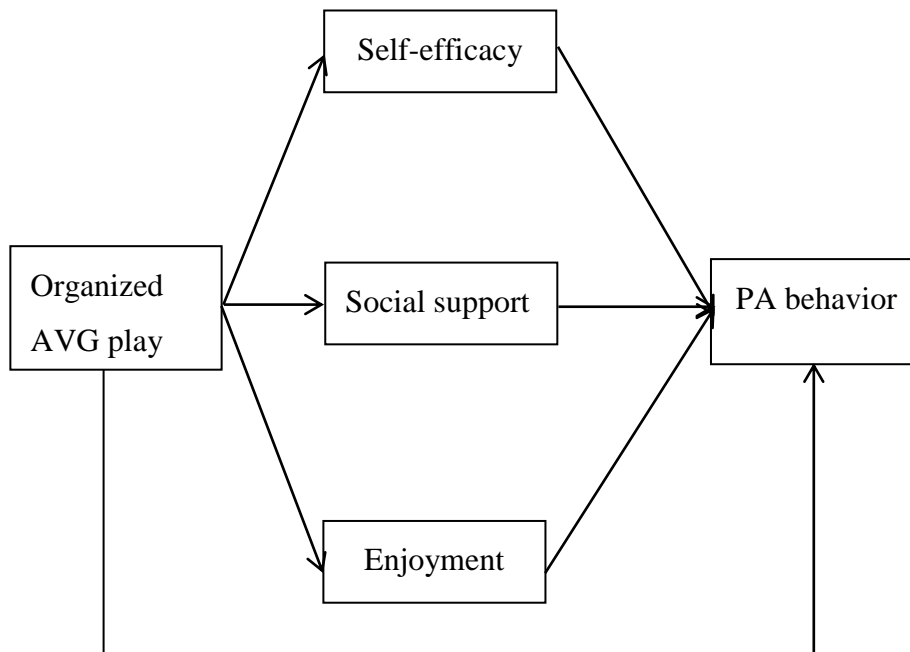
Figure 1. Conceptual model of the thesis

1.2 OBJECTIVES OF THE THESIS

The overall aim of this thesis is to identify opportunities for interventions using AVGs to promote PA among children, to develop and evaluate an AVG intervention on PA and PA-related psychosocial factors in Hong Kong Chinese children.

For the purpose of the thesis, three interrelated studies were conducted. The first study (Chapter 3) is a systematic review that evaluated the effects of AVGs on PA and PA-related outcomes. The second study (Chapter 4) is a validation study that examined the validity (a tool that measures what it is intended to measure [de Vet, Terwee, & Bouter, 2003]) and reliability (the consistency of a measure [Atkinson, 2012]) of three translated scales (English to Cantonese Chinese) to gauge the PA correlates (i.e. self-efficacy, social support, and enjoyment) among Hong Kong children. The third study (Chapter 5) aims to analyze the effects of a school-based AVG intervention on PA, sedentary time, body composition, and PA-related psychosocial factors (i.e. self-efficacy, social support, and enjoyment) of Hong Kong children. This final study also intends to explore whether the selected psychosocial factors can act as mediators or moderators of the treatment effect on PA. The third study is the main focus of this thesis.

1.3 SIGNIFICANCE OF THE THESIS

The prevalence of physical inactivity and its potential negative health outcomes among Hong Kong children emphasize the need to increase their activity levels. This thesis documents the first attempt to develop a school-based indoor PA program for Hong Kong children given the insufficient outdoor space for PA in

Hong Kong primary schools.

A novel type of PA (AVGs) was used as the intervention strategy. This endeavor is the first to integrate AVGs into the extracurricular activities of Hong Kong primary schools to promote PA. The main study conducted for this thesis will inform the potential indoor PA interventions using AVGs in Hong Kong and in other cities with similar environmental constraints toward the activity of children.

None of the previous school-based AVG interventions studies applied objective measures to determine the intervention effects on habitual PA and sedentary behaviors. The present thesis fills this gap.

Moreover, no study has examined either the mediation or moderation effects of psychosocial factors on AVG interventions. The present thesis may provide information to clarify the mechanisms of AVG interventions on the PA levels of children and to identify the beneficiaries of a school-based AVG intervention.

Study 1 (a systematic review that evaluated the effects of AVGs on PA and PA-related outcomes) and Study 2 (a validation study that determined the validity and reliability of the scales used to measure three PA correlates, namely, self-efficacy, social support, and enjoyment among Hong Kong children) support the main study. Apart from informing the design of the main study, Study 1 also summarized evidence regarding the effects of AVGs on PA correlates. This evidence has not been addressed in previous reviews; thus, Study 1 provides insight into the potential mechanisms of AVGs on PA. This review study is also

the first to separately evaluate the effects of AVG interventions on PA levels of children in different settings, in particular to discriminate the free play and organized play of AVGs. Study 2 psychometrically supports the use of the tested scales in the main study and in future studies among children who speak Cantonese Chinese.

1.4 THESIS OUTLINE

This section describes each chapter of the current thesis. The three studies that comprise the research conducted throughout the doctoral training of the PhD candidate are presented in Chapters 3, 4, and 5 in manuscript style.

Chapter 1: Introduction

The first chapter introduces the background of the thesis and emphasizes the urgency of increasing the PA levels and reducing the sedentary behaviors of Hong Kong children. On the basis of the physical environmental constraints on PA in Hong Kong, an indoor PA intervention that used AVGs was proposed to promote PA among Hong Kong children. Three PA correlates (i.e., self-efficacy, social support, and enjoyment) were examined in this intervention. A conceptual model of this thesis was presented to depict how the AVG intervention may influence the PA levels of children through the three potential mediators. Finally, the objectives and the significance of the thesis were presented.

Chapter 2: Literature review

This chapter provides an overview of the literature on PA epidemiology (the study field of this thesis) among children through a behavior epidemiology framework.

Evidence regarding the measurement of PA, the link between PA and health, PA correlates, and PA intervention studies was summarized to provide the context and literature support for the entire thesis.

Chapter 3: Effects of AVGs on PA and related outcomes among healthy children: A systematic review

In this chapter, Study 1 is presented. Electronic databases were searched to retrieve articles published from January 2000 through August 2013. Included were original studies published in English in peer-reviewed journals with at least one subgroup of healthy participants not older than 18 years; and measured at least one PA-related psychosocial or behavioral outcome. All study designs were included, but only intervention studies with PA comparison between groups or across time were assessed for methodological quality. Evidence strength for intervention studies was stratified by settings [including the free-living home setting, the school, community or healthcare setting with structured AVG sessions (i.e. AVG play of participants was organized by teachers or researchers), and multi-settings]. This systematic review, including the tables and figures listed in the chapter, has been published in the Games for Health Journal (Liang & Lau, 2014).

Chapter 4: Validity and reliability of questionnaires measuring PA self-efficacy, social support, and enjoyment among Hong Kong Chinese children

Study 2 is presented in this chapter. Participants were recruited from two Hong Kong government primary schools. Confirmatory factor analyses (CFA) were conducted to assess factorial validity. Criterion validity was assessed by

correlating measured constructs with self-reported PA. Cronbach's alpha was computed to assess scale internal consistency. The intraclass correlation coefficient (ICC) was performed to assess test-retest reliability. This study has been published in the Preventive Medicine Reports (Liang, Lau, Huang, Maddison, & Baranowski, 2014).

Chapter 5: Getting active with AVGs: A quasi-experimental study

Chapter 5 presents Study 3. A quasi-experimental study was conducted in a Hong Kong government primary school. Children (grades 4-6) who did not participate in extracurricular exercise activities and had no contraindications to be active were recruited via school teachers. Children were allocated to either the intervention group or the control group based on personal preferences. The eight-week intervention involved children playing AVGs in a class during after-school hours for approximately twice a week. The class frequency decreased to around once a week in 9-15 weeks. The control group continued with usual activities. The primary outcome was change in MVPA from baseline to 8 weeks. The secondary outcomes included other accelerometer-determined PA outcomes at 8 weeks and 15 weeks, body composition, and psychosocial variables (i.e. self-efficacy, social support, and enjoyment).

Chapter 6: General discussion and conclusion

This chapter discusses the three studies that constitute the thesis in general. In particular, this chapter summarizes the study findings, along with the strengths and limitations of the thesis, and implications to the future studies. This chapter concludes the entire thesis.

CHAPTER 2. LITERATURE REVIEW

This chapter provides an overview of the literature regarding PA epidemiology (the study field of this thesis) among children through a behavioral epidemiology framework. This overview provides the context and literature support for the entire thesis. Specific reference is made to evidence obtained from studies conducted in Hong Kong.

2.1 EPIDEMIOLOGY OF PHYSICAL ACTIVITY

Chronic diseases that are related to the habitual behaviors of people (e.g., smoking, poor diet, and lack of PA) are a major challenge in the public health domain (Gordis, 2009, p.4). Research has been conducted for the specific purpose of understanding and influencing health-related behavior patterns as part of the population-wide initiatives to prevent disease and to promote health. This particular endeavor is called behavioral epidemiology (Sallis, Owen, & Fotheringham, 2000a). As a specific branch of behavioral epidemiology, PA epidemiology emerged as a new field of study approximately 60 years ago. It has been expanded to include interventions over the past 25 years (Dishman, Heath, & Lee, 2013, p.4).

Sallis and Owen (1999) advocated a five-stage behavioral epidemiology framework and adopted it to illustrate the main tasks in PA epidemiology. The five stages are as follows:

1. To establish links between PA and health

2. To develop methods for the accurate assessment of PA

3. To identify PA correlates

4. To evaluate interventions designed to promote PA

5. To translate findings from research into practice

This behavioral epidemiology framework is applied to review the literature relevant to PA epidemiology in children. The stage sequence described above is not linear, and the entire process is iterative (Biddle & Mutrie, 2008, p. 5). The second stage on PA measurement issues is essential to all of the other stages; therefore, it is presented first in this chapter.

2.2 MEASUREMENT OF PHYSICAL ACTIVITY IN CHILDREN

Assessment of PA is essential to determine the relationships between PA and health outcomes as well as those between PA and associated factors, to assess the prevalence of activity levels and the trends of PA, and to determine the efficacy of PA interventions. However, this stage of PA epidemiology is problematic and is an existing challenge (Sallis & Owen, 1999, p. 8) partly because of the complex nature of PA.

PA is multidimensional. The basic dimensions of PA include frequency (the number of PA events during a specific time period), intensity (the physiological effort associated with participation in a special type of PA), time (duration of a single bout of PA), and type of activity (Barisic, Leatherdale, & Kreiger, 2011; Warren et al., 2010). It is desirable to assess all of the PA dimensions given that each may affect different health outcomes. For example, weight-bearing exercise (e.g., jumping) positively affects the bones of children and can serve as an

osteoporosis prophylaxis (Behringer, Gruetzner, McCourt, & Mester, 2014; Hind & Burrows, 2007). The first three PA dimensions (i.e. frequency, intensity, and time) can be applied to calculate EE, which is a consequence of PA. However, these dimensions are distinct constructs, and no single ideal method can provide all of the required data on PA (Warren et al., 2010).

PA measures can be classified as either subjective (self-report) or objective. Self-report measurement tools should be validated before use against objective measures (shown as construct validity), such as activity monitors (i.e. accelerometers and pedometers), heart rate (HR) monitors, direct observation, doubly labeled water (DLW), and indirect calorimetry.

2.2.1 OBJECTIVE MEASURES

Indirect calorimetry and DLW are criterion measures of EE, which is a consequence of PA as mentioned above. However, EE and PA are distinct constructs. DLW assesses total caloric expenditure by measuring the production of CO_2 from the divergence in the enrichments of two isotopic labels in body water, that is, one of H, and one of O_2 (Speakman, 1998). DLW is a well-recognized criterion measure of free-living EE over a minimum of three days (Sirard & Pate, 2001). Nonetheless, it cannot provide information on any PA dimension. Indirect calorimetry uses gas analysis equipment to evaluate the consumption of O_2 and the production of CO_2 during different activities, including resting. Thus, this method could be used to calculate the MET value of a specific activity, thus determining intensity. Indirect calorimetry is mainly used in laboratory-based studies to estimate short-term EE, and is therefore seldom used to validate self-

report instruments that assess habitual PA. Nonetheless, this method has been used to verify the activity and HR monitors (Bitar et al., 1996; Eston, Rowlands, & Ingledew, 1998).

Direct observation requires trained observer(s) to record PA behaviors using codes for activity categories (such as intensity) at short regular intervals (usually ≤ 1 min). This method is the sole objective measure (in comparison with activity and HR monitors) that can provide qualitative information on PA, such as location or with whom the activity was undertaken (McKenzie, 2002). Direct observation can derive highly valid data on the PA of children and is a criterion measure for validating other objective measures of PA, such as activity monitors (McClain, Abraham, Brusseau, & Tudor-Locke, 2008; Scruggs, 2007). However, this method is considerably limited by cost. Multiple observers are required for each study, which may run for an extensive period. Moreover, each observer must undergo extensive initial training, as well as pass ongoing assessments and retraining (Sallis & Owen, 1999, p.89). Therefore, direct observation is seldom used to assess the habitual PA of children.

Accelerometers measure body movements in terms of acceleration (a change in speed with respect to time). The traditional output of this device is a digital series of numbers (counts) converted from acceleration signals and recorded to its internal memory (Chen & Bassett, 2005). Numerous studies have been conducted to convert the output of counts into activity intensities among children. Consequently, accelerometers can estimate the intensity of PA over time. However, no consensus has been reached regarding the best cut points of

accelerometer counts for classifying the PA levels of children (Kim, Beets, & Welk, 2012). A comparison study (Trost, Loprinzi, Moore, & Pfeiffer, 2011) recommended the cut points established by Evenson et al. (2008) (EV cut points) compared with other four sets of cut points (Freedson, Pober, & Janz, 2005; Mattocks et al., 2007; Puyau, Adolph, Vohra, & Butte, 2002; Treuth et al., 2004). The classification accuracy of EV cut points for different intensities was represented by kappa statistics (0.68) and the area under the receiver operating characteristic curve (value range of 0.70-0.90 for the respective intensities) against indirect calorimetry. The inter-instrument reliability of accelerometers has been demonstrated (ICC = 0.87) among children (Trost, Pate, Freedson, Sallis, & Taylor, 2000).

Accelerometry estimates the amount and intensity of PA and sedentary behaviors among children objectively, practically, reliably, and validly (Corder, Ekelund, Steele, Wareham, & Brage, 2008; de Vries, Bakker, Hopman-Rock, Hirasing, & van Mechelen, 2006; Reilly et al., 2008). However, accelerometer data are difficult to manage and interpret (Dollman et al., 2009). In addition, this method cannot accurately assess weight-bearing activities such as swimming and cycling. It also does not identify activity type, such as the type of sedentary activity undertaken during the identified sedentary time. Another limitation of this approach is data collection, which depends on the compliance of participants with wearing the device. This condition is particularly important for intervention studies that assess PA several times.

Pedometers estimate step counts by detecting the vertical acceleration of the hips

during ambulation (Tudor-Locke, Williams, Reis, & Pluto, 2002). A step is registered as a result of detected acceleration, and the accumulated step count is usually displayed on a screen. Pedometers provide a valid and reliable objective measure of the total volume of ambulatory activity of children (Clemes & Biddle, 2013). The strengths of these electronic devices include their low cost (Dollman et al., 2009; Eston et al., 1998), small size, simplicity in terms of data interpretation, and unobtrusive nature (Clemes & Biddle, 2013). However, the main disadvantage of pedometers is that they cannot assess activity intensities and sedentary behaviors. Given that children must accumulate PA with at least moderate intensity and minimize their sedentary behaviors, pedometers may not be a desirable measure of the treatment effect of a PA intervention.

HR monitors can indirectly assess PA. To interpret HR data, Livingstone et al. (1992) measured oxygen uptake (VO_2) and HR simultaneously in a laboratory, and determined the individual HR-VO_2 regression line of participants. Individual calibration can provide highly valid data; yet, implementing it in large-scale studies is burdensome and impractical. Some researchers applied a percentage of the maximum HR data to distinguish activity intensities. For example, 140 beats per minute (bpm; approximately 70% of maximum HR) was regarded as the threshold for the MVPA of primary school children in Hong Kong (Macfarlane & Kwong, 2003) and Singapore (Gilbey & Gilbey, 1995). Numerous HR thresholds have been established, thereby complicating the comparison of the results of different studies. This technique can be used to classify groups of individuals rather than to estimate individual EE or PA levels (Sirard & Pate, 2001). Many factors other than PA can also influence HR, including anxiety, emotional stress,

fatigue, body position, fitness level, food intake, ambient temperature, and humidity (Armstrong, 1998). Thus, HR monitors may not be appropriate for the continuous measurement of the PA levels of children. In practice, the chest belt can slip down and interrupt the recording (Dollman et al., 2009). Children may also remove the HR monitor because of discomfort (Rowlands, Eston, & Ingledew, 1999).

The objective measures of PA are usually moderately to highly correlated with one another (Cardon & De Bourdeaudhuij, 2007; Eston et al., 1998; Louie & Chan, 2003; Louie et al., 1999; McKee, Boreham, Murphy, & Nevill, 2005; Oliver, Schofield, Kolt, & Schluter, 2007; Rowlands, Eston, & Ingledew, 1999; Scruggs, 2007; Sirard & Pate, 2001; Treuth et al., 2003). Given the reduced cost and advantages of accelerometry, accelerometers have been widely and increasingly used in PA epidemiology among children (Dollman et al., 2009; Pate, O'Neill, & Mitchell, 2010).

2.2.2 SUBJECTIVE MEASURES

Self-report is the most widely used type of PA measure because of its relatively low cost and convenient administration, despite its numerous limitations. Specifically, its problematic reliability and validity are associated with recall and social desirability biases (Warren et al., 2010). Self-report instruments, such as diaries, interviewer-administered recalls, self-administrated recalls, and proxy reports, can be used to ask the subjects to recall all PA dimensions. However, these instruments are not as valid and reliable as objective measures are. PA recall is a highly complex cognitive task (Baranowski, 1988). Furthermore, many

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factors may influence the accuracy of self-report, including respondent characteristics, recall period, and the method of administration.

For adults, a diary is considered one of the most accurate subjective techniques (Sirard & Pate, 2001). This self-report instrument can successfully predict EE in children (Bratteby, Sandhagen, Fan, & Samuelson, 1997; Ekelund, Yngve, & Sjostrom, 1999). Bratterby et al. (1997) detected a mean difference of 1.2% between the EE estimated with a diary and that predicted with DLW among fifty 15-year old respondents. The limits of agreement (mean ± 2standard deviation [SD]) were −3.47 and 3.77 MJ/day. Ekelund et al. (1999) reported that the limits of agreement (mean ± 2SD) between the EE estimated with an HR monitor and that predicted with a diary were −3.54 and 2.74 MJ/day among thirty children (15 ± 1 years old). Both studies adopted an approach that was first established by Bouchard et al. (1983), which involves dividing a day into 96 15-min periods during which respondents rate their activity intensity on a scale of 1−9. Each of the numbers can be converted into a MET value. Bouchard et al. recruited 150 children (14.6 ± 2.9 years) and indirectly validated their diaries according to physical working capacity. Moreover, children aged 15 (the average age of the participants in the three studies described above) or older can recall their PA behaviors as well as adults can (Sallis & Owen, 1999, p. 83). Nonetheless, the performance of the similar forms of diaries in children younger than this range is unclear. Keeping a diary may influence the PA behaviors of respondents. Furthermore, compliance is a concern. In summary, the PA diary is a type of measure that is not commonly used for children, especially for those younger than 15 years old.

Assigning a trained administrator to interview children may improve the cognition and ability of the latter to recall their previous PA behaviors (Sirard & Pate, 2001). However, a comparison study (Sallis et al., 1996) that involved fifth-graders did not support this assumption. The researchers directly compared interview-administered (IA) and self-administered (SA) versions of the recall of a previous day's PA. This recall followed a checklist of 21 activities. The minutes spent on the activities as measured by both versions were significantly correlated with accelerometer counts (IA $r = 0.32$, SA $r = 0.30$) and with MVPA (indicated by an HR greater than the resting rate plus 60 bpm) (IA $r = 0.50$, SA $r = 0.58$). Given that individual interviews are highly costly in terms of human resources and other resources, Interview-administered PA recalls are less likely to be used in studies involving children than SA questionnaires are.

Chinapaw et al. (2010) noted that the validity of self-administered PA questionnaires as indicated by their correlations with accelerometers (the widely used objective measure to validate such questionnaires) ranged from very low (approximately 0) to high (0.77). The highest correlation among primary school children was obtained with the self-report instrument Assessment of Young Children's Activity Using Video Technology (ACTIVITY) (Tremblay, Inman, & Willms, 2001). Tremblay et al. employed video recording to demonstrate three categories of activity (i.e., non-moving, moving, and fast-moving) and requested the respondents (47 third-graders) to recall their previous day PA by selecting colored dots that corresponded to the activity intensity for segmented time periods. The activity intensity (0 for nonmoving, 2 for moving, and 4 for fast-

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moving) for each time segment was multiplied by the number of minutes in that particular segment. The sum of these segment scores was correlated with accelerometer counts per minute (CPM; r = 0.40, p < 0.001). The reliability of this particular instrument (ACTIVITY) has not been reported thus far. Reliability (particularly test-retest reliability) was less likely to be examined than validity was in previous studies. Moreover, some self-report questionnaires are poorly correlated with objective measures. Therefore, Chinapaw et al. concluded that none of the existing questionnaires exhibited both acceptable test-retest reliability (ICC > 0.7) and construct validity for measuring the PA of children.

Proxy reports in which parents or teachers report the PA of children were predominantly used in studies on pre-school children (Burdette, Whitaker, & Daniels, 2004; Corder et al., 2009; Janz, Broffitt, & Levy, 2005; Telford, Salmon, Jolley, & Crawford, 2004) and occasionally in those on primary school children (Basterfield et al., 2008; Ching & Dietz, 1995; Harro, 1997; Koo & Rohan, 1999; Telford et al., 2004). Such young children may have more difficulty answering PA questionnaires by themselves compared with older children. The correlations between proxy PA questionnaires and accelerometers in these studies ranged from approximately 0 (Telford et al., 2004) to 0.53 (Harro, 1997). Nonetheless, most proxy reports are invalid possibly because neither parents nor teachers can observe the children at all times (Chinapaw et al., 2010; Sallis & Owen, 1999, p.79). As with SA PA questionnaires, the reliability of proxy PA questionnaires was less likely examined than their validity was. Only one proxy report instrument (Telford et al., 2004) was rated with acceptable test-retest reliability (ICC > 0.70) by Chinapaw et al. (2010).

Self-report instruments should be validated for specific populations before usage. Only one self-report instrument has been validated for use with Hong Kong primary school children aged 9-12 (Huang et al., 2009), that is, the Children's Leisure Activities Study Survey questionnaire-Chinese version (CLASS-C). This questionnaire consists of 31 PAs and 14 sedentary activities that cover leisure activities, PE classes, and transportation-related activities. In the validation study, significant correlations between self-reported and accelerometer-determined MVPA and sedentary time were observed only in girls (r = 0.48 for MVPA, r = 0.25 for sedentary time; p < 0.05) and not in boys (r = 0.27 for MVPA, r = 0.06 for sedentary time, p > 0.05). The test-retest reliability for weekly MVPA (ICC = 0.71, 95% CI 0.61–0.77) was acceptable; a relatively lower reliability was obtained for weekly sedentary time (ICC = 0.69, 95% CI 0.59–0.77).

In summary, the objective measures of PA assess PA more validly and reliably than subjective instruments do. Thus, objective measures should be encouraged for use in PA epidemiology among children because the evidence obtained from objective measures is more powerful and persuasive. Accelerometry is the most commonly used objective measure for assessing both PA and sedentary behavior in field-based studies. Nevertheless, subjective measures remain useful, particularly in large-scale studies. However, the subjective measures of PA should be validated before use on a specific population.

2.3 PHYSICAL ACTIVITY AND HEALTH IN CHILDHOOD

This section summarizes the evidence from health outcomes related to childhood

PA, thereby reflecting Stage 1 of the behavioral epidemiology framework. The apparent links between childhood PA and health outcomes are often difficult to demonstrate because of PA measurement issues (i.e., whether a relevant PA dimension is measured with an appropriate instrument for linkage with a specific health outcome), and the length of time required for the disease endpoints to materialize from habitual PA behavior (Biddle et al., 2004). However, tackling the problem once the diseases have developed is too late. Accordingly, public health policies must focus on improving pediatric preventive care medicine (Lambrick, Stoner, Faulkner, & Hamlin, 2014). In particular, one concern is the increasing prevalence of childhood obesity worldwide over the past three decades (WHO, 2012). In some countries, the prevalence of obesity has plateaued recently (Ogden, Carroll, Kit, & Flegal, 2012).

Obesity is a consequence of a chronic positive energy balance, and its etiology is multifactorial (Hill, 2006). The consensus is that changes in lifestyle activities relevant to food (energy intake) and PA (EE) have fueled the obesity epidemic (Hill, Wyatt, Reed, & Peters, 2003). In addition to resting EE (approximately 60%) and the thermic effect of food (roughly 10%), PA also accounts for a large proportion of total EE (approximately 30%) among children (Ball et al., 2001; Ekelund et al., 2001). The activity levels of children in clearly defined contexts, such as active transport, school PE lessons, and organized sports, are on the decline in many countries (Dollman, Norton, & Norton, 2005; Knuth & Hallel, 2009). However, the overall level of PA is difficult to measure and track at the population level. Accordingly, this circumstance has partially caused arguments on the roles of food and PA changes in the obesity epidemic (Blair, Archer, &

Hand, 2013; Fisher, Hunter, & Allison, 2013; Hill & Peters, 2013; Luke & Cooper, 2013a, 2013b; Swinburn, 2013; Wareham & Brage, 2013). Some researchers argue that the increasing prevalence of obesity may be driven mainly by global food systems, which produce more processed, affordable, and effectively marketed food than before (Swinburn et al., 2011).

According to the rating system for the hierarchy of evidence, the systematic reviews and meta-analyses of all relevant RCTs support causal inferences the most effectively (Stillwell, Fineout-Overholt, Melnyk, & Williamson, 2010). In fact, a recent systematic review (Sun et al., 2013) of school-based RCTs for the direct delivery of PA without other components supported the idea that PA can reduce adiposity in children aged 5-18 years. Furthermore, this effect favored interventions with a high dose of PA.

A recent mendelian randomization study of 4,244 British children suggested that increased adiposity reduced PA and increased the sedentary time of the participants (Richmond et al., 2014). Mendelian randomization study utilizes genetic variants as a proxy for environmentally modifiable exposures, and is analogous to a RCT in which genotype is not susceptible to either reverse causation or confounding factors. No genetic variants have been robustly associated with PA thus far; hence, the sensitivity analyses to determine the reverse causality of PA on body mass index (BMI) were limited by low power in this mendelian study. The researchers indicated that no such causal effect existed. PA and sedentary behavior were objectively measured through accelerometry in this mendelian randomization study. This finding is consistent with those of

several longitudinal observational studies (Ekelund et al., 2012; Hjorth et al., 2014; Metcalf et al., 2011) that examined the bidirectional prospective associations between PA and fatness in children. Consequently, fatness predicted the objectively measured PA and sedentary behaviors, but not vice versa. By contrast, other longitudinal observational studies (Moore et al., 2003; Remmers et al., 2014; Riddoch et al., 2009) evaluated only the effect of objectively measured PA on adiposity in children and supported such prospective associations. These contradictory results may be partially explained by PA measurement issues. Until now, PA has not been measured as precisely as adiposity has been (Wareham & Brage, 2013). Thus, the relationship between PA and adiposity may be underestimated when the former is the exposure variable (Hutcheon, Chiolero, & Hanley, 2010). A vicious circle may be initiated between PA and adiposity. This circle influences the health of children further.

Childhood obesity has serious negative consequences on one's health and well-being both during childhood and in adult life eventually (Lakshman, Elks, & Ong, 2012). The acute health consequences of obesity in childhood include type 2 diabetes, major cardiovascular risk factors (e.g., high blood pressure, dyslipidemia, abnormalities in the left ventricular mass and/or function, abnormalities in endothelial function, and hyperinsulinemia and/or insulin resistance), asthma, chronic inflammation, musculoskeletal disorders, and psychological problems (Reilly et al., 2003). Thirty years ago, type 2 diabetes was deemed a rare occurrence in children, but its incidence has been increasing following escalating childhood obesity in many countries (Reinehr, 2013). In the US, the prevalence of pre-diabetes/diabetes in adolescents aged 12-19 years

increased from 9% to 23% from 1999 to 2008 (May, Kuklina, & Yoon, 2012). Although cardiovascular disease is not usually evident until middle-age at the earliest (Biddle et al., 2004), evidence has revealed that childhood adiposity is related to adult preclinical markers and independent of other youth risk factors (Magnussen, Smith, & Juonala, 2013).

Two pooled analyses (Juonala et al., 2011; Park, Sovio, Viner, Hardy, & Kinra, 2013) of prospective cohorts evaluated the relative contributions of obesity to cardiovascular risk at different life stages. Juonala et al. analyzed data from four large-scale studies that followed participants from childhood into adulthood: the Bogalusa Heart Study (conducted in the US; Li et al., 2003), the Muscatine study (US; Davis, Dawson, Riley, & Lauer, 2001), the Childhood Determinants of Adult Health (Australia; Tapp et al., 2014), and the Cardiovascular Risk in Young Finns Study (Finland; Raitakari et al., 2003). On the basis of their pooled analyses ($n = 6,328$), Juonala et al. determined that subjects who were overweight/obese in childhood and obese in adulthood developed an increased risk of type 2 diabetes with a relative risk of 5.4 (95% CI 3.4–8.5) in comparison with persons who had a normal BMI as children and were non-obese as adults. Risks of cardiovascular disease also increased. The increased risks were similar among persons who were obese as adults but had a normal BMI as children.

By contrast, another pooled analysis (Park et al., 2013) of three British cohorts (n=11,447) suggested that subjects with a consistently high adiposity status (overweight/obese as children and obese as adults) exhibited a 12.6- and 6.6-fold increase in the odds of developing type 2 diabetes and coronary heart disease in

adulthood (34-53 years), respectively. Obesity in adulthood but not in childhood was associated with lower risks for both diseases (5.5- and 3.8-fold increase in odds, respectively).

Longitudinal studies have determined that overweight/obese children are more likely to become obese adults (Gordon-Larsen, The, & Adair, 2010; Guo, Roche, Chumlea, Gardner, & Siervogel, 1994; Whitaker, Wright, Pepe, Seidel, & Dietz, 1997). The aforementioned pooled analyses (Juonala et al., 2011; Park et al., 2013) specified that the small proportion of persons who were overweight/obese during childhood but were non-obese as adults displayed risks of the outcomes similar to those who consistently maintained a normal BMI from childhood to adulthood. These findings highlight the importance of preventing and treating obesity early in life.

With respect to PA itself, the PA measured objectively using accelerometry is negatively correlated with a composite score of cardiovascular risk factors (systolic blood pressure, triglyceride, total cholesterol/high-density lipoprotein ratio, insulin resistance, sum of four skinfolds, and aerobic fitness) in a large sample of European children (9-15 years old) independent of adiposity (Andersen et al., 2006). This finding highlights the independent role of PA in metabolic health, although adiposity is a stronger predictor of risk factors than PA in the same sample of children (Ekelund et al., 2006).

Researchers also examined the independent associations of PA and aerobic fitness with individual metabolic risk factors and clustered metabolic risk in the above

mentioned European sample (Ekelund et al., 2007). Ekelund et al. discovered that total PA, PA subcomponents, and aerobic fitness were separately and independently associated with clustered metabolic risk. The association between aerobic fitness and clustered risk was attenuated when waist circumference was adjusted further as a confounder; yet, the association with total PA was unchanged. These findings suggest that aerobic fitness and PA may affect metabolic risk through different pathways. In addition, PA subcomponents were weakly correlated with aerobic fitness (r=0.08-0.14, p<0.0001) in this study (Ekelund et al., 2007).

Determining the universally recommended PA levels for all health outcomes is difficult considering the other benefits of PA on one's health and well-being (e.g., bone and mental health). However, substantial evidence indicates that important health and fitness benefits can be expected to accrue in the majority of children who participate in MVPA for 60 min or more on a daily basis (Physical Activity Guidelines Advisory Committee, 2008). Janssen & LeBlanc (2010)) elaborated that whether or not children must be required to engage in 60 min of MVPA every day is unknown. Instead, they recommended an average of at least 60 min of MVPA per day. For children who are highly inactive, a realistic goal that does not reach the recommended levels may still induce health benefits because participation in as little as two or three hours of MVPA per week is associated with certain health benefits (Janssen & LeBlanc, 2010).

In summary, the evidence provided above implies that a complicated relationship exists among PA, obesity, cardiovascular fitness, and metabolic and

cardiovascular risks among children. Increasing the activity levels of children to a desirable level is important in preventing and treating childhood obesity, averting adulthood obesity and related diseases, and enhancing the overall health and well-being.

2.4 CORRELATES OF PHYSICAL ACTIVITY IN CHILDREN

PA correlates must be thoroughly understood according to the behavioral epidemiology framework. In particular, the modifiable factors that may influence PA behaviors are important because they can act as potential mediators and be the target of interventions (Baranowski et al., 1998). This section reflects Stage 3 of the behavioral epidemiology framework.

Theories help identify potential PA correlates by associating PA with a set of concepts (called constructs) and by illustrating how these constructs relate to one another, as well as to PA behavior (Glanz, Rimer, & Lewis, 2002). SCT is the most frequently used theory to understand PA behavior in both adults and children (Baranowski, Perry, & Parcel, 2002; Keller et al., 1999). Within the boundaries of SCT, Bandura elucidated that human behavior interacted reciprocally with environmental variables and personal factors such as cognitions (Bandura, 1986, Figure 2).
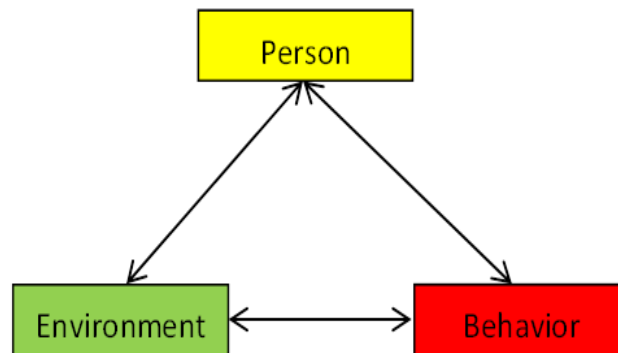
Figure 2. Triadic reciprocal model of social cognitive theory.

Note. Adapted from Social Foundations of Thought and Action by Bandura A., 1986.

Table 1 summarizes the main constructs and examples in SCT as provided by Ward et al. (2007, p26). The modifiable factors of PA alone are summarized in this table, but most PA correlates can be classified into one of the three categories. For example, demographic factors belong to the personal factors and are associated with the PA of children (Sallis et al., 2000b; van der Horst et al., 2007).

Table 1 CONSTRUCTS IN SOCIAL COGNITIVE THEORY

Constructs	Specific Constructs	What the Construct Means
Cognitive or personal factors	Perceived self-efficacy	A person's belief about his or her ability to be successful in initiating and continuing a specific activity.
	Expected outcome	A person's belief about what will happen if he or she engages in a specific activity (i.e., positive and negative consequences of being physical active).
	Coping	How a person deals with emotional (e.g., fear of failure or embarrassment) or physiological arousal (e.g., misinterpreting the normal physiological response to physical activity)
Behavioral factors	Behavioral skills	The ability of the individual to manage his or her own behavior including setting goals, monitoring and adjusting a plan based on what works, and using self-reinforcement (e.g., rewarding oneself when goals are reached).
	Behavioral capability	Having skills needed to engage in the behavior itself (e.g., being able to dance or having specific sport skills).
Environmental factors	Social environment in which the behavior takes place (e.g., social norms, social support, role model)	Family members, other adults, best friends, and peers have some influence on physical activity behavior (e.g., encouraging or discouraging it and providing such assistance as transportation).
	Physical environment in which the behavior takes place	Opportunity and safe access to a facility or program are needed to be physically active (e.g., sidewalks to school, sport programs with open enrolment).

Note. From Ward, Saumders, & Pate, 2007, p26.

As mentioned previously, environmental factors may be particularly relevant to children because they have less autonomy in their behaviors and are more likely than adults to be influenced by the environment (Ding et al., 2011). An increasing number of studies has explored the influence of environmental factors on the PA of children. A systematic review (de Vet, de Ridder, & de Wit, 2011) identified 12 reviews on the environmental correlates of PA among children. In the school setting, equipment/play structures (Davison & Lawson, 2006) and the time allowed for free play, outdoor activity, and field trips (Ferreira et al., 2007; Ridgers, Stratton, & Fairclough, 2006) were positively correlated with children's PA (examined in at least three studies, and at least 60% of the studies were conducted in the same direction; this criterion for consistent correlation is applied to all of the following variables). Built environment, including road and sidewalk infrastructures, can promote the active commuting of children and is therefore positively associated with their PA (Davison & Lawson, 2006; Davison, Werder, & Lawson, 2008; Limstrand, 2008). In the home setting, the time spent outdoors has always been positively correlated with the PA of children (Ferreira et al., 2007; Sallis et al., 2000b).

No social environmental factors have been consistently correlated with the PA of children (de Vet et al., 2011). Nonetheless, social support is one of the most commonly analyzed social environmental factors. Considerable evidence indicates that parental support is positively correlated with the PA of young children (≤ 12 years old) (Gustafson & Rhodes, 2006; Limstrand, 2008; Pugliese & Tinsley, 2007; van der Horst et al., 2007). However, this result was not supported by Ferreira et al. (2006) and Sallis et al. (2000b). Similarly, an indeterminate relation

has been detected between the PA of children and the social support they receive from friends and significant others (Ferreira et al., 2006; Limstrand, 2008; Sallis et al., 2000b; van der Horst et al., 2007). A large proportion of the evidence regarding social support from friends/significant others is derived from the adolescent population (>12 years old). A recent cluster RCT (Eather, Morgan, & Lubans, 2013) indicated that social support from classroom teachers had a mediating effect on PA (measured through pedometry) among children (fifth- and sixth-graders) during a six-month follow-up on a school-based intervention.

Previous PA has been associated with the current PA levels of children (Sallis et al., 2000b). A recent meta-analysis (Pearson, Braithwaite, Biddle, van Sluijs, & Atkin, 2014) implied a small but significant negative association between PA and sedentary behavior among children (r= -0.108, 95% CI -0.128 – -0.087, p<0.001). Moderator analyses suggested that stronger associations were observed in studies that used objective measures (r= -0.233, 95% CI -0.330– -0.137, p<0.001), as well as in high-quality studies (r= -0.176, 95% CI -0.215– -0.138, p<0.001). TV viewing has been widely examined (n=101) as a specific sedentary behavior, and has been negatively correlated with PA (r= -0.064, 95% CI -0.084– -0.045, p<0.001). Similarly, total screen time has been negatively associated with PA (r= -0.080, 95% CI -0.101– -0.060, p<0.001). Meanwhile, a small number of studies revealed that computer use (n=37) and video game play (n=26) were unrelated to PA. By contrast, Internet use (n=3) was negatively associated with PA (r= -0.051, 95% CI -0.097– -0.006, p<0.05). The weak association between PA and sedentary behavior signifies that they "should not be considered functional opposites or two sides of the same coin" (Pearson et al., 2014).

Behavioral skills such as goal setting, self-monitoring, and self-reinforcement have seldom been examined and applied among young children (Sallis et al., 2000b; van der Horst et al., 2007), because they have lower cognitive ability to develop plans and anticipate consequences than it is with older ones (Ward et al., 2007, p.27).

Personal characteristics (e.g., demographic/biological and cognitive factors) are associated with the PA levels of children. Two previous reviews (Sallis et al., 2000b; van der Horst et al., 2007) presented analogous evidence supporting the premise that male children engage in more PA than females do. The correlation between age and the PA of children is unclear (Sallis et al., 2000b; van der Horst et al., 2007). Three national surveys that employed accelerometers to measure PA posited that children engage in less MVPA as they age, that is, at 6-19 years old in the US (Troiano et al., 2008), 4-15 years old in the UK (Townsend et al., 2012), and 9-17 years old in China (Wang, Chen, & Zhuang, 2013).

Self-efficacy is the most commonly examined cognitive factor in cross-sectional studies among children. This factor is consistently associated with the PA of children across different ages (Sallis et al., 2000b; van der Horst et al., 2007). It is positively correlated with the PA of school children up to those in the sixth grade across countries when measured with accelerometers (Bergh et al., 2011; Gao, 2012b; Kitzman-Ulrich, Wilson, van Horn, & Lawman, 2010; Silva, Lott, Wickrama, Mota, & Welk, 2012; Trost, Pate, Ward, Saunders, & Riner, 1999a; Trost, Pate, Ward, Saunders, & Riner, 1999b). Fisher et al. (2011) noted that self-

efficacy was associated with both total PA (CPM) and MVPA (> 2,000 CPM) of boys in the UK (7-9 years old) but not those of girls. Most of these studies measured self-efficacy with a validated questionnaire that was developed by either Saunders et al. (1997) or by Motl et al. (2000). Motl et al. modified the questionnaire developed by Saunders et al., and reduced the number of items from 17 to 8, as well as the number of dimensions (from three dimensions to only one dimension). Therefore, the two measures measured overall self-efficacy in PA along the same link.

Self-efficacy is also the most widely assessed outcome in PA interventions among children (Brown, et al., 2013; Lubans, Foster, & Biddle, 2008; Salmon, Brown, & Hume, 2009). This outcome mediated the intervention effects on the PA of children (Dishman et al., 2004; Haerens et al., 2008; Taymoori & Lubans, 2008). All of these interventions which performed mediating analyses were conducted on middle-school students.

The enjoyment of PA has not been as significantly explored as self-efficacy has been among children. No consistent evidence supports the association between enjoyment and the PA of children aged 13-18 years (Sallis et al., 2000b; van der Horst et al., 2007). Researchers grouped enjoyment and preference together for young children (≤ 12 years old) and determined that PA enjoyment/preference was associated with PA (van der Horst et al., 2007). Enjoyment also mediated a school-based intervention effect on the PA of adolescent girls (13.6±0.6 years old) (Dishman et al., 2005).

No other cognitive variables are consistently correlated with the PA of young children (≤ 12 years old) (Sallis et al., 2000b; van der Horst et al., 2007). By contrast, intention and goal orientation/motivation are associated with the PA of children older than this range.

Huang et al. (2013) found that the participation in school sport teams and self-efficacy of Hong Kong primary school children (n=303, grades 4-6) was positively associated with the PA of boys. Participation in school sport teams, peer support, a supportive home environment for PA, and additional time spent on homework were positively associated with PA among girls. The screen-based sedentary behaviors of boys were negatively associated with family support for PA but were positively correlated with time spent on homework. Population density was positively associated with the Internet use/video game playing of boys. BMI and the parental modeling of TV viewing behavior were associated with TV viewing among girls. Meanwhile, PA self-efficacy and sedentary opportunities in the home were positively associated with the Internet use/video game playing of girls.

The reliability and validity of questionnaires used in the study conducted by Huang et al. (2013) to measure the PA self-efficacy and social support among Hong Kong children have been investigated (Huang, Wong, Salmon, & Hui, 2011). The self-efficacy scale focuses on "children's confidence in finding and creating an environment to support their PA" (Huang et al., 2011). Thus, such a scale may not suitably measure the overall PA self-efficacy. Peer support was determined with two items ("being physically active with me" and "offer

encouragement to be physically active"), whereas family support was gauged with four items ("Are the following people usually physical active with you: The whole family; father; mother; and siblings?"). The limited activities covered by these items may inhibit the use of these scales to measure social support for PA. No other scales have been developed and validated to determine the social cognitive factors related to the PA of Hong Kong children thus far.

A comparative study used previous validated English scales to measure PA and social support for PA among Australian and Hong Kong children (using translated versions of the English scales previously validated among Australian children) aged 11-16 years (Ha, Abbott, Macdonald, & Pang, 2009). This study found that Hong Kong children reported spending significantly ($p<0.05$) less time on PA and lower social support than their Australian contemporaries. Parental support was not correlated with PA among Hong Kong children, but friend support (Spearman r=0.232) and teacher support showed significant ($p<0.01$) correlations (Spearman r=0.127) with PA.

In summary, environmental, behavioral, and personal factors all influence PA. Certain factors that are consistently correlated with PA must be given additional attention. The majority of the previous interventions that examined effects on psychosocial correlates of PA did not conduct mediating analyses among children, especially among the young children. A few findings suggest that self-efficacy, social support, and enjoyment are important correlates of PA and may predict change in interventions on the PA of children. However, these factors have not been extensively examined using validated scales among Hong Kong children.

2.5 PHYSICAL ACTIVITY INTERVENTIONS IN CHILDREN

This section provides an overview of the literature relevant to PA interventions on children. When interventions are proven effective (Stage 4), they are expected to be translated into real-world settings at a large scale (Stage 5), as per the behavioral epidemiology framework (Sallis & Owen, 1999, p. 9). Several large-scale PA interventions, such as the Child and Adolescent Trial for Cardiovascular Health (McKenzie et al., 1996) conducted in 96 US public schools, have been developed and applied to children. The evidence from these studies is generally not reviewed separately with regard to the intervention effects on the PA of children. Therefore, this section reflects both Stages 4 and Stage 5 of the behavioral epidemiology framework.

The interventions have been conducted across various settings to improve PA levels among children, including the community, schools, home and healthcare settings; however schools have been the predominant setting. To illustrate, van Sluijs et al. (2008) systematically reviewed RCTs and controlled trials (CTs) aiming to promote PA among children (published before 2007), and of the 57 included studies, 47 invovled schools. Two reviews also posited that the school setting was the most effective setting for improving PA levels among children (Salmon et al., 2007; van Sluijs et al., 2008).

The selection of the school as a setting for intervention is intuitive because this area is where children spend most of their waking hours. The physical and social enviromental factors in school are relatively stable and can continously influence

the behaviors of children. The school setting provides many possible avenues for promoting PA through PE classes, health education, recess activities, extracurricular activities, and homework.

Salmon et al. (2007) compared previous interventions according to PA measures, and found that objective measures were more likely to induce positive treatment effects among children (64% of the reviewed RCTs and CTs) than subjective measures did (38% of the reviewed studies). Thus, the effectiveness of several previous interventions may have been masked by subjective measures.

A recent systematic review and meta-analysis (Metcalf, Henley, & Wilkin, 2012) identified and analyzed RCTs and CTs that lasted for at least four weeks and aimed to increase the habitual PA of children ($\leq$ 16 years old). All of the included intervention studies used acclerometers to measure PA. The pooled intervention effect on MVPA was small (standardized mean difference 0.16, 95% CI 0.08-0.24; p<0.01) and was equal to approximately 4 min per day. Similarly, the pooled intervention effect on total PA was small (standardised mean difference 0.12, 95% CI 0.04-0.20; p<0.01). Moreover, the systematic review did not detect a heterogeneity of intervention effects as a result of age (< 10 years vs. $\geq$ 10 years), BMI (children across all BMI values vs. overweight/obese children), duration ($\leq$ 6 months vs. >6 months), setting (home/family vs. school), or study quality (high quality vs. low quality).

All of the aforementioned reviews included studies that did not directly provide children with PA sessions. The details of interventions with PA components must

be investigated to establish an appropriate intervention design for Hong Kong children. The results of previous interventions that employed accelerometers to assess the treatment effects on PA provide a reference range for comparison. Therefore, PA interventions that consisted of PA sessions for children aged 12 or younger were derived from the review conducted by Metcalf et al. These interventions are summarized in Table 2.

Of the twelve included studies, nine reported significant intervention effects on the objectively measured PA in the middle or the end of the intervention, involving daily MVPA in the intervention group ranged from 4-24 min greater than in the control group. More than half of the studies were multicomponent (10/12), and targeted both PA and related health outcomes (9/12). Thus, determining effective strategies used in the interventions that successfully increased the PA of children is difficult.

Seven out of the twelve studies were conducted in the school setting, three school-based studies noted that significant treatment effects were mainly attributed to group differences during the program periods, as per sensitivity analyses (Kriemler et al., 2010; Magnusson, Sigurgeirsson, Sveinsson, & Johannsson, 2011; Wilson et al., 2011). These findings suggest that providing children with PA opportunities at school is a successful component of PA interventions. However, the other components in these interventions may not effectively influence PA. The effects of interventions can be interpreted more easily by examining the novel strategies separately instead of combining many components.

Different approaches were used in previous interventions to assess habitual PA using accelerometers (i.e. accelerometer models, epoch lengths, and cut points of accelerometer counts to determine time spent at different PA levels, and validation methods for habitual PA). Moreover, no consensus has been reached regarding the ideal accelerometer output for a PA intervention. Therefore, directly comparing the intervention effects is difficult.

No intervention studies on Hong Kong children that adopted accelerometers have been located in electronic databases. McManus et al. (2008) conducted a four-week, school-based intervention among primary school children in Hong Kong (10.44 ± 0.85 years old) to test the effect of HR feedback on PA measured by HR monitors. Three schools from Hong Kong Island were randomly selected and assigned as either a control school ($n = 69$) or as one of the two intervention schools. One intervention school ($n = 67$) involved an education program (EP) that was implemented within the PE curriculum to generate information regarding heart health and the use of HR feedback to meet an activity target. The other intervention school incorporated the usual PE curriculum ($n = 61$). Following the 2-weeks EP, the participants in both intervention schools completed 2-weeks with HR feedback and 2-weeks without HR feedback (counterbalanced). HR did not differ among the two intervention groups. HR feedback increased total daily PA and VPA, but MPA remained constant. During a six-month follow-up, the treatment effect on PA was not retained.

The number of intervention studies among Hong Kong children is scarce despite their insufficient PA engagement; this is a research gap that must be filled.

2.6 CHAPTER SUMMARY

Appropriate measures of PA must be carefully selected based on research purpose and resources in PA epidemiology. The use of objective measures is highly encouraged because of their validity and reliability, which are higher than those of subjective measures. Moreover, several key correlates of PA should be addressed among children to understand and modify their PA behaviors. No consistent evidence highlights the ideal strategies for promoting PA among children. There is a call for further intervention studies to promote the PA of Hong Kong children.

Table 2 INTERVENTION STUDIES USING ACCELPEROTERS TO DETERMINE TREATMENT EFFECTS ON PA AMONG CHILDREN AGED 12 YEARS OR YOUNGER

Study & Country	Design	Participant Characteristics				Setting	Duration	Intervention	Main Findings
		Age	Number	[a]BMI	Group Differences				
Caballero et al., 2003, US	Cluster-RCT	7.6(0.6)	1704 (I:879, C:825)	I:19.0, C:19.1	No differences	School	3 year	The multicomponent intervention consisted of health education, food service, PE (increasing the frequency and quality of PE classes), introducing classroom activity breaks and guided play during recess), and family involvement.	There was no intervention effect on objectively measured PA (CPM) (20.43, 95% CI -19.05 to 59.92; p=0.31) in a randomly selected subsample (n=278); while self-reported 1-day PA levels were decreased less in the intervention group than the control group. This study found that there was no intervention effect on percentage body fat, and BMI.
Wilson et al., 2005, US	CT	I:11.(0.6), C:11(0.7); 11-14	58 (I:28, C:20)	I:21(4), C:21(5)	No differences	School	4 weeks	Three components were used: A PA component that included students-selected activities each week, a behavioral modification component, and a homework-snack component. Intervention children received three sessions of intervention a week after school, while the comparison group received	Significant (p<0.02) group by time interactions were found in averaged daily MPA, VPA, and MVPA assessed in five consecutive days (Monday to Friday), with group differences favoring the intervention group. This study also found significant group by time interactions in PA motivation (p<0.01) and self-

								equivalent hours of general health education during regular school time.	concept (p<0.05), but not in self-efficacy and enjoyment.
Verstraete et al., 2007, Belgium	Cluster-RCT	9.7(0.7)	810	Not reported	Not reported	School	2 academic years	The multicomponent intervention included: (1) a health-related PE program, (2) classroom-based health education lessons on healthy lifestyle knowledge and behavioral skills, and (3) an extracurricular PA program, in which extracurricular PA were provided once a week during lunch break and after-school hours (game equipment was also provided during other days to encourage PA).	The objectively measured MPA and MVPA were significantly (p<0.01) greater in the intervention group compared with the controls at post-test in a randomly selected subsample (n=111). The sum of skinfolds were significantly (p<0.05) higher in the controls at post-test. No intervention effects were found on fitness and psychosocial PA correlates.
Taylor et al., 2007, New Zealand	CT	I:7.7(1.8), C:7.7(1.6)	469 (I:251, C219)	I:17.4(2.4), zBMI 0.61(0.82); C:18.2(3.3), zBMI 0.80(0.87)	zBMI: I<C	School	2 years	Intervention components included an activity program that focused on non-curricular lifestyle activities managed by activity coordinators in year 1, and nutrition education in year 2.	Children from the intervention schools (n=384) significantly engage in more PA at year 1 (167 CPM, 95% CI 4 to 329, p<0.05) than the control schools (n=346), but not at year 2 (-75 CPM, 95% CI -215 to 65), although baseline PA was significantly higher in the intervention schools. The zBMI was significantly lower in the interventions group than the control group at year 1 and year 2. There was no intervention effect on the TV viewing time.

Study	Design	Age	N	BMI	Baseline diff	Setting	Duration	Intervention	Outcome
Weintraub et al., 2008, US	RCT	I:9.5(0.6), C:10.3(0.8)	21 (I:9, C:12);	I:27.17 (4.96), zBMI 2.15(0.44); C:29.01 (4.77), zBMI 2.22(0.33)	Not reported	Community	6 months	A soccer program was provided in the after-school hours 3 times a week initially. The frequency was increased to 4 times a week during month 5.	Significant (p<0.05) intervention effects were found on total PA (106 CPM, 95% CI 3 to 208), daily MPA (10.57 min, 95% CI 1.42 to 19.73), and VPA (4.37min, 95% CI 0.73 to 8.01) at 3 months, compared with an active control group (receiving a weekly information-based nutrition and health education). The intervention effect disappeared at six months. Intervention children significantly decreased zBMI at 3 months, and at 6 months. There was no intervention effect on the self-reported sedentary screen time.
Farpour-Lambert et al., 2009, Switzerland	RCT	8.9(1.5)	44 (I:22, C:22)	I:25.4(4.6), C: 25.1(4.7)	No differences	Healthcare	3 months	The intervention consisted of mixed aerobic and strengthening exercises (60 min per session, and 3 times per week) during after-school hours.	A significant (p<0.05) group difference was found in change of the overall PA (48.1 CPM) at 3 months favoring the intervention group. This PA program also found significant (p<0.05) treatment effect on zBMI (-0.9 unit), total and abdominal adiposity, and fat-free mass.
Kriemler et al., 2010, Switzerland	Cluster-RCT	Grade 1, Grade 5	502 (I:297, C:205)	I:17.13 (2.53), C:17.04 (2.63)	No differences	School	9 months	Intervention children were provided with two additional PE lessons to enhance the three compulsory PE lessons per week and several short activity breaks. Intervention children	The change of standardized daily MVPA (measured in five weekdays) was significantly greater in the intervention group at 9 months, corresponding to 11 more min. This effect was mainly

								were also assigned 10 min of PA homework every day.	attributed to the increase of the in-school MVPA, but not in out of school MVPA. There was no intervention effect on the overall PA (CPM) or the out -school PA (CPM), while change of the in-school PA was significant (p=0.003) higher in the intervention group. There were also positive intervention effects on zBMI, the sum of skinfolds, and aerobic fitness.
Robinson et al., 2010, USA	RCT	9.4(0.9), 8-10	261 (I:134, C:1277), F	I: 20.70 (4.95), zBMI 0.94(1.07); c:20.68 (4.82), zBMI 0.98(1.07)	Resting HR:I<C, TV viewing: I<C, Eating breakfast with the TV on: I<C	Community, family	2years	The intervention group was provided culturally tailored dance classes for African American girls, which were organized 5 days per week during after-school time. There was also a family-based component aimed to reduce screen media use.	There were no treatment effects on objectively measured PA, self-reported sedentary behaviors or BMI compared with an active control group in which children got information-based health education on nutrition, PA, and reducing cardiovascular and cancer risk.
Cliff et al., 2011, Australia	RCT	8(1), 5.5-9	165 (PA:63, Diet: 42, PA+Diet: 60)	PA:25.2 (4.1), Diet: 24.6 (3.0), PA+Diet: 24.4 (3.7)	Not reported	Community, family	6 months	There were three intervention arms: 1) a child-centered PA skill development program (PA), 2) a parent-centered dietary modification program (Diet), and 3) a combination of the above components (PA+Diet). The PA program was divided into two components: a 10-week face-to-face program and a minimal-contact 3-month	Except for a significant increase of VPA was found in the PA+DIET group, changes in other PA variables at 6 or 12 months were not significantly different across groups. All of the three groups decreased the total screen time reported by parents at 6 months, and the decreases persisted in PA and PA+DIET groups at 12 months. There were no group

									differences of change in perceived athletic competence at any time. The intervention effect on adiposity was reported in another article (Okely et al., 2010). All three groups reduced zBMI at 6 and 12 months, but participants in the Diet group and PA+Diet group reduced more compared with the PA group.
								maintenance phase. The first component included weekly group sessions (90 min of PA per session), and weekly home activities.	
Wafa et al., 2011, Malaysia	RCT	7-11	107 (I:52, C:55)	27.8(5.5), zBMI 2.92(0.61)	No differences	Healthcare	26 weeks	This was a relative low intensive (8 hours contact over 26 weeks) intervention targeting on parents' behavior modification techniques. When parents attended behavioral modification sessions, their children attended PA sessions.	There were no intervention effects on children's habitual PA or zBMI at 6 months.
Wilson et al., 2011, USA	cluster-RCT	11.3(0.6), Grade 6	1422 (I:729, C:693)	I:22.80 (6.16), C:22.86 (5.88)	Not differences	School	17 weeks	The intervention consisted of three components for each session: homework/snack (30 min), MVPA activities (60 min), and a behavioral component (30 min). There were three sessions per week during after-school time.	Compared with an active control group (participated in a general health program), a significant (p<0.05) intervention effect at mid-intervention was found on daily MVPA (4.87 min, 95% CI 1.18 to 8.57), but not at 2-weeks post-intervention (19 weeks). Further analyses demonstrated that the intervention effect was mainly attributed to the differences in MVPA during the program time (9.11 min, 95% CI 5.73 to 12.48).

Magnusson et al., 2011, Iceland	cluster-RCT	I:7.3(0.2), C:7.4(0.2)	196 (I:100, C:96))	I:15.8(1.1), C:16.3(1.0)	BMI:I<C	School	2 years	PE teachers in the intervention schools were encouraged to perform PA with students and to become the implementers of change to affect children's lifestyles regarding PA and diet. Intervention children had opportunities to engage in PA during PE lessons, recesses, and during classes (PA was integrated into various subjects on the general curriculum). After the first year, an additional PE lesson was provided.	Compared with the control group, the intervention group engaged in more MVPA during school hours at year 1 suggesting by a significant time by group interaction (p<0.01), but not at year 2. There were no intervention effects on the overall PA (CPM) or MVPA during after-school hours on weekdays at any time.

Note.[a] Data reported with zBMI according to the reference populations which authors chose.

BMI, body mass index; C, control group; CPM, counts per minute; CT, controlled trial; F, female; I, intervention group; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; PA, physical activity; PE, physical education; RCT, randomized controlled trial; VPA, vigorous physical activity, zBMI, body mass index z score.

CHAPTER 3. EFFECTS OF ACTIVE VIDEO GAMES ON PA AND RELATED OUTCOMES AMONG HEALTHY CHILDREN: A SYSTEMATIC REVIEW

3.1 INTRODUCTION

Several reviews have mainly or partially focused on the PA outcomes of AVGs in children (Barnett, Cerin, & Baranowski, 2011; Biddiss & Irwin, 2010; Daley, 2009; Foley & Maddison, 2010; LeBlanc et al., 2013; Peng et al., 2013; Peng, Lin & Crouse, 2011). All previous reviews suggested the potential of AVGs to increase PA or decrease sedentary behaviors, but found mixed or inconsistent evidence to demonstrate it. One review indicated it was more promising to employ AVGs in structured exercise programs for group play (Peng et al., 2013). However, none of these reviews have separately evaluated the effects of AVGs in structured or non-structured play. Given that heterogeneity of study settings may facilitate or inhibit structured group play, evaluating the effects of AVGs stratified by settings may result in a clearer and more definite conclusion. The other limitations of the previous reviews were: 1) including limited PA variables, 2) a mixture of children with different health statuses, and 3) not systematically reviewing the strategies used to promote PA. Also, the rapid increase in AVG studies indicates an up to date review is needed. This review systematically and comprehensively evaluates the effects of AVGs on PA-related psychosocial and behavioral outcomes. Because health status may confound the effects, this review is restricted to healthy children only. In this review, AVGs are restricted to video games that require body movement more than just finger usage, to control the avatar or on screen objects with or without peripheral equipment (e.g., a dance mat).

3.2 METHODS

3.2.1 DATA SCOURCE AND SEARCH STRATEGY

The following keyword strings: (child* OR adolescent* OR teenage* OR youth) AND (active video game OR exergame OR interactive game OR health game) AND (physical activity OR exercise OR fitness OR energy expenditure OR

energy cost) were used to search for articles in ISI Web of Knowledge, Medline, SCOPUS, SPORTDiscus, and Ovid databases (including AMED, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Cochrane Central Register of Controlled Trials, Embase, and Ovid MEDLINE). Review papers were also searched for potentially useful references.

3.2.2 SELECTION CRITERIA

Inclusion criteria were AVG articles that: 1) had been published in peer-reviewed journals in English; 2) had been published from January 2000 to August 2013, because AVG technology did not exist before 2000 (Foley & Maddison, 2010); 3) included at least one subgroup of healthy participants (including overweight and obese but without any reported dysfunction) not older than 18 years; and 4) measured at least one PA-related variable, which could be psychosocial (e.g., social support for PA and PA self-efficacy), behavioral (i.e., EE, steps, counts, observed or self-reported PA levels), or physical fitness. Because AVG studies are still in their infancy, all study designs were included.

Studies that focused on weight control or loss but without any PA measurement were excluded. Studies which included participants who had metabolic complications, such as endothelial dysfunction, were excluded. If there were multiple publications from one AVG project, only the article with the PA outcomes was included.

3.2.3 DATA EXTRACTION

Because of the substantial heterogeneity in AVGs, study designs and measures of PA-related outcomes, a meta-analysis was not conducted. Studies were divided by their PA outcomes: 1) the immediate PA effects of AVGs (i.e., EE or PA levels during AVG play), and 2) the effects of AVGs on habitual PA or change of PA.

To compare the EE results, different units were transformed to the same (kcal/kg/min), and VO_2 was converted into EE using the constant of 1 L of O_2=4.9kcal (McArdle, Katch, & Katch, 1991). To compare the intensities of AVGs, the child-specific MET value (dividing activity VO_2 by resting VO_2) for each AVG was extracted (Spadano, Must, Bandini, Dallal, & Dietz, 2003).

Intensities of AVGs are considered as light (<3 METs), moderate (3-6 METs), or vigorous (>6 METs) (Ainsworth, Montoye & Leon, 1996). For the intervention studies, study source, design, participant characteristics, intervention duration, setting, AVGs, used strategy, and main findings were extracted.

3.2.4 DATA SYSTHESIS

3.2.4.1 Effect of AVG intervention on PA

The effects of AVG interventions with PA comparison (between groups or across time) were examined. To compare the effects of AVG interventions on PA-related outcomes across studies, effect sizes (Hedge's g) were calculated when sufficient data were reported according to established formulas (Borenstein, Hedges, Higgins, & Rothstein, 2009; Lipsey & Wilson, 2001). An effect size <0.5 was interpreted as small, 0.5-0.8 as medium, and >0.8 as large (Cohen, 1988).

3.2.4.2 Assessment of methodological quality

Methodological quality of intervention studies was assessed using a 10-item scale developed for a previous PA interventions review (Table 3) (van Sluijs et al., 2008). Each item was rated as positive, negative, or unknown. A methodological quality score (ranging from 0-10) was calculated by accumulating all the positive rates. Quality was defined as high when a RCT scored at least six or other kinds of study scored at least five (because there was a specific item on the randomization procedure) (van Sluijs et al., 2008).

3.2.4.3 Strength of the evidence

Based on a previously used evidence synthesis method (Engbers, van Poppel, Chinapaw, & van Mechelen, 2005; van Sluijs et al., 2008; van Sluijs, van Poppel, & van Mechelen, 2004), the effects of AVG interventions on PA were evaluated using an evidence rating system. Five levels (strong, moderate, limited, inconclusive, and no effect) were defined based on study design and methodological quality (Figure 3). Studies were stratified based on setting. Following a previous review (van Sluijs et al., 2008), if at least two-thirds of the relevant studies had significant results in the same direction, the overall results were considered consistent.

Table 3. SCALE FOR STUDY METHODOLOGICAL QUALITY
ASSESSMENT

Item	Description
A	Groups comparable at baseline on key characteristics (e.g., age, gender, weight, PA relevant outcome measures) was statistically tested; and for all studies only positive when differences observed were controlled for in analyses
B	Randomisation procedure clearly described and adequately carried out
C	Unit of analysis was individual (negative if unit of analysis was school level or school level randomisation not accounted for in individual level analysis)
D	Validated measure of PA used (positive if validation of measures of PA was reported or referred to)
E	Dropout described and not more than 20% for studies with follow-up of six months or shorter and 30% for studies with follow-up of more than six months
F	Timing of measurements comparable between intervention and control groups
G	Blinding outcome assessment (positive if those responsible for assessing PA at outcome were blinded to group allocation of individual participants)
H	Participation followed up for a minimum of six months
I	Intention to treat analysis used
J	Potential confounders accounted for in analyses

Note. PA, physical activity.
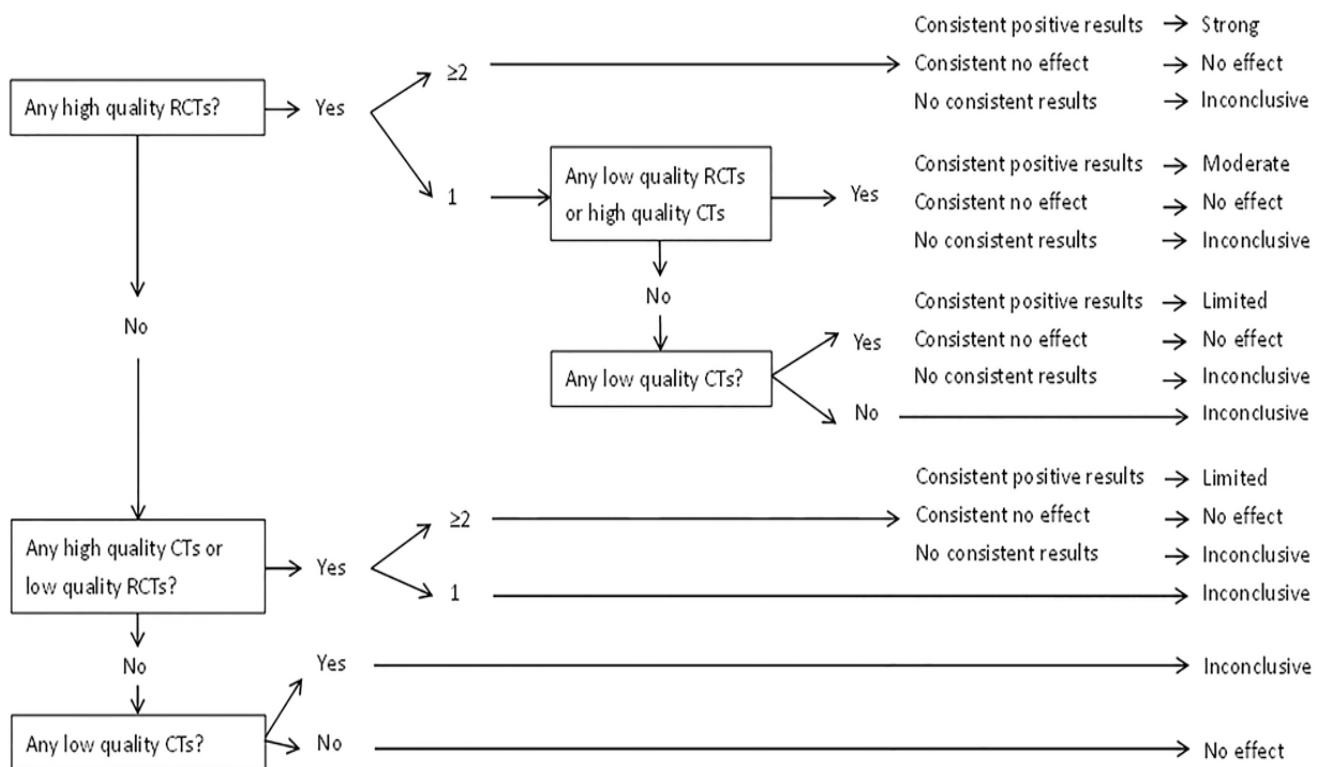
Figure 3. Flow chart of decision-making process for levels of evidence based on study design and quality.
Note. Adapted from van Sluijs et al., 2008.
RCT, randomized controlled trial; CT, controlled trial.

3.3 RESULTS

3.3.1 INCLUDED STUDIES

The flow of studies through the selection process is reported in Figure 4. Titles and abstracts of the 642 initially identified articles were screened. Seventy-two full text articles were retrieved, and 18 articles were excluded for the following reasons: Not an AVG study, duplicate publications, or without any PA measurement. Fifty-four studies were included in the review, including 32 studies that examined the immediate PA effects of AVGs, and 22 studies that examined the effects of AVGs on habitual PA or change of PA.

3.3.2 EFFECTS OF AVGS ON IMMEDIATE PA OUTCOMES

3.3.2.1 Studies on the AVG play only

These studies (see Table 4) focused on EE or PA during a short or several short sessions of AVG play. Studies that reported MET values consistently indicated

AVGs could elicit light to moderate intensities of PA. One study found a MET that marginally exceeded 6 by indirect calorimetry (Bailey & McInnis, 2011). One study found two AVGs exceeded 6 METs by accelerometry (Miller, Vaux-Bjerke, McDonnell, & DiPietro, 2013). However, this result was not consistent with other studies using indirect calorimetry.

Inconsistent findings in EE were obtained when samples were divided by BMI. Three studies indicated no difference in EE between normal weight and overweight children if analyses controlled for body mass (Lanningham-Foster et al., 2006; Penko & Barkley, 2010; Unnithan, Houser, & Fernhall, 2006). However, in other studies, overweight children spent more energy to play AVGs when lean body mass was controlled (Bailey & McInnis, 2011), participants with a higher BMI exerted more energy compared with those with a lower BMI (Staiano & Calvert, 2011), and BMI had no significant effect on EE in the presence of the other covariables (age and gender) (Miller et al., 2013).

Four studies (Graf, Pratt, Hester, & Short, 2009; Graves, Stratton, Ridgers, & Cable, 2008a; Smallwood, Morris, Fallows, & Buckley, 2012; Staiano & Calvert, 2011) found more EE in male participants than females on certain AVGs, whereas others did not find or report gender differences.

One study found that younger children expended more energy per kilogram of body weight than older children (Miller et al., 2013).

In summary, AVGs have effects on the immediate PA outcomes, which led to light- to moderate-intensity PA. Demographic moderator effects have been examined, and no conclusive evidence favored larger BMI, males, or younger children.

3.3.2.2 Studies on the choices between AVGs and sedentary alternatives

It is not clear whether children would play AVGs as a substitute for sedentary time. Table 5 gives a summary of three studies that provided participants with the choice between AVGs and sedentary alternatives. One study found that the reinforcing value (i.e., where participants spent their time) depended on the

content of the games (Epstein, Beecher, Graf, & Roemmich, 2007), whereas two studies indicated that children almost equally split their time between AVGs and content-matched sedentary video games (Lam, Sit, & McManus, 2011; Sit, Lam, & McKenzie, 2010). Thus, AVGs could compete with sedentary video games in the short time of these studies.


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┌─────────────────────────┐      ┌─────────────────────────┐
│ Records identified      │      │ Additional records      │
│ through database        │      │ identified through      │
│ searching*              │      │ other sources           │
│ (n=624)                 │      │ (n=18)                  │
└───────────┬─────────────┘      └───────────┬─────────────┘
            │                                │
            └──────────────┬─────────────────┘
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            ┌─────────────────────────┐
            │ Records after duplicate │
            │ removed                 │
            │ (n=486)                 │
            └───────────┬─────────────┘
                        ▼
            ┌──────────────────┐      ┌──────────────────┐
            │ Records screened │─────▶│ Records excluded**│
            │ (n=486)          │      │ (n=414)          │
            └───────┬──────────┘      └──────────────────┘
                    ▼
            ┌──────────────────┐      ┌──────────────────┐
            │ Full-text        │─────▶│ Full text        │
            │ articles         │      │ articles         │
            │ assessed for     │      │ excluded, with   │
            │ eligibility      │      │ reasons***       │
            │ (n=72)           │      │ (n=18)           │
            └───────┬──────────┘      └──────────────────┘
                    ▼
            ┌──────────────────┐
            │ Studies included │
            │ in review        │
            │ (n=54)           │
            └──────────────────┘
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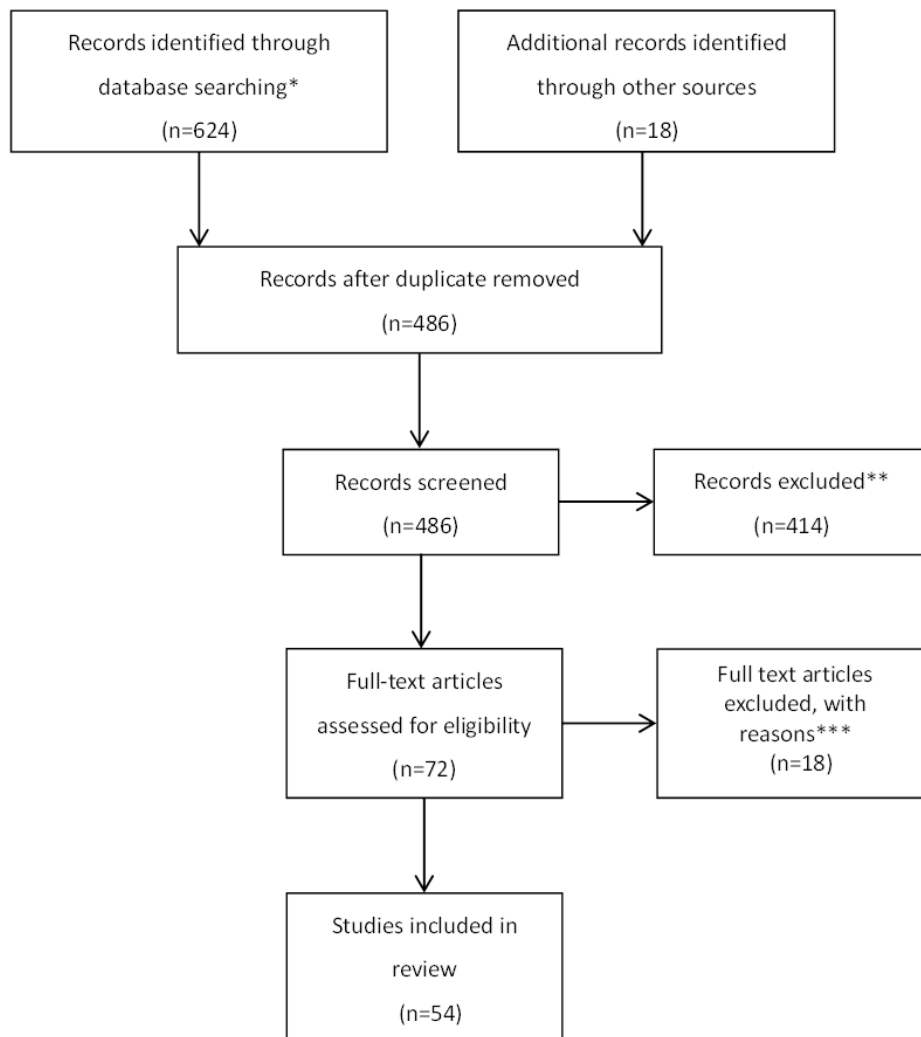
Figure 4. Flow of articles identification and selection

Note. *Medline (n=54), SPORTDiscus (n=42), Web of Knowledge (n=426), SCOPUS (n=7), Ovid databases (n=95). **Studies may be excluded for multiple reasons, but for exclusively classified, they were excluded for only one of these reasons with sequence: Not an AVG study (n=327), not target age groups (n=35), not healthy children (n=16), not original study (n=23), without PA variable measurement (n=13).***Studies were excluded for the below reasons: Not an AVG study (n=6), duplicate publications (n=8), or without PA variable measurement (n=4).

3.3.3 EFFECTS OF AVGS ON HABITUAL PA OR CHANGE OF PA

A cross-sectional survey indicated a positive association between AVG play and PA (Simons, Bernaards, & Slinger, 2012). Among the 21 intervention studies (see Table 6), 13 were RCTs and 4 RCTs (Maloney et al., 2008; Maloney, Stempel, Wood, Patraitis, & Beaudoin, 2012a; Mhurchu et al., 2008; Paw et al., 2008) indicated they were pilot studies.

3.3.3.1 Effects of AVG interventions on PA

One intervention study (Maloney et al., 2012a) was excluded from the evaluation because it measured PA levels in only 4 out of 58 participants at end of the intervention. Effect sizes for the intervention studies are presented in Table 7. Compared with a control group, eight of fifteen intervention studies found positive effects of AVGs on PA-related outcomes, including psychosocial variables (Gao et al., 2012; Gao & Podlog, 2012; Lwin & Malik, 2012; Staiano et al., 2013; Wagener et al., 2012), behavioral outcomes (Gao et al., 2012; Gao & Podlog, 2012; Lwin & Malik, 2012; Maloney et al., 2012b; Norman et al., 2013), and physical fitness (Gao et al., 2013a). Two studies found AVGs increased children's PA in early sessions but not in later sessions (Duncan & Staples, 2010; Mhurchu et al., 2008). Without a control group, the remaining five studies all reported positive effects of AVGs on PA (Bethea, Berry, Maloney, & Sikich, 2012; Christison & Khan, 2012; Owens, Garner, Loftin, van Blerk, & Ermin, 2011; Quinn, 2013; Sun, 2013).

Four out of eleven studies reported positive intervention effects of AVGs on PA behavioral outcomes (including physical fitness) between an AVG and a non-AVG control group. Two self-reported PA measures had large effect sizes (Maloney et al., 2012b), and one self-reported PA measure had a small effect size (Lwin & Malik, 2012). One study showed a positive effect favoring the non-AVG control group (Duncan & Staples, 2010). In addition, two studies compared AVG intervention groups (Gao & Podlog, 2012; Norman et al., 2013). One study found that compared with the do-your-best group, PA levels increased in the difficult-goal group with a large effect size, whereas PA levels increased in the easy-goal group with a moderate effect size (Gao & Podlog, 2012). PA increased in the

higher contingency (behavior-consequence) AVG group, while decreased in the lower contingency AVG group; the effect size of the difference was small (Norman et al., 2013).

All four studies comparing an AVG and a non-AVG group reported positive intervention effects on the psychosocial PA-related outcomes (Gao et al., 2012; Lwin & Malik, 2012; Staiano et al., 2013; Wagener et al., 2012). Two effect sizes were small (Lwin & Malik, 2012), one was medium (Staiano et al., 2013), and one was large (Wagener et al., 2012). Thus, AVGs had larger effects on psychosocial outcomes than behavioral outcomes.

3.3.3.2 Methodological quality
Methodological quality scores are presented in Table 7. Overall, nine studies (45%) exhibited high quality. Low methodological quality was attributed mainly to failure to report the blinding outcome assessment (90%), using intention to treat analysis (80%), comparable groups at baseline (75%), long term follow-up (75%), the randomization procedure (65%), and accounting confounders in analyses (50%).

3.3.3.3 Strength of the evidence
3.3.3.3.1 Home setting
Eight studies were conducted in the home setting, including five high-quality RCTs (Baranowski et al., 2012; Graves et al., 2010a; Maddison et al., 2011; Maloney et al., 2012b; Mhurchu et al., 2008), two low-quality RCT (Maloney et al., 2008; Norman et al., 2013), and one pre-post study (Owens et al., 2011). Compared with a non-AVG group, only one study reported a significant intervention effect on PA (Maloney et al., 2012b). Therefore, no effect of AVGs on PA was identified at home.

3.3.3.3.2 School, community, and healthcare settings
Ten studies were conducted in school, community or clinic environments to provide structured AVG sessions, including one high-quality RCT (Gao & Podlog, 2012), three low-quality RCTs (Lwin & Malik, 2012; Staiano et al., 2013; Wagener et al., 2012), two high-quality CTs (Duncan & Staples, 2010; Gao et al.,

2012), one high-quality pre-post study (Sun, 2013), and three low-quality pre-post studies (Christison & Khan, 2012; Quinn, 2013; Sun, 2013). All the RCTs and one CT (Gao et al., 2012) reported a positive intervention effect, and another CT (Duncan & Staples, 2010) reported a negative intervention effect, equating to moderate evidence of effectiveness of structured AVG play on PA promotion.

3.3.3.3.3 Multiple settings

Two low-quality studies (Bethea et al., 2012; Paw et al., 2008) provided inconclusive evidence for the effects of AVGs in multiple settings on PA.

In summary, no effect of AVGs on PA in the home setting was determined. Moderate evidence was found that structured AVG play could promote PA.

3.3.4 STRATEGIES USED FOR PROMOTING AVG USE OR PA

3.3.4.1 Home setting

In the home setting, all eight studies provided participants with AVG(s) and/or consoles (including peripheral equipment). Three studies provided two peripherals to each participant to encourage non-solo play among families (Graves et al., 2010a; Maloney et al., 2008; Maloney et al., 2012b), and two reported positive intervention effects on PA (Maloney et al., 2008; Maloney et al., 2012b). Three studies provided a specific prescription for playing AVGs (Maddison et al., 2011; Maloney et al., 2008; Mhurchu et al., 2008), and one study reported increased VPA within the AVG group (Maloney et al., 2008). This study (Maloney et al., 2008) also provided coaching sessions, and reported that it did not improve results. One study provided children game choices to enhance intrinsic motivation and reported no effect on PA (Baranowski et al., 2012). Two studies offered one additional AVG or a package of AVGs to participants in the middle of the interventions (Baranowski et al., 2012; Maddison et al., 2011). Although one study found increased AVG play after an additional AVG was provided (Baranowski et al., 2012), both studies reported no intervention effects on PA.

3.3.4.2 Structured AVG sessions

In the structured AVG sessions, one study controlled the intensity by adjusting game difficulty, and the measured outcome (perceived exercise competence)

favored the AVG group (Wagener et al., 2012). The results of one study (Staiano et al., 2013) favored the cooperative condition (pairs of participants were instructed to coordinate as a team) over the competitive condition (pairs of participants were instructed to compete against each other to earn the most points). One study reported that PA levels increased after setting specific goals (step counts) for the AVG play (Gao & Podlog, 2012). Only one multicomponent intervention was identified (including AVG-based exercise program, nutrition education, and behavioral management discussions), and it found self-reported exercise time increased after the intervention (Christison & Khan, 2012).

Two interventions were conducted in multiple settings (Bethea et al., 2012; Paw et al., 2008). One invited participants to a weekly multiplayer class in addition to AVG home play and found the dropout rate in the multiplayer group was significantly lower than in the home group (Paw et al., 2008). In the other study, participants had access to a dance game at home and also in an after-school program (Bethea et al., 2012). This study also provided each participant two dance mats at home, and reported improved physical fitness and increased AVG play (Bethea et al., 2012).

None of these strategies has been used sufficiently to reach a firm conclusion regarding the effects. However, encouragement of non-solo play and a combination of strategies may be effective to promote PA.

3.4 DISCUSSION
3.4.1 EFFECTS OF AVGS ON IMMEDIATE PA OUTCIMES
AVG play consistently led to light- to moderate-intensity PA with some exceptions. Two studies (Bailey & McInnis, 2011; Miller et al., 2013) that reported vigorous intensity levels of AVGs were not consistent with other studies. Although the more intensive AVGs deserve more attention, the fact that most AVGs cannot reach vigorous intensity does not inhibit their potential to promote PA in children.

Indirect calorimetry and accelerometry have been used to estimate the MET values. One study found that accelerometry underestimated the intensity of AVG

play compared with indirect calorimetry (Reading & Prickett, 2013). However, another study (Miller et al., 2013) reported much higher intensity of one AVG ("DDR") using accelerometry than other studies using indirect calorimetry. The inconsistent findings need to be further examined.

No consistent findings supported that proposal that AVGs favored specific demographic groups. Future studies are needed to examine whether AVGs are truly neutral in terms of these demographic characteristics for immediate and habitual PA outcomes.

3.4.2 EFFECTS OF AVGS ON HABITUAL PA OR CHANGE OF PA
In the free-living home setting, AVGs did not increase children's PA. This may be because the fidelity of the AVG intervention was poor, or children decreased other activities to compensate the AVG play. Generally, AVGs use declined during the interventions. It seems hard for the current AVGs to keep the interest of players over the long term. Given the cost of AVG consoles and games, this review raises doubt about whether introducing AVGs to non-video-game-playing children for home use could promote PA. Alternatively, providing peripheral equipment, such as jOG™, the PlayStation Eye™ (Sony, Tokyo, Japan), or the Kinect® (Microsoft®, Redmond, WA) sensor to children who already have video game consoles may decrease sedentary play and increase PA.

Several strategies have been used in the home setting to promote PA. However, these strategies were not effective in influencing habitual PA. It is hard to monitor the compliance to these interventions, which inhibits a conclusion on the effects of the used strategies. Although some researchers noticed the social function of AVG play and encouraged non-solo play in their interventions, few relevant outcomes, such as social support for PA, have been reported on the effect of doing so, except for one study (Maloney et al., 2008).

In settings where structured AVG sessions could be implemented, no high-quality study has assessed the effect of AVGs on habitual PA. The only high-quality RCT examined the change in steps of AVG play in an after-school program (Gao & Podlog, 2012). In addition, no AVG studies objectively measured habitual PA in

these settings. Therefore, the moderate evidence of structured AVG play on PA needs to be interpreted with caution.

One multicomponent intervention and two multi-setting interventions have been conducted. These designs may have a stronger effect on PA (Salmon et al., 2007; van Sluijs et al., 2008), and thereby warrant future examination.

Only five studies (Baranowski et al., 2012; Christison & Khan, 2012; Gao & Podlog, 2012; Lwin & Malik, 2012; Norman et al., 2013) used behavior theories in their AVG interventions and four (Christison & Khan, 2012; Gao & Podlog, 2012; Lwin & Malik, 2012; Norman et al., 2013) reported improved PA. More AVG studies should use behavioral theories to promote PA.

Many researchers have used AVGs for obesity prevention and intervention (Christison & Khan, 2012; Madsen, Yen, Wlasiuk, Newman, & Lustig, 2007; Maddison et al., 2011; Maloney et al., 2012b; Quinn, 2013; Staiano et al., 2013; Wagener et al., 2012). Because this review focused on the effects of AVGs on PA, interested readers are recommended to read other reviews (Gao & Chen, 2014; Guy, Ratzki-Leewing, & Gwadry-Sridhar, 2011; Lu, Kharrazi, Gharghabi, & Thompson, 2013) regarding the effects of AVGs on body weight.

3.4.3 STRENTHS AND LIMITATIONS

The strength of this systematic review was using an established evidence synthesis method to examine the effects of AVGs on PA. Following a previous review (Lau, Lau, Wong del, & Ransdell, 2011), most PA-related outcomes were included for a comprehensive review.

The main limitation of this review is that sample size was not considered for the evidence syntheses. In one review (van Sluijs et al., 2008), the sample size of >250 subjects was considered as large, and studies of a large sample were given more weight than the small ones. However, in the existing AVG interventions, most studies have not reached this standard, and few studies provided sample size justification. Therefore, the conclusion regarding the evidence strength needs to be interpreted with caution. Eleven of the 21 intervention studies included used

dance games partially or mainly. This fact limits the conclusions of this review because other technologies may have different results.

3.5 CONCLUSION

Many studies have examined the immediate PA outcomes of AVG play among children, and found that several AVGs could lead to at least moderate intensity of PA. Based on intervention studies, the present review does not support using AVGs alone in the home setting to promote PA. Structured AVG play has the potential to promote PA among children. None of the strategies used in AVG interventions has reached a firm conclusion regarding the effects on PA. No structured AVG intervention studies have objectively measured habitual PA. Further high-quality intervention studies are warranted to examine the effects of AVGs on children's habitual PA.

Table 4 STUDUES THAT EXAMINED ASSOCIATION BETWEEN ACTIVE VIDEO GAME SESSION(S) AND IMMEDIATE PHYSICAL ACTIVITY

| | Participants characteristics | | | | | | EE | | | | | | |
Study	Age	N	Sex	[b]BMI	Console	Game	Original	Computed results (kcal/kg/min)	REE	[a]METs	HR(bpm)	Active monitors/ observation	Gender differences
Lanningham -Foster et al., 2006	9.7 (1.6), 8-12	25	F13(L8), M12(L7)	20(4), 71.5(24.7)%; L:18(2), 57.6(23.2)%, O:23(4), 91.7(4.5)%	Sony PS2 Eye Toy	Nicktoons Movin'	13.61(4.20) kJ/kg/h	0.05	6.47(1.18) kJ/kg/h	2.1			
					Sony PS2	DDR	17.26(4.28) kJ/kg/h	0.07	6.47(1.18) kJ/kg/h	2.7			
Unnithan et al., 2006	11-17	22	F6(L4), M16(L8)	L:18.6(2.9), O:27.4(3.3)	Sony PS2	DDR	L:21.3(4.8) ml/kg/min, O:18.3(4.2) ml/kg/min	L:0.10, O: 0.09	L:4.6(1.5) ml/kg/min, O: 5.1(1.0) ml/kg/min	L: 4.6, O:3.6	L: 146(14), O: 143(16)		
Maddison et al., 2007	12.4 (1.1), 10-14	21	F10, M11	20.3(4)	Sony PS2 Eye Toy	Knockout	24.5(4.9) ml/kg/min	0.12	4.9(0.9) ml/kg/min	5.0(0.8)	142(16)		[c]No
					Sony PS2 Eye Toy	Homerun	23.0(4.0) ml/kg/min	0.11	4.9(0.9) ml/kg/min	4.8(0.9)	138(18)		
					Sony PS2 Eye Toy	Groove	11.2(2.2) ml/kg/min	0.05	4.9(0.9) ml/kg/min	2.3(0.3)	111(12)		
					Sony PS2 Eye Toy	AntiGrav	14.0(3.8) ml/kg/min	0.05	4.9(0.9) ml/kg/min	2.9(0.6)	110(13)		
					Sony PS2	Dance UK	18.9(3.6) ml/kg/min	0.07	4.9(0.9) ml/kg/min	3.9(0.8)	127(13)		
Straker & Abbott, 2007	9-12	20	F8, M12	Not reported	Sony PS2 Eye Toy	Cascade	26.54(8.21) ml/kg/min	0.13			130.2 (21.0)		No

Study	Age	N	Gender		Console	Game						
Graves et al., 2008a	14.6 (0.5), 13-15	11	F5, M6	21.2(2.5)	Nintendo Wii	Wii Sport bowling	190.6(22.2) J/kg/min	0.05	81.3 (17.2) J/kg/min	2.3		No
					Nintendo Wii	Wii Sport tennis	202.5(31.5) J/kg/min	0.05	81.3 (17.2) J/kg/min	2.5		EE: M>F
					Nintendo Wii	Wii Sport boxing	198.1(33.9) J/kg/min	0.05	81.3 (17.2) J/kg/min	2.4		No
Graves et al., 2008b	15.1 (1.4), 11-17	13	F6, M7	22.0(2.6)	Nintendo Wii	Wii Sport bowling	182.1(41.3) J/kg/min	0.04	84.0(14.6) J/kg/min	2.2(0.5)	103.2 (16.7)	HR:F>M
					Nintendo Wii	Wii Sport tennis	200.5(54.0) J/kg/min	0.05	84.0(14.6) J/kg/min	2.4(0.7)	107.0 (15.2)	HR:F>M
					Nintendo Wii	Wii Sport boxing	267.2(115.8) J/kg/min	0.06	84.0(14.6) J/kg/min	3.2(1.4)	136.7 (24.5)	HR:F>M
Haddock et al., 2008	10.1 (2.2), 7-14	23	F5, M18	26.7(3.5), >85%	Xavix	Jackie Chan studio fitness game	14.03(3.54) ml/kg/min	0.07	4.06 ml/kg/min	3.5		Not reported
McDougall & Duncan, 2008	8-11	12	F7, M5	Not reported	Sony PS2 Eye Toy	Athletics games					F: 151(19), 52.5% time>139; M:145.7(6.5, 41.7% time>139	Steps F: 1303 (320.1), M 1503 (453.3)
Mellecker & McManus, 2008	9.6 (1.7), 6-13	18	F7, M11	18.1(2.9)	Xavix	bowling	0.06(0.01) kcal/kg/min	0.06	0.03 kcal/kg/min	2.0	102(20)	Not reported
					Xavix J-Mat	Jackie's Action Run	0.15(0.03) kcal/kg/min	0.15	0.03 kcal/kg/min	5.0	160(20)	Not reported
Graf et al., 2009	11.9 (1.2), 10-13	23	F9, M14	19.1(3.1), 3-98%	Sony PS2	DDR (beginner)	M:13.7(0.6) ml/kg/min, F:10.2(0.4) ml/kg/min	0.06	M: 4.8(0.3) ml/kg/min, F: 4.1(0.3) ml/kg/min	2.7	M: 111(3), F: 106(5)	EE:M>F , No in HR

Study	Age	N	Sex		Console	Game						
					Sony PS2	DDR (basic)	M:15.8(0.9) ml/kg/min, F:13.2(0.7) ml/kg/min	0.07	M: 4.8(0.3) ml/kg/min, F: 4.1(0.3) ml/kg/min	3.3	M: 121(4), F: 124(6)	EE:M>F , No in HR
					Nintendo Wii	Wii Sport bowling	M:10.0(0.7) ml/kg/min, F:7.7(0.6) ml/kg/min	0.04	M: 4.8(0.3) ml/kg/min, F: 4.1(0.3) ml/kg/min	2.0	M: 101(4), F: 98(3)	EE:M>F , No in HR
					Nintendo Wii	Wii Sport boxing	M:13.8(1.1) ml/kg/min, F:13.5(1.4) ml/kg/min	0.07	M: 4.8(0.3) ml/kg/min, F: 4.1(0.3) ml/kg/min	3.0	M: 127 (5), F: 140(8)	No
Haddock et al., 2009	10.9 (2.2), 7-14	20	F7, M13	30.9(8.3), >85%	GameBike with Sony PS2	Disney Cars	16.8(4.2) ml/kg/min	0.08	3.6(0.9) ml/kg/min	4.7	146.0 (21.4)	Not reported
Lanningham -Foster et al., 2009	12.1 (1.7), 9-15	22	F11, M11	20.2(3.3), 65.6(26.8)%	Nintendo Wii	Wii Sport boxing	5.14(1.71) kcal/kg/h	0.09	1.22(0.31) kcal/kg/h	4.2		No
Fawkner et al., 2010	14.0 (0.3)	19	F19	19.6(3.3)	ZigZag Xer-Dance	Dance Level 1	14.4(3.1) ml/kg/min	0.07	4.7(1.0) ml/kg/min	3.08 (0.40)	17.4 (15.7)	
						Dance Level 2	14.7(3.8) ml/kg/min	0.07	4.7(1.0) ml/kg/min	3.10 (0.35)	24.4 (16.7)	
						Dance Level 3	16.5(3.7) ml/kg/min	0.08	4.7(1.0) ml/kg/min	3.52 (0.42)	34.0 (16.7)	
Fogel et al., 2010	9	4	F2, M2	Not reported	10 different AVGs						30.7% time in PA	
Graves et al., 2010b	15.1 (1.4), 11-17	14	F4, M10	22.8(3.3)	Nintendo Wii	Wii Fit yoga	190.8(34.6) J/kg/min	0.05	111.7 (22.7) J/kg/min	1.7(0.3)	86.6 (16.2)	Not reported
					Nintendo Wii	Wii Fit muscle condition-ing	236.8(36.4) J/kg/min	0.06	111.7 (22.7) J/kg/min	2.2 (0.4)	90.2 (15.3)	

Study	Age	N	Sex	Body composition	Console	Game	Energy expenditure	p	Resting	MET	HR	MVPA/EE	Enjoyment
					Nintendo Wii	Wii Fit balance	188.2(31.0) J/kg/min	0.05	111.7 (22.7) J/kg/min	1.7 (0.4)	85.0 (15.6)		
					Nintendo Wii	Wii Fit aerobics	348.1(44.7) J/kg/min	0.08	111.7 (22.7) J/kg/min	3.2 (0.7)	101.9 (18.4)		
Penko & Barkley, 2010	8-12	24	F12, M12	LF: 66.1(20.4)%, OF: 95.4(3.6)%; LM:71.0(14.0)%, OM:92.3(4.3)%	Nintendo Wii	Wii Sport boxing	11.7(3.4) ml/kg/min	0.06	5.1(1.2) ml/kg/min	2.3	121.4 (20.3)		
Bailey & McInnis, 2011	11.5 (2.0), 9-13	39	F20, M19	23.5(5.5)	Nintendo Wii	Wii Sport boxing	16.7(6.2) KJ/min		4.6(1.6) KJ/min	3.6			Enjoyment: M>F
					Sony PS2	DDR Thirteen	20.5(6.0) KJ/min		4.6(1.6) KJ/min	4.5			Enjoyment: F>M
					Cybex Trazer	Goalie Wars	22.9(8.6) KJ/min		4.6(1.6) KJ/min	5.0			Enjoyment: M>F
					Xavix J-Mat	Jackie Chan Alley Run	28.1(8.5) KJ/min		4.6(1.6) KJ/min	6.1			Enjoyment: M>F
Mitre et al., 2011	8-12	19	F8(L5), M11(L6)	14-29	Nintendo Wii	Sega SuperStar Tennis	3.05(0.93) kcal/kg/h	0.05	1.47(0.24) kcal/kg/h	2.1			Not reported
Perron et al., 2011	9.4 (1.8)	30	F11, M19	18.0(2.4)	Nintendo Wii	Wii Fit					136.5 (9.6)	59.8% time MVPA	Not reported
					Nintendo Wii	EA Sports Active					144.0 (8.0)	64.6% time MVPA	
Staiano & Calvert, 2011	14.45 (1.67)	74	F45, M29	23.97(5.58), 69.28(28.06)%	Nintendo Wii	Wii Sport tennis						62.93(18.09) kcal/30 min for social play, 54.83(11.74) kcal/30 min for solitary play	EE:M>F

Study	Age	N	Sex	%	Console	Game							
White et al., 2011	11.4 (0.8)	26	M26	19.5	Nintendo Wii	Wii Sport tennis	14.1(3.8) ml/kg/min	0.07	6.9(1.1) ml/kg/min	2.16 (0.53)	106(22)		
					Nintendo Wii	Wii Sport bowling	14.0(4.9) ml/kg/min	0.07	6.9(1.1) ml/kg/min	2.03 (0.56)	107(13)		
					Nintendo Wii	Wii Sport boxing	20.2(5.0) ml/kg/min	0.10	6.9(1.1) ml/kg/min	3.05 (0.59)	140(27)		
					Nintendo Wii	Wii Sport step	17.0(4.9) ml/kg/min	0.08	6.9(1.1) ml/kg/min	2.43 (0.43)	122(18)		
					Nintendo Wii	Wii Sport ski	11.3(3.2) ml/kg/min	0.06	6.9(1.1) ml/kg/min	1.65 (0.59)	113(22)		
Gao, 2012a	13.55 (0.94)	195	F95, M100	Not reported		DDR						4.95(7.31) % time in MVPA, 28.77 (15.86)% time in LPA	Intrinsic motivation: M>F; External regulation: M<F
Roemmich et al., 2012	8-12	44	F22, M22	<95%	Nintendo Wii	4 Wii Sport Games	traditional games> AVGs in 87%					AVGs< traditional games	Active play time: AVG >traditional games in 87%	No in EE, HR; game choice had a greater effect on increasing girls' active time and intensity.
Smallwood et al., 2012	13.4 (1.2), 11-15	18	F8, M10	21.3(4.5), 59.7(34.3)%	Xbox360 Kinect	Dance Central	12.8(3.3) ml/kg/min	0.06	4.4(0.8) ml/kg/min	2.9	118		No in EE, REE: M>F
					Xbox360 Kinect	Kinect Sport boxing	17.7(5.1) ml/kg/min	0.09	4.4(0.8) ml/kg/min	4.0	131		EE:M>F
Sun, 2012	9-12	74	F40, M34	Not reported	Eight different AVG stations					2.14 (0.65)			Not reported
Gao et al., 2013b	10.3, 10-11	53	F29, M24	Not reported		DDR						21% of DDR play	Not reported

Study	Age mean (SD), range	N	Gender	BMI	Console	Game	EE	MET	MET value	Outcome	Gender diff
										in MVPA, 31% of aerobic dance in MVPA	
Huang & Gao, 2013	13.3 (1.0), 12-15	135	F65, M70	Not reported		DDR				6.10(9.31) % time in MVPA	No
Miller et al., 2013	11(2), 8-15	104	F58, M46	F:22.3(5.5), M: 20.3(5.1)		Winds of Orbis	0.13(0.09) kcal/kg/min	0.13	G3-5: [d]6.5(0.7); G6-8: [e]4.0(0.4)		No
						DDR	0.11(0.09) kcal/kg/min	0.11	G3-5: [d]6.7(0.7); G6-8: [e]3.2(0.4)		No
Reading & Prickett, 2013	8.3 (2.0), 5-12	41	F15, M26	18.3(3.8), 68.0(11.6)%	Xbox360 Kinect	Kinect Adventures			[f]4.4(0.9)	CPM 1921 (946)	Not reported

Note. Data are shown as mean (standard deviation).

[a]MET values which were reported without standard deviations were computed by the candidate.

[b]Data reported with percentages represent BMI percentiles according to the populations which authors chose.

[c]No refers to no significant gender differences were found.

[d]MET values were computed using 5.9 ml/kg/min as REE.

[e]MET values were computed using 4.6 ml/kg/min as REE.

[f]MET value was computed using 5.0 ml/kg/min as REE.

AVG, active video game; BMI, body mass index; bpm, beats per minute; CPM, counts per minute; DDR, "Dance Dance Revolution"; EE, energy expenditure; F, female; HR, heart rate; G3-5, grades 3-5; G6-8, grades 6-8; L, lean; LF, lean female; LM, lean male; LPA, light physical activity; M, male; MET, metabolic equivalents; MVPA, moderate-to-vigorous physical activity; N, number; O, overweight; OF, overweight female; OM, overweight male; PA, physical activity; REE, resting energy expenditure; SPM, steps per minute.

Table 5 STUDIES THAT EXAMINED THE CHOICES BETWEEN ACTIVE VIDEO GAMES AND SEDENTARY ALTERNATIVES

Study, Country	Participants characteristics	Study description	Console	Game	PA	Comparison between AVG and similar activities
Epstein et al., 2007, USA	NW17 (BMI≤85%), OW18 (BMI>95%); 8-12yrs; F17, M18	Reinforcing value was studied when providing children a choice of either playing one video dance or bicycle game using a handheld controller, or one of the three options: dancing or bicycling alone, dancing or bicycling while watching a video, or playing the interactive dance or bicycle game.	Sony PS2	DDR	NW: AVG>alternatives, OW: No differences across conditions	Only interactive dance game was more reinforcing than the other alternative choices. There was no difference across bicycling conditions.
			Cateye cycle with Sony PS2	EA Freekstyle	No difference was found on miles biked across conditions. Miles biked: F>M	
Sit et al., 2010, China	NW50, OW20; 9-12yrs; F35, M35	Children were systematically observed when providing a choice between an AVG and an online content-matched electronic game.	Xavix	bowling	MVPA time: M>F	Children spent 94% of session time to play games, and split time between AVGs (52%) and online electronic games (48%).
			Xavix	Aerostep	MVPA time: NW>OW	
Lam et al., 2011, China	9-12yrs; F39, M40	Children were provided a choice between an AVG and an online content-matched electronic game. Play pattern (frequency, duration and intensity) were assessed from observation, accelerometry and heart rate monitor.	Xavix	bowling	Counts: M>F	Children spent approximately half (48.0%) of the available time playing AVGs, and a similar amount of time (46.2%) playing sedentary video games.
			Xavix J-Mat	Jackie Chan Action Run	Counts: M>F	

Note. AVG, active video game; DDR, "Dance Dance Revolution"; F, female; M, male; NW, normal weight; OW, overweight; PA, physical activity; yrs, years.

Table 6.STUDIES THAT EXAMINED THE EFFECTS OF ACTIVE VIDEO GAMES ON HABITUAL PHYSICAL ACTIVITY OR CHANGE OF PHYSICAL ACTIVITY

Study & Country	Design	Participant Characteristics				Intervention Duration	Settings	AVG	Used Strategy	Main Findings
		Age	Number	[a]BMI	Group Difference					
Maloney et al., 2008, USA	RCT	7.5 (0.5), 7-8	60 (I:40, C:20); F30, M30	17.6 (2.7), zBMI 0.56 (0.92)	No differences	10 weeks, 28 weeks follow-up (both C and I get AVGs at home between weeks 10 and 28)	Home	DDR on Sony PS2	Each participant was provided a console, DDR, and two dance mats to encourage social and competitive play. A brief handout was provided about operation of AVG and strategies to improve skills. A half of the intervention group also received five weekly, 1:1 30 min coaching sessions. Hand controllers were not provided to restrict sedentary play. Participants were given a written physician prescription to play AVGs 120 min per week.	VPA significantly increased, and sedentary screen time significantly decreased in the intervention group at 10 weeks and 28 weeks. No significant group differences were found. Coaching did not improve results.
Mhurchu et al., 2008, New Zealand	RCT	12 (1.5), 10-14	20 (I:10, C:10); F8, M12	19.7 (3.6)	Age: C>I; time playing electronic games: C>I.	12 weeks	Home	Sony Eye Toy Active games on PS2	An AVG upgrade package (Eye Toy camera, one dance mat and AVGs) was provided. Participants and their parents or guardians were instructed to substitute usual non active video game play with AVG play.	PA was significantly higher in the intervention group compared to the control group at 6 weeks but not at 12 weeks. No group difference was found in MVPA. Waist circumference in the intervention group

										significantly decreased compared to the control group.
Paw et al., 2008, the Netherlands	RCT	10.6 (0.8), 9-12	27; F14, M13	Not reported	Not reported	12 weeks	Home & sport fitness centre	Dance game	All participants were provided an AVG at home. Participants in the multiplayer group were also invited to play against each other weekly in a 60-min multiplayer class under supervision of an instructor at a fitness centre.	Dropout in the multilayer group was significantly lower than the home group.
Duncan & Staples, 2010, UK	CT	10.4 (0.5) , 10-11	30 (I:15, C:15); F18, M12	18.6	Not reported	6 weeks	School	Wii Sports tennis, Sonic and Mario at the Olympics, and Celebrity Sports Showdown on Nintendo Wii	The intervention group played AVG twice weekly instead of their regular recess activities. Games were rotated in each session in order to avoid children being bored and also ensure that children played all games in each session.	Children in the intervention group had significantly greater PA than the control group during the first week; however, this pattern was reversed at the mid and end points. Irrespective of time point, the intervention group spent a lesser percentage of time in MVPA than the controls during the recess time.
Graves et al., 2010a, UK	RCT	8-10	58 (I:29, C:29); F19, M39	I:18.9 (4.5), C:19.7 (4.3)	No differences (p>0.05).	12 weeks	Home	Games on Sony PS2, PS3 with jOG™	Two jOG™ devices were provided for home use to encourage multiplayer play.	No differences were found between groups in PA and body fat. Children in the intervention group increased AVG play while decreased sedentary video gaming at 6 weeks compared to the control group.

Study	Design	Age	N	BMI/other	Baseline PA	Duration	Setting	Game	Intervention	Results
Maddison et al., 2011, New Zealand	RCT	11.6 (1.1), 10-14	322 (I:160, C:162); F87, M235	I:25.6 (4.1), C: 25.8 (4.3)	No differences	24 weeks	Home	Eye Toy active games on Sony PS2, PS3	An AVG upgrade package (Eye Toy camera, one dance mat and AVGs) was provided. Participants were encouraged to meet PA recommendations (60 minutes of MVPA on most days of the week) by supplementing periods of inactivity with AVG play, and substituting sedentary video game play with AVG play. A package of new AVGs was provided at 12 weeks to ensure the sustainability of the intervention.	No differences were found between groups in PA outcomes. The changes of BMI and body fat were significant different between groups. The treatment effect favored the intervention group.
Owens et al., 2011, USA	Pre-post study	10.0 (1.6), 8-13	12; F6, M6	19.4 (4.4)	NA	3 months	Home	Wii Fit active games on Nintendo Wii	Consoles and AVGs were provided. The participating families were given a brief tutorial on the setup and use of AVG, no recommendations were made to the families regarding how much AVG should be played.	No significant effects were found in daily PA, muscular fitness, flexibility, balance, or body composition. Daily AVG use per household declined by 82% from 21.5±9.0 min/day during the first 6 weeks to 3.9±4.0 min/day during the second 6 weeks. Children significantly increased peak VO$_2$ after 3 months.
Baranowski et al., 2012, USA	RCT	11.3 (1.8)	78 (I:41, C:37); F38, M40	81.8 (50-99)%	No differences (p>0.01)	12 weeks	Home	Active Life-Extreme Challenge, EA Sports Active, DDR, Wii Fit Plus,	The same consoles were provided to all participants, with one active game to the intervention group, while one non-active video game to the control group. After 6 weeks, another game for each group was	There were no differences between groups at any time in terms of PA.

									Wii Sports on Nintendo Wii	provided. Participants could choose one game from among five to enhance intrinsic motivation. No prescription was provided to remain naturalistic circumstances, and no prohibitions were provided against purchasing or using other video games.	
Bethea et al., 2012, USA	Pre-post study	9.9 (0.7), 8-11	28; F10, M18	19.8 (3.9), 68.4 (28.7)%	NA	30 weeks	School & home	DDR on Sony PS2		Children had access to DDR up to 3 days a week for around 30 min during after-school time, and had unlimited access at home. A game console, DDR, and two dance mats were provided for each child.	Physical fitness increased at 12 weeks and was sustained through 30 weeks. Trends suggested increased total MVPA, decreased LPA, and a modest increase in sedentary screen time. During the intervention, participants maintained an increase of DDR play. There were no significant changes in BMI, fasting lipids, or glucose.
Christison & Khan, 2012, USA	Pre-post study	11.2 (2.2), 8-16	40; F22, M18	31.07 (6.41), zBMI 2.24 (0.41), ≥85%	NA	10 weeks	Community	Eight different games		This multidisciplinary program had 3 main components: AVG based exercise, nutrition education, and behavioral management discussions. Parent/guardian involvement was required in the nutrition and psychosocial classes. They were also encouraged to do exercise with participants during the AVG based sessions. There	Self-reported exercise hours per week increased, while screen time and soda intake reduced. The average Global Self-Worth score improved. BMI decreased significantly.

						were 5 one-hour AVG sessions in the first 5 weeks and 5 one-hour combined AVG/traditional exercise sessions in the latter 5 weeks. The equipment was used on a rotational basis. Participants were also encouraged to engage in 3 additional hours of exercise per week.				
Gao et al., 2012, USA	CT	10.36 (0.98)	101 (I:50, C:51); F49, M52	Not reported	No differences were reported.	9 months	School	DDR	The intervention group played DDR three times a week during recess. Daily recess is 30 min (2 sessions of 15-min recess) in the participating school. Four participants shared one AVG station to play DDR, with two master dance pads (connected to the monitor) and two practicing dummy dance pads. Children switched to another kind of pad song by song. Researchers monitored the program.	Children in the intervention group displayed significantly higher self-reported PA, greater increased self-efficacy and social support after the intervention. No difference was found in the change of outcome expectancy between groups.
Gao & Podlog, 2012, USA	RCT	8.46 (1.26), 7-13	98; F51, M47	Not reported	Not reported	8 weeks	School	DDR	Participants received feedback about their steps in the first week and were asked to: 1) do your best, 2) increase 10% of the baseline steps, or 3) increase 30% of the baseline steps during AVG play. Children were instructed not to discuss their PA levels and goals with peers.	Children who set specific goals had significantly greater increased PA levels than those in the do-your-best group. In addition, children in the difficult-goal group increased PA levels significantly higher than those in the easy-goal group.

Lwin & Malik, 2012, Singapore	RCT	Children: 10.2 (0.55) PAS: 12.2 (0.54)	1112 (I: 557, C:555); F510, M602	Not reported	Not reported	6 weeks	School	DDR, Wii Sports tennis, boxing on Nintendo Wii	The intervention group played Wii once weekly in one of their two PE lessons. Three consoles were provided to each class. Two participants took turns to play at one console. Three games were played in weekly rotation.	Participants in the intervention group more likely had positive beliefs towards PA attitude, subjective norm and intention, and undertook a higher level of strenuous exercise compared to the control group. Age significantly influenced outcome variables, with the effect of AVGs more pronounced among children than PAS in attitude, moderate and mild exercise behaviors.
Maloney et al., 2012b, USA	RCT	9-17	64 (I:33, C:31); F34, M30	>85% I:96.57 (3.69)% C:96.64 (2.69)%	F:I<C; age: I >C; weight: I>C; no differences in BMI, body fat and VO_{2max}	12 weeks	Home	DDR	One console, DDR and two dance pads were provided to encourage non-solo play.	Self-reported MVPA increased significantly from baseline to 12 weeks for the intervention group and declined for the comparison group. There were no significant group differences based on the accelerometer or pedometer data. The decline in MPA was significant in the comparison group and not significant in the intervention group. Both groups declined VPA, but

										the intervention group declined less.

| Maloney et al., 2012a, USA | RCT | 13.7 (0.6) | 58 (I:29, C: 29); F29, M29 | 69.5 (29.3)% | Not reported | 20 weeks | School | Dance game (In the Groove) on Sony PS2 | Two consoles and two dance mats were provided for each participating school. No hand controllers were provided to discourage student from playing other games on the consoles. Participants were encouraged to play AVG 10 min (two rounds) per day on 4-5 school days per week. If participants danced behind the dance pads but not on the dance mats, they could still document this time as time dancing to allow more than two students to play at a time and encourage social play. | The average self-reported dance time per child was 49 min per week in the first 10 weeks, versus 54 min per week in the second 10 weeks (in the first 10 weeks, only the intervention group were allowed to play AVG while all participants played AVG in the second half of the study). Mean BMI percentile decreased by 5.6 for the intervention group, compared with 0.2 for the control group. At end point, accelerometers showed that (four randomly selected participants) over half of the dance time was spent in MVPA. |
| Simons et al., 2012, the Netherlands | Cross-sectional survey | 13.9 (1.3), 12-16 | 179; F90, M89 | Not reported | Age: Regular gamers< non-regular gamers; no differences in gender, education level, | NA | NA | Any AVG | NA | 11% adolescents who had an AVG console never played. For the adolescents who played AVG, mean time spent on |

				ethnicity and sedentary behaviors						AVGs was 80 (136) min a week. Including AVG play, regular gamers engaged in PA more than non-regular gamers.
Wagener et al., 2012, USA	RCT	14 (1.66), 12-18	40(I:21, C:19); F27, M13	>95%	No differences (p>0.05)	10 weeks	Clinic	Dance-based AVGs	Participants played AVGs according to the target heart rate (75% maximum) by adjusting the difficulty level of the game.	Compared to the control group, participants in the AVG group significantly increased perceived competence to exercise. No pre-post differences in BMI were found within or between conditions.
Gao et al., 2013a, USA	Cross-over trial	Year1: 10.32 (0.91) Year 2: 10.28 (0.90). 10-12	Year1: 208; F87, M121. Year2: 165; F68, M97.	Year 1 I:G4: 19.5 (4.45) C: G3:19.3 (3.56), G5:21.15 (4.33). Year 2 I:G4:20.69 (4.37), C: G5: 21.33 (5.20), G6:20.83 (4.27).	Not reported	9 months	School	DDR	Children participated in a 30-min, DDR-based exercise program three times per week. Two children shared one DDR station. Classroom teachers supervised the AVG play.	Significant difference was found between groups in 1-min run and favored the intervention group. Children's BMI group changes differed only for the first year, and favored the AVG intervention group.
Norman et al., 2013, USA	RCT	13.21 (1.30), 11-15	63, F24, M39	Not reported	Obese participants: the higher contingency group>the lower contingency group;	4 weeks	Home	The higher contingency group: Xavix bowling, Xavix tennis; the Lower contingency	One of four games was randomly installed on a television at each participant's home. Participants were given an overview on how to play the game. They were asked to play the AVG as much as they liked.	Sedentary and light activities were stable over time, whereas MVPA increased in the higher contingency group and decreased in the lower

					no differences in other demographic characteristics				group: Xavix boxing, Xavix J-Mat		contingency group. Reported AVG play decreased in both groups.
Sun, 2013, USA	Pre-post study	9-12	70; F40, M30	Not reported	NA		Two semesters	School	Eight different AVG stations	Over two semesters, students had an AVG class every 2 weeks. In this class, children rotated between the eight stations (games that require only arm movement were eliminated from the study).	PA levels during AVG classes increased over two semesters. Three (challenge, exploration, and novelty) out of five dimensions of situational interest decreased over time. There were no gender differences in these three dimensions, and in attention. However, boys felt AVG more enjoyable than girls.
Quinn, 2013, USA	Pre-post study	10-12	86; F32, M54	Not reported	NA		6 weeks	School	Just Dance, DDR, Walk It Out on Nintendo Wii	PE teachers were trained before providing AVG based PE lessons. Four students' plays were projected on the screen. All students were required to participate by following the on-screen clues. Students rotated to allow additional participants to have time on the dance mats.	After the intervention, participants were significantly more active in PE classes than before, while change of PA at home was not found.
Staiano et al., 2013, USA	RCT	[b]15-19	54; F30, M24	33.10, 94.7 (6.0)%	No differences (p>0.05)		20 weeks	School	EA Sport Active on Nintendo Wii	Participants in the two AVG conditions could play 30-60 min every school day during the lunch or after-school time. AVG routines were designed to increase gradually in intensity, length, and difficulty to create continued	The cooperative players lost more weight than the control group, while the competitive players did not. The cooperative players increased in self-efficacy compared to the

challenge for participants. Cooperative and competitive groups were in separate classrooms. Participants were encouraged through periodic verbal reinforcement to complete AVG sessions. In the competitive group, pairs of participants were instructed to compete against each other to earn the most points. In the cooperative group, pairs of participants were instructed to coordinate to earn the most points as a team.	control group, while the competitive players did not. Both AVG groups increased in peer support more than the control group.

Note. Data are shown as mean (standard deviation).

[a]Data reported with percentages represent BMI percentiles according to the populations which authors chose.

[b]This study included participants who were older than 18. However, we decided to include it in this review. In addition, excluding it will not change the result regarding the effects of the structured AVG play on PA.

AVG, active video game; BMI, body mass index; C, control group; CT, controlled trial; DDR, "Dance Dance Revolution"; F, female; G3, grade 3; G4, grade 4; G5, grade 5; G6, grade 6; I, intervention group; LPA, light physical activity; M, male; MPA, moderate physical activity; MVPA, moderate and vigorous physical activity; NA, not applicable; PA, physical activity; PAS, pre-adolescents; PE, physical education; RCT, randomized controlled trial; VPA, vigorous physical activity; zBMI, body meass index z score.

Table 7. METHODOLOGICAL QUALITY SCORES AND THE EFFECTS OF AVG INTERVENTION STUDIES ON PA-RELATED OUTCOMES

Study	A	B	C	D	E	F	G	H	I	J	Score	PA outcome measure	[a]Effect Within-Group	Between-Group	Effect Size
Home setting															
Maloney et al.,2008	—	—	+	+	+	+	?	—	—	—	4	LPA	↓	O	0.36
												MPA	→	O	-0.08
												VPA	↑	O	0.25
Mhurchu et al., 2008	+	—	+	+	+	+	?	—	+	+	7	CPM	Not reported	O	NA
												MVPA	→	O	NA
												Self-reported PA	→	O	NA
Graves et al., 2010a	+	+	+	+	—	+	—	—	+	+	7	CPM	Not reported	O	-0.17
												MVPA	Not reported	O	-0.13
Maddison et al., 2011	+	+	+	+	+	+	—	+	+	+	9	MVPA	Not reported	O	0.03
												LPA	Not reported	O	NA
												CPM	Not reported	O	NA
												Physical fitness	Not reported	O	NA
Owens et al., 2011	NA	NA	+	+	+	NA	?	—	NA	—	3	MPA	→	NA	0.03
												VPA	→	NA	-0.22

Study												Outcome			
												Physical fitness	↑	NA	0.42
Baranowski et al., 2012	+	+	+	+	+	+	?	—	—	+	7	LPA	→	o	0
												MVPA	→	o	-0.14
												CPM	→	o	-0.03
Maloney et al., 2012b	+	+	+	+	+	+	—	—	—	+	7	Self-reported mild PA	→	o	-0.36
												Self-reported moderate PA	→	+	1.09
												Self-reported strenuous PA	→	+	1.47
												Steps/week	→	o	-0.72
												LPA	→	o	-0.18
												MPA	→	o	0.27
												VPA	→	o	0.48
Norman et al., 2013	—	—	+	+	+	+	—	—	—	—	4	LPA	→	o	0
												MVPA	↑	+	0.47
School															
Duncan & Staples, 2010	—	NA	+	+	?	+	+	—	+	+	6	SPM (In session)	↓	—	-1.19
Gao et al., 2012	—	NA	+	+	+	+	?	+	—	—	5	Self-reported PA	Not reported	+	NA
												Self-efficacy	Not reported	+	NA
												Social support	Not reported	+	NA
												Outcome expectancy	Not reported	o	NA
Gao & Podlog, 2012	—	+	+	+	+	+	—	—	—	+	6	SPM (In session)	↑	+	1.37[b]
Lwin & Malik, 2012	—	+	+	+	—	?	?	—	?	—	3	Attitude	NA	+	0.16

Study												Outcome			
												Subjective norm	NA	+	0.11
												Perceived behavior control	NA	o	-0.02
												Intention	NA	o	0.07
												Self-reported mild PA	NA	o	0.06
												Self-reported moderate PA	NA	o	0.02
												Self-reported strenuous PA	NA	+	0.06
Gao et al., 2013a	—	NA	—	—	+	+	—	+	—	+	4	Physical fitness	Not reported	+	NA
Sun, 2013	NA	NA	+	+	+	NA	—	+	—	+	5	MET value	↑	NA	0.99
Quinn, 2013	NA	NA	+	—	+	NA	?	—	NA	—	2	Self-reported PA in PE	↑	NA	0.25
												Self-reported PA at home	→	NA	0.19
Staiano et al., 2013	—	+	+	+	—	+	?	—	—	+	5	Self-efficacy	Not reported	+	0.61
Community															
Christison & Khan, 2012	NA	NA	+	—	+	NA	?	—	—	—	2	Self-reported exercise time	↑	NA	0.72
Clinic															
Wagener et al., 2012	—	—	+	+	+	+	+	—	—	—	5	Perceived competence in exercise	Not reported	+	0.83
Multi-settings															
Paw et al., 2008	?	—	+	?	—	+	?	—	—	—	2	Self-reported PA	Not reported	Not reported	NA

												Perceived competence in sports	Not reported	Not reported	NA
Bethea et al., 2012	NA	NA	+	+	+	NA	—	+	NA	—	4	Physical fitness	↑	NA	0.38
												Parental-reported PA	Not reported	NA	NA

Note. [a]The pre-post difference in PA-related outcome in the AVG intervention group was coded as "↑" for significant positive change, "→" for no change, and "↓" for significant negative change. The pre-post difference in PA-related outcome between the AVG intervention group and comparison group was coded as "+" (significant difference favoring the AVG intervention group), "O" (no difference), and "—" (significant difference favoring the comparison group).

[b] Compared with the do-your-best comparison group, effect size for the difficult-goal group is 1.37, effect size for the easy-goal group is 0.59.

CPM, counts per minute; LPA, light physical activity; MET, metabolic equivalent of task; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; NA, not applicable; PE, physical education; SPM, steps per minute; VPA, vigorous physical activity.

CHAPTER 4. VALIDITY AND RELIABILITY OF QUESTIONNAIRES MEASURING PHYSICAL ACTIVITY SELF-EFFICACY, SOCIAL SUPPORT, AND ENJOYMENT AMONG HONG KONG CHINESE CHILDREN

4.1 INTRODUCTION

Effective strategies are needed to promote PA among Hong Kong children. To increase PA levels of Hong Kong children, identifying and understanding the psychosocial factors associated with PA is needed (Sallis, & Owen, 1999).

In western countries, psychosocial variables such as self-efficacy and social support, have been positively associated with children's PA (van der Horst et al., 2007). Enjoyment of PA was a mediator of increased PA in a school-based PA intervention (Dishman et al., 2005). Unfortunately, few measures have been validated for such correlates of PA in Chinese individuals. One questionnaire, developed for Taiwanese adolescents, measured PA correlates based on the health promotion model (Wu, Ronis, Pender, & Jwo, 2002), and one questionnaire, developed for Hong Kong children, measured psychosocial and environmental correlates of PA (Huang et al., 2011). Huang et al. (2011) measured self-efficacy, peer support, and family support, but focused on the influence of environment. The self-efficacy measure focused on children's confidence in finding and creating an environment to support their PA, so it was not a suitable measure for overall self-efficacy including barriers-efficacy, seeking-support-efficacy, being active despite competitive activities, and engaging in the task of being regularly active. Peer support was only captured by two items; and enjoyment was not examined. Therefore, the use of this questionnaire is limited. Studies of PA correlates among children speaking Cantonese Chinese, like the children in Hong Kong, would be improved by developing validated full scales of self-efficacy, peer and family support, and enjoyment of PA.

This study examined the validity and reliability of instruments to assess PA-related self-efficacy, social support, and enjoyment among Hong Kong children.

4.2 METHODS

4.2.1 PARTICIPANTS

A sample of 273 Chinese children (134 girls and 139 boys) in grades 3-6 were recruited from two Hong Kong government primary schools. None of the participants had any restrictions (e.g., physical or psychological limitations) to engage in PA. Both participants and their guardians provided written informed consent (see Appendix A). The study was approved by the Committee on the Use of Human and Animal Subjects in Teaching and Research, Hong Kong Baptist University.

4.2.2 TESTED QUESTIONNAIRES

An 8-item scale was used to measure PA self-efficacy (see Appendix B). The items were taken from a previously validated instrument (Motl et al., 2000), and modified based on a published simpler version (Ward et al., 2007, p.243). The modifications included: 1) shortening the items, 2) specifying video games as sedentary video games, since AVGs could lead to light- to moderate-PA and have been positively associated with self-reported PA (Simons et al., 2012), and 3) replacing one item ("I have the coordination I need to be physically active during my free time on most days") with another one ("I can do active things because I know how to do them"). These modifications were based on the target population being younger than the previous study (Motl et al., 2000). Each item used a Likert scale ranging from 1 ("Disagree a lot") to 5 ("Agree a lot").

Ten items adapted from the Social Support for Exercise Scale (Sallis, Grossman, Pinski, Patterson, & Nader, 1987) were used to measure social support for PA (see Appendix C). The word "exercise" was changed to "PA" in the present study. Although the scale was developed for college students, the 10 items have been used in a younger population (12.55±0.65 years old) (Hsu et al., 2011). Children rated how often they received PA-related social support (e.g., "During the past three months, my family or friends discussed PA with me") on a 5-point scale (1=none to 5=very often). There was also a rating of "does not apply".

A 5-point Likert scale (Ward et al., 2007, p.244) was used to measure PA

enjoyment ranging from 1 ("Disagree a lot") to 5 ("Agree a lot"). All 7 items (e.g., "When I am active, I feel bored") were negatively worded, thus higher scores indicated lower PA enjoyment (see Appendix D). These 7 items were taken from a modified 16-item version (Motl et al., 2001) of Physical Activity Enjoyment Scale (PAES) (Kendzierski & DeCarlo, 1991). The other 9 items were all positively worded, and were found associated with an irrelevant methodologic effect which may explain the lack of support for the unidimensional structure of the original PACES (Motl et al., 2001).

No culture-specific items were identified (judged by the candidate and the principal supervisor) in the English items. Therefore, all the items were translated from English to Chinese by two bilingual Chinese researchers (two PhD students who have experience in PA epidemiology and translating surveys from English to Chinese), and consensus was achieved by discussion with a bilingual expert panel (including the translators, two researchers in exercise science, the candidate and the principal supervisor). The principal supervisor made all final decisions based on the discussion. Back-translation was then conducted by an independent translator. A satisfactory version was reached by discussion of the panel. Cognitive interviews were conducted with a separate sample (n=16) of similar age from one of the participating schools. Participants were asked whether they completely understood the items in the translated questionnaires, and if not, which of the alternative expressions sounded more understandable. Minor changes (e.g., because children did not understand "does not apply" in the social support scale, this rating was excluded) were made by the expert panel based on the responses from these interviews. This multistep approach was conducted for the translation because it "could provide a series of filters that function in tandem to ferret out both obvious and subtle defects in the questions" (Willis et al., 2010).

4.2.3 CHILDREN'S PHYSICAL ACTIVITY BEHAVIOR

To test scale criterion validity, children's physical activity behavior was measured by CLASS-C (Huang et al., 2009). Children reported the total time they spent in PA in the past week with a checklist of activities during weekdays and weekend days. The questionnaire was scored for the daily time spent in MVPA (Huang et al., 2011).

4.2.4 HEIGHT AND WEIGHT

Children reported their heights and weights in questionnaires. BMI was computed (weight in kilograms divided by height in meters squared), and BMI percentiles were computed based on an international sample as recommended by Cole and Lobstein (2012).

4.2.5 PROCEDURES

The study was conducted from May to June, 2013. Children were surveyed during PE classes or school recesses, and were encouraged to ask questions as necessary. To assess test-retest reliability, the questionnaires were administered on two occasions 7 days apart. Each time took approximately 15-20 min for participants to complete the questionnaires.

4.2.6 DATA ANALYSIS

Scale factorial validity was tested by CFA using Amos 21.0 (IBM Inc. Armonk, NY) with the maximum likelihood model. The sample size was adequate to conduct CFA since the ratio of the sample size to the number of freely estimated parameters was greater than 10:1 (Bentler and Chou, 1987). Since the scales were supposed to be unidimensional, the one-factor model was assessed for each scale using data from the first administration. Model fit was assessed using the chi square statistic, the Comparative Fit Index (CFI, >0.9) (Bentler, 1992), the root mean square error of approximation (RMSEA, <0.08) (Browne & Cudeck, 1993), and the standardized root mean square residual (SRMR, ≤0.08) (Schreiber, Nora, Stage, Barlow, & King, 2006).

Cronbach's alpha was computed for each scale to assess internal consistency with 0.7 considered minimally acceptable (Nunnaly, 1978). Ratings of each scale were averaged, and scale test-retest reliability was assessed by an ICC. If one value was missing for a subject, the average score was computed on the remaining items. If more than one value was missing, the participant was excluded from the analyses. Test-retest reliability was considered acceptable if ICC>0.7 (Baumgartner & Jackson, 1999). Criterion validity was examined by Pearson correlations between the measured constructs and PA behavior. Enjoyment scale ratings were recoded (e.g., 1 to 5) because of the negatively worded items.

4.3 RESULTS

4.3.1 CHARACTERISTICS OF THE PARTICIPANTS

Participant age and BMI characteristics by gender are presented in Table 8. On average, these children were just over 10 years of age, and their BMI percentile was above 50%.

Table 8. CHARACTERISTICS OF THE PARTICIPANTS

	Boys	Girls	All
Age (y)	10.2(1.0)	10.3(1.0)	10.3(1.0)
BMI(kg/m^2)	18.6(3.5)	17.1(2.5)	17.8(3.1)
BMI percentile	63.69(32.67)	50.66(30.08)	57.23(32.02)

Note. Data are shown as mean (standard deviation).

BMI, body mass index.

4.3.2 FACTORIAL VALIDITY OF THE SCALES

Table 9 shows initial CFA model fit results for a one-factor model with no correlations across the items in each scale. The CFI for each scale was greater than 0.90. SRMR also suggested acceptable model fit. However, only the self-efficacy scale showed acceptable RMSEA.

For the social support from family scale, error covariance was detected between items 1 and 2. Items 1 and 2 were similar, but not redundant. The final model with parameters set free to vary had acceptable model fit indices [Chi square=79.35, df=34, RMSEA=0.07 (90% CI, 0.05-0.09), SRMR=0.04].

For the social support from friend scale, error covariances were also detected between items 1 and 2, and items 9 and 10. The model was thereby modified by setting the mentioned parameters free to vary. The final model with such modifications had acceptable model fit indices [Chi square=65.90, df=33, RMSEA=0.06 (90% CI, 0.04-0.08), SRMR=0.04].

For the enjoyment scale, error covariances were detected between items 3 and 5, items 2 and 7, and items 1 and 4. The model was thereby modified by setting the

mentioned parameters free to vary from their previously fixed values of zero. The final model had acceptable model fit indices [Chi square=29.74, df=11, RMSEA=0.08 (90% CI, 0.05-0.11), SRMR=0.03].

Table 9. CFA RESULTS FOR EACH SCALE

Scales	χ^2	df	p	CFI	RMSEA (90%CI)	SRMR
Self-efficacy	45.68	20	0.001	0.94	0.07(0.04-0.10)	0.05
SSFA	98.48	35	<0.001	0.93	0.08(0.06-0.10)	0.05
SSFR	144.95	35	<0.001	0.91	0.11(0.09-0.13)	0.06
Enjoyment	70.11	14	<0.001	0.95	0.12(0.09-0.15)	0.04

Note. SSFA, social support from family; SSFR, social support from friends.

4.3.3 SCALE CRITERION VALIDITY

Bivariate Pearson coefficients between the scales and self-reported PA were all significant (p<0.01) and in the expected directions, supporting the criterion validity of the tested scales (Table 10).

4.3.4 SCALE RELIABILITY

The scales' Cronbach's alpha values are listed in Table 10, demonstrating acceptable internal consistency reliability. Test-retest reliability for each scale also indicated acceptable values.

Table 10. INTERNAL CONSISTENCY, TEST-RETEST RELIABILITY OF THE SCALES, AND CORRELATIONS BETWEEN THE MEASURED PA CORRELATES AND SELF-REPORTED PA

	Cronbach's Alpha	ICC (95%CI)	r
Self-efficacy	0.78	0.88(0.84-0.91)	0.40 [a]
SSFA	0.86	0.86(0.82-0.89)	0.40 [a]
SSFR	0.90	0.91(0.88-0.93)	0.35 [a]
Enjoyment	0.90	0.82(0.77-0.86)	0.23 [a]

Note. SSFA, social support from family; SSFR, social support from friends.
[a] p<0.01

4.4 DISCUSSION

This study examined the validity and reliability of translated scales previously developed in English to measure PA correlates (self-efficacy, social support, and

enjoyment) among Hong Kong Chinese children. Although all the items were derived from published instruments, and used among youth, none of the scales have been validated with a young (8-12 years old) Chinese population.

4.4.1 FACTORIAL VALIDITY OF THE SCALES

Factorial validity was supported with reasonably good model fit of the one-factor model for each scale, when several items were allowed to covary. The validation studies of the original self-efficacy (Motl et al., 2000) and enjoyment scales (Motl et al., 2001) conducted in US adolescent girls, supported the unidimensionality of these English scales. The validation study of the original social support scale (Sallis et al., 1987) conducted in American college students used exploratory factor analyses instead of CFA, and suggested the 10 items in the present study loaded on one factor. Thus, the present study was consistent with the previous studies and suggested similar structure among Chinese students.

4.4.2 CRITERION VALIDITY OF THE SCALES

The significant correlations of all scales with self-reported PA ($p<0.01$) supported the scales' criterion validity in Hong Kong children.

The self-efficacy scale in the present study showed a moderate correlation with self-reported PA, and the correlation was stronger (0.40>0.25) than the previous study (Huang et al., 2011). The same questionnaire (CLASS-C) was used to measure PA in the two studies, and the demographic characteristics of the participants were similar. Thus, items in the present study reflecting more aspects of self-efficacy (barriers-efficacy, seeking-support-efficacy, being active despite competitive activities, and engaging in the task of being regularly active) may explain the stronger correlations. This significant correlation confirmed that self-efficacy was an important correlate of PA among Chinese children (Huang et al., 2013), and was consistent with the evidence found in western countries (van der Horst et al., 2007).

In contrast to the previous study in which only friend support was correlated with Hong Kong children's PA (Huang et al., 2011), both social support from family and friends correlated with children's self-reported PA, and the influence from

family was relatively stronger. In the previous study (Huang et al., 2011), social support from family was assessed by accumulating the agreements of "being physically active with me" from different family members (whole family, father, mother, and siblings). The social support scale in the present study represents more aspects of the construct, which may have resulted in the significant correlation. Peer support may become more important when children approach adolescence (van der Horst et al., 2007). Therefore, the relative weaker correlation between social support from friends, than from family, and self-reported PA may reflect that most participants were still in the stage where they were influenced more by family than by peers.

PA enjoyment has not previously been studied in Hong Kong children, and showed the smallest correlation with self-reported PA. However, the significant correlation supports examining PA enjoyment as a correlate of PA among Hong Kong children.

4.4.3 RELIABILITY OF THE SCALES

Internal consistency of the tested scales was acceptable. All the items correlated with the corresponding scale with a minimum value of 0.40 (Blunch, 2013). Test-retest reliability of the original English scales has not been reported. In the present study, test-retest reliability of each scale was acceptable.

4.4.4 STRENGTHS AND LIMITATIONS

This study included a reasonably large sample to study the psychometrics of the scales. A previously validated questionnaire specifically for Hong Kong children (CLASS-C) was used to assess scale criterion validity. Comparison between the present study with one previous study (Huang et al., 2011) was enabled because the same target population and similar methodology.

There were, however, several limitations. First, a convenience sample was recruited, which may limit the generalizability of the study. However, the characteristics of participants in the present study were similar with the previous study (Huang et al., 2011), which recruited school students from multiple areas and formed a representative sample. In addition, all the participating schools were

typical Hong Kong government primary schools, with similar classrooms that served around 30 children, limited outdoor play space, and standard school schedules. Second, children's PA were measured using self-report which suffers numerous limitations. Self-reported MVPA was weakly correlated ($r=0.27$ for boys, $r=0.48$ for girls) with objectively measured MVPA among Hong Kong children (Huang et al., 2009). Third, none of the items in the present study were developed specifically for Hong Kong children. A culture-specific measure may be more appropriate for the target population. In addition, studies have suggested that self-efficacy (Ryan & Dzewaltowski, 2002) and social support (Duncan, Duncan, & Strycker, 2005) may be of different types. It may be promising to further develop scales to measure PA self-efficacy and social support of a multidimensional structure among Hong Kong children.

4.4.5 IMPLICATIONS FOR FUTURE STUDIES

Tests of the sensitivity of these scales to change over time are warranted with longitudinal studies; the magnitude of correlations of these scales with Hong Kong children's PA at different ages would also be important in a more representative sample.

4.5 CONCLUSION

The present study provided psychometric support for the use of measures of PA self-efficacy, social support for PA, and PA enjoyment among Hong Kong Chinese children with acceptable factorial validity, criterion validity, internal consistency, and test-retest reliability.

CHAPTER 5. GETTING ACTIVE WITH ACTIVE VIDEO GAMES:

A QUASI-EXPERIMENTAL STUDY

5.1 INTRODUCTION

It is widely recommended that children engage in at least 60 minutes of MVPA per day for health, well-being and development benefits (Marshall & Welk, 2008; WHO, 2010). However, a recent questionnaire survey suggested that only 9% of Hong Kong primary school children achieved these recommendations (HKSAR Government Sport Commission, 2012). The lack of PA is associated with a plethora of negative consequences and contributes to childhood obesity, though the etiology of obesity is complex (WHO, 2012). From 1998 to 2013, the prevalence of overweight/obesity among Hong Kong primary school students increased from 16.4% to 20.8%, with greater prevalence among boys than girls (HKSAR Government Department of Health, 2014). These data highlight the importance of developing effective strategies to increase PA and prevent obesity among Hong Kong children.

As introduced previously, Hong Kong is one of the most densely populated places in the world (HKSAR Government Information Services Department, 2013). This fact limits the availability of outdoor space in Hong Kong primary schools. Given the constraints of outdoor PA programs (facility accessibility, safety concern, air pollution, and inclement weather), indoor programs may provide alternatives to increase activity levels. AVG technology may provide an attractive option for displacing sedentary screen time and increasing PA among children. Within the laboratory and several free-living environments, certain AVGs have been shown to elicit moderate intensity activity among children (Foley & Maddison, 2010; Gao, 2012a; Gao et al., 2013b; Huang & Gao, 2013; Peng et al., 2013; Reading & Prickett, 2013), and could be used as a possible indoor intervention strategy to increase PA levels.

Several pieces of evidence (see Chapter 2) suggest that structured AVG play can improve PA. However, none of the previous school-based AVG interventions have measured habitual PA and sedentary behavior objectively; used Xbox Kinect

games; and considered the AVG class frequency on the intervention effect on PA. Furthermore, few of these studies have examined the effects of AVGs on both PA and its psychosocial factors. Such research may inform the potential mechanisms of structured AVGs on PA. Therefore, the aim of the current study was to determine the effects of a school-based AVG intervention on objectively measured PA and sedentary time, body composition, and psychosocial factors among Hong Kong children. The research hypotheses of the study were:

1. AVG play could improve PA and reduce sedentary behavior at 8 and 15 weeks;

2. AVG play could reduce BMI and percentage body fat at 8 and 15 weeks;

3. AVG play could improve PA-related psychosocial factors (self-efficacy, social support from friends, social support from family, and enjoyment) at 8 and 15 weeks.

When significant group differences in PA outcomes were found, this study also determined to examine the mediation and moderation effects of psychosocial factors within the intervention.

5.2 METHODS

5.2.1 PARTICIPANTS

Children in grades 4-6 from Hong Kong primary schools were eligible to participate in the study if they (1) were free from physical or psychological constraints to being active, (2) did not participate in any school sports team, and (3) did not participate in an extracurricular exercise class. The study was approved by the Committee on the Use of Human and Animal Subjects in Teaching and Research, Hong Kong Baptist University. Written informed consent was provided by both participants and their guardians (See Appendix E, F).

5.2.2 DESIGN

A quasi-experimental design was used. Children were allocated to either the intervention group (school-based extracurricular AVG class) or the control group (no change) based on personal preference but were not randomized.

5.2.2.1 Intervention

The intervention group had access to AVGs during after-school extracurricular classes for 8 weeks, with approximately two one-hour (3:00pm-4:00pm) sessions

a week (Tuesday and Friday). After 8 weeks, children in the intervention group continued to play AVGs with a lower frequency (approximately once a week) until 15 weeks. This design was chosen to fit the school schedule. In total, 18 sessions were scheduled: 13 in the first 8 weeks and 5 in the last 7 weeks.

At the beginning of each 60-min session, the participants underwent a 10-15 min warm-up (led by the candidate or a research assistant). Research assistants (trained graduate students) set up the classrooms for playing the AVGs. Four classrooms were used for the AVG intervention. Two game consoles (Xbox 360 Kinect) that supported multiplayer use (2-4 children can play AVGs simultaneously) were connected to a TV set and a projector in each classroom. Pairs of participants shared one console and were rotated to play the games either on the TV or the projector for each entire session (the children who played AVGs on the TV would play AVGs on the projector in the next class). To encourage children to play AVGs, at most two pairs of children played AVGs in each classroom. Therefore, children did not need to wait for their turns to play AVGs. Children selected their preferred playing partner. After two episodes of game play, all pairs were stabilized. This approach was designed to enhance the perceived social support of the participants. Children were allowed to take short breaks during AVG classes to drink water and go to the toilet. After 4:00pm, the intervention children stopped playing and left school.

In the first 4 weeks, Kinect "Adventures" (Good Science Studio, Microsoft Game Studios), which consists of five games ("20000 Leaks", "River Rush", "Rally Ball", "Reflex Ridge", and "Space Pop"), was used. These games require both upper and lower body movements. "Adventures" has been shown to elicit moderate intensity PA among children (METs=4.4; Reading & Prickett, 2013). The participants could freely choose from the games to enhance their intrinsic motivation (Fortier, Sweet, O'Sullivan, & Williams, 2007). In week 4, the participants were encouraged to join a competition to enhance their interest in the intervention and increase their activity intensity. For the competition, pairs of participants were instructed to coordinate to earn points while playing "Reflex Ridge". All the points earned by each pair were accumulated as the team score. The research assistants recorded the scores, and the winning two pairs with the

highest scores were given the prerogative to choose the games for the next week. The winners were able to choose either Season 1 or Season 2 of Kinect "Sports" (Rare, Microsoft Games Studios). Each season of Kinect "Sports" consists of six sports simulation games. Of the games available in Kinect "Sports", boxing has been shown to elicit moderate intensity activity (METs=4.0) in children (Smallwood et al., 2012).

5.2.2.2 Control

The control participants engaged in their usual activities during the intervention periods, either leaving school or participating in non-exercise-based extracurricular activities at school during the intervention periods. All of the control children, as well as the intervention children, took part in their usual PE lessons.

5.2.3 RECRUITMENT

Recruitment of participants was done via schools from March to September, 2013. Following expression of interest, invitation letters were sent to school principals with a brief introduction of the study. One of the five contacted schools agreed to take part in the study. The main concern of the other schools was the time conflict with existing school activities. Therefore, all of the participants were recruited from one school in the New Territories of Hong Kong. The participating school is a typical Hong Kong government primary school with approximately 150 children in each grade. Students from grades 4-6 were asked to sign up for an after-school extracurricular AVG class, which was one of the options students could choose for after-school activities organized at the school. Intervention children who attended at least 80% of the sessions were reimbursed for the extra school bus fees incurred for attending the AVG classes. Recruitment was conducted at the beginning of the two semesters across the academic year 2013-2014.

5.2.4 PROCEDURE

Assessments were conducted by trained researchers at baseline, 8 weeks and 15 weeks. Except for the accelerometer-determined PA and sedentary behavior outcomes, all other measurements were conducted at the end of the school day.

The inclusion criteria were assessed using a screening questionnaire (see Appendix G) and confirmed by school teachers. The participants attended a briefing on the measurement of accelerometry before the baseline assessment. Children were instructed to wear the accelerometer on their right hip with an elastic belt during waking hours, except sleeping, bathing, and when doing water activities and contact sports. A wearing log (see Appendix H) with written information was provided after the briefing. Participants recorded wearing details, such as when they put on and remove the accelerometer, and the reason for each removal (e.g., swimming). The log was used to encourage the participants to wear the device; however, it was not used to impute non-wear time.

The participants received individualized health recommendations in sealed envelopes regarding their PA levels and body composition after all assessments to promote their compliance. The participants in semester 1 were asked not to share recommendations with the other students to minimize contamination with the participants in semester 2.

5.2.5 MEASURES

5.2.5.1 Anthropometrics

Anthropometric data were measured using a standard protocol (McArdle et al, 1991). Standing height was measured twice to the nearest 0.1 cm using a portable stadiometer (Seca, Model 214, Hamburg, Germany). A third measure was taken if the difference was greater than 0.5 cm. The average value of the closest two measures was recorded for height. Weight (measured to the nearest 0.1 kg) and percentage body fat were assessed using a foot-to-foot bioelectrical impedance analyzer (Tanita, Model TBF-410GS, Tokyo, Japan). This analyzer has demonstrated validity to assess percentage body fat among Hong Kong Chinese children (Sung, Lau, Yu, Lam, & Nelson, 2001). BMI was computed by weight in kilograms divided by height in meters squared; BMI z score (zBMI) was computed as recommended by Cole and Lobstein (2012) using an international reference sample that included Hong Kong children.

5.2.5.2 Physical activity and sedentary behavior

Objectively measured PA and sedentary behavior were assessed using the GT3X, GT3X+, and wGT3X accelerometers (ActiGraph, Pensacola, USA). For each outcome assessment, participants were asked to wear the accelerator for seven consecutive days. However, only weekday data were used because this study was a school-based intervention.

Activity counts were collected in 5-sec epochs, and integrated to 1-minute intervals for analyses. Only the data recorded between 7:00 am and 10:00 pm were considered as waking time due to various sleep patterns in children (Weintraub et al., 2008). Non-wearing time was defined as 60 minutes or more of consecutive zero records. A valid day included 480 minutes or more of wearing time. At least two valid days of data were required for inclusion in the analyses (Kriemler et al., 2010). In addition, data were further reduced from 3:00 pm to 10:00 pm in order to determine the treatment effect during the targeted after-school time. The participants who provided at least two days of after-school time data (60 min or more of wearing time for one day) were included for the additional analyses.

Time spent in different intensities of PA and sedentary behavior were derived based on the cut points of the vertical axis counts established by Evenson et al. (2008), which have been demonstrated to estimate the different intensities of PA in the targeted age group (Trost et al., 2011). Average vector magnitude counts were calculated using the equation$\sqrt{Axis1^2 + Axis2^2 + Axis3^2}$. CPM in VA and VM were used to represent overall PA (Yildirim et al., 2011).

5.2.5.3 Psychosocial factors

The PA-related psychosocial variables, namely, self-efficacy, social support, and enjoyment, were measured via questionnaires that have been validated in Hong Kong children (see Chapter 4).

5.2.5.4 Process evaluation

Attendance for the AVG classes was recorded. The proportion of the PA data obtained from the days with intervention sessions in the intervention group was

identified. The intervention participants were interviewed at 15 weeks to rate the class on a scale of 1-5.

5.2.6 OUTCOMES

The primary outcome was change in daily MVPA (min) from baseline to 8 weeks. The secondary outcomes included change in daily MVPA at 15 weeks, as well as change in daily light PA (LPA), MPA, VPA, sedentary behavior, vertical axis counts per minute (VACPM) and vector magnitude counts per minute (VMCPM), after-school PA and sedentary behavior, BMI z score, percentage body fat (%), self-efficacy, social support from friends and family, and enjoyment at 8 and 15 weeks.

5.2.7 SAMPLE-SIZE CALCULATION

A targeted sample size of 80 participants (40 children per group) was estimated to provide 80% power at 5% level of significance (two tails) in detecting a group difference of 10 min in daily MVPA, assuming a SD of 15 min (Baranowski et al., 2012) and 10% loss to follow up.

5.2.8 STATISTICAL ANALYSIS

Due to the large size of raw accelerometer data, professional statistical software SAS version 9.3 (SAS Institute Inc., Cary, NC) was used to import and process the data following the validation protocol described in Section 5.2.5.2. All statistical analyses were conducted using IBM SPSS Statistics version 21.0 (IBM Inc., Armonk, NY). Statistical tests were two-tailed at 5% significance level.

To test the research hypotheses (see Section 5.1), statistical null hypotheses were generated as below:

1. There were no significant group differences in objectively measured PA and sedentary behaviour at any assessment adjusting for baseline outcome value, age, gender, zBMI, and average daily wearing time;

2. There were no significant group differences in BMI z score or percentage body fat at any assessment adjusting for baseline outcome value, age and gender;

3. There were no significant group differences in PA-related psychosocial factors (self-efficacy, social support from friends, social support from family, and

enjoyment) at any assessment adjusting for baseline outcome value, age, gender and zBMI.

Descriptive statistics were used to summarize all measures of interest at baseline, by treatment group and gender. Continuous variables were presented as mean and standard deviation, and tested using independent t-test between groups. Categorical variables were presented as frequency and percentage, and tested using Chi-square test between groups. Linear regression analyses were conducted on primary and secondary outcomes at 8 and 15 weeks, adjusting for important baseline prognostic factors. For PA outcomes measured using accelerometer, the models were controlled for baseline outcome value, age, gender, zBMI, and average daily wearing time. For psychosocial outcomes, the models were controlled for baseline outcome value, age, gender and zBMI. For body composition outcomes, the models were controlled for baseline outcome value, age and gender.

Model assumptions were tested as necessary, including additivity and linearity (using partial plots between each predictor and dependant variable), normality of residuals (using a p-p plot of standardized residual for each model), independence of residuals and homoscedasticity (using plots of standardized predicted values and standardized errors). Multicollinearity was checked by the Pearson correlation coefficients between the continuous independent variables, and the variance inflation factor. The overall model significance was assessed using the F-test in analysis of variance (ANOVA) table, and individual t-tests were used to test the predictive effect of independent variables in the model. Normality of the continuous outcome variables were checked using K-S test. For a moderate sample size of n≥30 per group (like the current study), the central limit effect works reasonably well if the original distribution is close in shape to the Normal distribution (Wild & Seber, 2000). The bias corrected and accelerated bootstrapped confidence intervals (BCa CI) of the group differences based on 1000 samples, which should be robust to violations of assumptions of statistical tests and outliers as recommended by Field (2013), were obtained in order to reduce bias. The missing data were excluded from analyses. Adjusted group means and standard errors, group difference with associated 95% BCa CI and p

value in each outcome were reported. Hedge's g was calculated to determine the effect size based on established formulas (Borenstein et al., 2009; Lipsey & Wilson, 2001). An effect size <0.5 was interpreted as small, 0.5-0.8 as medium, and >0.8 as large (Cohen, 1988).

Potential mediation and moderation effects of psychosocial factors were examined using hierarchical regression models. According to Kraemer et al. (2002), the mediators are post-treatment measures, while the moderators are pre-treatment measures. For the former, the change score of each psychosocial factor (i.e. self-efficacy, social support from friends, social support from family, and enjoyment) from baseline to 8 weeks was added to the regression models (described above for estimating the treatment effects on PA outcomes) plus the interaction term with the group variable to estimate its mediation effect (they were entered into the previously described model together as step 2). If the main effect or the interaction effect of one factor was significant in the regression model, it was considered as a mediator of the treatment effect. Similarly, the baseline measure of each psychosocial factor was added to the regression models as a potential moderator, plus its interaction term. If the interaction effect of one factor was significant in the regression model, it was considered as a moderator of the treatment effect.

5.3 RESULTS

A total of 95 children volunteered to participate in the study, of which eight children were screened out based on the inclusion criteria. For the 87 participants, 30 children (6 girls) participated in the AVG group, and 57 children (27 girls) in the control group. A flow chart of participants through the study is presented in Figure 5. One girl in the intervention group dropped out because of time constraints with extracurricular academic activities outside of school.
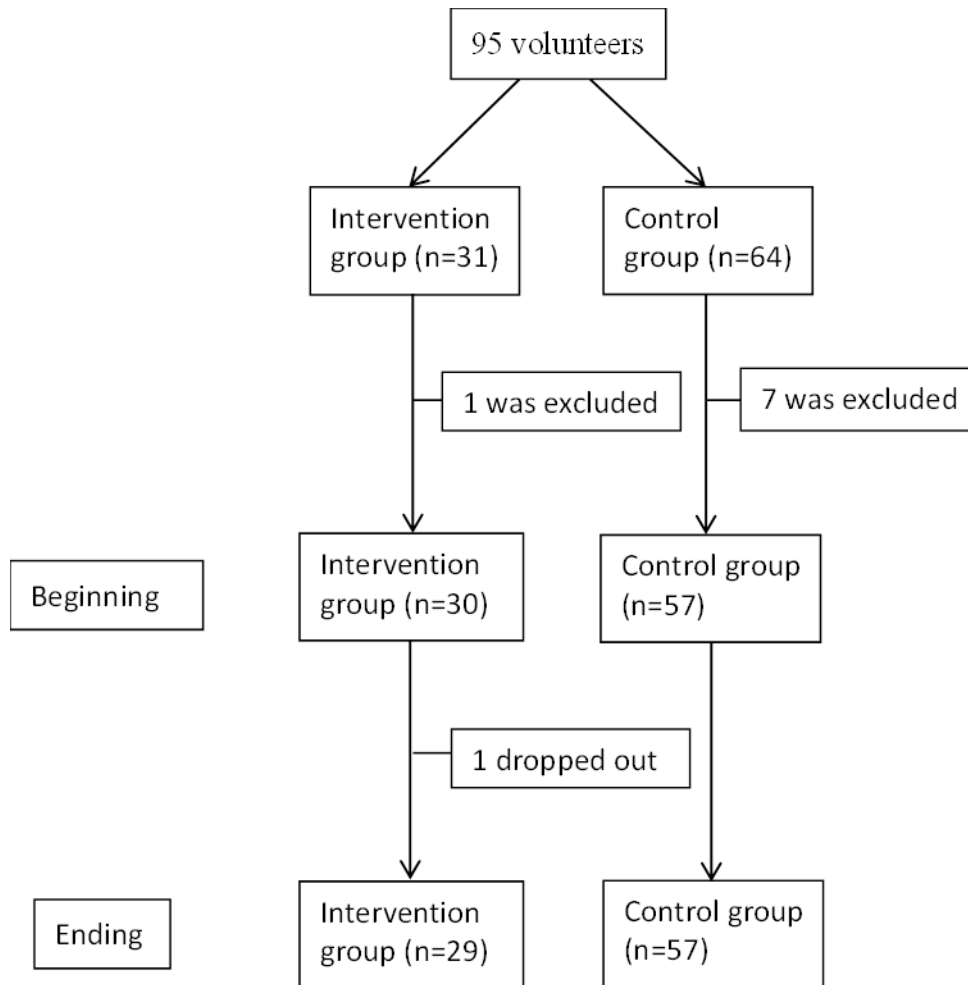
*Figure 5.*Flow chart of participants through the study

Baseline characteristics of all participants are presented in Table 11. No group differences were found at baseline, except that more boys were in the intervention group than in the control group (80% vs. 53%, p = 0.02). Complete PA data sets were available for 23 intervention children (4 girls) and 35 control children (12 girls) for estimating the 8-week intervention effect. Baseline characteristics are presented in Table 12 by gender. With the observed differences in PA variables between boys and girls, additional sub-analyses were conducted for boys (n=54) to evaluate the consistency of main findings obtained from all participants.

Table 11. BASELINE AND FOLLOW UP CHARACTERISTICS OF ALL PARTICIPANTS (N=87)

	Baseline		8 weeks		15 weeks	
	Intervention(n=30)	Control (n=57)	Intervention(n=29)	Control(n=50)	Intervention(n=28)	Control(n=47)
Demographics						
Age	10.45(0.73)	10.44(0.78)				
Male (n[%])	24(80)	30(53)				
Anthropometrics						
zBMI	0.45 (1.36)	0.42(1.18)	0.42(1.30)	0.36(1.19)	0.49(1.31)	0.39(1.20)
BMI (kg/m^2)	18.42(3.96)	18.18(3.28)	18.35(3.72)	18.02(3.11)	18.64(3.85)	18.23(3.15)
Height (cm)	138.43(6.99)	141.20(7.09)	139.65(6.81)	140.67(6.00)	140.96(7.34)	142.16(6.78)
Weight (kg)	35.58(9.12)	36.73(9.44)	36.08(9.04)	36.00(8.36)	37.36(9.52)	37.25(8.91)
Percentage body fat(%)	21.07(8.51)	19.84(6.76)	19.81(7.45)	19.45(6.89)	21.03(9.15)	19.69(6.94)
Waking time accelerometer data						
Wearing time(min/day)	764.48(92.27)	761.63(84.28)	734.45(104.02)	732.53(96.59)	672.40(94.33)	708.99(92.00)
MVPA(min/day)	21.38(9.37)	20.33(9.64)	21.96(11.33)	18.89(10.18)	21.78(12.64)	17.47(9.66)
MPA(min/day)	18.02(7.60)	17.56(7.84)	18.63(8.95)	15.99(8.04)	18.62(11.01)	15.12(8.15)
VPA(min/day)	3.36(2.43)	2.77(2.25)	3.32(3.17)	2.90(2.55)	3.16(2.83)	2.35(2.10)
LPA(min/day)	276.54(82.59)	261.49(68.48)	268.84(96.60)	242.29(72.16)	227.53(89.58)	225.49(90.28)
Sedentary time (min/day)	466.56(71.11)	479.80(70.97)	443.65(72.46)	471.35(65.81)	423.09(80.85)	466.03(81.72)
VACPM	318.25(76.55)	297.48(79.23)	337.17(102.61)	284.38(80.40)	322.82(112.83)	277.35(104.03)

VMCPM	762.66(195.42)	709.32(180.94)	791.45(232.85)	681.47(176.71)	743.72(271.25)	670.87(255.56)
After-school time accelerometer data						
Wearing time(min/day)	303.98(86.93)	299.18(90.48)	271.38(82.98)	275.73(82.30)	227.55(89.44)	259.56(95.54)
MVPA(min/day)	8.66(5.70)	9.35(6.75)	8.79(5.64)	7.08(6.70)	9.36(9.38)	7.25(5.28)
MPA(min/day)	7.18(4.90)	7.98(5.57)	7.20(4.72)	6.09(5.81)	8.07(8.33)	6.43(4.70)
VPA(min/day)	1.48(1.42)	1.36(1.47)	1.59(1.70)	0.99(1.19)	1.28(1.75)	0.82(1.21)
LPA(min/day)	110.67(58.12)	105.28(45.52)	101.37(60.16)	80.98(47.84)	73.33(45.44)	82.15(48.31)
Sedentary time(min/day)	184.66(42.07)	184.55(54.52)	161.22(41.26)	187.67(49.33)	144.87(51.40)	170.16(61.18)
VACPM	302.74(111.41)	334.30(120.84)	352.95(141.55)	260.69(144.77)	333.99(176.93)	302.06(125.26)
VMCPM	683.76(248.29)	733.38(230.33)	763.99(295.18)	567.06(270.63)	686.05(356.61)	650.13(248.64)
Psychosocial factors						
Self-efficacy	3.70(0.75)	3.66(0.82)	3.28(0.97)	3.63(1.00)	3.76(1.10)	3.46(0.89)
Social support from friends	2.11(1.08)	2.27(1.06)	2.16(1.16)	2.35(1.28)	2.20(1.12)	2.32(1.04)
Social support from family	2.61(1.12)	2.78(1.03)	2.69(1.21)	2.53(1.20)	2.11(1.04)	2.65(1.17)
Enjoyment	1.89(0.97)	1.62(0.78)	2.31(1.18)	1.95(1.05)	1.96(1.11)	1.86(0.87)

Note. Mean (standard deviation) are reported, unless otherwise stated.

BMI, body mass index; cm, centimeter; kg, kilogram; LPA, light physical activity; m, meter; min, minute; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; n, number; PA, physical activity; VACPM, vertical axial counts per minute; VMCPM, vector magnitude count per minute; VPA, vigorous physical activity; zBMI, standardized body mass index.

Table 12. BASELINE CHARACTERISTICS OF ALL PARTICIPANTS BY GENDER

	Boys	Girls
Demographics	n=54	n=33
Age	10.52(0.72)	10.33(0.82)
Anthropometrics	n=53	n=32
zBMI	0.53 (1.18)	0.27(1.33)
BMI (kg/m^2)	18.49(3.51)	17.91(3.53)
Height (cm)	139.88(6.50)	140.87(8.16)
Weight (kg)	36.50(8.79)	36.07(10.20)
Percentage body fat(%)	20.73(7.00)	19.62(8.06)
Waking time accelerometer data	n=49	n=30
Wearing time(min/day)	766.49(88.67)	756.25(83.97)
MVPA(min/day)	22.52(10.37)	17.70(7.06)
MPA(min/day)	19.22(8.38)	15.26(5.81)
VPA(min/day)	3.30(2.50)	2.44(1.88)
LPA(min/day)	277.85(80.32)	248.32(57.15)
Sedentary time (min/day)	466.12(71.03)	490.24(69.09)
VACPM	319.01(86.02)	281.01(58.16)
VMCPM	763.88(202.59)	668.22(140.56)
After-school time accelerometer data	n=51	n=32
Wearing time(min/day)	315.47(88.43)	277.56(85.50)
MVPA(min/day)	10.70(7.14)	6.57(3.81)
MPA(min/day)	8.98(5.90)	5.67(3.48)
VPA(min/day)	1.72(1.62)	0.90(0.92)
LPA(min/day)	115.54(52.41)	93.81(43.38)
Sedentary time(min/day)	189.23(48.72)	177.18(52.54)
VACPM	341.90(124.53)	293.59(101.45)
VMCPM	756.99(243.76)	650.79(211.88)
Psychosocial factors	n=53	n=33
Self-efficacy	3.79(0.81)	3.48(0.73)
Social support from friends	2.14(1.05)	2.34(1.07)
Social support from family	2.70(1.13)	2.75(0.95)
Enjoyment	1.65(0.74)	1.82(1.02)

Note. Mean (standard deviation) are reported

BMI, body mass index; cm, centimeter; kg, kilogram; LPA, light physical activity; m, meter; min, minute; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; n, number; PA, physical activity; VACPM, vertical axial counts per minute; VMCPM, vector magnitude count per minute; VPA, vigorous physical activity; zBMI, standardized body mass index.

5.3.1 PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR (8 WEEKS)

Linear model which predicted the primary outcome was summarized in Table 13. The mean changes from baseline to 8 weeks in daily time spent in MVPA were 1.21 min and -2.43 min in the intervention and control groups respectively (Table 14), with a group difference of 3.63 min (unstandardized regression coefficient for the group variable), 95% BCa CI for this group difference was -0.62 to 7.78, p=0.12. Because there were multiple outcomes in this study, and only the unstandardized regression coefficients for the group variable in the linear models (group differences adjusted for covariates) represented the treatment effects (reported in Table 14 and Table 15), no other regression coefficients were further reported.

Table 13. LINEAR MODEL OF PREDICTORS OF PRIMARY OUTCOME

	B	SE B	β	p
(Constant)	-7.40 (-47.18, 30.96)	19.19		.71
Age	-.01 (-3.10, 3.25)	1.69	.00	1.00
Male	.39 (-4.32, 4.80)	2.29	.02	.88
average daily wearing time at 8 weeks	.01 (-0.01, 0.03)	.01	.17	.24
baseline MVPA	-.24 (-0.51, 0.07)	.14	-.30	.12
zBMI	-.08 (-1.57, 1.39)	.83	-.013	.93
Group	3.63 (-0.62, 7.78)	2.26	.23	.12

Note. R^2=0.15, p>0.05.
The bias corrected and accelerated bootstrapped 95% confidence intervals are reported in parentheses, confidence interval and standard errors based on 1000 bootstrap samples. For the group variable, the AVG intervention group was coded as 1, and the control group was coded as 0.
β, standardized regression coefficient; B, unstandardized regression coefficient ; MVPA, moderate-to-vigorous physical activity; SE B, standard error of unstandardized regression coefficient; zBMI, standardized body mass index.

Group differences towards statistical significance were observed for the change in average daily time spent in MPA (3.41min, 95% BCa CI -0.26 to 7.28; p=0.06), and sedentary activities (-33.94 min, 95% BCa CI -70.76 to 4.80; p=0.07) favoring the intervention group but not for VPA. Significant differences were found for the change in LPA (34.91 min, 95% BCa CI 8.69 to 58.21; p=0.01), VACPM (53.74, 95% BCa CI 8.64 to 104.15; p=0.04), and VMCPM (116.67, 95% BCa CI 21.00 to 221.21; p=0.04), in favor of the intervention group.

During after-school time, the group difference in change in MVPA from baseline was 3.01 min (95% BCa CI 0.23 to 5.92; p=0.07) in favour of the intervention group. Similar trend was obtained for MPA (2.41min, 95% BCa CI -0.24 to 5.10; p=0.08), but not for VPA. A significant treatment effect occurred on after-school LPA (24.98min, 95% BCa CI 13.66 to 34.50; p<0.01), sedentary behavior (-23.48 min, 95% BCa CI -41.65 to -5.44; p=0.01), VACPM (109.39, 95% BCa CI 36.38 to 178.78; p=0.01), and VMCPM (234.16, 95% BCa CI 101.52 to 358.76; p=0.01), all favoring the intervention group.

5.3.2 PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR (15 WEEKS)

At 15 weeks, no significant group differences were found in objectively measured PA or sedentary behavior during waking hours (Table 15).

5.3.3 BODY COMPOSITION

No significant group differences were found in zBMI, or percentage body fat at any time (Table 14, Table 15).

Table 14. ESTIMATED TREATMENT EFFECTS AT 8 WEEKS

| | I, mean (SD) | | C, mean (SD) | | Change from baseline outcome | | | | |
	Baseline	8 weeks	Baseline	8 weeks	I, mean (SE)	C, mean (SE)	I-C difference (95% CI)	P value	Effect Size (Hedge's g)
Waking time PA and sedentary behaviour (I n=23, C n=35**)**									
MVPA (min/day)	21.29(9.56)	22.61(11.87)	21.39(10.37)	18.89(10.18)	1.21(1.59)	-2.43(1.28)	3.63 (-0.62,7.78)	0.12	0.33
MPA (min/day)	17.97(7.89)	19.17(9.36)	18.38(8.46)	15.99(8.04)	1.09(1.29)	-2.32(1.04)	3.41 (-0.26,7.28)	0.06	0.39
VPA (min/day)	3.32(2.31)	3.44(3.35)	3.01(2.33)	2.90(2.55)	0.07(0.50)	-0.08(0.40)	0.16 (-1.11,1.64)	0.86	0.06
LPA (min/day)	272.43(86.29)	278.11(93.67)	275.56(64.95)	242.29(72.16)	3.24(9.49)	-31.67(7.66)	34.91 (8.69,58.21)	0.01	0.42
Sedentary time (min/day)	465.31(71.86)	439.54(76.15)	470.43(73.60)	471.35(65.80)	-30.14(12.40)	3.80(10.01)	-33.94 (-70.76,4.80)	0.07	-0.47
VACPM	318.61(80.25)	346.34(105.29)	309.56(79.93)	284.38(80.40)	28.23(16.60)	-25.51(13.40)	53.74 (8.64,104.15)	0.04	0.58
VMCPM	764.70(207.56)	814.26(235.84)	755.63(173.36)	681.47(176.70)	45.30(34.64)	-71.37(27.96)	116.67 (21.00,221.21)	0.04	0.57

After-school time PA and sedentary behaviour (I n=25, C n=38)

MVPA(min/day)	8.37(5.66)	8.82(5.84)	10.45(7.40)	7.08(6.70)	-0.04(1.13)	-3.05(0.91)	3.01 (0.23, 5.92)	).07	0.46
MPA(min/day)	7.02(5.07)	7.39(4.93)	8.91(5.99)	6.09(5.81)	-0.10(1.00)	-2.51(0.80)	2.41 (-0.24,5.10)	).08	0.44
VPA(min/day)	1.35(1.17)	1.43(1.44)	1.54(1.60)	0.99(1.19)	0.003(0.24)	-0.50(0.19)	0.50 (-0.15,1.22)	0.16	0.34
LPA(min/day)	107.83(60.08)	101.61(60.65)	113.32(45.60)	80.98(47.84)	-7.16(4.69)	-31.72(3.79)	24.98 (13.66,34.50)	0.001	0.45
Sedentary time (min/day)	182.77(44.82)	164.85(40.32)	190.23(54.03)	187.67(49.33)	-22.82(6.31)	0.66(5.11)	-23.48 (-41.65, -5.44)	0.01	-0.50
VACPM	297.36(114.10)	349.68(144.75)	344.81(132.61)	260.69(144.77)	36.01(28.38)	-73.38(22.84)	109.39 (36.38,178.78)	0.01	0.75
VMCPM	673.95(260.81)	763.92(303.56)	762.55(248.24)	567.06(270.63)	59.02(51.41)	-175.14(41.41)	234.16 (101.52,358.76)	0.01	0.82
Body composition									
zBMI (I n=26, C n=46)	0.38(1.40)	0.38(1.31)	0.31(1.19)	0.36(1.19)	0.00(0.04)	0.04(0.03)	-0.04 (-0.14,0.06)	0.42	
Percentage body fat(%) (I n=26, C n=39)	20.64(8.45)	19.59(7.51)	19.74(6.60)	19.14(6.65)	-0.91(0.41)	-0.69(0.33)	-0.22 (-1.45,0.90)	0.71	

Psychosocial factors

Self-efficacy (I n=28, C n=49)	3.69(0.77)	3.28(0.99)	3.73(0.82)	3.62(1.00)	-0.43(0.17)	-0.09(0.13)	-0.34 (-0.81,0.14)	0.17
SSFR (I n=27, C n=49)	1.95(0.98)	2.17(1.18)	2.24(1.07)	2.31(1.27)	0.09(0.20)	0.15(0.15)	-0.06 (-0.60,0.55)	0.85
SSFA (I n=28, C n=49)	2.55(1.13)	2.69(1.23)	2.76(1.08)	2.50(1.19)	0.08(0.21)	-0.23(0.16)	0.31 (-0.28, 0.86)	0.31
Enjoyment (I n=27, C n=49)	1.82(0.91)	2.36(1.18)	1.59(0.80)	1.95(1.06)	0.59(0.22)	0.34(0.16)	0.26 (-0.34, 0.80)	0.39

Note. Outcome values at baseline and 8 weeks of the participants who were included in the analyses are reported. Mean (SE) of change from baseline outcome are reported, with adjusted group difference, 95% CI and associated p-value based on 1000 bootstrap samples, and estimated effect size. C, control group; CI, confidence interval; cm, centimeter; I, intervention group; kg, kilogram; LPA, light physical activity; m, meter; min, minute; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; PA, physical activity; SD, stand deviation; SE, stand error; SSFA, social support from family; SSFR, social support from friends; VACPM, vertical axial counts per minute; VMCPM, vector magnitude count per minute; VPA, vigorous physical activity; zBMI, standardized body mass index.

Table 15. ESTIMATED TREATMENT EFFECTS AT 15 WEEKS

| | I, mean (SD) | | C, mean (SD) | | Change from baseline outcome | | | |
| | | | | | I, mean (SE) | C, mean (SE) | I-C difference (95% CI) | P value |
	Baseline	15 weeks	Baseline	15 weeks				
Waking time PA and sedentary behaviour (I n=17, C n=26**)**								
MVPA (min/day)	19.28(9.58)	21.05(12.51)	19.86(9.41)	17.47(9.66)	1.50(2.28)	-2.22(1.81)	3.72 (-3.25,12.21)	0.27
MPA (min/day)	16.87(8.18)	17.87(10.94)	17.43(8.10)	15.12(8.15)	0.88(2.03)	-2.23(1.62)	3.11 (-2.90,10.36)	0.33
VPA (min/day)	2.41(1.85)	3.18(2.86)	2.43(1.76)	2.35(2.10)	0.62(0.52)	0.02(0.41)	0.60 (-0.79,2.10)	0.41
LPA (min/day)	273.26(95.59)	240.15(81.08)	255.18(68.01)	225.49(90.28)	-18.98(16.36)	-38.93(12.99)	19.95 (-23.22, 58.34)	0.31
Sedentary time (min/day)	471.90(62.30)	413.99(80.78)	488.60(64.84)	466.03(81.72)	-56.89(19.05)	-23.23(15.18)	-33.66 (-78.36, 14.43)	0.17
VACPM	302.07(79.44)	329.70(113.20)	287.07(76.33)	277.35(104.03)	29.90(24.02)	-11.21(19.12)	41.11 (-27.12, 114.36)	0.27
VMCPM	729.52(210.23)	772.05(266.54)	695.04(177.39)	670.87(255.56)	38.89(55.74)	-21.80(44.37)	60.69 (-93.03, 228.19)	0.43

After-school time PA and sedentary behaviour (I n=23, C n=32)

MVPA(min/day)	7.91(5.16)	9.30(9.33)	11.07(6.47)	7.25(5.28)	0.25(1.32)	-3.00(1.10)	3.25 (-0.97, 8.07)	0.14
MPA(min/day)	6.73(4.80)	7.99(8.34)	9.49(5.27)	6.43(4.70)	0.34(1.21)	-2.40(1.02)	2.73 (-1.16, 7.64)	0.21
VPA(min/day)	1.18(1.03)	1.31(1.78)	1.58(1.44)	0.82(1.21)	-0.03(0.29)	-0.65(0.24)	0.62 (-0.12, 1.32)	0.13
LPA(min/day)	108.72(57.07)	77.77(46.64)	109.58(42.11)	82.15(48.31)	-25.78(5.42)	-31.15(4.57)	5.37 (-8.06, 19.14)	0.46
Sedentary time (min/day)	185.68(40.14)	145.01(53.38)	194.09(42.16)	170.16(61.18)	-35.73(6.15)	-27.48(5.19)	-8.24 (-25.80, 8.55)	0.35
VACPM	296.97(105.26)	339.29(174.11)	351.02(114.96)	302.06(125.26)	18.96(29.07)	-32.17(24.38)	51.14 (-38.41, 145.50)	0.28
VMCPM	676.79(242.09)	709.86(354.28)	753.35(208.03)	650.13(248.64)	-3.84(56.54)	-76.69(47.57)	72.85 (-89.31, 218.80)	0.42
Body composition								
zBMI (I n=27, C n=47)	0.44(1.41)	0.46(1.33)	0.30(1.18)	0.40(1.20)	0.02(0.05)	0.10(0.04)	-0.07(-0.18, 0.03)	0.26
Percentage body fat(%) (I n=27, C n=42)	21.16(8.82)	20.62(9.06)	18.90(6.46)	19.75(6.86)	-0.55(0.73)	0.85(0.57)	-1.40 (-3.58, 0.48)	0.17

Psychosocial factors

Self-efficacy (I n=23, C n=41)	3.71(0.74)	3.76(1.12)	3.69(0.86)	3.52(0.81)	0.06(0.19)	-0.08(0.17)	0.23 (-0.26, 0.67)	0.40
SSFR (I n=23, C n=40)	2.10(1.05)	2.22(1.14)	2.25(1.07)	2.29(1.03)	0.03(0.21)	0.10(0.16)	-0.08 (-0.66, 0.42)	0.78
SSFA (I n=23, C n=40)	2.59(1.11)	2.09(1.05)	2.74(1.10)	2.63(1.17)	-0.53(0.21)	-0.10(0.16)	-0.43 (-0.94, 0.08)	0.11
Enjoyment (I n=23, C n=40)	1.86(0.85)	1.98(1.13)	1.64(0.86)	1.86(0.88)	0.23(0.21)	0.16(0.15)	0.07 (-0.53, 0.69)	0.79

Note. Outcome values at baseline and 8 weeks of the participants who were included in the analyses are reported. Mean (SE) of change from baseline outcome are reported, with adjusted group difference, 95% CI and associated p-value based on 1000 bootstrap samples, and estimated effect size. C, control group; CI, confidence interval; cm, centimeter; I, intervention group; kg, kilogram; LPA, light physical activity; m, meter; min, minute; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; PA, physical activity; SD, stand deviation; SE, stand error; SSFA, social support from family; SSFR, social support from friends; VACPM, vertical axial counts per minute; VMCPM, vector magnitude count per minute; VPA, vigorous physical activity; zBMI, standardized body mass index.

Table 16. ESTIMATED TREATMENT EFFECTS AMONG BOYS AT 8 WEEKS

Change from baseline outcome	Intervention group	Control group	Group difference	Lower 95% CI	Upper 95% CI	P value
Waking time PA and sedentary behavior						
MVPA (min/day)	1.09(1.88)	-2.78(1.71)	3.87	-0.85	9.15	0.18
MPA (min/day)	0.59(1.48)	-2.62(1.34)	3.22	-0.95	7.63	0.13
VPA (min/day)	0.42(0.61)	-0.09(0.56)	0.52	-1.18	2.38	0.58
LPA (min/day)	4.74(9.89)	-35.66(8.98)	40.40	13.32	64.40	0.01
Sedentary time (min/day)	-30.14(12.91)	11.23(11.73)	-41.37	-79.76	0.06	0.04
VACPM	36.28(19.06)	-31.79(17.31)	68.07	21.47	117.85	0.02
VMCPM	70.22(39.27)	-76.63(35.63)	146.85	46.11	242.11	0.02
After-school time PA and sedentary behavior						
MVPA(min/day)	-1.64(1.31)	-3.84(1.15)	2.20	-1.54	6.20	0.26
MPA(min/day)	-1.55(1.14)	-3.17(0.99)	1.63	-1.51	4.77	0.31
VPA(min/day)	-0.15(0.30)	-0.62(0.26)	0.47	-0.31	1.46	0.27
LPA(min/day)	-10.49(5.23)	-36.31(4.59)	25.83	12.33	37.71	0.003
Sedentary time (min/day)	-24.49(6.91)	1.44(6.06)	-25.93	-47.31	-4.35	0.01
VACPM	13.87(34.56)	-90.48(30.18)	104.35	10.96	194.81	0.03
VMCPM	18.03(62.02)	-202.11(54.18)	220.14	45.01	392.17	0.02

Body composition

zBMI	-0.03(0.03)	0.06(0.03)	-0.10	-0.18	-0.01	0.04
Percentage body fat(%)	-1.29(0.70)	-0.10(0.70)	-1.18	-2.88	0.52	0.23
Psychosocial factors						
Self-efficacy	-0.44(0.19)	-0.08(0.17)	-0.36	-0.90	0.21	0.19
Social support from friends	0.19(0.25)	0.35(0.22)	-0.16	-0.77	0.61	0.60
Social support from family	0.11(0.25)	-0.29(0.23)	0.40	-0.23	1.06	0.25
Enjoyment	0.69(0.27)	0.53(0.24)	0.16	-0.52	0.79	0.67

Note. Mean (standard error),) are reported, with adjusted group difference, 95% confidence interval and associated p-value based on 1000 bootstrap samples.
cm, centimeter; kg, kilogram; LPA, light physical activity; m, meter; min, minute; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; PA, physical activity; VACPM, vertical axial counts per minute; VMCPM, vector magnitude count per minute; VPA, vigorous physical activity; zBMI, standardized body mass index.

Table 17. ESTIMATED TREATMENT EFFECTS AMONG BOYS AT 15 WEEKS

Change from baseline outcome	Intervention group	Control group	Group difference	Lower 95% CI	Upper 95% CI	P value
Waking time PA and sedentary behavior						
MVPA(min/day)	2.09(2.64)	-1.31(2.56)	3.40	-5.48	14.27	0.44
MPA(min/day)	1.05(2.36)	-1.61(2.28)	2.66	-5.56	12.56	0.52
VPA (min/day)	1.03(0.62)	0.31(0.60)	0.71	-1.17	3.07	0.44
LPA time(min/day)	-20.11(17.74)	-29.08(17.15)	8.97	-36.42	58.02	0.68
Sedentary time (min/day)	-49.28(21.25)	-33.31(20.54)	-15.98	-88.31	49.23	0.60
VACPM	32.92(27.42)	6.49(26.52)	26.43	-55.84	120.40	0.55
VMCPM	52.46(62.20)	30.38(60.15)	22.08	-154.10	226.82	0.83
After-school time PA and sedentary behavior						
MVPA(min/day)	-0.50(1.59)	-2.72(1.51)	2.23	-2.35	8.13	0.37
MPA(min/day)	-0.34(1.48)	-2.21(1.41)	1.86	-2.57	7.23	0.48
VPA (min/day)	-0.09(0.35)	-0.57(0.33)	0.48	-0.45	1.71	0.30
LPA(min/day)	-32.90(6.07)	-29.90(5.77)	-3.00	-19.40	16.16	0.71
Sedentary time (min/day)	-40.41(6.81)	-42.30(6.47)	1.89	-15.33	16.75	0.86
VACPM	29.92(34.35)	0.53(32.57)	29.39	-80.82	136.61	0.57
VMCPM	14.31(67.13)	-0.44(63.70)	14.76	-190.52	233.34	0.88
Body composition						
zBMI	-0.02(0.05)	0.13(0.04)	-0.15	-0.27	-0.02	0.02
Percentage body fat(%)	-0.66(0.92)	1.30(0.94)	-1.96	-5.04	0.56	0.16

Psychosocial factors

Self-efficacy	0.03(0.21)	-0.24(0.20)	0.27	-0.33	0.75	0.36
Social support from friends	0.07(0.22)	0.27(0.21)	-0.20	-0.81	0.40	0.56
Social support from family	-0.63(0.23)	-0.12(0.22)	-0.51	-1.15	0.03	0.12
Enjoyment	0.05(0.23)	0.25(0.22)	-0.20	-0.84	0.48	0.56

Note. Mean(standard error) are reported, with adjusted group difference, 95% confidence interval and associated p-value based on 1000 bootstrap samples. cm, centimeter; kg, kilogram; LPA, light physical activity; m, meter; min, minute; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; PA, physical activity; VACPM, vertical axial counts per minute; VMCPM, vector magnitude count per minute; VPA, vigorous physical activity; zBMI, standardized body mass index.

5.3.4 PSYCHOSOCIAL FACTORS

No significant group differences were found in any of the measured PA-related psychosocial factors, specifically in self-efficacy, social support from friends, social support from family, and enjoyment, at any time (Table 14, Table 15).

5.3.5 MEDIATING AND MODERATING ANALYSES

Changes of VACPM, VMCPM, daily MVPA from baseline to 8 weeks were used as the dependant variables in respective regression models to examine the mediation and moderation effects. None of the PA-related psychosocial factors met the criteria for mediators or moderators as mentioned in statistical analyses (Section 5.2.8). The same dependant variables during after-school time were also used to test regression models, neither mediation nor moderation effects of PA-related psychosocial factors were noted as well.

5.3.6 PROCESS EVALUATION

Average attendance (90.98%) in the 8-week AVG intervention was high. However, it decreased to 84.83% at 9-15 weeks. At 8 weeks, 38% of the validated days to estimate the PA of intervention participants during waking hours were with intervention sessions, and 35% of the validated days to estimate the PA of intervention participants during after-school hours were with intervention sessions. At 15 weeks, the proportion became 22% and 21% for the waking hours and after-school hours, respectively. These data were consistent with the frequency of the AVG classes. The intervention participants rated the AVG class just above the middle point (3.6).

5.3.7 ADDITIONAL ANALYSES FOR MALE PARTICIPANTS

Among the male participants, no group differences were noted at baseline. Treatment effects at 8 weeks and 15 weeks are reported in Table 16 and Table 17 respectively. In general, these results were similar with those obtained from all the participants. However, significant treatment effects were found on BMI z score among boys both at 8 weeks (-0.10, 95% BCa CI -0.18 to -0.01; p=0.04) and 15 weeks (-0.15, 95% BCa CI -0.27 to -0.02; p=0.02).

5.4 DISCUSSION

This study aimed to determine the effects of a school-based AVG intervention on PA, sedentary time, body composition, and psychosocial factors (self-efficacy, social support, and enjoyment) among Hong Kong children. It also examined the possible mediation and moderation effects of the psychosocial factors within the intervention.

5.4.1 TREATMENT EFFECTS ON PA AND SEDENTARY BEHAVIORS

The current intervention delivered during after-school hours increased overall PA levels and decreased sedentary behavior at week 8 compared with a control group; however this treatment effect was not maintained at 15 weeks. Collectively, these findings suggest that playing AVGs once per week (from weeks 9-15) was not sufficient to influence habitual PA.

This study is one of the few intervention studies that present the treatment effects of AVGs on habitual PA compared with a non-AVG control group. Two similar quasi-experiment studies (Gao et al., 2012; Gao & Xiang, 2014) determined that the intervention children who played DDR three times a week (each session lasted 30 min) during recesses over nine months reported more PA than the control children. Moreover, a cluster RCT study (Lwin & Malik, 2012) reported a positive treatment effect on self-reported PA at the end of the six-week intervention, which incorporated Wii boxing, Wii tennis and DDR into PE lessons compared with a control group engaging in the usual PE lessons. These consistent findings of the structured AVG play on habitual PA support the further use of this strategy to promote PA among children. Self-report measures used in the aforementioned three studies are subject to numerous limitations particularly associated with recall bias and social desirability bias (Warren et al., 2010). Therefore, the present intervention enhanced the evidence strength with an objective measure of PA.

In addition, the after-school setting may be important to induce the positive treatment effect on PA in the first eight weeks. After-school hours are crucial to target PA and sedentary behavior among children, because during this time children engage in a considerable proportion of leisure time activity freed from

the constraints of school and parental curfews that may restrict behavior in the evening (Atkin, Gorely, Biddle, Cavill, & Foster, 2011). The current AVG intervention delivered in the after-school hours may replace the sedentary behaviors usually performed by participants during the intervention periods. Another AVG intervention study (Staiano et al., 2013) delivered in after-school time also found positive treatment effects on PA related outcomes (self-efficacy and weight loss) among children. However, this study (Staiano et al., 2013) did not measure PA and sedentary behavior.

In other circumstances, the effects of AVGs on PA warrant careful examination. Evidence suggests that AVGs may not be as intensive as the usual activities during recesses (Duncan & Staples, 2010) and PE lessons (Sun, 2012) using objective measures of PA, despite the aforementioned three intervention studies delivered in recesses (Gao et al., 2012; Gao & Xiang, 2014) and PE lessons (Lwin & Malik, 2012) reported positive treatment effects on self-reported PA.

The console used in the intervention (Xbox Kinect) may also play an important role to induce positive effect. As previously introduced, this console allows users to control and interact with AVGs without a game controller or any other peripheral equipment. Holding a controller may act as a "reality check" and prevent players absorb in the game (Wood, Griffiths, Chappell, & Davies, 2004). Therefore, the used console may help keep the interest of participants to engage in the AVG play during the intervention sessions. Trost et al. (2014) used the same console in their trial, and demonstrated a positive treatment effect of AVG play at home on objectively measured habitual PA. This finding was not consistent with other AVG interventions in the home setting (Baranowski et al., 2012; Graves, et al., 2010a; Maddison et al., 2011; Maloney et al., 2008; Maloney et al., 2012b; Mhurchu et al., 2008), which found no effects of AVG play at home on habitual PA among children. The unique feature of Xbox Kinect may have generated this contradictory result.

5.4.2 TREATMENT EFFECT ON BODY COMPOSITION

Across 8 and 15 weeks, the null effects of the AVG intervention on zBMI and percentage body fat were noted, despite the consistent trend effects in these

outcomes favoring the intervention group. These findings are consistent with a nine-month school-based intervention conducted in 185 American primary school children (Gao & Xiang, 2014). However, the present study was not long enough and sufficiently powered to determine the treatment effect on body composition. By contrast, Staiano et al. (2013) observed that the structured AVG play as a single component could produce body weight loss among overweight/obese adolescents over 20 weeks. In the home setting, Maddison et al. (2011) determined a small effect of home-based AVG play over 24 weeks on BMI and body composition among overweight/obese children. Trost et al. (2014) found that integrating AVGs into a family-based weight management program over 16 weeks had a positive effect on body composition among overweight/obese children. These three studies among overweight/obese children suggest that the baseline weight status may moderate the effects of AVG interventions on body composition. A significant treatment effect on BMI was found among male participants (zBMI was greater in boys than girls in the current study, see Table 12), which also suggests that the heavier the participants, the greater treatment effect of AVG interventions on body composition.

5.4.3 TREATMENT EFFECTS ON PA-RELATED PSYCHOSOCIAL FACTORS

The null effects of this intervention on PA-related self-efficacy, social support, and enjoyment were noted. In contrast to the present study, two previous studies (Gao et al., 2012; Staiano et al., 2013) found favorable intervention effects of structured AVG play on self-efficacy; and one study (Gao et al., 2012) found a treatment effect on social support. In the present study, children played AVGs in a relatively small group (at most, four children per classroom). The group influence on psychosocial factors was possibly decreased. Children indicated that they enjoyed AVG play in a previous intervention study (Baranowski et al., 2012) and in two laboratory-based studies (Graves et al., 2010b; Penko & Barkley, 2010). However, the enjoyment of PA has not been examined in previous AVG studies. The lack of treatment effect on PA enjoyment in the present study suggests that the specific enjoyment of AVG paly cannot be transferred to the enjoyment of PA. Given that the baseline level of PA enjoyment was high among the participants, a ceiling effect may explain the null effect as well.

In general, commercial AVGs are not particularly designed to enhance the psychosocial factors related to PA. Other factors, such as group size, organizers, and play partners, may be important in the influence of structured AVG play on the PA-related psychosocial factors among children.

5.4.4 MEDIATING AND MODERATING ANALYSES

No mediation effects of the selected PA-related psychosocial factors (self-efficacy, social support, and enjoyment) were observed in the current intervention. These findings were mainly due to the lack of treatment effects on these PA-related variables. The mediating analyses in the present study supported that the treatment effect on PA was attributed to the direct effect of the structured AVG play.

Mediation effects of PA-related psychosocial factors were seldom examined in interventions among primary school children (Brown et al., 2013). It may because children are lack of behavior autonomy and cognitive ability in this age group. Thus, other factors may be important for the explanations of the treatment effects of AVG interventions on PA and other relevant outcomes. Maddison et al (2012) found that aerobic fitness mediated the treatment effect of a home-based AVG intervention on BMI. Fitness level is warranted to be examined in future AVG interventions.

Moderation effects of the selected psychosocial factors were examined as well, and null effects were noted. The small number of the participants who provided the complete PA data across assessments may limit the power of the moderating analyses. Furthermore, the heterogeneity in these psychosocial factors among participants may not be sufficient to examine the moderation effects.

5.4.5 STRENGTHS AND LIMITATIONS

Strengths of the study included the use of an objective measure of PA, the use of scales that have previously been validated among Hong Kong children to measure PA-related psychosocial variables, and the easy and available implementation of intervention for Hong Kong primary schools.

The major limitation of this study was related to the use of a preference approach for group allocation, which may have affected the internal validity of the study. Second, the lack of adherence with the accelerometer measurement limited the power to determine the treatment effect. In addition, schedules of PE lessons were not recorded for the participants. This fact made it impossible to exclude the influence of PE lessons on the treatment effect. Another limitation was that all of the participants were recruited from the same school, which may have introduced contamination between groups, limited external validity, and overestimated the treatment effect compared with a more heterogeneous sample. Finally, different models of accelerometers were used to measure PA in this study. While research comparing the GT3X and GT3X+ models have shown identical output (Robusto & Trost, 2012), no data comparing the wGT3X with older models exist. Given these limitations, the reported findings should be interpreted with caution.

5.4.6 IMPLICATIONS FOR FUTURE STUDIES

Further study with a more robust scientific study design and a larger sample size is warranted to determine the effect of school-based AVG interventions on habitual PA among children. Future interventions should consider the frequency of the structured AVG play to increase PA. Based on the current study, it is recommended that such activity should be done at least twice a week. A more prolonged AVG play may be needed to examine the treatment effect on body composition. Other strategies may be combined with structured AVG play to further increase PA levels among Hong Kong children.

5.5 CONCLUSION

A school-based AVG intervention delivered during after-school hours has positive effects on children's overall PA levels and sedentary behavior among Hong Kong children. AVGs are promising to be used to promote PA among children in places where outdoor space for PA engagement is limited.

CHAPTER 6. GENERAL DISCUSSION

Physical inactivity is associated with a plethora of negative health consequences among children, and may subsequently influence PA patterns and health in adulthood. A recent review found that more than 60% of the Hong Kong population of all ages were not active for 30 min/week or walk 8000 steps a day. Moreover, the physical fitness levels of Hong Kong people have declined in recent years (Fu, Guo, & Zang, 2012). Very few Hong Kong children are physically active according to a local survey (HKSAR Government Sports Commission, 2012). In particular, only 9% of primary school children met the recommended levels of PA (60 min of MVPA daily).

Interventions aimed at promoting the PA of children have produced a small effect (Metcalf et al., 2012). The lack of effectiveness may be due to a failure to understand the various factors associated with PA. For example, environmental factors unique to Hong Kong, including the dense population and high urbanization, suggest that specific strategies may be necessary for this population; however, few interventions have been developed to address this demand. AVGs may be a useful intervention strategy for Hong Kong children because AVG play does not require outdoor school space, and may positively influence PA-related psychosocial factors among children as illustrated in the thesis introduction (Chapter 1). However, no such interventions have been designed for Hong Kong children. This thesis sought to fill this research gap by exploring the potential of AVGs to increase PA and decrease sedentary behavior among Hong Kong primary school children.

In order to achieve the research aims, three interrelated studies were undertaken and reported in the current thesis. A systematic review (Chapter 3) was conducted to establish the effects of AVGs on PA-related psychosocial and behavioral outcomes. The purpose of this review was to determine the existing evidence regarding the effects of AVGs on PA outcomes, to identify opportunities for future interventions, and to identify potential AVGs and strategies that can be used in an AVG intervention developed for Hong Kong children. A validation study (Chapter

4) was conducted to test three translated scales (English to Cantonese Chinese) to measure PA-related self-efficacy, social support, and enjoyment among Hong Kong children. This study was to provide psychometric support for the use of the tested scales in an AVG intervention developed for Hong Kong children. Lastly, a quasi-experimental study (Chapter 5) was conducted to examine the effects of a school-based AVG intervention on PA, sedentary time, body composition, and PA-related psychosocial factors among Hong Kong children. It also examined potential mediators/moderators of the intervention effect on PA.

6.1 SUMMARY OF STUDIES

6.1.1 STUDY 1: EFFECTS OF AVGS ON PA AND RELATED OUTCOMES AMONG HEALTHY CHILDREN: A SYSTEMATIC REVIEW

In order to design an AVG intervention for Hong Kong children to improve PA, what was already known regarding the effects of AVGs on PA among children was required. Although AVG studies are still in their infancy, several reviews have been published (Barnett et al., 2011; Biddiss & Irwin, 2010; Daley, 2009; Foley & Maddison, 2010; LeBlanc et al., 2013; Peng et al., 2013; Peng et al., 2011). However, none of these reviews could particularly address the purpose of the current thesis. For example, none of the reviews had addressed the strategies used to enhance PA, which is essential for developing a new intervention. Peng et al. (2013) indicated that it was more promising to employ AVGs within structured exercise programs for group play; however, none of the previous reviews had evaluated the effects of AVGs in structured and non-structured play separately. Furthermore, evidence, in previous reviews, was derived from children with various health statuses in previous reviews. These issues were addressed in Study 1, a systematic review evaluating the effects of AVGs on PA-related psychosocial and behavioral outcomes among healthy children.

Fifty-four articles published between January 2000 and August 2013 were included in this review. Among these studies, 32 examined the immediate PA effects of AVGs (i.e. EE and PA levels during AVG play); one was a survey study examining the association between AVG play and habitual PA levels of children; and 21 intervention studies aimed to promote PA.

Studies that have examined the immediate PA effects of AVGs have suggested several games (see Table 4) to generate MVPA (suggested by child-specific METs ≥3). These games could be used in interventions to increase MVPA of children. Among these games, Xbox Kinect games had been released later than the other popular games played on Wii, PlayStation, and Xavix® (Shinsedai, San Diego, CA), and had not been used in interventions at the time this review study (Study 1) was completed. Xbox Kinect allows users to control and interact with AVGs without holding a game controller or stepping on any other peripheral equipment compared to other consoles. Therefore, examining the effects of Xbox Kinect games on activity levels among children is warranted.

Intervention studies to examine the effects of AVGs on habitual PA have been predominantly conducted in the home setting, based on the assumption that AVGs could replace sedentary leisure activities, such as video game playing, TV viewing, and computer use. Most of these studies have used RCT designs and measured PA objectively. No overall effect was found in the current review regarding AVGs on habitual PA in the home setting. Given the cost of AVG consoles and games, this review raises doubt about introducing AVGs to non-video-game-playing children for home use with the purpose to promote PA.

No high-quality studies have existed to assess the effects of AVGs on habitual PA in settings where structured AVG sessions could be implemented. In addition, no previous AVG studies have objectively measured habitual PA in these settings. Therefore, the effect of structured AVG play on the habitual PA of children remains unclear. This research gap was addressed in Study 3 (Chapter 5).

Few interventions (see Table 7) have examined both PA and PA-related psychosocial factors, and conducted mediating analyses. Such research may inform the potential mechanisms of structured AVGs on PA. This research gap was also addressed in Study 3.

None of the strategies used in AVG interventions have been sufficiently studied to reach a firm conclusion regarding the potential effects on PA. However, encouragement of non-solo play (Graves et al., 2010a; Maloney et al., 2008;

Maloney et al., 2012b; Paw et al., 2008) and cooperative play (i.e. pairs of participants were instructed to coordinate as a team; Staiano et al., 2013), and the provision of additional AVGs during an intervention (Baranowski et al., 2012; Maddison et al., 2011), have been suggested to be promising for use in future studies. These strategies were then used in Study 3 to develop an AVG intervention for Hong Kong children (see Chapter 5).

Based on this systematic review (identified research gaps and potential strategies used to promote PA), a school-based AVG intervention was designed for Hong Kong children.

6.1.2 STUDY 2: VALIDITY AND RELIABILITY OF QUESTIONNAIRES MEASURING PHYSICAL ACTIVITY SELF-EFFICACY, SOCIAL SUPPORT, AND ENJOYMENT AMONG HONG KONG CHINESE CHILDREN

It has been recommended to examine PA determinants in interventions to understand the intervention mechanisms by potential mediation effects (Baranowski et al., 1998). However, few instruments have been validated among Hong Kong children to measure PA-related psychosocial factors. Three social cognitive factors (self-efficacy, social support, and enjoyment) were selected to be studied in an AVG intervention among Hong Kong children. Study 2 validated three scales to measure the selected psychosocial factors. Three English scales, which had been previously validated or used with children, were selected and translated into Cantonese Chinese through a multistep approach.

Factorial validity, criterion validity, internal consistency, and test-retest reliability of the tested scales were established in a sample of 273 Hong Kong primary school children aged 9-12 years. The results provide psychometric support for using the scales to measure PA correlates among Hong Kong Chinese children.

The significant correlations of the studied psychosocial factors with PA of Hong Kong children highlight the importance of examining these variables in this population. PA enjoyment has not been studied among Hong Kong children, and the enjoyment scale enables further research to examine the influence of this factor on PA. Compared with existing scales to measure self-efficacy and social

support in Hong Kong children (Huang et al., 2011), the scales tested in the current study generated stronger correlations with self-reported PA. Given that Huang et al. (2011) focused on the environmental influences on PA, the current research provided alternative instruments with which to measure general PA self-efficacy, and social support for PA among Hong Kong children. The validation of self-efficacy, social support, and enjoyment scales is beneficial in PA epidemiology among children who speak Cantonese Chinese.

6.1.3 STUDY 3: GETTING ACTIVE WITH AVGS: A QUASI-EXPERIMENTAL STUDY

Based on Study 1 and Study 2, a school-based intervention was designed to examine the effects of an AVG intervention on PA, sedentary time, body composition, and psychosocial factors among Hong Kong children. It also aimed to examine the mediation and moderation effects of psychosocial factors within the intervention.

A total of 87 children (grades 4-6), who did not participate in extracurricular exercise activities and had no contraindications to being active, were allocated to either the intervention group or the control group based on personal preference (intervention n = 30; control n = 57). The intervention group played AVGs during after-school hours approximately twice a week in the first 8 weeks. The class frequency decreased to around once a week from week 9-15. In total, 13 sessions were scheduled in the first 8 weeks and 5 sessions were scheduled in the last 7 weeks. The control group continued with their usual activities.

The main findings from this intervention study were: (1) total PA was increased and sedentary time was decreased in the intervention group compared with the control group at week 8, (2) the treatment effect was not maintained at 15 weeks, (3) null effects of the AVG intervention on zBMI and percentage body fat were observed, (4) null effects of this intervention on PA-related self-efficacy, social support, and enjoyment were noted, (5) no mediation or moderation effects were found as a result of this intervention. These study findings support the use of AVGs to promote PA levels among Hong Kong children within structured exercise settings with sufficient AVG dosage.

6.2 STRENGTHS AND LIMITATIONS

The strengths and limitations of the three studies that have formed the current thesis have already been discussed in the respective chapters. This section will address the strengths and limitations of the current research as a whole.

Firstly, considering the lack of suitable outdoor space in which Hong Kong children can engage in PA, the current research is the first to develop an indoor PA program with the objective of improving the PA levels of Hong Kong children. Secondly, the development of Study 3 was based on formative work (Study 1 and Study 2). Thirdly, the current AVG intervention was a high-quality study (6/10) using established intervention evaluation criteria (see Table 3). Therefore, this fills the research gap identified in Study 1 (i.e., there is no high-quality study to examine the structured AVG play on the habitual PA of children). Lastly, this is one of the first pieces of research that has determined the intervention effect of structured AVG play on objectively measured habitual PA among children.

The main limitation of the current thesis is that the samples in both Study 2 and Study 3 were not representative of the Hong Kong primary school children. This is mainly due to the lack of resources available whilst conducting the study.

6.3 IMPLICATIONS

There is lack of PA epidemiology evidence derived from Hong Kong children. The findings presented in this thesis indicate a number of implications for future research.

As illustrated by literature in Chapter 2, objective measures should be encouraged for use in PA epidemiology among children. Few studies using objectively measures of PA have been reported among Hong Kong children. Using HR monitors, McManus et al. (2008) observed that 210 children on Hong Kong Island (aged 9-11 years) engaged in MVPA of less than 20 min per day. Mellecker (2010) measured and tracked PA using accelerometry in a small sample of Hong Kong primary school children (n=26), and reported that only 5% of the children attained

at least 60 minutes of MVPA per day in grade 1, while none attained this standard in grade 5.

In the current thesis, the baseline accelerometer data measured for Study 3 suggests that this sample of Hong Kong children (aged 9-12 years) engage in approximately 20 min of MVPA per day, and spend approximately 8 hours on sedentary activities per day. None of the participants could reach the recommended levels of PA at any assessment. A rough comparison (resulting from the heterogeneity in the PA measurement and participants' characteristics) suggests that Hong Kong children recruited in Study 3 (Chapter 5) only reached 50%-70% of their counterparts in England (Graves et al., 2010a) and US (Weintraub et al., 2008) based on VACPM. Compared with the previous studies using self-report measures (Huang et al., 2013; Huang et al., 2009; Lam et al., 2010), objectively measured PA in Study 3 suggests a more serious physical inactivity problem among Hong Kong children. It should be noted that these participants represented a sample with lower levels of PA compared with the population of Hong Kong children. With this in mind, a comprehensive assessment of PA and sedentary behavior using objective measures in a representative sample of Hong Kong children is warranted. Such research can provide information regarding the PA levels of Hong Kong children, and identify groups of children who may more urgently require appropriate intervention.

There is a call for PA interventions designed specifically for Hong Kong children, given that the existing evidence suggests such low levels of PA engagement and high levels of sedentary behavior. Understanding correlates of PA can help design effective interventions. However, PA correlates have not been extensively studied in Hong Kong children. This is partially due to the lack of validated instruments to measure these variables. The current thesis has validated three scales with which to measure self-efficacy, social support, and enjoyment, which enables further research to evaluate the influence of these factors on the PA of Hong Kong children. To date, only a small number of studies have been conducted to address the correlates of PA in this population (e.g., He, Cerin, Huang, & Wong, 2014; Huang et al., 2013; Huang et al., 2011), and paid more attention to the environmental factors. Future research should measure all aspects of PA

correlates, including personal, environmental, and behavioral factors in representative samples of Hong Kong children towards a more comprehensive understanding of the overall situation. This means more instruments should be validated. Culturally specific items should be particularly considered for Hong Kong children through appropriate qualitative studies from which to develop new instruments.

Based on the lack of outdoor school space for Hong Kong children to engage in PA, this thesis has designed and evaluated a school-based AVG intervention, and has demonstrated a positive treatment effect on objectively measured habitual PA. This simple, single-component intervention can be applied or integrated into other strategies in future research aiming to promote PA among Hong Kong children.

Generally speaking, the methods of the present AVG intervention are practical and feasible for use in other Hong Kong primary schools. However, some issues need to be addressed regarding the translation of these findings into practice.

Firstly, the lack of representativeness of the study sample was partially due to the inactive responses of the schools who were initially contacted to participate. The positive attitudes of relevant stakeholders, including school principals, teachers, parents, and participants towards school-based PA interventions are crucial for the implementation of future studies. The intervention ratings that were examined in the intervention group were positive. Children rated the present AVG intervention on a 1-5 scale, and the average rating was 3.6. This finding suggests the intervention was generally well accepted by the children, although there is room for improvement. Potential strategies could be: (1) providing more games to increase choice, (2) providing introductions on the simulated sports, (3) involvement of the family to promote PA, and (4) integrating AVG interventions into other available extracurricular time slots, such as recess.

Secondly, academic performance is highly valued in Hong Kong culture, and the time spent playing AVGs may be considered as time which could be better spent on academic activities. Therefore, academic performance is recommended to be measured in future PA interventions with Hong Kong children. If academic

achievement can be found to be unrelated to PA levels, or associated with higher PA levels, in young Hong Kong children, this may help to ease the concerns of teachers and parents, and encourage the facilitation of future PA interventions.

6.4 CONCLUSION

There is a lack of research examining PA epidemiology among Hong Kong children. The preliminary evidence established in the current thesis provides a foundation for further research. The unique factors in Hong Kong should be considered when developing interventions to promote the PA of children. Given that outdoor space is not sufficient for PA engagement, indoor programs may be a promising research area for this population. The structured AVG play after school is supported by the current thesis to increase overall PA and decrease sedentary behavior among Hong Kong children. Further intervention research using robust study designs and additional strategies should be conducted. Such interventions should be developed based on the improvement in understanding of the correlates of PA among Hong Kong children.

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APPENDIX A:

INFORMED CONSENT FORM FOR STUDY 2

香 港 浸 會 大 學
HONG KONG BAPTIST UNIVERSITY

社 會 科 學 院
FACULTY OF SOCIAL SCIENCES

體 育 學 系
Department of Physical Education

體感遊戲促進學生體力活動量研究
同意書 (家長/監護人)

大量研究顯示，體力活動有益於兒童的身心健康。有研究資料表明大部分香港兒童的體力活動量未能達到促進健康的程度。因此，香港浸會大學體育學系將進行一項研究，探究在學校的課外活動中應用體感遊戲是否有利於提高香港小學生的體力活動量。

為了提高香港小學生的體力活動量，我們首先需要對其現時參與體力活動的情況及其對體力活動的看法進行瞭解。我們邀請您的孩子參與我們的前期項目。你的參與是相當有用的。此次參與內容只**包括填寫關於體力活動的問卷**，問卷調查將分兩次在學校的體育堂進行，預計共需時約 20 分鐘。

參與是次研究計劃屬於自願性質，學童在研究過程中，有權隨時終止或退出而無須負上任何責任，倘若貴子弟退出是次研究計劃，其資料將被銷毀。問卷內資料絕對保密，並在研究結果發表後銷毀。若有任何疑問，請與香港浸會大學體育學系博士研究生梁妍聯絡(電話：3411 2721)。多謝您的合作。

我已閱讀及明白以上的資料，並同意我的孩子 ＿＿＿＿＿＿＿＿＿＿＿＿＿（班別：＿＿＿＿ , 學號：＿＿＿＿）參加這個研究計劃。

參加者簽署: ＿＿＿＿＿＿＿＿＿＿＿＿＿　　日期　＿＿＿＿＿＿＿＿＿＿＿＿

家長或監護人簽署: ＿＿＿＿＿＿＿＿＿＿＿＿＿　　日期　＿＿＿＿＿＿＿＿＿＿＿＿

APPENDIX B:

PHYSICAL ACTIVITY SELF-EFFICACY QUESTIONNAIRE

Physical Activity Self-Efficacy Questionnaire

1 I can be physically active on most days of the week.

2 I can ask my parent or other adults to do physically active things with me.

3 I can be physically active during my free time on most days even if I could watch TV or play (sedentary) video games instead.

4 I can be physically active on most days even if it is very hot or cold outside.

5 I can ask my best friend to be physically active with me on most days.

6 I can be physically active even at home.

7 I can do active things because I know how to do them.

8 I can be physically active during my free time on most days no matter how busy my day is.

體力活動自我效能量表

請細閱以下問題，在最能形容你及你的感覺的方格內填上"√"號。
1＝非常不同意 , 5＝非常同意

	非常不同意	有點不同意	無意見	有點同意	非常同意
	1	2	3	4	5
1. 一星期中的大部分日子我都能進行體力活動	☐	☐	☐	☐	☐
2. 我可以叫爸爸媽媽或其他成人和我一起做體力活動	☐	☐	☐	☐	☐
3. 即使我可以選擇看電視或玩（靜態）電子遊戲，大多數日子在空閒時我都會進行體力活動，	☐	☐	☐	☐	☐
4. 即使外面非常炎熱或非常寒冷，大多數日子我都可以進行體力活動。	☐	☐	☐	☐	☐
5. 大多數日子，我可以叫好朋友和我一起做體力活動	☐	☐	☐	☐	☐
6. 即使在家，我也可以進行體力活動	☐	☐	☐	☐	☐
7. 我可以進行體力活動，因為我知道如何去做	☐	☐	☐	☐	☐
8. 無論我有多忙，我可以在大多數日子的空閒時間里做體力活動。	☐	☐	☐	☐	☐

APPENDIX C:

SOCIAL SUPPORT FOR PHYSICAL ACTIVITY

QUESTIONNAIRE

Social Support for Physical Activity Questionnaire

Please rate how often your family members (parents, siblings, relatives, or anyone living in your household) or your friends (classmates, neighbors, or acquaintances) have said or done what is described during the last three months. Please write one number from the following rating scale in each space:

None	rarely	a few times	often	very often
1	2	3	4	5

During the past three months, my family or friends:

1. Did physical activities with me.

2. Offered to do physical activities with me.

3. Gave me helpful reminders to engage in physical activity ("Are you going to exercise tonight?").

4. Gave me encouragement to stick with my physical activity program.

5. Changed their schedule so we could do physical activities together.

6. Discussed physical activities with me.

7. Planned for exercise on recreational outings.

8. Helped plan physical activities.

9. Asked me for ideas on how they can engage in physical activities.

10. Talked about how much they like physical activities.

體力活動社會支持量表

請回顧在過去 3 個月中，你的家庭成員（指父母，兄弟姐妹或親戚及任何和你居住在一起的人）或 朋友 (指同學, 鄰居或其他認識的人)曾經對你講過或做過多少次以下列表中的事項, 然後寫上在最能形容你感受的數字。

沒有	很少	有時	經常	十分頻密
1	2	3	4	5

	家人	朋友
例子:		
跟我一起進行體力活動	*3*	*4*

	家人	朋友
1. 跟我一起進行體力活動	_____	_____
2. 提議跟我一起進行體力活動	_____	_____
3. 給予有益的提示讓我進行體力活動 (如: "你今晚是否要去做運動呀?")	_____	_____
4. 鼓勵我堅持進行我的體力活動計劃	_____	_____
5. 為了跟我一起進行體力活動而改變他們的時間表	_____	_____
6. 與我一起討論有關體力活動的話題	_____	_____
7. 計劃進行戶外休閒運動	_____	_____
8. 幫我計劃一些體力活動	_____	_____
9. 問我關於他們怎樣可以參與更多體力活動的意見	_____	_____
10. 告訴我他們有多喜歡進行體力活動	_____	_____

APPENDIX D:

PHYSICAL ACTIVITY ENJOYMENT QUESTIONNAIRE

Physical Activity Enjoyment Questionnaire

When I am active…

1 I feel bored.

2 I dislike it.

3 It's not fun at all.

4 It makes me depressed.

5 It frustrates me.

6 It's not at all interesting.

7 I feel as though I would rather be doing something else.

體力活動愉悅度量表

請在最能形容你的感覺的方格內填上"√"號。
1 = 非常不同意 , 5 = 非常同意

	非常不同意	有點不同意	無意見	有點同意	非常同意
當我正在進行體力活動時	1	2	3	4	5
1. 我感到沉悶	☐	☐	☐	☐	☐
2. 我並不喜歡體力活動	☐	☐	☐	☐	☐
3. 我覺得一點樂趣也沒有	☐	☐	☐	☐	☐
4. 讓我感到不快	☐	☐	☐	☐	☐
5. 我感到氣餒	☐	☐	☐	☐	☐
6. 我覺得一點也沒有趣味	☐	☐	☐	☐	☐
7. 我寧願做其他事情	☐	☐	☐	☐	☐

APPENDIX E:

INFORMED CONSENT FORM FOR THE INTERVENTION

GROUP IN STUDY 3

香港浸會大學
HONG KONG BAPTIST UNIVERSITY

社會科學院
FACULTY OF SOCIAL SCIENCES

體育學系
Department of Physical Education

體感遊戲促進學生體力活動量研究
同意書(家長/監護人)

香港浸會大學體育學系將進行一項研究,探究在學校的課外活動中應用體感遊戲是否有利於提高香港小學生的體力活動水準,我們希望邀請您的孩子參與我們的研究。大量研究顯示,體力活動有益於兒童的身心健康,然而大部分香港兒童的體力活動量不足以達到促進健康的程度。

希望您和您的孩子能予以支援,學生參與的內容包括:

1. 參加為期一個學期,每週兩次的課外體感遊戲活動,每次約一小時。

2. 填寫關於體力活動的問卷（預計每次需時 10 分鐘,共進行三次）。

3. 量度身高,體重,及體成分（脂肪含量等）(共三次)。

4. 配戴動作感應器並填寫佩戴時間表,參加者每次（共三次）需要連續七天佩戴動作感應器（我們懇切希望您在家中可以提醒孩子及時佩戴及除去動作感應器）。研究證明動作感應器是一個安全,可靠和有效的工具用以量度兒童的體力活動量。

5. 參加小組訪談。在參加全部體感遊戲小組活動後,學生將被邀請參與訪談,訪問他們關於此次參加的感受等,預計用時一小時。

參與是次研究計劃屬於自願性質,學生在研究過程中,有權隨時終止或退出而無任何責任。完成研究的學生可以得到參與證書並獲得參與其間的校車補助。若有任何疑問,請與香港浸會大學體育學系博士研究生梁妍聯絡（3411 2721）。多謝你的合作。

我已閱讀及明白以上的資料,並同意我的孩子 ＿＿＿＿＿＿＿＿（班別:＿＿＿ ,學號:＿＿＿ ）
參加這個研究計劃。

參加者簽署: ＿＿＿＿＿＿＿＿＿＿　　日期　＿＿＿＿＿＿＿＿＿

家長或監護人簽署: ＿＿＿＿＿＿＿＿＿＿　　日期　＿＿＿＿＿＿＿＿＿

APPENDIX F:

INFORMED CONSENT FORM FOR THE CONTROL

GROUP IN STUDY 3

香港浸會大學
HONG KONG BAPTIST UNIVERSITY

社 會 科 學 院
FACULTY OF SOCIAL SCIENCES

體育學系
Department of Physical Education

促進香港小學生體力活動水準研究
同意書(家長/監護人)

　　香港浸會大學體育學系將進行一項研究, 探究如何結合學校的課外活動提高香港小學生的體力活動水準, 為此我們首先需要瞭解香港小學生的日常體力活動水準, 我們希望邀請您的孩子參與我們的研究。大量研究顯示, 體力活動有益於兒童的身心健康, 然而大部分香港兒童的體力活動量不足以達到促進健康的程度。

　　希望您和您的孩子能予以支援, 學生參與的內容包括:

1.　　量度身高, 體重, 及體成分（脂肪含量等）。

2.　　填寫關於體力活動的問卷（預計每次需時約 10 分鐘, 共進行三次）。

3.　配戴動作感應器並填寫佩戴時間表, 參加者每次（共三次）需要連續七天佩戴動作感應器（我們懇切希望您在家中可以提醒孩子及時佩戴及除去動作感應器, 我們將在學校對參加者進行佩戴說明）。研究證明動作感應器是一個安全, 可靠和有效的工具用以量度兒童的體力活動量, 並不會影響兒童的日常生活。

　　參與是次研究計劃屬於自願性質, 學生在研究過程中, 有權隨時終止或退出而無任何責任。完成研究的學生可以得到參與證書並獲得體力活動量的個性化健康建議。若有任何疑問, 請與香港浸會大學體育學系博士研究生梁妍聯絡（3411 2721）。多謝你的合作。

我已閱讀及明白以上的資料, 並同意我的孩子 ＿＿＿＿＿＿＿＿＿＿（班別:＿＿＿ , 學號:＿＿＿）
參加這個研究計劃。

參加者簽署:　　　　　＿＿＿＿＿＿＿＿＿　　　　　＿＿＿＿＿＿＿＿＿
　　　　　　　　　　　　　　　　　　　　　日期

家長或監護人簽署:　　＿＿＿＿＿＿＿＿＿　　　　　＿＿＿＿＿＿＿＿＿
　　　　　　　　　　　　　　　　　　　　　日期

APPENDIX G:

SCREENING QUESTIONNAIRE FOR PARTICIPANTS IN

STUDY 3 BASED ON INCLUSION AND EXLUSION

CRITERIA

請小朋友根據實際情況回答以下問題，答案並沒有錯對之分。

請仔細閱讀以下問題，在你選擇的方格內加上 "√" 號。

1. 在過去的一年，你是否有參加過學校組織的藝術體操校隊活動？是□，否□。

2. 在過去的一年，你是否有參加過學校以外的，以體力活動為主的興趣班？是□，否□。

3. 在你的家中是否有體感遊戲機，如果有，請選擇遊戲機種類：

   Xbox □　Wii □　Sony Play Station □　其他 □ ＿＿＿＿＿＿(請填寫遊戲機的名稱).5

4. 在過去一星期（7 日）的空餘時間裏，您每天進行下列活動的總時間:

	10分鐘或以下	11 - 30 分鐘	31 - 59 分鐘	1-2 小時	2 小時以上
a) 看電視	□	□	□	□	□
b) 打電子遊戲 / 上網	□	□	□	□	□

APPENDIX H:
A WEARING LOG AND INTROCUTION ON WEARING ACCELEROMETERS

動作感應器佩戴說明及佩戴日誌

動作感應器是一個紅色，小巧的塑膠小盒，通過一條彈力腰帶佩戴在身體的右側，大致在腰部下方一塊突出的骨頭附近。它可以測量兒童的體力活動量而不會影響日常活動。

在測量期間，參加者應該在起床後即刻想起佩戴動作感應器，並在晚上睡覺前除下。

動作感應器佩戴在**身體右側**，如圖所示的位置。佩戴時，**上面的字母應該是正立的。** 請自行調整腰帶的長度，非常重要的一點是要保證動作感應器**緊貼身體（不需緊貼皮膚）**。如果它松松地佩戴上，將不能準確進行測量。

在冲涼和游泳時請記得除下動作感應器，因為其並不防水。

任何時候，當你除下動作感應器（如睡覺，冲涼，游泳），請儘快重新佩戴，並在背面的佩戴日誌上記錄這些時間。

我們建議你能夠連續七日佩戴，以便提供完整的資料可以分析你的日常體力活動量。但是如果由於任何原因，某一日你不能保證佩戴 9 個小時以上（可以根據佩戴日誌記錄時間自行計算），請記得在隨後的日子繼續佩戴。收回動作感應器的時間是 X 月 X 日。如果不能提供**至少三個日常日子**（星期一—星期五）和**一個週末（星期六和星期日）或假日**的資料，分析將不夠完整準確。結束所有的測量後，我們會提供一份報告說明您的資料，並給出一定的健康建議。

如果動作感應器（約 HK$3000）有損壞或丟失，參加者不需賠償，我們懇切希望家長協助參加者妥善保管，參加者需自己佩戴，不可以借給他人。
如果您有任何疑問，請致電香港浸會大學體育學系博士研究生梁妍（3411 2721）。

非常感謝您的參與！

動作感應器佩戴日誌

姓名：＿＿＿＿＿＿＿＿　　班別：＿＿＿＿＿＿　學號：（　）

請寫下佩戴動作感應器的日期，每天早上幾時佩戴動作感應器，以及睡前除下動作感應器的時間。

如果有時在一天中，你由於某些原因（比如沖涼，游泳）除下動作感應器，請寫下你什麼時候除下以及什麼時候重新佩戴，並記錄原因。

日期	早上佩戴	夜晚除下	日中除下	重新佩戴	除下動作感應器的原因
例如 第一日 **9 月 27**	*7.30 am*	*8.20pm*	*12.45pm*	*2.15pm*	*游泳*
第一日 ＿＿＿					
第二日 ＿＿＿＿					
第三日					
第四日					
第五日					
第六日					
第七日					

請將佩戴日誌和動作感應器在 **X 月 X 日**交還學校，非常感謝您參與我們的研究。

CURRICULUM VITAE

Academic qualifications of the thesis author, Miss LIANG Yan:

- Received the degree of Bachelor of Law in Sociology from China Agricultural University, July 2007.

- Received the degree of Master of Education in Sport Sociology from Peking University, July 2010.

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