U.PORTO

FACULDADE DE DESPORTO
UNIVERSIDADE DO PORTO

CIAFEL

Actividade Física Habitual em Crianças e Adolescentes - Estudo por acelerometria dos contextos de realização da prática.

Pedro Miguel Ribeiro Silva

Orientador: Professor Doutor Jorge Augusto Pinto Silva Mota

Porto 2009

Este trabalho foi desenvolvido no Centro de Investigação em Actividade Física, Saúde e Lazer, CIAFEL, da Faculdade de Desporto da Universidade do Porto, unidade de Investigação da Fundação para a Ciência e Tecnologia.

A presente dissertação foi escrita para a obtenção do título de Doutor no âmbito do Curso de Doutoramento em Actividade Física e Saúde, organizado pelo CIAFEL.

Este trabalho foi apoiado pela Fundação para a Ciência e Tecnologia através da bolsa SFRH/BD/23088/2005.

Silva, Pedro (2009). *Actividade Física Habitual em Crianças e Adolescentes - Estudo por acelerometria dos contextos de realização da prática.*

Porto: P. Silva. Dissertação de Doutoramento em Actividade Física e Saúde. Centro de Investigação em Actividade Física, Saúde e Lazer.
Faculdade de Desporto. Universidade do Porto.

Palavras-chave: PADRÕES DE ACTIVIDADE FÍSICA, ACELEROMETROS, CONTEXTOS DA ACTIVIDADE, JOVENS.

Try not to become a man of success but rather
try to become a man of value.

Albert Einstein

Agradecimentos / Acknowledgements

Agradeço a Deus pelo que É e pelo que sou.

À Daniela por sermos um. A...-te
À Gabriela por se ter juntado a nós no meio deste caminho para dar um novo sentido a tudo. À Isabela que veio dar forças para a meta final.

À nossa família por estarem sempre connosco mesmo nós mais ausentes.

Aos professores Jorge Mota e Gregory Welk que foram os meus mentores, que reconheço não ser tarefa fácil...

Aos colegas de doutoramento pela partilha do pioneirismo e das aventuras neste processo.

Ao Dale Esliger por partilhar comigo um pedaço do seu caminho.

A todos do CIAFEL pelas lições partilhadas, desafios propostos e barreiras transpostas.

Às instituições que permitiram e apoiaram a execução deste projecto, nomeadamente: a Fundação para a Ciência e Tecnologia pela concessão da bolsa de investigação e o Centro de Investigação em Actividade Física, Saúde e Lazer da Faculdade de Desporto da Universidade do Porto; ao Ministério da Educação pela concessão de equiparação a bolseiro.

Table of Contents

Acknowledgements/ Agradecimentos .... **V**

Table of Contents .... **VII**

List of Figures .... **X**

List of Tables .... **XII**

List of abbreviations .... **XIV**

Resumo .... **XV**

Abstract .... **XVII**

Resumé .... **XIX**

Chapter 1: **1.1 Introduction** **23**

1.2 Aims **25**

Chapter 2: **2.1 Physical Activity Contexts**

Manuscript: Psychosocial correlates of Physical Activity in two cultural contexts: Different pathways?

2.1.1 Abstract **31**

2.1.2 Introduction **32**

2.1.3 Methods **34**

2.1.4 Results **40**

2.1.5 Discussion **48**

2.1.6 References **52**

Chapter 3: **3.1 Individual contexts**

Manuscript: Lifespan snapshot of Physical activity assessed by accelerometry in Porto

3.1.1 Abstract **57**

3.1.2 Introduction **58**

3.1.3 Methods **59**

3.1.4 Results **61**

3.1.5 Discussion **68**

3.1.6 References **74**

Chapter 4: **4.1 Time contexts – the accelerometer**

Manuscript: Technical Reliability Assessment of the

Actigraph GT1M Accelerometer
4.1.1 Abstract ……….………………………………….. 81
4.1.2 Introduction ……….………………………………. 82
4.1.3 Methods ……….………………………………….. 83
4.1.4 Results ……….…………………………………… 87
4.1.5 Discussion ……….……………………………….. 93
4.1.6 References ….. 97
4.2 Season
Manuscript: Seasonal Differences In Physical Activity And Sedentary Patterns: The Relevance Of The PA Context.
4.2.1 Abstract ……….……………………………… 103
4.2.2 Introduction ……….……………………………. 104
4.2.3 Methods ……….……………………………… 105
4.2.4 Results ……….………………………………….. 108
4.2.5 Discussion …..………………………………... 114
4.2.6 References …..………………………………... 118
Chapter 5: 5.1 Space contexts – Country, Community
Manuscript: Differences in the Physical Activity pattern between Portuguese and Spanish adolescents
5.1.1 Abstract ……….……………………………… 123
5.1.2 Introduction …...………………………………. 124
5.1.3 Methods ……….……………………………… 125
5.1.4 Results …..……………………………………….. 127
5.1.5 Discussion …..………………………………... 132
5.1.6 References …..………………………………... 136
5.2 School free-time
Manuscript: Physical Activity in High School during the “free-choice” periods
5.2.1 Abstract ……….………………………………….. 139
5.2.2 Introduction ……….……………………………. 140
5.2.3 Methods ……….……………………………… 141
5.2.4 Results ……….………………………………….. 143

5.2.5 Discussion ….....…………………………………….. 147
5.2.6 References …..…………………………………….. 152
5.3 School sports
Manuscript: Physical activity patterns in Portuguese adolescents the contribution of extra-curricular sports
5.3.1 Abstract ……...……………………………………… 157
5.3.2 Introduction ……...………………………………… 158
5.3.3 Methods ……...……………………………………… 159
5.3.4 Results ……...……………………………………….. 161
5.3.5 Discussion …..………………………………………... 166
5.3.6 References …..………………………………………... 170
Chapter 6: 6.1 Individual in Spacetime - Key Findings ……...……….. 177
6.2 Strengths and Limitations ……...…………………….. 182
6.3 Future Directions ……...……………………………….. 185
References ……...……………………………………………………………… 187
List of Publications ……...……………………………………….………… 209

List of Figures

Chapter 2

Figure 1 – Conceptual diagram of the YPAPM core. **…………………………..…... 36**

Figure 2 – Conceptual diagram of the YPAPM core applied in the USA sample (standardize regression weights; * p<.001, [a] p= .029, [b] p= .008; CFI= .986; RMSEA= .031). The standardized coefficients for the overall test of the model when statistically significant are accompanied by an asterisk or letter. **……… 44**

Figure 3 – Conceptual diagram of the YPAPM core applied in the PT sample (standardize regression weights; * p<.001, [a] p=.018; CFI= .92; RMSEA= .06). The standardized coefficients for the overall test of the model when statistically significant are accompanied by an asterisk or letter. **…………………………... 47**

Chapter 3

Figure 1 – Differences between genders in the physical activity intensities (Mean), according to age groups. **………………………………………………… 65**

Figure 2 – Differences in sustained physical activity, for periods of at least 10 minutes in MVPA. **…………………………………………………………………….. 67**

Chapter 4

Figure 4. Mechanical shaker table complete with Actigraph GT1M accelerometers positioned for calibration testing. **………………………………… 84**

Figure 2. Average counts per 15sec epoch for 50 Actigraph GT1M accelerometers across 6 test conditions (error bars represent 1SD). **………... 89**

Figure 3. Mean different percent error among a batch of 50 Actigraph GT1M accelerometers across the six test conditions. **………………………………….. 90**

Chapter 4.2

Figure 1 – Seasonal differences in MVPA (min) according to in-school and after-school periods (repeated measures analyses of variance). **…………… 110**

Figure 2 – Mean differences in MVPA between seasons according to gender. **……………………………………………………………………………………… 111**

Figure 3 – Mean differences in sedentary activity between seasons according to gender. **……………………………………………………………………………… 112**

Chapter 5

Figure 1 –Differences between the two cities in mean MVPA (min) by day of the week. **……………………………………………………………………………………… 130**

Chapter 5.2

Figure 1 – Mean counts.min^{-1} during the different school free-choice periods by gender and school type. **…………………………………………………………… 146**

Chapter 5.3

Figure 1 – Minutes of MVPA by gender, in each day of the week, for the four different groups: 1) No EC Sports; 2) School Sports; 3) Club Sports; 4) With both Sports (shaded box represents PA guidelines Zone). **………………….. 163**

List of Tables

Chapter 2

Table 1 – Descriptive characteristics for adolescents participating in the study. ………………………………………………………………………………………… **41**

Table 2 - Bivariate Pearson Product-Moment Correlations (below the diagonal), Means and Standard Deviations of Physical Activity and Psychosocial Correlates in the USA. ……………………………………………………..………… **43**

Table 3 - Bivariate Pearson Product-Moment Correlations (below the diagonal), Means and Standard Deviations of Physical Activity and Psychosocial Correlates in the Portugal. …………………………………………..………..… **46**

Chapter 3

Table 1 – Characteristics of the sample (Mean and SEM). ..…………………..… **62**

Table 2 – Physical activity intensities (Mean and SEM), according to age groups. ..……………………………………………………………………………..… **64**

Table 3 – Number of days with compliance of the physical activity guidelines, adjusted to the number of accelerometer valid days (Mean Percentage). …... **66**

Chapter 4

Table 1. Comparison of mean counts per 15sec epoch and reliability statistics across the six test conditions in Experiment 1. ……………………………......… **87**

Table 2. Comparison of mean steps per 15sec epoch and reliability statistics across the six test conditions in Experiment 1. ……………………………......… **88**

Table 3. Intra-class Correlation of the twenty replicate, 15 second epochs across each of the six test conditions in Experiment 1. ……………………...… **91**

Table 4. Comparison of mean counts per 15 seconds and reliability statistics across the eighteen test conditions in Experiment 2. . ……………………...… **92**

Chapter 4.2

Table 1 – Descriptive characteristics for participants in the study, mean (SD). ..……………………………………………………………………………………… **109**

Table 2 – Mean MVPA minutes (SD) on after-school period, and the context of those activities (reported by diary), according to gender and season. ……… **113**

Chapter 5

Table 1 – Descriptive characteristics for participants in the study, mean (SD). ……………………………………………………………………………………… **128**

Table 2 – Linear regression model for the PA response variables, using City, Gender, Age and BMI as explanatory variables. ……………………………… **131**

Chapter 5.2

Table 1 – Descriptive characteristics for adolescents participating in the study. ……………………………………………………………………………………… **144**

Table 2 – Linear regression predicting PA (cpm) in the different free-choice periods. ………………………………………………………………………… **145**

Chapter 5.3

Table 1 – Descriptive characteristics (Mean Standard deviation) for adolescents participating in the study. ……………………………………………………… **162**

Table 2 – Logistic regression model for the recommended amount of PA given the participation on EC-sports for the entire sample. ……………………………… **164**

Table 3 – Logistic regression model for the recommended amount of PA given the participation on EC-sports by gender. ………………………………………… **165**

Chapter 6

Table A - Most common criteria's to process the accelerometer data. ……… **184**

List of abbreviations

BMI - Body Mass Index

CHD – Cardiovascular Disease

PA – Physical Activity

LPA – Light Physical Activity

MPA – Moderate Physical Activity

VPA – Vigorous Physical Activity

VVPA – Very Vigorous Physical Activity

MVPA – Moderate To Vigorous Physical Activity

CSA – Computer Science Application Accelerometer

MTI – Manufacturing Technology Inc.

SPSS - Statistical Package for the Social Sciences

AMOS – Analysis of MOment Structures

YPAP – Youth Physical Activity Promotion Model

YMCLS – Youth Media Campaign Longitudinal Survey

CDC – Centers for Disease Control and Prevention

VERB – Youth Media Campaign

PACES – Physical Activity Enjoyment Scale

LEAP - Lifestyle Education For Activity Project

NHANES - National Health and Nutrition Examination Survey

EYHS – European Youth Heart Study

MET - Metabolic Equivalent

Resumo

Desenvolvimentos recentes nos monitores de actividade baseados na acelerometria tornam possível a avaliação objectiva da actividade física (AF) de uma forma sistemática. O objectivo deste trabalho pretende descrever os padrões da AF e o seu contexto. A série de estudos foi elaborada de forma a ampliar (*zoom*) a análise da AF, isto é, progride dos principais factores de influência até intervalos de espaço-tempo onde esta ocorre. No estudo 1, o modelo da promoção da AF em jovens (Welk, 1999), que analisa mediadores da AF, foi aplicado pela primeira vez em jovens Portugueses e comparado com os EUA. Avançamos no detalhe da análise da AF (estudo 2) ao avaliar as diferenças na quantidade de AF, de acordo com a idade e género, numa abrangente população residente na área do Porto. O acelerómetro foi central no nosso trabalho para fornecer o constructo do tempo, por isso a sua fiabilidade foi estudada (estudo 3). O estudo 4 caracterizou a variação sazonal da AF e do comportamento sedentário, tentando compreender as implicação dos contextos das actividades. O constructo do espaço foi considerado no estudo 5 ao comparar a AF de jovens de diferentes países. A escola é considerada como o espaço mais relevante para os jovens. Por isso, a quantidade de AF em diferentes períodos de “tempo livre” na escola e o impacto das actividades desportivas extra-curriculares foram também analisados (estudo 6 e 7 respectivamente). Os resultados apontam para o facto de que os jovens mais novos poderão receber o apoio dos pares para a AF através do gosto pela prática, enquanto que os mais velhos através do sentido de competência. Colectivamente, este trabalho apresenta informação relevante acerca dos padrões de AF e suas tendências na população da área do Porto. Os jovens foram mais activos no verão e apresentaram valores superiores de AF fora da escola. O inverno poderá ser uma barreira para o contexto preferido da AF nos rapazes. O local de residência teve impacto no cumprimento da recomendações de AF e os padrões de AF foram mais diferenciados ao fim-de-semana. O recreio como espaço activo diminuiu com a idade. Assim, podemos concluir que os baixos níveis de AF dos jovens da área do Porto deverá ser um motivo de preocupação e intervenção. Grande ênfase deverá ser dada á escola para a disponibilização de contextos que promovam AF.

Palavras-chave: ACTIVIDADE FÍSICA, ACELERÓMETRO, ESCOLA, ESPAÇO-TEMPO.

Abstract

Recent developments of portable accelerometry-based activity monitors make it possible to objectively monitor physical activity behavior in a more systematic way. The aim of this research was to better decipher the patterns and context of physical activity behavior. The series of studies uses a "zooming" perspective that progresses from research on behavioral correlates to time settings and contexts (space-time) for physical activity and ultimately to public health surveillance. In study 1, the Youth Physical Activity Promotion Model (Welk, 1999), that addresses correlates of physical activity (PA), was applied in the Portuguese youth and compared to the US. In study 2, we "*zoom in"* by evaluating age and gender differences in levels of PA in a large and diverse sample of Porto area residents. The accelerometer was central in our research to provide the time construct; therefore in study 3 we studied the reliability of the Actigraph GT1M model. The next study (study 4), also used a time perspective by characterizing seasonal variation in PA and sedentary behavior, and understand the implication of activity choices and settings. The space construct was considered next by comparing adolescents' PA patterns living in two different countries (study 5). School is considered the most relevant space for youth. Therefore, the amount of PA on different "free-time" periods in school, and the impact of extra-curricular sports (EC-Sports) in youth's PA were also analyzed (study 6 and study 7). Our results point to the fact that younger youth might receive peer support through enjoyment, and older youth received the influence of peer support through skill and self-worth processes. Collectively, the study provides valuable information about physical activity patterns and trends in the Porto population. Youth were more active in the summer and activity levels were higher after school than in school. Winter season may be a barrier to boy's preferred PA context. Location of residence was found to have impact on the achievement of PA guidelines, and PA patterns differences were more marked on weekends. The relevance of recess as an active opportunity is reduced with the age increase. The low level of PA in Porto adolescents is a matter of concern and suggests that interventions are needed. These results emphasize the role of schools to provide contexts where youth can increase PA.

Key-words: PHYSICAL ACTIVITY, ACCELEROMETER, SCHOOL, SPACE-TIME CONTEXTS.

Resumé

Des développements récents, dans le cadre des engins moniteurs de l'activité et doués d'accéléromètres, ont rendu possible l'observation de l'activité physique (AP) de façon plus systématisée. L'objectif de cette recherche est d'améliorer l'interprétation des tendances qui sont propres au comportement de l'AP et d'encadrer ces tendances dans leur contexte spatio-temporel. Cette étude aborde plusieurs plans à diverses échelles qui vont depuis la corrélation du comportement de l'AP dans son contexte spatial et temporel, jusqu'à la surveillance de la santé publique. Le modèle dit de «Promotion de l'AP Chez les Jeunes» (Welk, 1999), qui modélise ces corrélations, a été appliqué à un ensemble de jeunes Portugais dont les résultats ont été comparés avec ceux des jeunes des Etats-Unis (étude 1). Un des plans abordés par cette étude consiste à évaluer des différences d'âge et de sexe entre les niveaux d'AP d'un échantillon représentatif des résidents de la zone de la ville de Porto (étude 2). L'accéléromètre a été central dans notre recherche pour fournir des données en continu dans le cadre du contexte temporel. Du coup, il aura fallu procéder à la validation de l'accéléromètre en tant qu'instrument de mesure pour cet effet; et une étude (étude 3) sur la fiabilité du modèle GT1M d'Actigraph fut réalisée. Par la suite, avec ces données, il fut possible de caractériser la variation saisonnière de l'AP, ainsi que le comportement sédentaire (étude 4). Ceci a permit de comprendre les implications du choix du type d'activité et du choix du contexte spatio-temporel. D'autre part, une comparaison fût faite entre les AP des adolescents vivants dans deux pays différents (étude 5). L'école est considéré le lieu le plus important pour les jeunes. Du coup, la quantité d'AP selon les divers temps-libres procurés dans l'enceinte de l'école, ainsi que l'impact des sports extracurriculaires (Sports-EC), furent soumit à l'analyse (étude 6 et 7). Les résultats montrent que les plus jeunes sont stimulés à l'AP par leurs pairs à travers l'amusement, alors que les adolescents le sont plutôt à travers la mise en valeur de leurs capacités physiques. Les résultats de cette étude montrent que dans la ville de Porto, dans les quartiers résidentiels, les taux de conformité de l'AP étaient bas par rapport aux directives d'AP actuels. Ce résultat se classifie comme étant fiable par le fait qu'il est basé sur une étude d'accélérométrie, doublée du fait que l'accéléromètre fut considéré comme étant un instrument fiable. Les résultats montrent aussi que les jeunes sont plus actifs pendant l'été que pendant l'hiver, et que les niveaux d'activités sont plus élevés après l'école que pendant l'école. La saison d'hiver peut être une barrière aux lieux favoris d'AP pour les garçons. Le lieu de résidence fut trouvé comme ayant un impact significatif sur l'accomplissement des directives d'AP ; et les différences entre les tendances d'AP sont plus marquées pendant les week-ends. La récréation en tant qu'opportunité active d'engager de l'AP perd ce statut avec l'âge. Les bas niveaux d'AP des adolescents de la ville de Porto sont matière de préoccupation et suggèrent qu'une intervention serait salutaire. Ces résultats mettent en valeur le rôle de l'école comme contexte privilégié où les jeunes peuvent augmenter leur AP.

Mots-clef: ÉCOLE, ACTIVITE PHYSIQUE, ACCELEROMETRES, CONTEXTE D'ESPACE-TEMPS.

Chapter 1

Chapter 1

1.1 Introduction

Studying the health behaviors in the population is justified by the fact that a significantly proportion of mortality and mobility in developed societies is a result of negative behavior patterns to health, and because these behavior patterns can be changed.

The combined effects of the transition to a sedentary lifestyle and attendant dietary changes have resulted in high rates of coronary heart disease and an epidemic of overweight/obesity in postindustrial societies. Although mortality associated with coronary heart disease has declined, due largely to biomedical advances, overweight and obesity have increased at a consistent pace. The primary contributors to this trend are population reductions in physical activity (energy expenditure) and increased calorie (energy) consumption (Malina & Little, 2008).

Portugal is among the European countries with higher prevalence in Obesity. A survey in adults (aged 18-64) collected objective body mass index (BMI) values of 8116 participants, and the main findings were as follows: 2.4% of the sample had low weight (BMI < 18.5); 39.4% were overweight (BMI between 25.0 and 29.9); and 14.2% obese (BMI > or = 30). Moreover, the study stated that the overall overweight/obesity prevalence increased from 49.6% (in 1995-1998) to 53.6% (in 2003-2005) (do Carmo, et al., 2008). Other studies also have shown a high prevalence of overweight and obesity (31%) in Portuguese children aged 7-9 years (Padez, Fernandes, Mourao, Moreira, & Rosado, 2004), and in adolescents (Ribeiro, et al., 2003). Those obesity rates are comparable with childhood obesity prevalence rates found in other Southern European countries, and higher than those found in North European countries (Lobstein & Frelut, 2003).

Consistent with the higher overweight prevalence, research has demonstrated that physical activity levels, assessed through questionnaires, in this population are also lower compared to other countries (Vaz de Almeida, et al., 1999). The potential burden on public health has led to worldwide interest in understanding physical activity behavior. Most research and reports have relied on self-reported measures, and participants are generally categorized into activity levels on the basis of overall descriptions of activity frequency and intensity, without attempting to categorize the potential differences in the pattern of accumulated physical activity over time (Metzger, et al., 2008). Recent developments of portable accelerometry-based activity monitors make it possible to objectively monitor physical activity behavior in a more systematic way. They are particularly useful because they eliminate the potential for recall bias and social desirability bias, and they do not depend on literacy. Accelerometers provide more powerful information that may help define the dose necessary to provide health outcomes. They can also enhance our understanding of physical activity (PA) behavior, provide better ways to assess interventions and improve population surveillance.

Some studies have been carried out using accelerometry in or with Portuguese youth. (Sardinha, et al., 2008) demonstrated that PA is associated with insulin resistance independent of total and central fat mass in children. These results emphasize the importance of decreasing sedentary behavior and increasing time spent in moderate- and vigorous-intensity activity in children, which may have beneficial effects on metabolic risk factors regardless of the degree of adiposity.

In a study by (Lopes, Vasques, Maia, & Ferreira, 2007) boys had more minutes a day of vigorous PA (VPA) and very vigorous PA (VVPA) than girls. PA decreased with age. The subjects of this study, aged 6 to 15, fulfilled the recommendations of 60 min per day of moderate to vigorous PA (MVPA). Another Portuguese study (Santos, Guerra, Ribeiro, Duarte, & Mota, 2003) with 157 children (boys n=64 and girls n=93), aged 8 to 15 years-old. The CSA activity monitor (now called the MTI or Actigraph) was used as an objective measure of daily physical activity. Each student in the study wore the CSA 3 times during the week of monitoring. Boys were involved in more MVPA than girls, however only in the 11-13 year old group were found significant differences ($p<0.05$). Within gender, significant differences were found out among 11-13 years old (48.7 min) and 14-16 years (72.2 min).

One of the first studies in Portugal analyzing the context of PA behavior (Mota, et al., 2005) showed that participation in MVPA during recess contributes significantly more to the total amount of physical activity ($P < 0.05$) for girls (19%) than boys (15%) While the percentage of time engaged in MVPA during recess time at school accounts for a small amount of the daily MVPA (6% for boys and 8% for girls), the results suggest that school recess time is an important setting to promote MVPA and contributes to daily physical activity in young children, especially in girls.

Numerous studies have been conducted on correlates of physical activity in youth and the literature indicates that children’s and adolescents’ PA are influenced by a large group of factors, including, environmental, social, psychological and cultural ones (Dishman, et al., 2004; Sallis & Owen, 1999b; Sallis, Kraft, & Linton, 2002b; Van Der Horst, Paw, Twisk, & Van Mechelen, 2007). Hence, adolescent´s PA is best described as a profile rather than a single entity, and such profiles are characterized as a complex matrix of behaviors that take place in a range of social contexts, each with its own set of physiological, psychological and sociological determinants and outcomes.

Research on the tracking of physical activity over the lifespan has been somewhat equivocal, so one approach to clarifying this issue is to determine the types and elements of PA that cause some youth to be more active than others. This may help identify patterns that facilitate long term involvement or, alternately, identify groups that may be at risk of dropping out from a more active lifestyle (Tammelin, 2005).

1.2 Aims

The main theme of this research was to better decipher the context of physical activity behavior across the lifespan. The series of studies uses a “zooming” perspective that progresses from research on behavioral correlates to settings and contexts for physical activity and ultimately to public health surveillance. The overall goal was to generate evidence that could be used to better inform youth public health guidelines for physical activity. The thesis is presented in manuscript format, and each of the seven manuscripts addresses a specific component of the physical activity assessment and contexts.

Manuscript 1- focuses on the youth physical activity promotion model proposed by Welk (1999). Establish a comparison of the model correlates between two different cultural contexts, such as the United States of America and Portugal. If the YPAP model adequately explains youth physical activity behavior, in two different cultures and with two different sets of instruments, it would suggest that the model has broad utility for youth activity promotion. Submitted to Journal of Physical Activity and Health.

Manuscript 2 – examines the variation of physical activity amount in different age groups and genders (individual correlates). The specific aims of this study were (1) to report data regarding the different physical activity intensities and sedentary behavior from a lifespan perspective and (2) to analyze the compliance of the physical activity guidelines. Submitted (revised version) to Journal of Physical Activity and Health.

Manuscript 3 – because the cornerstone instrument to measure PA in this research is the accelerometer, and there have been no studies reporting on the reliability of the GT1M accelerometer for assessing activity counts and steps. Likewise, little information is available that describes the threshold detection levels of the Actigraph. Therefore, the purpose of this study was 1) to determine the intra-instrument and inter-instrument reliability of the GT1M, and 2) to determine its acceleration threshold detection levels using a controlled mechanical setup. Submitted to Measurement in Physical Education & Exercise Science (*in press*).

Manuscript 4 - explores whether physical activity patterns changes in two different seasons. Therefore, the aims of this pilot study were (1) to determine the regular physical activity and sedentary patterns in children aged 10-13 years old across two seasons and (2) to analyze the potential seasonal differences by identifying the contexts where those differences occur. Submitted to Journal of Sports Science Medicine.

Manuscript 5 - Research is needed to examine the physical activity consistency across different populations and cultures. Therefore, the aims of this study were: 1) to describe the physical pattern of high school adolescents attending public schools in Portugal and in Spain; 2) to compare the differences between the two countries in the PA pattern. Submitted (revised version) to Archives of Exercise in Health and Disease.

Manuscript 6 - If students chose to be active during 5 “free-choice” periods in the school schedule, such as commute to school, morning recess, lunch, afternoon recess, and after-school, they would get 25 more opportunities be active per week. To better utilize these opportunities, it is important to better understand the contribution of different school settings to activity levels in youth. The aim of this study is to determine how gender, age, body mass index, and school influence the amount of PA during different “free-choice” periods during the school schedule of Portuguese students attending two high schools. Submitted to European Physical Education Review.

Manuscript 7 – School sports are present in the majority of high schools, although the club sports have a stronger tradition for after school programming. This study aims to address the contributions of extracurricular sports (EC-sports), performed in both contexts to activity profiles of Portuguese adolescents. A secondary goal is to examine possible variability in these effects by age and gender. Submitted to European Physical Education Review.

Chapter 2

Chapter 2

2.1 Physical Activity Contexts

Manuscript: Psychosocial correlates of Physical Activity in two cultural contexts: Different pathways?

2.1.1 Abstract

Background: If the Youth Physical Activity Promotion (YPAP) model adequately explains youth PA behavior, in two different cultures and with two different sets of instruments, it would suggest that the model has broad utility for youth activity promotion.

Methods: Two samples from different countries were used (study 1 – US and study 2 – PT). Study 1 had a sample of 159 students (83 girls) with a mean age of 11.52 ± 1.40 years, and study 2 comprised 203 students (125 girls), with a mean age of aged 14.99 ± 1.55 years. PA was assessed by accelerometry. The YPAP model provided the theoretical framework for the correlates and the causal pathways. The model was analyzed through structural equation modeling using AMOS (version 17.0).

Results: In study 1, social-support had a direct association with the MVPA amount (β=-.20, p<.05) and enjoyment (β=-.51, p<.05). Self-efficacy had a direct association with enjoyment (β=-.43, p<.05). In study 2, Social-support had a direct association with the MVPA amount (β=.41, p<.05), and with self-efficacy (β=.69, p<.05).

Conclusions: Constructs relationships were relevant in both countries, with different pathways. Younger youth might receive peer support through enjoyment, and older youth received influence of peer support through skill and self-worth processes.

2.1.1 Introduction

Influences on young peoples' physical activity are multi-factorial. A variety of psychological, social and physical environmental correlates of physical activity for young people have been identified. Social-cognitive models that emphasize intrapersonal and micro-environmental influences hold great promise for better understanding and promoting physical activity participation (Ommundsen, Klasson-Heggebo, & Anderssen, 2006).

Youth physical activity (from here on abbreviated as PA) is best described as a profile rather than a single entity, and such profiles are characterized as a complex matrix of behaviors that take place in a range of social contexts, each with its own set of physiological, psychological and sociological determinants and outcomes. To develop a better understanding of "what works", researchers have focused on building an evidence base for potential mediators of behavior change. The wide range of correlates supports the application of ecological models of behavior to improve understanding of the influences on youth physical activity (Sallis, Taylor, Dowda, Freedson, & Pate, 2002).

Social ecologic models highlight the importance of targeting different settings and environments that influence individual behavior, but a testable mediating variable framework is needed to facilitate the development and evaluation of effective interventions. A model that may prove useful in this regard is the Youth Physical Activity Promotion (YPAP) Model (Welk, 1999). This model integrates a diverse array of individual and environmental variables into a testable mediating framework. Typical psychosocial correlates (e.g. attitudes, beliefs, self-perceptions) are viewed as "predisposing" factors , social and interpersonal variables (e.g. support or non-support of family, teachers, and friends) are viewed as "reinforcing" factors and individual variables (e.g. skill, fitness) and environmental variables (e.g. access and opportunity) are viewed as "enabling" factors.

Longitudinal studies suggest that declines in physical activity during the period from late middle school through late high school are inversely associated with self-efficacy for overcoming barriers to physical activity and also with perceived support from family (Dowda, Dishman, Pfeiffer, & Pate, 2007) and friends (Duncan, Duncan, Strycker, & Chaumeton, 2007). It is widely accepted that perceived competence and enjoyment influence young peoples' physical activity, and social support from family and peers have also been identified as positive correlates (Sallis, Prochaska, & Taylor, 2000b). However, we know far less about the extent to which age and gender interact with psychological, social and physical environmental factors in their influence on physical activity. Elements of the model and associated measures have been tested in studies of youth physical activity behavior with significant effects shown on physical activity (Welk, Wood, & Morss, 2003), but the overall fit of the model has not been extensively evaluated.

Preliminary research with structural equation modeling was conducted on a sample of 673, 3rd -6th grade youth (340 boys and 333 girls), to examine the utility of the model. The results supported the structural links proposed, the model provided a good fit to the data [CFI=.97; NFI =.94, NNFI =.96 and chi-square= 143 (df=80)]. Overall, the model predicted 43% of the variance in PA (Welk, Babke, & Brustad, 1998). To more fully evaluate the utility of the model it is important to determine if elements of the model hold for different cultural contexts. Welk (Welk, 1999) contend that while elements of these models may apply in youth and adults, it’s premature to assume that they are influenced in the same way. Dishman and colleagues (Dishman, Saunders, Motl, Dowda, & Pate, 2008) also recommended that research on social cognitive influences of physical activity include efficacy beliefs specific to overcoming social barriers to physical activity and compare the influence of the cultural environment with influences of the physical and social environments in racially or ethnically diverse samples of adolescents.

The present study advances research in this area by evaluating the utility of YPAP constructs for explaining physical activity behavior in two different samples – one from the United States and one from Portugal. This research does not aim to accept or reject the YPAP model; rather, it is an extension of the preliminary development of the model. If the YPAP model adequately explains youth physical activity behavior, in two different cultures and with two different sets of instruments, it would suggest that the model has broad utility for youth activity promotion. The model may prove useful as an evaluation framework in future studies and possibly to examine causal pathways within a multi-faceted social ecological intervention. We tested our theoretical model using maximum likelihood to test the model hypotheses.

2.1.3 Methods

Theoretical Model and Selection of Psychosocial Correlates

The YPAP model (Welk, 1999) provided the theoretical framework for the selection of correlates and the proposed causal pathways. Consistent with social ecological theory, the YPAP is population and behavior specific and incorporates a broad perspective on the factors that influence physical activity behavior in youth. The original model includes Reinforcing, Predisposing, and Enabling Factors. The Reinforcing factors are theorized to influence activity directly and indirectly through the Predisposing Factors (Welk, 1999). The Enabling factors capture environmental variables (e.g. access) as well as physical characteristics (e.g. skill, fitness) that may enable youth to act on their predispositions – and be physically active. For the present study, we focused only on the Reinforcing and Predisposing Factors since these domains capture the primary psychosocial areas of interest in the study.

Reinforcing factors in the YPAP model include variables that reinforce (either directly or indirectly) youth PA behavior. Reinforcement can come from parents, peers, coaches or other significant individuals; however, for the present study only peer influences was examined. The extant literature on child development suggests that peer influence becomes increasingly important as children move through the development transition from childhood into adolescence (Weiss, Smith, & Theeboom, 1996). Because the samples included pre- or early adolescents we focused the model on peer influences. The decision to focus on peer influences is supported by the detailed literature review conducted by Sallis et al. (Sallis, Taylor, et al., 2002). Peer support was one of the two significant correlates of objectively monitored activity in multiple subgroups. A similar and more recent review by Van Der Horst et al. (Van Der Horst, et al., 2007) found positive associations between physical activity and friend support. Moreover, friendships may increase youth's motivation to engage in physical activity and promote greater physical activity in non-overweight and overweight youth (Salvy, et al., 2009).

Predisposing factors in the YPAP model include variables that collectively increase the likelihood that a person will be physical active on a regular basis (Welk, 1999). This component has been viewed from a social-cognitive theory perspective (Bandura, 2004) and includes components that reflect both efficacy expectations (*Am I Able?*) and outcome expectations (*Is it Worth it?*). Youth need to be able to answer both questions affirmatively to be predisposed to be active. Measures of self-efficacy were used to capture the *Am I Able* component since there is broad consensus regarding the importance of this self-evaluative construct on youth behavior (Welk, 1999). The other component (Is it worth it?) include both cognitive (attitudes, perceived benefits, and beliefs about PA) and affective (enjoyment and interest of PA) variables. In the present study, we utilized measures of enjoyment to capture overall interest in PA.

As described above, the YPAP model provides a flexible, social-ecological framework for evaluating physical activity correlates. A simplified version of YPAP Model core illustrating the association and direction of reinforcing and predisposing factors on physical activity is provided in Figure 1. The focus of the present study is on the relative utility of this model for explaining physical activity behavior in adolescents from two different cultures.

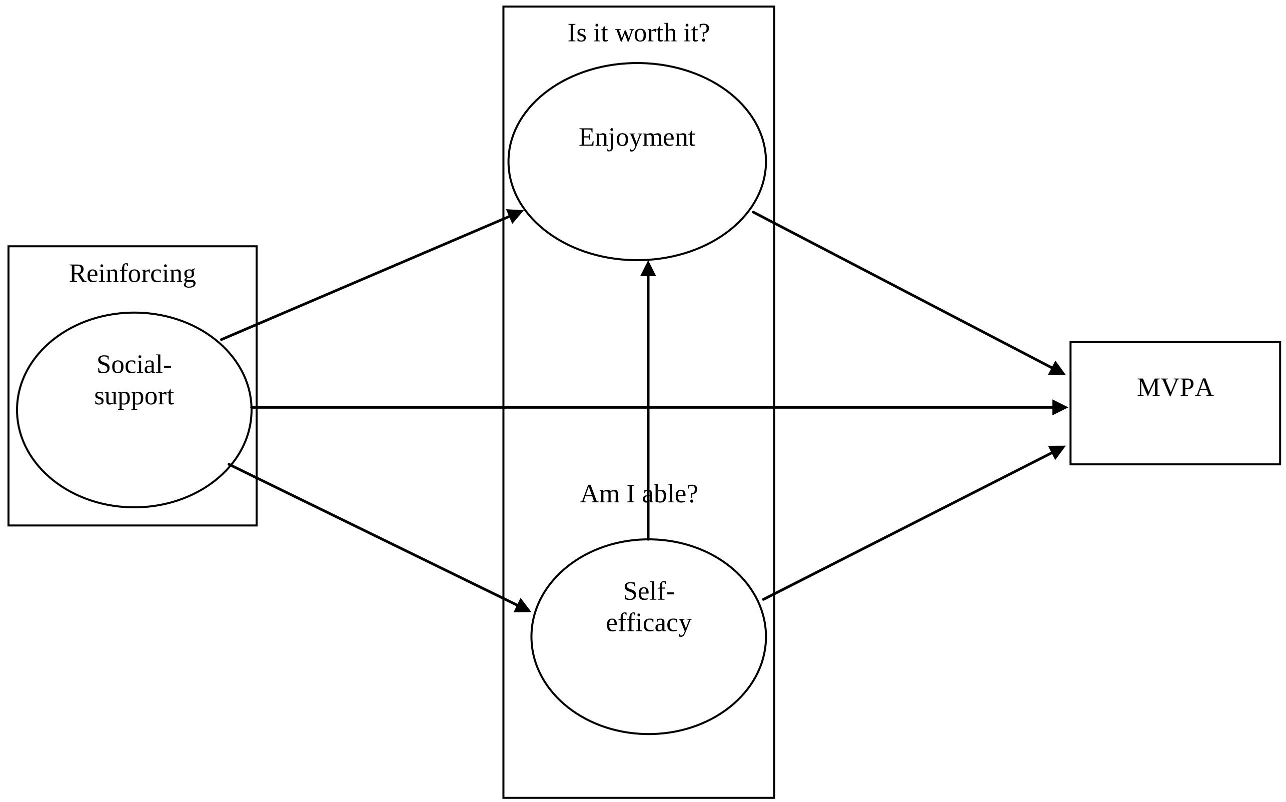


Figure 5 – Conceptual diagram of the YPAPM core.

Data Sets and Descriptions of Measures

***Study 1 (USA)*:**

Data for Study 1 were obtained from a previous study examining the validity of the Youth Media Campaign Longitudinal Survey (Welk, et al., 2007). The youth media campaign longitudinal survey (YMCLS) was used by the CDC to evaluate the VERB social marketing campaign and includes a detailed battery of physical activity questions and psychosocial correlates that have been used in previous research. The independent evaluation of the YMCLS survey (Welk, et al., 2007) involved a sample of 190 students that wore an accelerometer (MTI Actigraph monitor) for the week prior to completing the YMCLS survey. For the present study, we used a subsample of 159 students (83 girls and 76 boys) that had complete data on the survey and the accelerometer (mean age of sample was 11.52 ± 1.40 years). Stature was measured in the study using a wall stadiometer. Body mass was measured on a balance beam scale with the participant attired in gym shorts and T-shirt without shoes. BMI was calculated from stature and body mass ($kg \cdot m^2$).

The YMCLS survey questions were designed to evaluate the effectiveness of the VERB national media campaign to promote PA among children.[44] The battery included established psychosocial correlate measures (based on social cognitive theory constructs) but modifications were used to fit the specific purpose of the campaign.

Social Support – Social influences were assessed using 6 items that collectively captured child perceptions of peer support and social norms for being active. The items were scored on a four-point scale (*really agree* to *really disagree*). The reported internal consistency of the items was 0.70.

Am I Able? The *Am I Able construct was* assessed with four items that captured youth's perceptions about confidence in overcoming barriers to being physically active (aka self-efficacy). The barriers included being busy, being tired and challenges due to bad weather. An additional item assessed overall confidence in being physically active. The reported internal consistency was 0.66 (alpha reliability).

Is it Worth it? – The *Is it Worth it* construct was assessed with five items that captured children's perceptions outcome expectations for PA. The items assessed whether children felt that PA would be boring, fun, help them make new friends, help them play with friends or help them feel good about themselves. The items were scored using a 4 point likert scale (*really agree, sort-of agree, sort-of disagree,* and *really disagree)* and negatively worded items were recoded.

***Study 2 (PT)*:**

Data for Study 2 were obtained from an ongoing evaluation of physical activity in school aged youth population in the Porto metropolitan area (Aires, et al., 2008). For the present study, the sample comprised 203 students (125 girls, 78 boys), with a mean age of aged 14.99 ± 1.55 years. Standard anthropometric techniques were used to collect data on height, weight and BMI. Height was measured to the nearest mm in bare or stocking feet with the youth standing upright against a Holtain portable stadiometer. Weight was measured to the nearest Kg, lightly dressed (underwear and tee-shirt) using a portable digital beam scale (Tanita Inner Scan BC532). The BMI was estimated from the ratio weight/height^2 (Kg/m^2).

Details of the psychosocial correlates used in the evaluation of the YPAP model are summarized below:

Social Support - The *social-support* scale was adapted from Ward et al. (Ward, Saunders, & Pate, 2007) and originally developed by Sallis et al. (Sallis, Taylor, et al., 2002), this study included assessments of modeling, verbal encouragement, and participation with the subject from family members and peers. This is a more complete examination of potential social influences than has been reported previously, although in this study we only considered the peer influence. The psychometric properties of survey variables, as indicated by internal consistency reliabilities and test-retest were strong: peer influences (Cronbach alpha= .74; ICC= .70).

Am I Able?: The Am I Able construct was assessed using an adapted *Self-efficacy* scale that was originally developed by Motl et al. (Motl, et al., 2000) and later modified by Ward et al. (Ward, et al., 2007). The scale has eight items rated on a 5-point Likert-type scale ranging from 1 (Disagree a lot) to 5 (Agree a lot), this scale was invariant across one year (Motl, et al., 2000).

Is it Worth ir? – The *Is it Worth it* construct was assessed using a modified version of the *enjoyment* scale adapted by Ward et al. (Ward, et al., 2007). The original scale called Physical Activity Enjoyment Scale (PACES) was developed to measure physical activity enjoyment using college-aged students (Kendzierski & DeCarlo, 1991). Motl et al. (Motl, et al., 2001), tested the construct validity of the original PACES scale scores by using structural equation modeling of hypothesized relationships between enjoyment and factors influencing enjoyment of physical education, physical activity, and sport involvement. This study conclude that evidence of factorial validity and convergent evidence for construct validity indicate that the PACES is a valid measure of physical activity enjoyment among adolescent girls, suitable for use as a mediator variable in interventions designed to increase physical activity.

Assessment of physical activity

The MTI Actigraph activity monitor was used to obtain objective data on youth's physical activity behavior on both countries. The MTI is the most widely used accelerometry-based activity monitor. It was selected for use in the present study based on its established reliability and validity and because past work has established acceptable calibration equations to facilitate usage with youth.

The accelerometer was worn over 7 consecutive days in order to obtain a reliable picture of the habitual PA (Trost, McIver, & Pate, 2005), the adolescents wore the accelerometer in an elastic waistband on the right hip during waking time, except while bathing and during other aquatic activities. A data sheet was given to students who were instructed to record the time when the monitor was attached in the morning and detached in the evening. The accelerometer was setup to use an epoch of 1 minute, similar to other studies (Andersen & van Mechelen, 2005; Welk, Schaben, & Morrow, 2004). A specialized software (Kinesoft) was used for data reduction and further analyses, and the daily time spent in moderate and vigorous physical activity (>3MET) was calculated by summing the minutes of moderate, vigorous, and very vigorous PA for each day. For the MVPA (moderate to vigorous physical activity) determination, the age-specific count ranges corresponding to the intensity levels developed by Freedson (Freedson, Pober, & Janz, 2005) were adopted.

Statistical analyses

Descriptive statistics were used to describe participant's characteristics and the PA data. Independent samples *t*-test assessed the gender differences within each country. The Psychosocial scales reliability was given by Crombach's alpha. The fit indices of the YPAP model were analyzed through structural equation modeling (SEM) using AMOS (version 17.0). The measurement model specified the relationships between the observed indicators and the latent variables and the structural equation model specified the relationships amongst the latent variables. Maximum likelihood estimation procedures were used for calculating item loadings on the specified latent variables. Psychometric properties of the variables were evaluated by examining the internal reliability of the component scales and by subscale inter-correlations. Items were constrained a priori to load on their previously established constructs. Given that the traditional chi-square test is sensitive to sample size (Marsh, Balla, & McDonald, 1988), results were further evaluated with goodness of fit indices (CFI) and the root mean square error of approximation (RMSEA).

2.1.4 Results

Sample characteristics from both countries are presented in Table 1. In the US sample, no gender differences were found in the anthropometric variables or in the psychosocial correlates. In the PT sample, significant gender differences (p<.001) were found in the weight and height measures.

Table 4 – Descriptive characteristics for adolescents participating in the study

Characteristics	**USA**		**PT**	
(Mean ± SD)	**Boys**	**Girls**	**Girls**	**Boys**
Age	11.45 ± 1.38	11.58 ± 1.42	14.94 ± 1.58	15.08 ± 1.48
Weight	49.18 ± 13.94	52.45 ± 16.54	57.82 ± 9.75*	65.87 ± 11.87
Height	1.52 ± .10	1.52 ± .10	1.61 ± .06*	1.72 ± .08
BMI	20.93 ± 4.43	22.28 ± 5.18	22.12 ± 3.22	22.11 ± 3.39
Psychosocial				
Self-efficacy	1.49 ± .46	1.53 ± .47	2.43 ± .36**	2.56 ± .41
Enjoyment	1.48 ± .47	1.50 ± .45	1.48 ± .66	1.33 ± .54
Social-support	2.23 ± .30	2.22 ± .34	1.95 ± .28*	2.22 ± .31
Physical Activity				
Week MVPA minutes	129.72 ± 54.26*	100.52 ± 46.49	222.74 ± 103.85*	275.76 ± 125.60

* Significant difference between genders: $p<.001$; ** $p=.039$

Gender differences were also found in two psychosocial variables, self-efficacy (p<.05) and social-support (p<.001). In both countries, significant gender differences (p<.001) were found in the recorded amount of moderate to vigorous physical activity.

Study 1 (USA): the correlation matrix means and standard deviations for the US study variables are presented in Table 2. Social-support indicators, such as peer encouragement, were significantly correlated with self-efficacy indicators, such as social, mastery, and with one enjoyment indicator (mood). Peer involvement was also significantly correlated with the mastery indicator in the self-efficacy construct, and with the enjoy and mood items in the enjoyment construct. Of all the indicators, only peer involvement was significantly correlated with the MVPA amount.

Figure 2 shows the latent-variable structural equations model used to examine the proposed theoretical model (Figure 1) in the USA. Four different significant paths were observed. Social-support had a direct association with the MVPA amount (β=-.20, p<.05). Social support also directly influenced enjoyment (β=-.51, p<.05). A significant association was observed where social support directly predicts self-efficacy (β=-.36, p<.05). Finally, self-efficacy had a direct association with enjoyment (β=-.43, p<.05).

The overall fit of the model was good, as indicated by chi-square statistics of 214.53 with 97 degrees of freedom. The CFI was .99, which exceeds the recommended .95 for good fit, and although the chi-square was significant, the RMSEA was .03, well within the recommended range.

Table 5 - Bivariate Pearson Product-Moment Correlations (below the diagonal), Means and Standard Deviations of Physical Activity and Psychosocial Correlates in the USA.

Variables	Peer encour.A	Peer encour.B	Peer involve.A	Peer involve.B	Lifestyle	Social	Mastery	Enjoy	Mood	Interest	MVPA	Mean	SD
Peer encour.A	1											1.45	.643
Peer encour.B	-.035	1										1.78	.898
Peer involve.A	-.002	-.196*	1									2.78	.602
Peer involve.B	-.162*	-.166*	.205**	1								2.89	.720
Lifestyle	.104	.071	-.099	-.117	1							1.89	.824
Social	.186*	.230**	-.072	-.069	.275**	1						1.33	.633
Mastery	.253**	.190*	-.164*	-.224**	.214**	.209**	1					1.20	.447
Enjoy	.044	.116	-.107	-.244**	.282**	.084	.212**	1				1.40	.676
Mood	.188*	.148	-.195*	-.360**	.216**	.182*	.180*	.589**	1			1.29	.532
Interest	.061	.027	-.118	-.142	.220**	.101	.090	.139	.165*	1		1.25	.463
MVPA	.025	-.054	.206**	.259**	-.098	-.017	-.062	-.062	-.108	-.042	1	114.48	52.28

* Significant at the 0.05 level; ** Significant at the 0.01 level

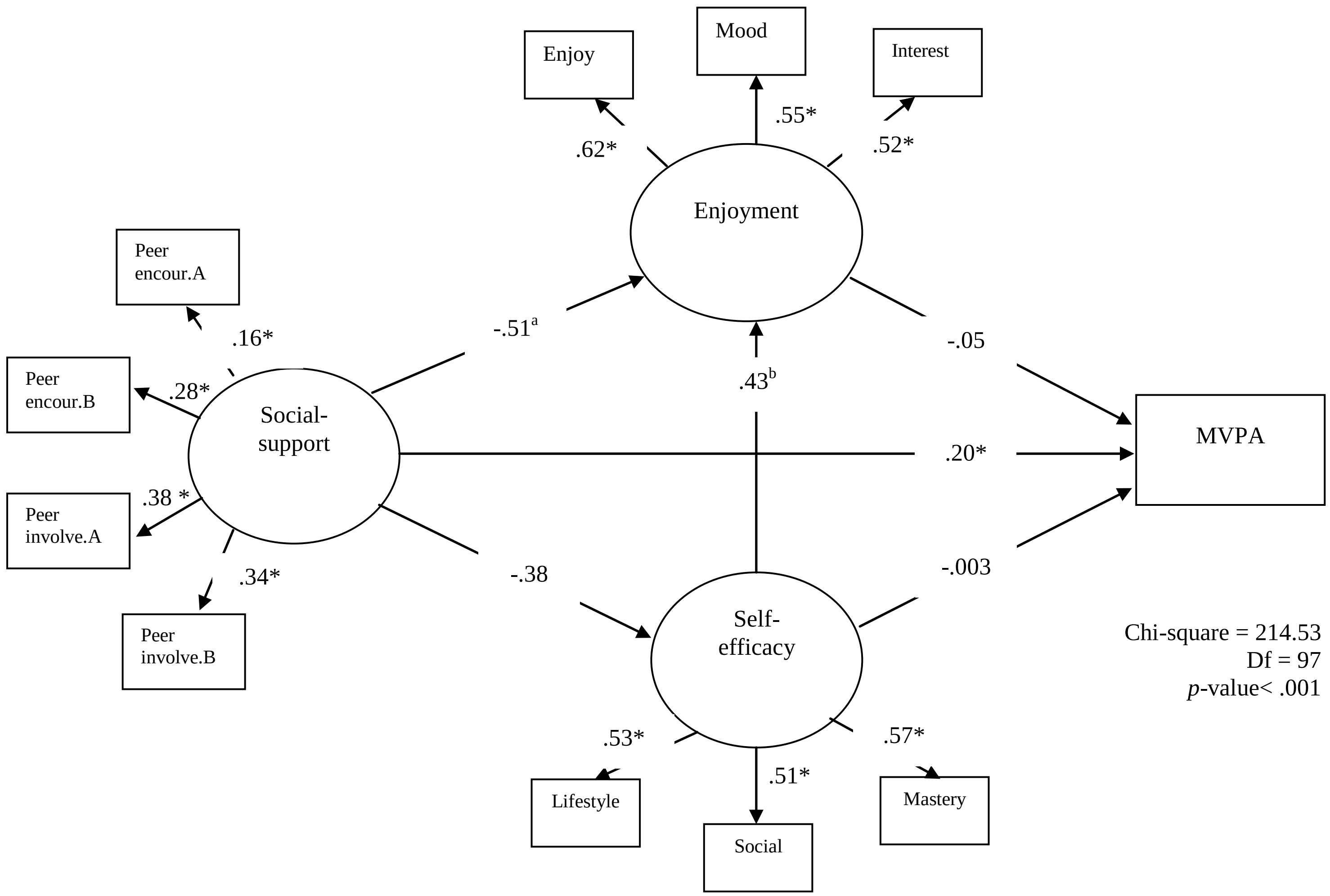


Figure 6 – Conceptual diagram of the YPAPM core applied in the USA sample (standardize regression weights; * *p*<.001, [a] *p*= .029, [b] *p*= .008; CFI= .986; RMSEA= .031). The standardized coefficients for the overall test of the model when statistically significant are accompanied by an asterisk or letter.

Study 2 (PT): the correlation matrix means and standard deviations for the PT study variables are presented in Table 3. All the social-support indicators were significantly correlated with all the self-efficacy indicators. Peer encouragement was also significantly correlated with enjoy and interest items, in the enjoyment construct. Peer involvement indicators were significantly correlated with all the enjoyment indicators. Of the all the indicators, only peer involvement was significantly correlated with the MVPA amount.

Figure 3 shows the latent-variable structural equations model used to examine the proposed theoretical model in PT. The standardized coefficients for the overall test of the model when statistically significant are accompanied by an asterisk or letter.

In the PT sample a different pattern of significant paths emerged. Social-support had a direct association with the MVPA amount (β=.41, p<.05) but the path from social-support to enjoyment was not significant as in the US sample (β=-.23, p>.05). Instead, the path from social-support to self-efficacy was highly significant (β=.69, p<.05) and in the reverse direction.

The overall fit of the model was very good, as indicated by the *chi-square* statistic of 70.67 with 47 degrees of freedom. The CFI was .95, which match the recommended .95 for good fit, and although the qui-square was significant (p= .014), the RMSEA was .05.

Table 6 - Bivariate Pearson Product-Moment Correlations (below the diagonal), Means and Standard Deviations of Physical Activity and Psychosocial Correlates in the Portugal.

Variables	Peer encour.A	Peer encour.B	Peer involve.A	Peer involve.B	Lifestyle	Social	Mastery	Enjoy	Mood	Interest	MVPA	Mean	SD
Peer encour.A	1											1.90	.52
Peer encour.B	.485**	1										1.95	.44
Peer involve.A	.462**	.351**	1									2.10	.50
Peer involve.B	.399**	.239**	.497**	1								1.99	.37
Lifestyle	.367**	.285**	.324**	.339**	1							2.46	.42
Social	.306**	.158*	.226**	.252**	.475**	1						2.34	.58
Mastery	.285**	.189*	.305**	.296**	.452**	.303**	1					2.70	.40
Enjoy	-.310**	-.202*	-.178*	-.301**	-.296**	-.238**	-.239**	1				1.46	.73
Mood	-.103	-.014	-.068	-.243**	-.153	-.180*	-.195*	.645**	1			1.30	.62
Interest	-.310**	-.150	-.195*	-.255**	-.263**	-.226**	-.196*	.760**	.620**	1		1.52	.72
MVPA	.143	.143	.224**	.150	.062	-.008	.069	-.056	.054	-.040	1	243.12	115.33

* Significant at the 0.05 level; ** Significant at the 0.01 level

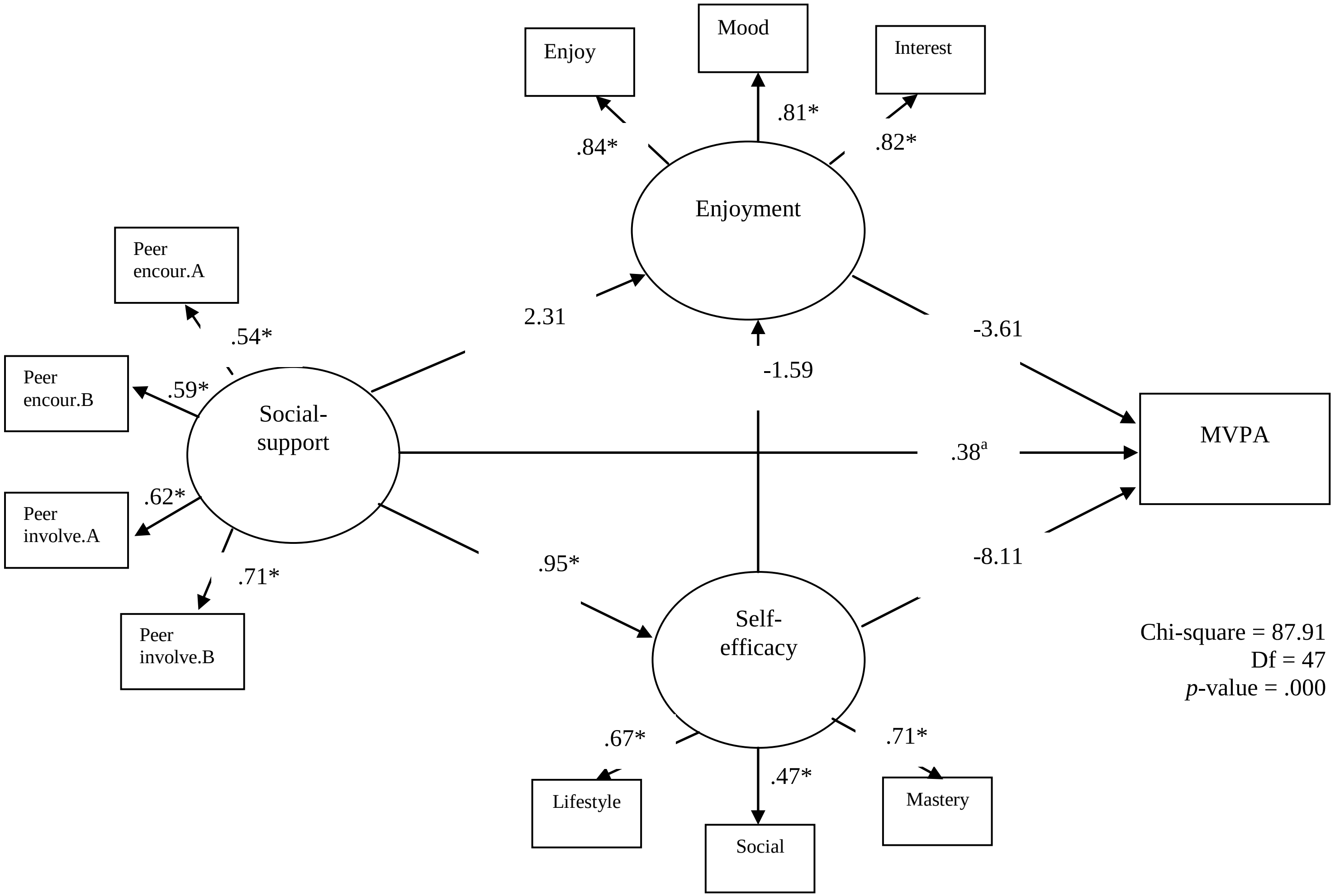


Figure 7 – Conceptual diagram of the YPAPM core applied in the PT sample (standardize regression weights; * *p*<.001, [a] *p*=.018; CFI= .92; RMSEA= .06). The standardized coefficients for the overall test of the model when statistically significant are accompanied by an asterisk or letter.

2.1.5 Discussion

This study provides an evaluation of the mediating variable framework proposed in the YPAP model to account for differences in physical activity in two different cultural contexts. The study provides new information about the utility of the YPAP Model (Welk, 1999) and extends preliminary validation work on different countries. Previous research has provided evidence supporting the utility of the YPAP model but this is the first study to investigate model fit using two different measurement batteries and in two different cultures.

Some modifications to the original model were necessary, but this is justifiable since the YPAP model was designed specifically for this purpose. Rather than specifying measures or constructs, the YPAP uses broad domains of influence to facilitate evaluation of youth activity behaviors (predisposing, reinforcing and enabling) (Welk, 1999). Although the two studies used different measurement instruments, the psychosocial correlates selected for inclusion captured the same underlying domains and constructs within the YPAP model.

This study supports the important contributions peer influences on children's predisposition to physical activity. The predisposing factors are viewed as the central component in the model since they reflect the child's drive or interest (predisposition) to be physically activity. The predisposing factors are the youth's perception of "Am I able?" and "Is it worth it?" to physical activity. Social cognitive variables (i.e., beliefs that are formed by social learning and reinforcement history) are recognized influences on self-initiated change in health behaviors such as physical activity (Bandura, 2004). They may be especially important during early adolescence, when physical activity increasingly becomes a leisure choice (Dishman, et al., 2008).

In concordance with our results, previous work also showed peer influence (a Reinforcing variable) to be an important factor in youth physical activity. Efficacy to overcome barriers, physically active friends, and social support from friends all played roles in reducing the decline in physical activity (Duncan, et al., 2007). Sallis et al. (Sallis, Taylor, et al., 2002) in a study in young people from grade 1 through 12, also with accelerometers, found that the most consistent correlates of physical activity was peer support. Salvy et al. (Salvy, et al., 2009) found that friendships may increase youth's motivation to engage in physical activity and promote greater physical activity in non-overweight and overweight youth. Moreover, youth who report greater presence of peers in their lives also report engaging in greater physical activity (Beets, Vogel, Forlaw, Pitetti, & Cardinal, 2006; De Bourdeaudhuij, et al., 2005; Duncan, Duncan, & Strycker, 2005; Salvy, et al., 2008).

Self-efficacy is one of the most studied correlates of physical activity (Sallis, et al., 2000b). Dishman et al. (Dishman, et al., 2008) in a study in high school girls stated that their self-efficacy about overcoming barriers to physical activity is formed by the eighth grade. Therefore, physical activity interventions designed to enhance self-efficacy might be especially needed during preadolescence. Since, low self-efficacy for overcoming barriers to physical activity appears to limit girl's attempts to be more active or their persistence regardless of changing perceptions of social support. Another study by Dishman et al. (Dishman, et al., 2004) demonstrated that the intervention had a direct effect on self-efficacy which had a subsequent direct effect on physical activity. This was first and only experimental evidence showing that increased self-efficacy directly results in increased physical activity among adolescent girls.

The observed correlations among enjoyment, physical activity, and sport involvement lend support to the importance of the enjoyment (i.e., intrinsic motivation) component of expectancy-value theories as a possible target for interventions (Motl, et al., 2001). Similar to the self-efficacy study, the LEAP intervention study, Dishman et al. (Dishman, et al., 2005) showed that increases in enjoyment partially mediated the positive effect of the intervention. Another study (Barr-Anderson, et al., 2007), with six grade girls, concluded that Interventions that increase self-efficacy and enjoyment of PE could result in greater participation in structured PA and higher overall PA levels among adolescent girls. Paxton et al. (Paxton, Estabrooks, & Dzewaltowski, 2004) had shown a similar mediating effect of attraction (Is it worth it?) in the relationship between perceived competence (Am I able?) and physical activity, but that model did not include the link of peer influence.

The different observed paths within the both countries are an interesting finding. This difference might be attributed to the difference in the age of the two samples, with the US sample being younger than the PT sample. This might point to the fact that younger youth might receive peer support through enjoyment, and older youth received the influence of peer support through skill and self-worth processes.

The YPAP model showed good fit to the data and had greater parsimony (lower degrees of freedom) without sacrificing the variance in physical activity explained by the model. The use of structural equation modeling allowed a more comprehensive examination of the factors that affect physical activity, this technique also has the advantage of showing more accurate estimates for the relations between latent constructs (such as psychosocial variables) by explicitly modeling the measurement error. It allows examination of problems similar to the way they occur in a natural setting: simultaneous influences of multiple factors. Since physical activity promotion is multi-faceted, it makes good theoretical sense to evaluate those factors using this technique. The dilemma in examining physical activity in a psychosocial and social ecological theoretical framework is balancing parsimony with comprehensiveness. Structural equation modeling has been highly recommended for evaluating longitudinal intervention studies since it makes it possible to determine *how* an intervention worked, rather than simply that it did work. Ward et al. (Ward, et al., 2006) have used structural equation modeling to evaluate the effectiveness of a large-scale longitudinal intervention to increase youth physical activity.

The strengths of this study included the use of previously validated survey instruments to examine the psychosocial correlates of physical activity, the use of accelerometer as an objective measure of PA, and the use of structural equation modeling to extend previous work testing mediating variables predicting youth physical activity. One of the limitations of this study was the cross-sectional design. Although, while an increase emphasis on descriptive longitudinal studies may help to identify more highly predictive causal mediators, the global pediatric obesity epidemic and general decline in physical activity amount require immediate interventions (Lubans, Foster, & Biddle, 2008).

Human health is a social matter, not just an individual one. A comprehensive approach to health promotion also requires changing the practices of social systems that have widespread effects on human health (Bandura, 2004). The results indicate that the YPAP model provides a useful framework for studying the psychosocial correlates and mediators of physical activity in both countries, pointing to an adequacy and relevance in different cultural contexts. An additional advantage of the YPAP model is its inherent simplicity; the conceptual links provide ways to integrate potential influences from school, family, and community interventions into a single model of activity behavior. Once a model becomes so complex that it cannot be easily applied or disseminated, it loses some of its inherent value (Welk, 1999).

The present study extended previous research by: (1) employing established and validated measures of the physical activity correlates, (2) demonstrating that the constructs relationships were relevant in both countries, with different pathways, and (3) the use of SEM rather than traditional analytic approaches of bivariate correlation and multiple regression analyses on observed variables. Future research using the Youth Physical Activity Promotion model may extend the utility of the YPAP as an evaluation framework for intervention studies, and further evaluation of enabling or ecological measures for use in the model may also enhance the overall utility of the YPAP.

Acknowledgments

This study was supported by FCT - SFRH/BD/23088/2005.

2.1.6 References

Ommundsen Y, Klasson-Heggebo L, Anderssen SA. Psycho-social and environmental correlates of location-specific physical activity among 9- and 15-year-old Norwegian boys and girls: the European Youth Heart Study. *Int J Behav Nutr Phys Act.* 2006;3:32.

Sallis JF, Taylor WC, Dowda M, Freedson P, Pate R. Correlates of Vigorous Physical Activity for Children in Grades 1 Through 12: Comparing Parent-Reported and Objectively Measured Physical Activity. *Pediatric Exercise Science.* 2002;14:30-44.

Welk G. The youth physical activity promotion model: A conceptual bridge between theory and practice. *Quest.* 1999(51):5-23.

Dowda M, Dishman RK, Pfeiffer KA, Pate RR. Family support for physical activity in girls from 8th to 12th grade in South Carolina. *Prev Med.* Feb 2007;44(2):153-159.

Duncan SC, Duncan TE, Strycker LA, Chaumeton NR. A cohort-sequential latent growth model of physical activity from ages 12 to 17 years. *Ann Behav Med.* Feb 2007;33(1):80-89.

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

Welk G, Wood K, Morss G. Parental influences on physical activity in children: An exploration of potential mechanisms. *Pediatric Exercise Science.* 2003(15):19-33.

Welk G, Babke M, Brustad R. Casual links among determinants of physical activity in children: A structural equation model. *Med Sci Sports Exerc.* 1998;30(5):S182.

Dishman RK, Saunders RP, Motl RW, Dowda M, Pate RR. Self-Efficacy Moderates the Relation Between Declines in Physical Activity and Perceived Social Support in High School Girls. *J Pediatr Psychol.* Sep 30 2008.

Weiss MR, Smith AL, Theeboom M. "That's What Friends Are For": Children's and Teenagers' Perceptions of Peer Relationships in the Sport Domain. *Journal of Sport & Exercise Psychology.* 1996;18(4):347-379.

Van Der Horst K, Paw MJ, Twisk JW, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth. *Med Sci Sports Exerc.*

Aug 2007;39(8):1241-1250.

Salvy SJ, Roemmich JN, Bowker JC, Romero ND, Stadler PJ, Epstein LH. Effect of peers and friends on youth physical activity and motivation to be physically active. *J Pediatr Psychol.* Mar 2009;34(2):217-225.

Bandura A. Health promotion by social cognitive means. *Health Educ Behav.* Apr 2004;31(2):143-164.

Welk GJ, Wickel E, Peterson M, Heitzler CD, Fulton JE, Potter LD. Reliability and validity of questions on the youth media campaign longitudinal survey. *Med Sci Sports Exerc.* Apr 2007;39(4):612-621.

Aires L, Silva P, Santos R, Santos P, Ribeiro JC, Mota J. Association of physical fitness and body mass index in youth. *Minerva Pediatr.* Aug 2008;60(4):397-405.

Ward DS, Saunders R, Pate R. *Physical Activity Interventions in Children and Adolescents*. Champaign, IL: Human Kinetics; 2007.

Motl RW, Dishman RK, Trost SG, et al. Factorial validity and invariance of questionnaires measuring social-cognitive determinants of physical activity among adolescent girls. *Prev Med.* Nov 2000;31(5):584-594.

Kendzierski D, DeCarlo K. Physical activity enjoyment scale: two validation studies. *J Sport Exerc Psychol.* 1991;13(1):50-64.

Motl RW, Dishman RK, Saunders R, Dowda M, Felton G, Pate RR. Measuring enjoyment of physical activity in adolescent girls. *Am J Prev Med.* Aug 2001;21(2):110-117.

Trost SG, McIver KL, Pate RR. Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc.* Nov 2005;37(11 Suppl):S531-543.

Welk GJ, Schaben JA, Morrow JR, Jr. Reliability of accelerometry-based activity monitors: a generalizability study. *Med Sci Sports Exerc.* Sep 2004;36(9):1637-1645.

Andersen LB, van Mechelen W. Are children of today less active than before and is their health in danger? What can we do? *Scand J Med Sci Sports.* Oct 2005;15(5):268-270.

Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children. *Med Sci Sports Exerc.* Nov 2005;37(11 Suppl):S523-530.

Marsh HW, Balla JR, McDonald RP. Goodness of fit indexes in confirmatory factor analysis: The effect of sample size. *Psychol Bull.* 1988(103):391-410.

Beets MW, Vogel R, Forlaw L, Pitetti KH, Cardinal BJ. Social support and youth physical activity: the role of provider and type. *Am J Health Behav.* May-Jun 2006;30(3):278-289.

Salvy SJ, Bowker JW, Roemmich JN, et al. Peer influence on children's physical activity: an experience sampling study. *J Pediatr Psychol.* Jan-Feb 2008;33(1):39-49.

De Bourdeaudhuij I, Philippaerts R, Crombez G, et al. Stages of change for physical activity in a community sample of adolescents. *Health Educ Res.* Jun 2005;20(3):357-366.

Duncan SC, Duncan TE, Strycker LA. Sources and types of social support in youth physical activity. *Health Psychol.* Jan 2005;24(1):3-10.

Dishman RK, Motl RW, Saunders R, et al. Self-efficacy partially mediates the effect of a school-based physical-activity intervention among adolescent girls. *Prev Med.* May 2004;38(5):628-636.

Dishman RK, Motl RW, Saunders R, et al. Enjoyment mediates effects of a school-based physical-activity intervention. *Med Sci Sports Exerc.* Mar 2005;37(3):478-487.

Barr-Anderson DJ, Young DR, Sallis JF, et al. Structured physical activity and psychosocial correlates in middle-school girls. *Prev Med.* May 2007;44(5):404-409.

Paxton RJ, Estabrooks PA, Dzewaltowski D. Attraction to physical activity mediates the relationship between perceived competence and physical activity in youth. *Res Q Exerc Sport.* Mar 2004;75(1):107-111.

Ward DS, Dowda M, Trost SG, Felton GM, Dishman RK, Pate RR. Physical activity correlates in adolescent girls who differ by weight status. *Obesity (Silver Spring).* Jan 2006;14(1):97-105.

Lubans DR, Foster C, Biddle SJ. A review of mediators of behavior in interventions to promote physical activity among children and adolescents. *Prev Med.* Nov 2008;47(5):463-470.

Chapter 3

Chapter 3

3.1 Individual contexts

Manuscript: Lifespan snapshot of Physical activity assessed by accelerometry in Porto

3.1.1 Abstract

Background: The purpose of the study is to evaluate age and gender differences in objectively measured levels of physical activity (PA) in a large and diverse sample of residents from an urban area in Porto Portugal.

Methods: Participants included 822 residents, 334 males (41%) and 488 females (59%), aged 6-90 years. GT1M accelerometer was used to assess daily PA over 7 consecutive days, and the measurement was from October (2007) to June (2008).

Results: Males were more active than females. This difference was attenuated in the two oldest age groups (40-59 and 60+ yrs). An accentuated declined in all PA variables occurred between the youngster group (6-11 yrs) and adolescents group (12-19 yrs). Surprisingly, young adults (20-39 yrs) engaged in more MVPA than adolescents. Further, females also had higher MVPA in the fourth group (40-59 yrs) compared to the second group (12-19 yrs). Males had higher compliance rates of PA guidelines than females regardless the age group considered. Adolescents had very low compliance rates (females= 18.18%; males=33.50%).

Conclusions: Porto metropolitan area residents had low rates of compliance with current PA guidelines. A low level of PA in Porto adolescents is a matter of concern and suggests that interventions are needed.

Key-words: Physical activity guidelines, children, adolescents, adults, older adults.

3.1.2 Introduction

The global epidemic of obesity has led to considerable interest in patterns of physical activity in the population. A better understanding of the factors that influence active lifestyles is needed to help improve the effectiveness of public health activity programming (Sallis, et al., 2000b).

Portugal is among the European countries with higher prevalence of Obesity. A large study on over 8000 adults (aged 18-64) reported that 39.4% of the sample was overweight (BMI between 25.0 and 29.9) while an additional 14.2% were obese (BMI > or = 30). From 1995 to 2005 the overall prevalence of overweight/obesity increased from 49.6% to 53.6% (do Carmo, et al., 2008). Studies also have shown a high prevalence of overweight and obesity (31%) in Portuguese children aged 7-9 years (Padez, et al., 2004), and in adolescents (Ribeiro, et al., 2003). Those obesity rates are comparable with childhood obesity prevalence rates found in other Southern European countries, and higher than those found in North European countries (Lobstein & Frelut, 2003). It is presently not known if these patterns are due to lifestyle factors or to underlying social, cultural and genetic factors.

Recent studies have reported that levels of physical activity in Portugal may be lower than in other countries (Vaz de Almeida, et al., 1999). However, those reports relied on self-reported measures that reflect general levels of activity and are susceptible to problems with recall, social desirability and literacy (Metzger, et al., 2008). Accelerometers are now accepted as a more effective (and objective) way to capture information about physical activity in the population.

In the United States, accelerometers have been incorporated into large surveys such as the 2003–2004 National Health and Nutrition Examination Survey (NHANES). In this survey, the accelerometry data were collected during a 7-d period, allowing for an assessment of the number of minutes of physical activity accumulated by each participant on each day of a 7-d week, providing the first nationally representative sample of objectively measured physical activity in the United States (Troiano, et al., 2008). A study with similar methodology was also carried out in Sweden, in 1114 adults (Hagstromer, Oja, & Sjostrom, 2007).

Accurate data about physical activity in the population is important for public health surveillance and for identifying groups that may require targeted interventions. The present study utilizes accelerometers to evaluate physical activity patterns from a large sample of Portuguese individuals to better understand the activity profiles of this population. The specific aims of this study were (1) to report data regarding the different physical activity intensities and sedentary behavior from a lifespan perspective and (2) to analyze the compliance of the physical activity guidelines.

3.1.3 Methods

Participants

The participants in the study included 822 residents in Porto metropolitan area, 334 males (41%) and 488 females (59%). The participants were recruited primarily through local schools and universities, however concerted efforts were made to recruit participants across a wide range of ages, body sizes and social classes. Parents of children in elementary, middle school and high school were recruited (along with their children) in order to obtain samples of typical youth (6-17 yrs old) and adult (30-50 yrs old) residents. Young adults (18-30 yrs old) were recruited through the universities and older adults (50+ yrs old) were recruited through older adult programming that was provided to residents through the universities. The participants ranged in age from 6-90 years and data were collected over a 9 month period from October (2007) to June (2008). To be included in the study the subjects needed to be free of health problems and be willing to comply with the activity monitoring protocol. The Portuguese Ministry for Science and Technology provided permission to conduct this study, and informed written consent was obtained from each participant or their parents if minor of age.

Anthropometry

Stature was measured using the Harpenden Portable Stadiometer (Holtain Ltd, UK), and the values were recorded in centimeters to the nearest mm. Body mass was measured to the nearest 0.1 kg with an electronic weighing scale (Tanita Inner Scan BC 532, UK), with the subjects using light clothes. Body mass index (BMI) (kg/m2) was calculated from the ratio of weight/height^2, and subjects were categorized by levels of BMI based on Cole cut-points (Cole, 2002).

Physical Activity and sedentary behavior

The accelerometer model GT1M from Actigraph was used to obtain detailed information about daily PA and inactivity over 7 consecutive days. This lightweight, biaxial monitor is the latter model available by the manufacturer, and studies have demonstrated that it is a technically reliable instrument, both within and across monitors (Rothney, Apker, Song, & Chen, 2008). All the subjects were informed about the utility of the accelerometer and the objectives of the study prior to participating. The accelerometer was attached tightly in the hip, on the right side, with the notch faced upwards, according to established procedures (Leenders, Sherman, & Nagaraja, 2000). The *epoch* was set to 15 seconds epochs to allow a more detailed estimate of physical activity intensity (Nilsson, Ekelund, Yngve, & Sjostrom, 2002a; Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005).

The accelerometer data was analyzed by an automated data reduction program (MAHUffe; see www.mrc-epid.cam.ac.uk) that provided options for screening the data and computing outcomes. Data files from individual participants were screened by detecting blocks of consecutive zeros. Periods with 60 minutes of consecutive zeros were detected and flagged as times in which the monitor was not worn (Troiano, et al., 2008). Participants had to have at least 10 hours of data to count as a valid day and to have at least 4 valid days to be included. The screening procedures are consistent with current accelerometry studies and also similar to the screening used in NHANES (Troiano, et al., 2008).

After screening was completed, the raw activity “counts” were processed for determination of time spent in the different physical activity intensities. Activity levels were expressed in mean counts.min^{-1} and also in estimates amounts of moderate to vigorous activity. The established accelerometer cut-points proposed by Freedson and published by Trost (Trost, et al., 2002) were used for participants less than 18 years of age. In adults, the cut-points used in the NHANES study (Troiano, et al., 2008) were used in order to permit comparisons. Sedentary behavior was identified using a cut-point of <500 counts.mint^{-1}, and sustained periods of PA were determined if subjects had at least 10 minutes of MVPA.

The focus of the study was on evaluating compliance with established physical activity guidelines. For youth less than 18 years old the target was considered to be at least 60 minutes of MVPA. For older subjects, the criteria of at least 30 minutes of MVPA was used (Pate, et al., 1995). The outcome variable of compliance was determined by dividing the number of days with the recommend guidelines by the number of valid accelerometer days.

Statistical Analysis

The subjects were divided in five different categories according to their age using the same age thresholds employed by Troiano et al. (Troiano, et al., 2008). Means and standard deviations were calculated to describe the participant's characteristics. Gender differences were examined withT-Test and Mann-Whitney testsfor two independent samples. A two (gender) by five (Age Groups) analyses of variance (ANOVA) was used to assess the age groups differences, and post-hoc test were used with the Bonferroni adjustments. Differences in achieving recommendations were analyzed using chi-square test for proportions. All analyses were performed by using the software Microsoft Excel 2003 and the Statistical Package for Social Sciences (SPSS, version 15.0 for WINDOWS; SPSS Inc, Chicago), and the level of significance was set at $p \leq 0.05$.

3.1.4 Results

The descriptive variables and anthropometric characteristics of the study sample are shown in Table 1. There were no significant differences between genders for the youngest age group (6-11 yrs). However, significant gender differences were found in all anthropometric variables for the next oldest age group ($p<0.01$). In the other three remain age groups, males were significantly ($p<0.01$) heavier and taller than females, and a significant difference ($p<0.01$) was also found in BMI in the 40-59 yrs group.

Table 1 – Characteristics of the sample (Mean and SEM).

	6-11 yrs				12-19 yrs				20-39 yrs				40-59 yrs				60+ yrs			
	Female		Male		Female		Male		Female		Male		Female		Male		Female		Male	
N	60		46		252		176		37		23		41		35		83		40	
Age (yrs)	9.6	(0.5)	9.5	(0.6)	14.6	(0.2)	14.7	(0.3)	32.6	(0.6)	30.3	(0.8)	46.9	(0.6)	46.6	(0.6)	70.4	(0.4)	73.1	(0.6)
Weight (Kg)	37.2	(1.4)	36.9	(1.6)	54.8	(0.7)*	63.1	(0.8)	60.9	(1.8)*	74.1	(2.3)	61.2	(1.7)*	77.0	(1.8)	65.9	(1.2)*	76.9	(1.7)
Height (m)	1.4	(0.0)	1.4	(0.0)	1.6	(0.0)*	1.7	(0.0)	1.6	(0.0)*	1.7	(0.0)	1.6	(0.0)*	1.7	(0.0)	1.6	(0.0)*	1.7	(0.0)
BMI ($Kg.m^{-2}$)	18.5	(0.4)	18.5	(0.5)	21.3	(0.2)*	22.1	(0.3)	23.3	(0.6)	24.3	(0.7)	24.4	(0.5)*	26.1	(0.6)	26.9	(0.4)	27.6	(0.5)
Overweight [a]	23.3		26.1		16.3*		28.4		13.5		26.1		26.8		51.4		53.0		50.0	
Obese [a]	10		6.5		3.2*		7.4		2.7		4.3		7.3		5.7		18.1		22.5	

[a] Classification based on Cole (2000) cut-points (percentage values).
* Significant gender difference (p<0.01)

Descriptive data on physical activity are provided in Table 2. Males generally had higher values than females in count.min^{-1}, moderate PA (MPA), vigorous PA (VPA) and moderate to vigorous PA (MVPA) variables, in all age groups, but this difference was attenuated in the two oldest age groups (40-59 and 60+ yrs). There were significant ($p<0.01$) differences between genders in all the PA variables including sedentary time, in the 12-19 yrs group. The same pattern was evident in the 6-11 yrs with the exception of light PA (LPA). In these two age groups boys also had higher light PA values and lower sedentary values.

Males were also more active than females in the 20-39 years age range, with statistically significant differences evident in MPA and MVPA. The patterns of sedentary activity and LPA were different for these older ages. While younger males had significantly lower levels of sedentary activity, older males tended to have higher sedentary values. The opposite relationship occurred in LPA (although not statistically significant) with males having lower levels of LPA in the third, fourth and fifth age groups.

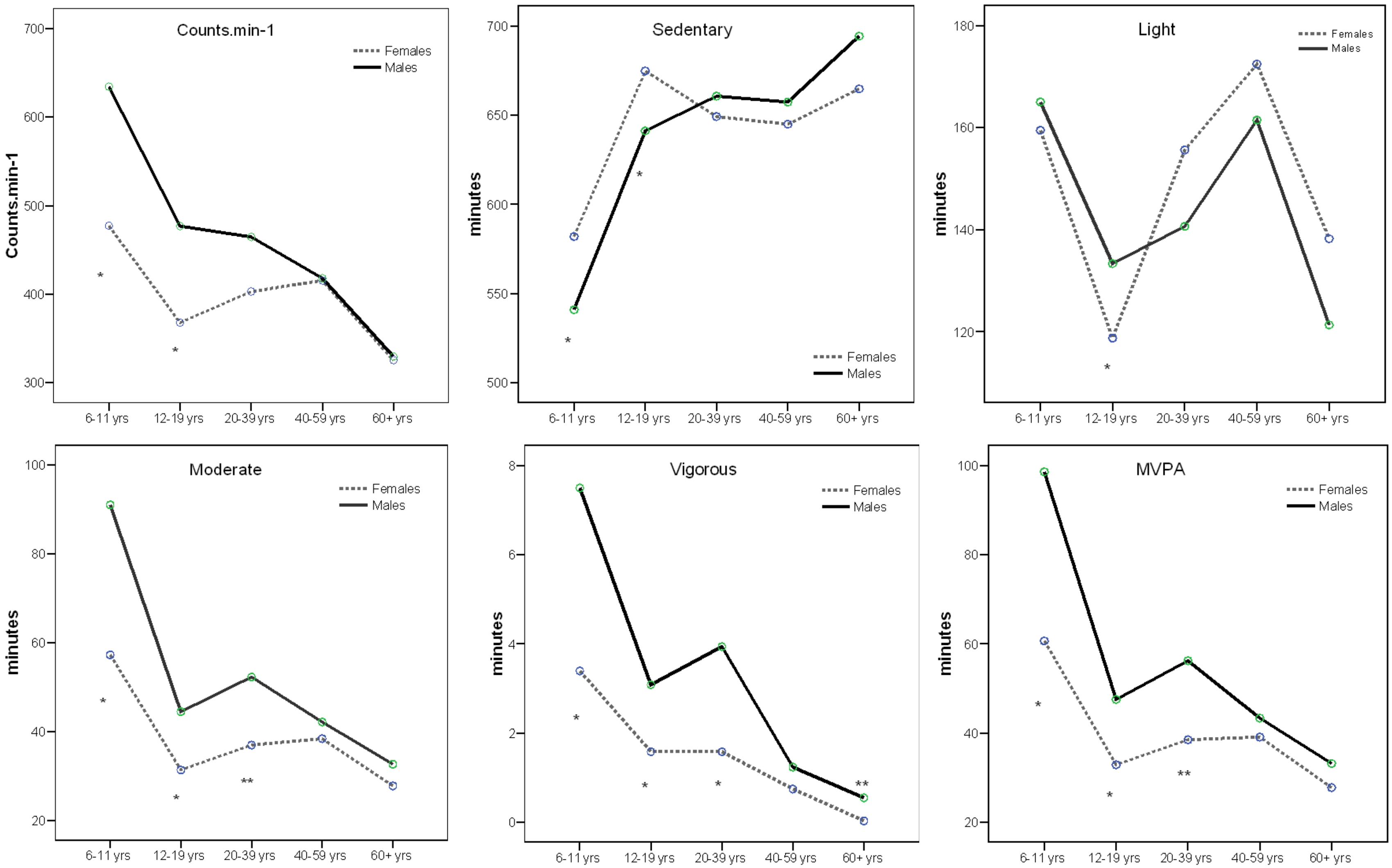
Figure 1 demonstrates an accentuated decline in all PA variables occurred between the first age group (6-11 yrs) and the second (12-19 yrs). Surprisingly, there was no evidence of declining PA between group 2 (12-19 yrs) and group 3 (20-39 yrs). The older group had higher LPA, MPA, VPA and MVPA values than the second, and this was consistent for males and females. Even more surprising is the observation that females in the fourth group (40-59 yrs) had higher counts.$^{min-1}$, MVPA, LPA, MPA, and MVPA values than the females in the second age group. To notice the higher sedentary values the females from the 12-19 yrs group.

Table 2 – Physical activity intensities (Mean and SEM), according to age groups.

		Count. min^{-1}	Sedentary (min)	Light (min)	Moderate (min)	Vigorous (min)	MVPA (min)
6-11 yrs	**Female**	477.3 (16.9)*†	582.0 (11.1)$^{*\text{✟}}$	159.5 (5.6)^{ab}	57.3 (2.8)*†	3.4 (0.5)$^{*h\text{✟}}$	60.7 (3.0)*†
	Male	634.3 (19.2)*	541.0 (12.7)*	165.0 (6.4)^{ab}	91.1 (3.2)*	7.5 (0.5)^{*h}	98.6 (3.4)*
12-19 yrs	**Female**	367.9 (8.3)†	674.7 (5.5)†	118.8 (2.8)^{acd†}	31.3 (1.4)^{f†}	1.6 (0.2)^{gh†}	32.9 (1.5)^{f†}
	Male	476.9 (9.8)	641.2 (6.5)	133.4 (3.3)^{acd}	44.5 (1.6)^{f}	3.1 (0.3)^{gh}	47.6 (1.7)^{f}
20-39 yrs	**Female**	403.1 (21.9)	649.1 (14.4)	155.6 (7.3)^{c}	37.0 (3.6)^{f}‡	1.6 (0.6)^{fh}	38.5 (3.9)^{f}‡
	Male	464.6 (27.8)	660.6 (18.3)	140.6 (9.2)^{c}	52.3 (4.6)^{f}	3.9 (0.7)^{fh}	56.2 (4.9)^{f}
40-59 yrs	**Female**	415.6 (20.1)	644.9 (13.2)	172.4 (6.7)^{de}	38.4 (3.3)^{f}	0.7 (0.5)^{gh}	39.1 (3.5)^{f}
	Male	418.0 (21.6)	657.3 (14.2)	161.5 (7.2)^{de}	42.1 (3.6)^{f}	1.2 (0.6)^{g}	43.4 (3.8)^{f}
60+ yrs	**Female**	325.6 (14.0)**	664.7 (9.2)	138.2 (4.7)^{be}	27.8 (2.3)**	0.0 (0.4)^{h}	27.8 (2.5)**
	Male	329.6 (20.5)**	694.2 (13.5)	121.3 (6.8)^{be}	32.6 (3.4)**	0.6 (0.6)^{h}	33.2 (3.6)**

* Significant difference from the other Age groups $p< 0.001$
** Significant difference from the other Age groups $p< 0.01$
^{a,b,c,d,e,h} Significant difference between Age groups $p< 0.001$
^{f} Significant difference from first and last Age groups $p< 0.001$
^{g} Significant difference between Age groups $p< 0.001$

† Significant gender difference $p< 0.001$
$^{\text{✟}}$ Significant gender difference $p< 0.01$
‡ Significant gender difference $p< 0.05$



* Significant difference between genders $p<0.001$ ** Significant difference between genders $p<0.05$

Figure 1 – Differences between genders in the physical activity intensities (Mean), according to age groups.

Table 3 demonstrates that all age groups exhibited low compliance with current PA guidelines. There was a significant ($p<0.001$) gender difference in the youngest age groups (6-11 yrs and 12-19 yrs), with males having higher compliance rates. The second youngest group (12-19 yrs) had the worst compliance rates with only 18.18% of females and 33.50% of males meeting the standard. This was also a significant ($p<0.001$) difference between the others age groups.

Table 3 – Number of days with compliance of the physical activity guidelines, adjusted to the number of accelerometer valid days (Mean Percentage).

		Percentage	SEM	Gender *p*
6-11 yrs [a]	**Female**	44.97	3.70	
	Male	76.95	4.21	0.001
12-19 yrs [a b]	**Female**	18.18	1.83	
	Male	33.50	2.16	0.001
20-39 yrs	**Female**	56.50	4.80	
	Male	64.99	6.08	0.29
40-59 yrs	**Female**	52.17	4.40	
	Male	56.15	4.73	0.57
60+ yrs [a c]	**Female**	36.87	3.07	
	Male	42.09	4.50	0.40

[a] Significant difference between Age groups $p< 0.001$

[b,c] Significant difference between all Age groups $p< 0.001$

The data was also analyzed to examine the amount of MPA accumulated in bouts of ten minutes or more. Figure 2 displays gender differences in MPA bouts between genders and age groups. We can see that males present higher values than females in all age groups, but this is only statistically significant ($p<0.001$) in the two youngest groups. Males also presented higher changes in sustained PA between age groups, with the first and third age groups showing higher values. Females had more similar values between age groups, but to notice a slight increase in the third and fourth age groups.

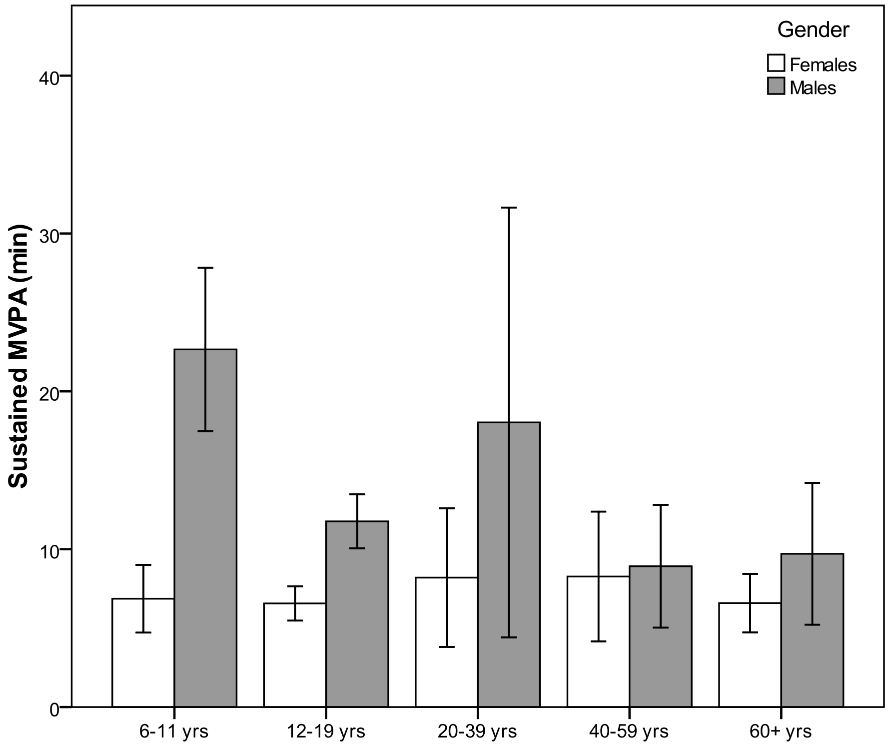


Figure 2 – Differences in sustained physical activity, for periods of at least 10 minutes in MVPA.

3.1.5 Discussion

This was the first study in Portugal that has reported objectively measured physical activity levels in such a broad sample. Although this is a timely topic relatively few accelerometer studies have been conducted in European countries thus far (Armstrong & Welsman, 2006). The levels of PA realized, at any point of an individual lifespan, reflect a complex interaction of biological, psychological and sociological factors (Sallis & Hovell, 1990). Therefore, the PA patterns of any individual, in terms of mode, frequency and intensity, will not remain stable from childhood into adulthood. The standardized use of accelerometers across the diverse ages in this study avoids problems associated with recall or social desirability (Livingstone, Robson, Wallace, & McKinley, 2003) and allows age related patterns to be objectively examined.

Data were obtained over 7 days but the results were interpreted as being indicative of habitual PA. The results showed that in almost all PA variables males were more active than females; but females had higher values than males on LPA after the third age group (20-39 yrs). The results show that participation in PA doesn't decrease in a linear fashion with age. There was a steeper decrease from the first age group (6-11 yrs) to the second (12-19 yrs) and then a slightly increase from the second to the third age group (20-39 yrs). After this age group, there was a consistent decline for the remaining age groups. Vigorous PA values were very low in all the subjects presented in this study.

Sedentary behavior had somewhat opposite results and there were some clear gender differences in the patterns observed across age groups. Females from the first two age groups had higher levels of sedentary behavior but, after the second age groups the males had higher values than females.

Our results were consistent with a recent study in the U.S. population (Troiano, et al., 2008), which also reported a dramatically decrease of PA assed by accelerometry during adolescence. The steep declines in activity during adolescence are also consistent with survey results obtained from a large sample of Portuguese youth (Teixeira e Seabra, et al., 2008). The decrease in levels of physical activity (PA) in adolescence is an important public health issue. While tracking studies are not conclusive, it is possible that lower levels of activity may increase the likelihood of being sedentary later in life. Physical inactivity has some negative health consequence for youth (Raitakari, et al., 1994) and there is clear evidence of significant health problems later in life including early onset of CHD, osteoporosis or adult obesity (Fox & Riddoch, 2000; Strong, et al., 2005).

There have been few studies reporting activity levels in young adults with accelerometers, and none to date in Europe. In the U.S., a study with a sample of college students (Dinger & Behrens, 2006) reported similar values for time spent in moderate physical activity (males = 51.7 ± 19.8 $min.d^{-1}$ vs females = 42.5 ± 17.0 $min.d^{-1}$, $P<0.01$). Our results for adults were also similar to those reported by Matthews et al. (Matthews, Ainsworth, Thompson, & Bassett, 2002). They reported values of 32.6 $min.day^{-1}$ for males and 27.6 $min.day^{-1}$ for females and these are similar to the values for the same age group in our study (males: 42.1 $min.day^{-1}$ and females: 38.4 $min.day^{-1}$).

Results with adults were also similar to a large accelerometry study in Swedish adults (Hagstromer, et al., 2007). The average intensity of moderate and vigorous physical activity decreased with age and was progressively lower among progressively higher body mass index (BMI) values. It was found that men spent more time than women in moderate and vigorous physical activity, although without significant gender differences. Whereas, our study showed significant gender differences at age 20-39 years in Moderate, Vigorous and MVPA, and also in vigorous PA in the more than 60 years old age group.

An interesting anomaly in our data was the slight increase from the second to the third age groups. This pattern was also observed in a study of 14018 adults from UK (Allender, Foster, & Boxer, 2008). The authors of this study concluded that occupational PA provides a substantial contribution to those meeting the government target for PA. Moreover, they also found a large reduction in PA around the time of retirement, with men aged 65-74 being less likely to meet the PA target than those aged 55-64. For women aged 16-24, only 25% met the guidelines, but nearly 69% of youth aged 15 or lower met the guideline.

Accelerometry studies in older adults are increasingly common (Murphy, 2009), however data on European older adults is scarce. One study, The Better Ageing project (Davis & Fox, 2007), assessed adults aged 70 and over in three European countries (UK, France and Italy). The study found lower levels of PA in older adults compared to young adults. Older adults were more restricted in activity intensity range performing significantly fewer minutes of MVPA per day than young adults (Older Females 16.7 +/- 12.2 vs. Young Females 38.4 +/- 18.4, $P < 0.001$; Older Males 23.8 +/- 20.0 vs. Younger Males 40.4 +/- 19.2, $P = 0.001$).

A number of public health guidelines have been released to describe the recommended levels of PA for different groups. Youth less than 18 years old should participate in at least 60 minutes of MVPA each day of the week (Strong, et al., 2005), and adults are advised to do 30 min of at least moderate-intensity physical activity on most, preferably all, days of the week (Pate, et al., 1995); this 30 min can be accumulated in several bouts of at least 10-min duration (Pollock, et al., 1998). For adults the intensity of activity (i.e., moderate intensity or higher) might be the key characteristic of health-enhancing physical activity (HEPA), because moderate-intensity (51-69% $V{\cdot}O_{2max}$, or 3-6 METs) activity seems to be sufficient for the prevention and treatment of many chronic diseases (Haskell, 2001).

The percentages of the population achieving the age-specific guidelines were reported to assess compliance with the PA guidelines in this population. Compliance was higher in males than females in all age groups. In the youngest age group (6-11 yrs), the gender differences become smaller as the age groups increased, findings similar to those in the US population (Troiano, et al., 2008). The low compliance rates for the adolescents (12-19 yrs) are a particular concern. Only 33.5% of males and 18.2% of females in this age group achieved the guideline – and these were the lowest rates of any age group. Although, these values are low, some studies also corroborate similar findings. A longitudinal study on tracking of sedentary behavior (Gordon-Larsen, Nelson, & Popkin, 2004) reported that the majority of the adolescents don’t reach 5 or more periods per week of MVPA. Janssen et al. (Janssen, et al., 2005) in a study of school-aged youth from 34 countries suggested that only 25,4% of Portuguese students, between 10 – 16 years-old, participate in MVPA, 60 minutes or more, in 5 or more days per week. Ekelund et al. (Ekelund, et al., 2004) reported on data from 4 distinct regions in Europe (including Portugal – Madeira) and found similar values for participation in recommended amounts of MVPA (17,4% for boys and 12% in girls). On the other hand, there are also studies showing high activity rates in this age group. For example, a study on Spanish adolescents (Martínez-Gómez, Welk, Calle, Marcos, & Veiga, 2009) found that over 71.1% of the adolescents (82.2% boys and 60.7% girls) reached the recommendation of ≥ 60 min/d in MVPA. The differences in this study may be do to the way in which the accelerometer data were processed and analyzed. A strength of the present study is that we utilized the same procedures recently used by Troiano et al. (Troiano, et al., 2008) for processing the NHANES data in the United States. While our data are not considered to be representative of the country they provide useful comparisons.

Establishing the optimal volume of physical activity necessary to produce physiological adaptations (i.e. dose–response relationship), continues to be an important research priority (Riddoch & Boreham, 1995). A study comparing activity patterns in adolescents found differences in compliance depending on how the data were interpret (Gilson, Cooke, & Mahoney, 2001). The majority of adolescents were active with respect to an accumulated heart rate criterion yet inactive with respect to a sustained heart rate criterion. Although sustained physical activity (at least 10 minutes in MVPA) is an important outcome it is important for researchers utilizing accelerometers in free-living conditions to assess, analyze, and report both accumulated physical activity (counts per day and minutes per day spent at different intensities) and minutes per day spent in moderate or vigorous physical activity in sessions of at least 10 min (Dinger & Behrens, 2006). Moreover, the ACSM suggests that adults should engage in aerobic exercise for 20–60 min (in sessions of at least 10 min), at 55/65% to 90% maximal heart rate, 3–5 dIwkj1 to improve or maintain cardiorespiratory fitness (Pollock, et al., 1998).

A gender difference in sustained physical activity (at least 10 minutes in

MVPA) was noted and this may have important implications for public health. Females in all age groups were less likely to perform sustained MVPA. The lower bouts of activity, also parallel the US (Troiano, et al., 2008) estimates where less than 5% were found to do sustained PA. A Swedish study (Hagstromer, et al., 2007) also found small amounts of sustained PA. Approximately 52% of the sample accumulated 30 min of at least moderate activity per day, but only 1% accumulated the 30 min by three or more 10-min bouts per day.

A longitudinal study of 12 years, by means of questionnaires, in Finland (Yang, Telama, Leino, & Viikari, 1999) among 2411 children and adolescents aged 9, 12, 15 and 18 years, with the purpose to examine how adult physical activity is influenced by early physical activity and current social and health-related factors, showed that early physical activity and current social and health-related behaviors were significantly related to the level of adult physical activity. Moreover, multivariate analyses indicated that early physical activity, in particular, was the best predictor of adult physical activity in all groups, with the exception of the 21-year-old women. The same author on a more recent study (Yang, et al., 2008) with study 2060 young adults (24-39 yr), with the aim to examine the relationship of physical activity and its changes over a 9-yr follow-up to the prevalence of metabolic syndrome, showed that persistent physical activity during 9 years was associated with a lower prevalence of metabolic syndrome than persistent physical inactivity on all definitions (all $P < 0.05$). They conclude that a physically active lifestyle across the lifespan may prevent or delay the onset of metabolic syndrome in young male and female adults.

The major strengths of our study were the use of the accelerometer as a measure of PA. Objective estimates of physical activity yield lower values and a different activity pattern compared with those obtained by commonly used self-reports. This highlights the need to better understand the nature and measurement issues of health-enhancing physical activity (Hagstromer, et al., 2007). Accelerometer data can provide information about activity as well as inactivity while some self report tools do not (Troiano, et al., 2008). On the other hand, this tool also has drawbacks that need to be acknowledged. For example, there remains no universal or standardized cut-point for processing actigraph data (Freedson, et al., 2005). The use of a single value for all adults may lead to an underestimate of moderate PA intensity for older adults (Troiano, et al., 2008). Another limitation is the use of a convenience sample which may not be representative of Portugal as a whole. Efforts were made to recruit participants from within a single metropolitan area in order to better characterize the physical activity patterns in this region. Additional research with larger samples is certainly warranted. Despite these limitations, the resulting information provides valuable information for determining target populations for future physical activity interventions. The study highlights the specific need to target adolescents since the activity levels were particularly low for this age group. A recent review (Allender, Hutchinson, & Foster, 2008) presented studies in which life events have been studied in relation to their effect on participation of PA. In 19 papers, five life changes were identified: employment status; residence; physical status; relationships; and family structure. A previous review by the same author (Allender, Cowburn, & Foster, 2006) found that among teenagers and young women these changes include the transition from childhood to adulthood, changing schools, first time employment, and changing tastes for types of activity with age.

Understanding these lifespan changes is important for designing effective activity promotion programs Enhancing PA monitoring can positively impact physical activity promotion (Waxman, 2004). But any attempt to increase or even reverse trends in population PA must address the impact of changes in life events or life circumstance on PA participation (Allender, Hutchinson, et al., 2008). Epidemiological relationships based on objective measures might result in different indicators of PA compliance (Troiano, et al., 2008). The low rates of PA in Porto adolescents and the lower compliance with the PA guidelines of the Porto metropolitan area residents should be a matter of concern and intervention.

Acknowledgments

This study was supported by FCT - SFRH/BD/23088/2005.

3.1.6 References

Malina RM. Tracking of physical activity and physical fitness across the lifespan. *Res Q Exerc Sport.* Sep 1996;67(3 Suppl):S48-57.

Hill JO, Melanson EL. Overview of the determinants of overweight and obesity: current evidence and research issues. *Med Sci Sports Exerc.* Nov 1999;31(11 Suppl):S515-521.

Johansson SE, Sundquist J. Change in lifestyle factors and their influence on health status and all-cause mortality. *Int J Epidemiol.* Dec 1999;28(6):1073-1080.

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

Malina RM, Little BB. Physical activity: the present in the context of the past. *Am J Hum Biol.* Jul-Aug 2008;20(4):373-391.

do Carmo I, Dos Santos O, Camolas J, et al. Overweight and obesity in Portugal: national prevalence in 2003-2005. *Obes Rev.* Jan 2008;9(1):11-19.

Padez C, Fernandes T, Mourao I, Moreira P, Rosado V. Prevalence of overweight and obesity in 7-9-year-old Portuguese children: trends in body mass index from 1970-2002. *Am J Hum Biol.* Nov-Dec 2004;16(6):670-678.

Ribeiro J, Guerra S, Pinto A, Oliveira J, Duarte J, Mota J. Overweight and obesity in children and adolescents: relationship with blood pressure, and physical activity. *Ann Hum Biol.* Mar-Apr 2003;30(2):203-213.

Lobstein T, Frelut ML. Prevalence of overweight among children in Europe. *Obes Rev.* Nov 2003;4(4):195-200.

Vaz de Almeida MD, Graca P, Afonso C, D'Amicis A, Lappalainen R, Damkjaer S. Physical activity levels and body weight in a nationally representative sample in the European Union. *Public Health Nutr.* Mar 1999;2(1A):105-113.

Metzger JS, Catellier DJ, Evenson KR, Treuth MS, Rosamond WD, Siega-Riz AM. Patterns of objectively measured physical activity in the United

States. *Med Sci Sports Exerc.* Apr 2008;40(4):630-638.

Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc.* Jan 2008;40(1):181-188.

Hagstromer M, Oja P, Sjostrom M. Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc.* Sep 2007;39(9):1502-1508.

Cole TJ. A chart to link child centiles of body mass index, weight and height. *Eur J Clin Nutr.* Dec 2002;56(12):1194-1199.

Rothney MP, Apker GA, Song Y, Chen KY. Comparing the performance of three generations of ActiGraph accelerometers. *J Appl Physiol.* Oct 2008;105(4):1091-1097.

Leenders N, Sherman WM, Nagaraja HN. Comparisons of four methods of estimating physical activity in adult women. *Med Sci Sports Exerc.* Jul 2000;32(7):1320-1326.

Nilsson A, Ekelund U, Yngve A, Sjostrom M. Assessing physical activity among children with accelerometers using different time sampling intervals and placements. *Pediatr Exerc Sci.* 2002;14(1):87-96.

Ward DS, Evenson KR, Vaughn A, Rodgers AB, Troiano RP. Accelerometer use in physical activity: best practices and research recommendations. *Med Sci Sports Exerc.* Nov 2005;37(11 Suppl):S582-588.

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

Pate RR, Pratt M, Blair SN, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA.* Feb 1 1995;273(5):402-407.

Armstrong N, Welsman JR. The physical activity patterns of European youth with reference to methods of assessment. *Sports medicine (Auckland, N.Z.* 2006;36(12):1067-1086.

Sallis JF, Hovell MF. Determinants of exercise behavior. *Exercise and sport* *sciences reviews.* 1990;18:307-330.

Livingstone MB, Robson PJ, Wallace JM, McKinley MC. How active are we? Levels of routine physical activity in children and adults. *The Proceedings of the Nutrition Society.* Aug 2003;62(3):681-701.

Teixeira e Seabra AF, Maia JA, Mendonca DM, Thomis M, Caspersen CJ, Fulton JE. Age and sex differences in physical activity of Portuguese adolescents. *Med Sci Sports Exerc.* Jan 2008;40(1):65-70.

Raitakari OT, Porkka KV, Taimela S, Telama R, Rasanen L, Viikari JS. Effects of persistent physical activity and inactivity on coronary risk factors in children and young adults. The Cardiovascular Risk in Young Finns Study. *Am J Epidemiol.* Aug 1 1994;140(3):195-205.

Fox KR, Riddoch C. Charting the physical activity patterns of contemporary children and adolescents. *Proc Nutr Soc.* Nov 2000;59(4):497-504.

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

Dinger MK, Behrens TK. Accelerometer-determined physical activity of free-living college students. *Medicine and Science in Sports and Exercise.* Apr 2006;38(4):774-779.

Matthews CE, Ainsworth BE, Thompson RW, Bassett DR, Jr. Sources of variance in daily physical activity levels as measured by an accelerometer. *Med Sci Sports Exerc.* Aug 2002;34(8):1376-1381.

Allender S, Foster C, Boxer A. Occupational and nonoccupational physical activity and the social determinants of physical activity: results from the Health Survey for England. *J Phys Act Health.* Jan 2008;5(1):104-116.

Murphy SL. Review of physical activity measurement using accelerometers in older adults: considerations for research design and conduct. *Prev Med.* Feb 2009;48(2):108-114.

Davis MG, Fox KR. Physical activity patterns assessed by accelerometry in older people. *Eur J Appl Physiol.* Jul 2007;100(5):581-589.

Pollock ML, Gaesser GA, Butcher JD, et al. ACSM Position Stand on The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in

Adults. *Med Sci Sports Exerc.* 1998;30(6):975-991.

Haskell WL. What to look for in assessing responsiveness to exercise in a health context. *Med Sci Sports Exerc.* Jun 2001;33(6 Suppl):S454-458; discussion S493-454.

Gordon-Larsen P, Nelson MC, Popkin BM. Longitudinal physical activity and sedentary behavior trends: adolescence to adulthood. *American journal of preventive medicine.* Nov 2004;27(4):277-283.

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

Ekelund U, Sardinha LB, Anderssen SA, et al. Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). *The American journal of clinical nutrition.* Sep 2004;80(3):584-590.

Martínez-Gómez D, Welk G, Calle M, Marcos A, Veiga O. Preliminary evidence of physical activity levels measured by accelerometer in Spanish adolescents. The AFINOS Study. *Nutr Hosp.* 2009;In press.

Riddoch CJ, Boreham CA. The health-related physical activity of children. *Sports Med.* Feb 1995;19(2):86-102.

Gilson ND, Cooke CB, Mahoney CA. A comparison of adolescent moderate-to-vigorous physical activity participation in relation to a sustained or accumulated criterion. *Health Educ. Res.* June 1, 2001 2001;16(3):335-341.

Yang X, Telama R, Leino M, Viikari J. Factors explaining the physical activity of young adults: the importance of early socialization. *Scand J Med Sci Sports.* Apr 1999;9(2):120-127.

Yang X, Telama R, Hirvensalo M, Mattsson N, Viikari JS, Raitakari OT. The longitudinal effects of physical activity history on metabolic syndrome. *Med Sci Sports Exerc.* Aug 2008;40(8):1424-1431.

Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children.

Med Sci Sports Exerc. Nov 2005;37(11 Suppl):S523-530.
Allender S, Hutchinson L, Foster C. Life-change events and participation in physical activity: a systematic review. *Health Promot Int.* Jun 2008;23(2):160-172.
Allender S, Cowburn G, Foster C. Understanding participation in sport and physical activity among children and adults: a review of qualitative studies. *Health Educ Res.* Dec 2006;21(6):826-835.
Waxman A. WHO global strategy on diet, physical activity and health. *Food Nutr Bull.* Sep 2004;25(3):292-302.
Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. *CMAJ.* Mar 14 2006;174(6):801-809.
Pedersen PK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. *Scand J Med Sci Sports.* 2006;16(Suppl.1):S3-63.

Chapter 4

Chapter 4

4.1 Time contexts – the accelerometer

Manuscript: Technical Reliability Assessment of the Actigraph GT1M Accelerometer

4.1.1 Abstract

The purpose of this study was to determine the reliability of the Actigraph GT1M accelerometer activity count and step functions. Fifty GT1M accelerometers were initialized to collect simultaneous acceleration counts and steps data, using 15 second epochs. All reliability testing was completed using a mechanical shaker plate to perform six different test conditions in Experiment 1 and eighteen test conditions in Experiment 2. The overall intra- and inter-instrument reliability of the GT1M was CV_{intra}= 2.9% and CV_{inter}= 3.5% for counts and CV_{intra}= 1.1% and CV_{inter}= 1.2% for steps. No batch effects were evident in the 50 GT1M's. The Actigraph GT1M accelerometer demonstrated good reliability for measuring both counts and steps. However, the ability of the GT1M to consistently detect acceleration at a given acceleration and frequency condition varied widely. Future studies clarifying the filtering limitations and the threshold necessary to detect the occurrence of movement are warranted.

Key-words: Frequency, pedometer, filter, acceleration

4.1.2 Introduction

(Paragraph 1) Researchers have many options for assessing physical activity. The choice of assessment tool typically requires a trade-off between feasibility and validity. Accelerometers have gained acceptance as an effective option because they are objective, easy to use and provide reasonably valid indicators of activity. The acceptance has led accelerometers to even be used in large studies (Riddoch, et al., 2004; Troiano, et al., 2008; Tudor-Locke, Ainsworth, Adair, & Popkin, 2003). Best practice guidelines and research recommendations for using accelerometers in the physical activity assessment have been produced (Ward, et al., 2005), and recommendations for optimizing and standardizing the use of accelerometer data have also been developed (Esliger, Copeland, Barnes, & Tremblay, 2005a; Esliger & Tremblay, 2007). Although progress has been made, there are many unanswered questions. One fundamental issue that affects all research with accelerometers is the technical reliability of measured acceleration data. Since researchers make use of large numbers of accelerometers, it is important to understand how much variability exists between units and how variable responses may be over time (Welk, et al., 2004).

(Paragraph 2) The reliability of the original CSA/MTI 7164 accelerometer has been evaluated in laboratory settings (Patterson, et al., 1993; Westerterp, 1999), free-living settings (McClain, Sisson, & Tudor-Locke, 2007; Plasqui & Westerterp, 2007; Sirard, Melanson, Li, & Freedson, 2000), both laboratorial and field conditions (Bassett, et al., 2000; Nichols, Morgan, Chabot, Sallis, & Calfas, 2000; Puyau, Adolph, Vohra, & Butte, 2002; Welk, Blair, Wood, Jones, & Thompson, 2000), controlled mechanical settings (Brage, Brage, Wedderkopp, & Froberg, 2003; Esliger & Tremblay, 2006a; Metcalf, Curnow, Evans, Voss, & Wilkin, 2002), and also within different populations (Freedson, et al., 2005; Janz, 1994; Mattocks, et al., 2008; McClain, et al., 2007; Storti, et al., 2008; Toschke, von Kries, Rosenfeld, & Toschke, 2007). Results have been viewed as acceptable for most research applications; however, the company recently released a newer version (GT1M) with updated software and hardware configurations. The GT1M monitor was developed with solid state accelerometer circuitry and digital filtering to improve the reliability and repeatability of the measurements. The company reports that each unit is calibrated as part of Actigraph, LLC's standard manufacturing process and that calibration holds through the life of the product (Actigraph, 2008a). The company took specific steps to try to ensure that the new model would operate similarly to the old model (to ensure backward compatibility) but recent studies suggest that the GT1M count varies significantly from the original and that the bias varies with intensity (Corder, et al., 2007).

(Paragraph 3) Since the appearance of this new Actigraph model, some studies have started to examine reliability issues and to make comparisons with the earlier versions (S. Brage, van Hees, & Brage, 2009; Rothney, Apker, Song, & Chen, 2008). However, to the authors' knowledge, there have been no studies reporting on the reliability of the GT1M accelerometer for assessing activity counts and steps. Likewise, little information is available that describes the threshold detection levels of the Actigraph. Therefore, the purpose of this study was 1) to determine the intra-instrument and inter-instrument reliability of the GT1M, and 2) to determine its acceleration threshold detection levels using a controlled mechanical setup.

4.1.3 Methods

(Paragraph 4) Separated into two experiments, the GT1M accelerometers were exposed to 24 different conditions (varying in acceleration and/or frequency), to ensure that each unit performed within tolerable variability limits, and to indentify the threshold for counts detection.

GT1M accelerometer.

(Paragraph 5) The Actigraph GT1M accelerometer has the following characteristics: dimensions - L 38 x W 37 x H 18 (mm); weight 27 grams; solid state sensor - Micro-Electro-Mechanical Systems (MEMS); dynamic range of 0.05-2.5 g; and a frequency range of 0.25-2.5 (Hz) (Actigraph, 2008b). The manufacturer states that the GT1M series of products have swapped out the piezoelectric beam used in the original Actigraph with a highly accurate solid state accelerometer. The new MEMS accelerometer undergoes a precise batch manufacturing process to ensure high repeatability. The filter is now implemented within the software of the GT1M, effectively removing unit to unit variability due to this source, leaving only the accelerometer vendor's initial tolerance specification on sensitivity as the primary source of error. The accelerometer vendor manufactures the device to ensure the initial tolerance specification on sensitivity only varies by $\pm$ 10% (Actigraph, 2008a).

Mechanical setup.

(Paragraph 6) All reliability tests were performed using a mechanical apparatus as described in a previous study (Esliger & Tremblay, 2006a). The apparatus consists of a hydraulic shaker table (Figure 1) driven by a hydraulic cylinder (Sheffer, 1-1/18HHSL6ADY) controlled by an electrohydraulic servo valve with cylinder position feedback. A position transducer (Lucas 5000, DC-E) was used to measure position of the table and a high grade control accelerometer (calibrated at 98.1 $mV \cdot g^{-1}$ ±3.6%) (B&K model 4371) was attached to the table to measure vertical acceleration. The acceleration signal was transmitted to a charge amplifier (B&K model 2635) and band-passed filtered at 3 KHz. The amplifier input was provided by a function generator, which was programmed to accurately and reliably oscillate the platform at the various testing conditions using a sinusoidal oscillation procedure. The separation of the hydraulic power supply from the shaker table helped to minimize the vibration in the mechanical setup.

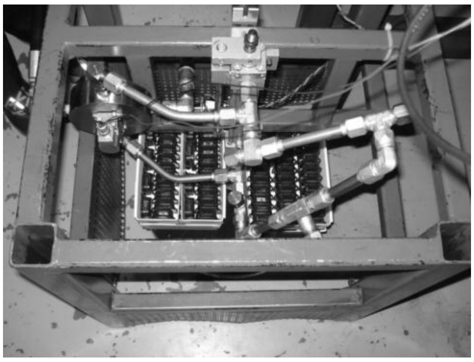


Figure 8. Mechanical shaker table complete with Actigraph GT1M accelerometers positioned for calibration testing.

Procedures

(Paragraph 7) Experiment 1: Fifty GT1M accelerometers were initialized to collect simultaneous acceleration count and step data using 15 second epochs. The computerized initialization function of the GT1M made time synchronization easy to attain. The accelerometers were mounted to the surface of the shaker plate (surface area approximately 1500 cm^2) using industrial quality hook and loop material. Care was taken to ensure that the monitors were secured firmly and were positioned vertically along their sensitive axis in order to maximize and standardize the output of the sensor.

(Paragraph 8) The hydraulic shaker table was switched on once all 50 accelerometers were in place and the first of the random ordered conditions was set, thereby accelerating all 50 monitors simultaneously in the vertical plane. The shaker table testing conditions were restricted by the displacement amplitude of the shaker plate (approximately 6.5 cm). Within this amplitude range, the possible conditions of acceleration and frequency of oscillation are described by the equation: acceleration ($m{\cdot}s^{-2}$) = (amplitude (m) $\cdot$ frequency^2 ($rad{\cdot}s^{-1}$). The six different conditions chosen were selected to produce a range of physiologically relevant accelerometer counts from light to moderate to hard within the limitations of the shaker plate (Table 1). The values are comparable to the range of speeds (2.5 to 6.75mph) used in a treadmill calibration study with the Actigraph (Trost, et al., 1998).

(Paragraph 9) The shaker table was warmed up to achieve optimal functioning of the hydraulics and the control electronics thereby ensuring the proper execution and maintenance of each of the six conditions for the 6 minute test periods. All conditions began at the turn of a 15 second interval (i.e., xx:15, xx:30, xx:45, xx:00) on the PC clock which was recorded along with the condition end time for data analysis purposes. After approximately 60 minutes of data collection (15 minute warm-up + (6 conditions x 6 minutes per condition) + (6 x 1 minute transitions between conditions)) the shaker was stopped and allowed to cool down.

(Paragraph 10) Experiment 2: Following the same procedures as outlined in

Experiment 1, the same 50 GT1M accelerometers underwent 18 further test conditions specifically selected to determine the threshold necessary for the GT1M start recording counts. The starting condition was determined within the limitations of the shaker plate, and by the reported lower band of the GT1M accelerometer model, which is 0.05g (Actigraph, 2008b). To avoid the shaker overheating and ensure the proper execution and maintenance of each of the eighteen conditions, Experiment 2 tests were shorter than Experiment 1 (i.e. 30 second durations rather than 6 minutes). Following Experiment 2, the accelerometers were removed from the shaker plate and downloaded to the initialization PC for further analysis.

Statistical Analyses

(Paragraph 11) Data were imported into a customized spreadsheet application using the common epoch-by-epoch time stamp to align the data vertically across units. The recorded condition start and end times were identified and the middle minutes of each condition were and extracted for further analysis.

(Paragraph 12) To determine the variability within a given accelerometer (intra-instrument reliability), standard deviation (SD), and coefficient of variation (CV_{intra}) were calculated from the replicate epochs for both counts and steps. In Experiment 1 each condition had 20 accelerometer observations (5min x 4 epochs of 15 seconds per minute), this interval variability characterizes the accelerometers' ability to consistently measure the given condition rendered by the shaker table. Previous research with the older model found that variability between units is greater than variability within units (Brage, et al., 2003); however, less variability (i.e., technological error) is expected using the present calculation methods as no trial effect was present. Inter-instrument reliability was calculated via standard deviation, coefficient of variation (CV_{inter}), intra-class correlation coefficients for each of the test conditions in both experiments. In addition, in order to determine unit specific variability statistics, mean difference percent was calculated for each condition. The formula used for this calculation is below:

Mean difference percent = (unit specific mean – condition grand mean) /

condition grand mean * 100

4.1.4 Results

(Paragraph 13) Experiment 1: All 50 GT1Ms were successfully dowloaded. Summary accelerometer data across all six conditions are provided in Tables 1 and 2 along with the reliability statistics: CV_{intra}= 2.9% and CV_{inter}= 3.5% for counts and CV_{intra}= 1.1% and CV_{inter}= 1.2% for steps. The 0.5 g at 2.5 Hz condition compared with the others presented the highest between device variability (i.e., CV_{inter} = 7.1%).

Table 1. Comparison of mean counts per 15sec epoch and reliability statistics across the six test conditions in Experiment 1.

				Intra-Instrument Reliability		**Inter-Instrument Reliability**	
Acceleration (g)	**($m \cdot s^{-2}$)**	**Frequency (Hz)**	**Counts**	**SD**	**CV**	**SD**	**CV**
0.5	4.9	2.5	341	22	6.54	24	7.01
0.5	4.9	2.0	653	14	2.08	18	2.79
0.5	4.9	1.5	1034	13	1.27	21	2.02
0.75	7.36	2.0	1470	36	2.47	45	3.08
1.00	9.81	2.5	1248	44	3.56	50	3.98
1.25	12.26	2.5	1715	28	1.64	36	2.10
Overall Mean			**1077**	**26**	**2.93**	**32**	**3.50**

Table 2. Comparison of mean steps per 15sec epoch and reliability statistics across the six test conditions in Experiment 1.

					Intra-Instrument Reliability		**Inter-Instrument Reliability**	
Acceleration (g)	**($m \cdot s^{-2}$)**	**Frequency (Hz)**	**Steps (Hz)**	**Steps**	**SD**	**CV**	**SD**	**CV**
0.5	4.9	2.5	2.5	37.5	0.51	1.37	0.50	1.32
0.5	4.9	2.0	2.0	30.0	0.04	0.12	0.12	0.39
0.5	4.9	1.5	1.5	22.5	0.51	2.28	0.50	2.22
0.75	7.36	2.0	2.0	30.0	0.04	0.12	0.14	0.48
1.00	9.81	2.5	2.5	37.5	0.51	1.37	0.50	1.33
1.25	12.26	2.5	2.5	37.5	0.51	1.37	0.50	1.32
Overall Mean				**32.5**	**0.35**	**1.10**	**0.38**	**1.18**

(Paragraph 14) Closer examination of data in tables 1 and 2 reveals that there is no systematic trend of increasing and/or decreasing variability with increasing intensity of the shaker plate conditions. This is evidenced by the lack of a trend in the reliability statistics (i.e., the data do not show heteroscedasticity). Figure 2 illustrates the relative acceleration count magnitude and the dispersion from the condition grand mean. Because the GT1M codes the serial number it is also possible to check for potential batch effects (i.e. the result of technical and/or experimental variation) with visual inspection.

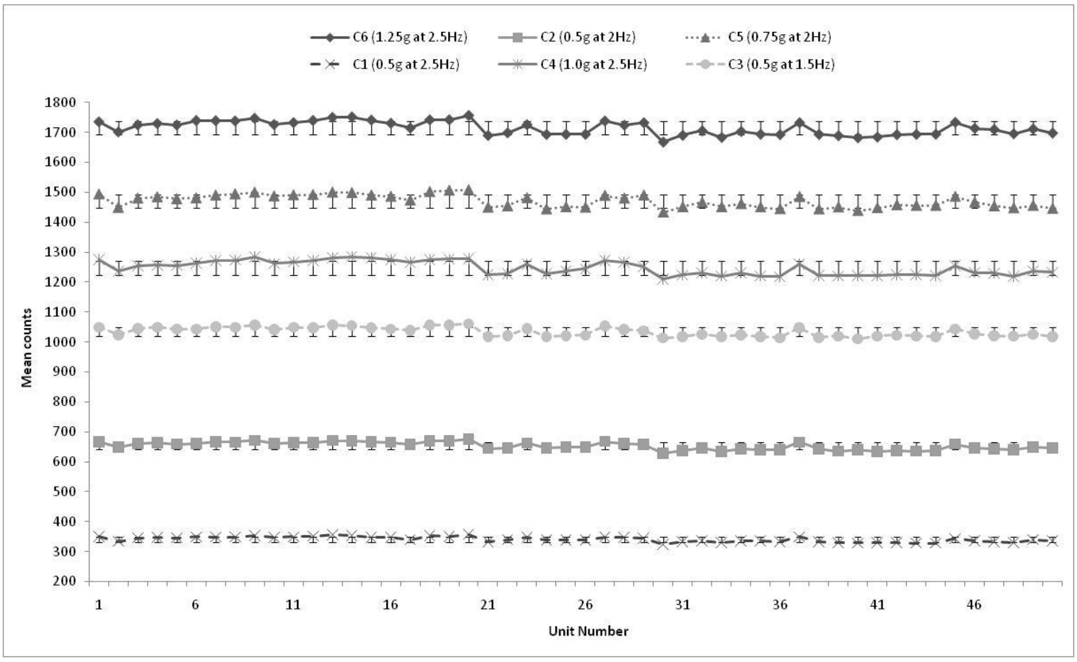


Figure 2. Average counts per 15sec epoch for 50 Actigraph GT1M accelerometers across 6 test conditions (error bars represent 1SD).

(Paragraph 15) In this set of 50 GT1M monitors, no batch effects were found. The calibration limit of ±10 % of the condition grand mean (mean difference percent) was used as a criterion since this is what is suggested for unit-specific assessment in the manufacturer's calibration procedures. To determine which, if any, of the 50 GT1M accelerometers are too variable to be used, unit specific mean difference percent (described previously) was calculated. The five minute average count value was calculated for each of the 50 GT1M accelerometers and a unit was deemed "out of calibration" if the unit mean deviated by greater than ± 10% from the grand mean. Because the condition grand mean is subtracted from the unit specific mean, a positive mean difference percent indicates that the unit was calibrated high and a negative mean difference percent means the unit was calibrated low. None of the 50 GT1M was found above or below the 10% threshold. This point is made clearer by looking at the data graphically (See Figure 3).

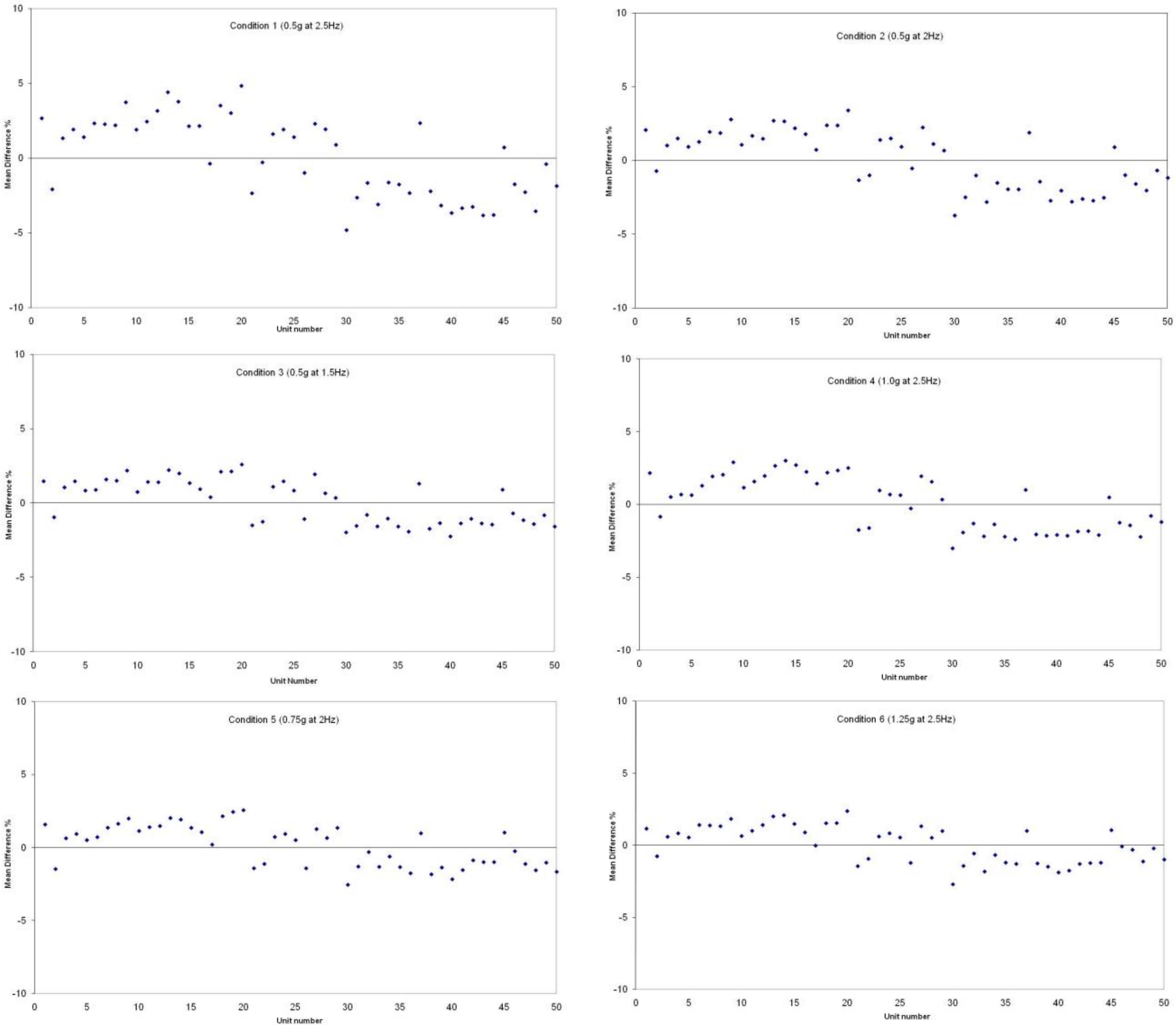


Figure 3. Mean different percent error among a batch of 50 Actigraph GT1M accelerometers across the six test conditions.

Table 3 shows the values of intra-class correlation for the six test conditions.

Table 3. Intra-class Correlation of the twenty replicate, 15 second epochs across each of the six test conditions in Experiment 1.

Acceleration (g)	**($m \cdot s^{-2}$)**	**Frequency (Hz)**	**Reliability Intra-class Correlation**	**95% C. I. Lower**	**Upper**
0.50	4.90	2.5	0.674	0.527	0792
0.50	4.90	2.0	0.944	0.918	0.964
0.50	4.90	1.5	0.954	0.934	0.971
1.00	9.81	2.5	0.809	0.722	0.878
0.75	7.36	2.0	0.813	0.729	0.881
1.25	12.26	2.5	0.918	0.882	0.948

(Paragraph 16) Experiment 2: Summary accelerometer count data (N=50) across all eighteen conditions is provided in Table 4. The variability in the low acceleration conditions was high, mainly because of the small number of devices consistently reporting counts. These data show that the GT1M begins to detect counts in the 0.05g at 1.0Hz condition with 10 of the 50 devices recording counts while the remaining monitors (92.42%) fail to register any acceleration. As the intensity of the acceleration increased, the number of units that detect counts increased, with lower frequencies within a given acceleration more likely to detect.

Table 4. Comparison of mean counts per 15 seconds and reliability statistics across the eighteen test conditions in Experiment 2.

Acceleration (g)	Acceleration ($m \cdot s^{-2}$)	Frequency (Hz)	Counts	Failed to Detect N	Failed to Detect %	Inter-Instrument Reliability SD	Inter-Instrument Reliability CV
0.05	0.49	2.0	0	50	100	-	-
		1.5	0	50	100	-	-
		1.0	0	49	98	0.14	707.11
0.06	0.59	2.0	0	50	100	-	-
		1.5	0	48	96	0.10	494.87
		1.0	1	32	64	2.68	235.11
0.07	0.69	2.0	0	50	100	-	-
		1.5	0	45	90	0.77	435.11
		1.0	32	5	10	24.37	77.03
0.08	0.79	2.0	0	49	98	0.07	707.11
		1.5	5	22	44	7.88	154.92
		1.0	148	0	0	16.49	11.17
0.09	0.88	2.0	0	48	96	0.50	643.70
		1.5	45	1	2	25.83	57.87
		1.0	234	0	0	14.76	6.31
0.10	0.98	2.0	0	44	88	0.82	365.40
		1.5	125	1	2	24.36	19.51
		1.0	306	0	0	14.31	4.69

4.1.5 Discussion

(Paragraph 17) If there is uncertainty with regards to feasibility of a specific data acquisition method, this should be tested before commitment to the full study (Corder, Ekelund, Steele, Wareham, & Brage, 2008). Researchers employing accelerometers to assess physical activity should treat their accelerometers with the same care as those working with laboratory based clinical chemistry to achieve good quality research. Reliability sets the limit on validity so proper checks should take place in all devices with each and every use. Also, technical assessments are very important for determining the acceleration responses in the batch of instruments being used, to prevent the use of defective instruments in the field (Moeller, et al., 2008).

(Paragraph 18) All GT1M reliability testing was completed using a mechanical setup as it permits precise control of the experimental conditions. This makes it possible to determine the variability attributed solely to the accelerometer. Although human trials can offer more real-life conditions, they can also introduce error, such as noise associated with external vibrations or inadequate attachment of the accelerometer (Chen & Bassett, 2005). The mechanical apparatuses make it possible to control the magnitude of the acceleration being imparted as well as the frequency of the oscillation, two key variables that contribute to the accelerometer's output. In the present study we eliminated potential trial effects because all units were simultaneously oscillated. This design feature allows us to specifically attribute variability to technical error.

(Paragraph 19) While the original Actigraph has been considered to have acceptable reliability, previous research has demonstrated variability within and between units. For example, Brage et al. (2003) reported that each unit was significantly different from the overall grand mean (all units), and that there was considerable heteroscedasticity across units in the response to different acceleration values. The variability was considerable enough for these investigators to recommend unit-specific calibrations. We found the intra-instrument variability of the new GT1M to be low (counts overall mean CV_{intra}= 2.9%; steps overall mean CV_{intra}= 1.1%). The inter-instrument variability was six times higher than the intra-instrument values with an overall mean CV_{inter}= 3.5%

for counts and an overall mean CV_{inter}= 1.2% for steps. On face value these reliability results seem worse than those reported by Rothney (Rothney, et al., 2008). However, if the present data are integrated from 15 second to 1 minute epochs the CV's are much more similar CV_{intra}= .61% and CV_{inter}= 1.85% (data not shown). The lack of batch effects (i.e., serial number clusters of high or low output units) also supports the fact that the Actigraph GT1M provides reliable information both in terms of activity counts and steps outputs.

(Paragraph 20) The responses varied somewhat across conditions. For counts, we found the highest between device variability (i.e., CV_{inter} = 7.0%) with the 0.5g at 2.5Hz condition. This condition was characterized by smaller acceleration and higher frequency. Although the CV is acceptable it points to a lesser precision under these conditions (i.e., relatively low acceleration and higher frequency).

(Paragraph 21) In the case of the steps output, the 0.5g at 1.5Hz condition yielded the highest between device variability (i.e., CV_{inter} = 2.2%) compared with the other conditions. This condition was characterized by small accelerations and lower frequency. These results for step counts are consistent with a previous study that evaluated the validity of the step function in accelerometers using treadmill walking (Esliger, et al., 2007). That study showed that the accuracy of both the Actical and Actigraph (model 7164) step count functions differed from the criterion of visually counted steps at the slow walking speed, with both accelerometers underestimating the number of steps taken (errors of 7.4 and 5.3% for the Actical and Actigraph, respectively). Because much of the day is spent performing short and slow movements around the office or home, this underestimation can amount to large differences during a 24-h period. The problem appears to be common in pedometer devices that are built just for step counts (Crouter, Schneider, Karabulut, & Bassett, 2003). The magnitude of the error would not present a major threat for most populations but it may be a more significant problem when monitoring frail older adults with slow gaits.(Le Masurier & Tudor-Locke, 2003).

(Paragraph 22) Another observed limitation of the Actigraph 7164 is the increasing tendency of the monitor to underestimate activity as speed/intensity is increased (Brage, 2003). This error is related to frequency-dependent filtering and assessment of acceleration in the vertical plane only (Rowlands, Stone, & Eston, 2007). These data highlight the fact that the Actigraph GT1M seems to carry the same limitation.

(Paragraph 23) A clear understanding of the technical capabilities of accelerometers is important for understanding limitations for different types of research. The present study extends previous research and demonstrates improved technical reliability with the new GT1M version of the Actigraph. The study is unique in evaluation of both counts and steps. The new GT1M provides time allocation in both counts and steps and the present study demonstrates some differences in the characteristics associated with detection of steps and counts.

(Paragraph 24) The study evaluated reliability across a range of conditions including the accelerometer sensitivity within the lower range of human motion. While developed primarily for assessing movement, there has been considerable interest in using accelerometers to also indicate levels of sedentary behavior (Healy, et al., 2008; Matthews, et al., 2008; Pate, O'Neill, & Lobelo, 2008; Reilly, et al., 2008; Sardinha, et al., 2008; Williams, et al., 2008). At the 0.05g threshold detection level of the GT1M only 10 of the 50 units registered movement. The results with our mechanical experiment are consistent with a previous study that reported increases in zero count values observed with GT1M data (Rothney, et al., 2008). Variability in threshold detection between units could have a significant impact on the number of sedentary epochs detected for a given study participant. This is particularly worrying considering how reliant the field has become on accelerometer data reduction procedures that scan and exclude continuous zero strings above a given threshold in an effort to determine accelerometer wear vs. non-wear. Further lab-based and field-based studies are warranted to clarify the impact of wide ranging threshold detection levels in the Actigraph GT1M accelerometer.

Acknowledgments: This study was supported by FCT - SFRH/BD/23088/2005.

Disclaimer: This study was not funded in any way by the accelerometer manufacturer. The results of this study do not constitute endorsement by the authors of the product described herein.

4.1.6 References

Actigraph (2008a). Actilife Users Manual, 2008, from http://www.theactigraph.com/index.php?option=com_docman&task=cat_view&gid=53&Itemid=64

Actigraph (2008b). GT1M Specifications, 2008, from http://theactigraph.com/index.php?option=com_docman&task=cat_view&gid=70&Itemid=64

Bassett, D. R., Jr., Ainsworth, B. E., Swartz, A. M., Strath, S. J., O'Brien, W. L., & King, G. A. (2000). Validity of four motion sensors in measuring moderate intensity physical activity. *Med Sci Sports Exerc, 32*(9 Suppl), S471-480.

Brage, S. r., Brage, N., Wedderkopp, N., & Froberg, K. (2003). Reliability and Validity of the Computer Science and Applications Accelerometer in a Mechanical Setting. *Measurement in Physical Education & Exercise Science, 7*(2), 101-119.

Chen, K. Y., & Bassett, D. R., Jr. (2005). The technology of accelerometry-based activity monitors: current and future. *Med Sci Sports Exerc, 37*(11 Suppl), S490-500.

Corder, K., Brage, S., Ramachandran, A., Snehalatha, C., Wareham, N., & Ekelund, U. (2007). Comparison of two Actigraph models for assessing free-living physical activity in Indian adolescents. *J Sports Sci, 25*(14), 1607-1611.

Corder, K., Ekelund, U., Steele, R. M., Wareham, N. J., & Brage, S. (2008). Assessment of physical activity in youth. *J Appl Physiol, 105*(3), 977-987.

Crouter, S. E., Schneider, P. L., Karabulut, M., & Bassett, D. R., Jr. (2003). Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc, 35*(8), 1455-1460.

Esliger, Copeland, J. L., Barnes, J. D., & Tremblay, M. S. (2005). Standardizing and Optimizing the Use of Accelerometer Data for Free-Living Physical Activity Monitoring. *JPAH, 2*(3), 366-383.

Esliger, Probert, A., Gorber, S. C., Bryan, S., Laviolette, M., & Tremblay, M. S. (2007). Validity of the Actical accelerometer step-count function. *Med Sci*

Sports Exerc, 39(7), 1200-1204.

Esliger, & Tremblay, M. S. (2006). Technical reliability assessment of three accelerometer models in a mechanical setup. *Med Sci Sports Exerc, 38*(12), 2173-2181.

Esliger, & Tremblay, M. S. (2007). Physical activity and inactivity profiling: the next generation. *Can J Public Health, 98 Suppl 2*, S195-207.

Freedson, P., Pober, D., & Janz, K. F. (2005). Calibration of accelerometer output for children. *Med Sci Sports Exerc, 37*(11 Suppl), S523-530.

Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., et al. (2008). Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care, 31*(4), 661-666.

Janz, K. F. (1994). Validation of the CSA accelerometer for assessing children's physical activity. *Med Sci Sports Exerc, 26*(3), 369-375.

Le Masurier, G. C., & Tudor-Locke, C. (2003). Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med Sci Sports Exerc, 35*(5), 867-871.

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., et al. (2008). Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am J Epidemiol, 167*(7), 875-881.

Mattocks, C., Ness, A., Leary, S., Tilling, K., Blair, S. N., Shield, J., et al. (2008). Use of accelerometers in a large field-based study of children: protocols, design issues, and effects on precision. *J Phys Act Health, 5 Suppl 1*, S98-111.

McClain, J. J., Sisson, S. B., & Tudor-Locke, C. (2007). Actigraph accelerometer interinstrument reliability during free-living in adults. *Med Sci Sports Exerc, 39*(9), 1509-1514.

Metcalf, B. S., Curnow, J. S., Evans, C., Voss, L. D., & Wilkin, T. J. (2002). Technical reliability of the CSA activity monitor: The EarlyBird Study. *Med Sci Sports Exerc, 34*(9), 1533-1537.

Moeller, N. C., Korsholm, L., Kristensen, P. L., Andersen, L. B., Wedderkopp, N., & Froberg, K. (2008). Unit-specific calibration of Actigraph accelerometers in a mechanical setup - is it worth the effort? The effect on random output variation caused by technical inter-instrument variability in the laboratory and in the field. *BMC Med Res Methodol, 8*, 19.

Nichols, J. F., Morgan, C. G., Chabot, L. E., Sallis, J. F., & Calfas, K. J. (2000). Assessment of Physical Activity with the Computer Science and Applications, Inc., Accelerometer: Laboratory Versus Field Validation. *Research Quarterly for Exercise and Sport, 71(1)*, 36-43.

Pate, R. R., O'Neill, J. R., & Lobelo, F. (2008). The evolving definition of "sedentary". *Exerc Sport Sci Rev, 36*(4), 173-178.

Patterson, S. M., Krantz, D. S., Montgomery, L. C., Deuster, P. A., Hedges, S. M., & Nebel, L. E. (1993). Automated physical activity monitoring: validation and comparison with physiological and self-report measures. *Psychophysiology, 30*(3), 296-305.

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

Puyau, M. R., Adolph, A. L., Vohra, F. A., & Butte, N. F. (2002). Validation and calibration of physical activity monitors in children. *Obes Res, 10*(3), 150-157.

Reilly, J. J., Penpraze, V., Hislop, J., Davies, G., Grant, S., & Paton, J. Y. (2008). Objective measurement of physical activity and sedentary behaviour: review with new data. *Arch Dis Child, 93*(7), 614-619.

Riddoch, C. J., Bo Andersen, L., Wedderkopp, N., Harro, M., Klasson-Heggebo, L., Sardinha, L. B., et al. (2004). Physical activity levels and patterns of 9- and 15-yr-old European children. *Med Sci Sports Exerc, 36*(1), 86-92.

Rothney, M. P., Apker, G. A., Song, Y., & Chen, K. Y. (2008). Comparing the performance of three generations of ActiGraph accelerometers. *J Appl Physiol, 105*(4), 1091-1097.

Rowlands, A. V., Stone, M. R., & Eston, R. G. (2007). Influence of speed and step frequency during walking and running on motion sensor output. *Med Sci Sports Exerc, 39*(4), 716-727.

Sardinha, L. B., Andersen, L. B., Anderssen, S. A., Quiterio, A. L., Ornelas, R., Froberg, K., et al. (2008). Objectively measured time spent sedentary is associated with insulin resistance independent of overall and central body fat in 9- to 10-year-old Portuguese children. *Diabetes Care, 31*(3), 569-575.

Sirard, J. R., Melanson, E. L., Li, L., & Freedson, P. S. (2000). Field evaluation of the Computer Science and Applications, Inc. physical activity monitor. *Med Sci Sports Exerc, 32*(3), 695-700.

Storti, K. L., Pettee, K. K., Brach, J. S., Talkowski, J. B., Richardson, C. R., & Kriska, A. M. (2008). Gait speed and step-count monitor accuracy in community-dwelling older adults. *Med Sci Sports Exerc, 40*(1), 59-64.

Toschke, J. A., von Kries, R., Rosenfeld, E., & Toschke, A. M. (2007). Reliability of physical activity measures from accelerometry among preschoolers in free-living conditions. *Clin Nutr, 26*(4), 416-420.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc, 40*(1), 181-188.

Trost, S. G., Ward, D. S., Moorehead, S. M., Watson, P. D., Riner, W., & Burke, J. R. (1998). Validity of the computer science and applications (CSA) activity monitor in children. *Med Sci Sports Exerc, 30*(4), 629-633.

Tudor-Locke, C., Ainsworth, B. E., Adair, L. S., & Popkin, B. M. (2003). Physical activity in Filipino youth: the Cebu Longitudinal Health and Nutrition Survey. *International Journal of Obesity, 27*(2), 181-190.

Ward, D. S., Evenson, K. R., Vaughn, A., Rodgers, A. B., & Troiano, R. P. (2005). Accelerometer use in physical activity: best practices and research recommendations. *Med Sci Sports Exerc, 37*(11 Suppl), S582-588.

Welk, G. J., Blair, S. N., Wood, K., Jones, S., & Thompson, R. W. (2000). A comparative evaluation of three accelerometry-based physical activity monitors. *Med Sci Sports Exerc, 32*(9 Suppl), S489-497.

Welk, G. J., Schaben, J. A., & Morrow, J. R., Jr. (2004). Reliability of accelerometry-based activity monitors: a generalizability study. *Med Sci Sports Exerc, 36*(9), 1637-1645.

Westerterp, K. R. (1999). Physical activity assessment with accelerometers. *Int J Obes Relat Metab Disord, 23 Suppl 3*, S45-49.

Williams, H. G., Pfeiffer, K. A., O'Neill, J. R., Dowda, M., McIver, K. L., Brown, W. H., et al. (2008). Motor skill performance and physical activity in preschool children. *Obesity (Silver Spring), 16*(6), 1421-1426.

4.2 Season

Manuscript: Seasonal Differences In Physical Activity And Sedentary Patterns: The Relevance Of The PA Context.

4.2.1 Abstract

The aim of this pilot study was to characterize seasonal variation in the moderate to vigorous physical activity (MVPA) and sedentary behavior of Portuguese school youth, and understand the implication of activity choices and settings. Students fully compliant were 24, aged 10-13 years. Accelerometers measured daily PA over 7 consecutive days, in different seasons May – June and January – February. In summer, boys accumulated more minutes in MVPA (928 minutes/week) than girls (793 minutes/week). In winter the pattern was reversed with girls accumulating more activity than boys (736 minutes/week vs. 598 minutes/week). The repeated measures ANOVA revealed significant effects for season ($F = 5.98$, $p = .023$) and day period ($F = 6.53$, $p = .018$). Youth were more active in the summer and activity levels were higher after school than in school. Summer season provided relevant contexts for youth physical activity realization. Winter season may have been a significant barrier to boy's preferred PA context. Differences in choices and access to active opportunities after school explained the gender differences in seasonal activity patterns.

4.2.2 Introduction

Participation in regular physical activity (PA) among children is linked to several health outcomes (Bouchard, Shephard, & Stephens, 1994), as well as to the development of social and academic abilities in youth (Trudeau & Shephard, 2008). Physical inactivity is also known to be associated with an increased risk for overweight and obesity (Hill & Melanson, 1999).

The reported decrease in level of PA during adolescence (Kahn, et al., 2008) has led to considerable interest in understanding the factors that influence active lifestyles in youth. If factors influencing behaviors can be better understood it may facilitate efforts to establish and maintain regular healthy habits in the future (Sallis, Prochaska, & Taylor, 2000a). Numerous studies have been conducted on correlates of physical activity in youth and the literature indicates that children's and adolescents' PA are influenced by a large group of factors, including, environmental, social, psychological and cultural ones (Dishman, et al., 2004; Sallis, Kraft, & Linton, 2002a; Sallis & Owen, 1999a).

Environmental factors have received considerable attention in recent years and there is clear evidence that they play an important role with regard to PA promotion in youth (Owen, Leslie, Salmon, & Fotheringham, 2000). For example, seasonal weather factors such as the temperature differences, amount of precipitation and sunlight exposure have been reported as barriers to PA (Gordon-Larsen, McMurray, & Popkin, 2000; Merrill, Shields, White, & Druce, 2005) and as factors influencing the amount of PA among populations (Berkey, Rockett, Gillman, & Colditz, 2003). An intervention study (Chan, Ryan, & Tudor-Locke, 2006) demonstrated that variations in day-to-day activity were associated with changes in the weather as well as day of the week and season. In young children aged 3-4 years-old, variation in seasonal activities of PA was explained by the quantity of time that children spend outside (Baranowski, Thompson, DuRant, Baranowski, & Puhl, 1993).

Although a number of studies have evaluated youth PA patterns with objective activity monitors few have examined seasonal variation in PA and sedentary activity. The direct effect of weather on PA also needs to be objectively assessed to better understand effects on outdoor recreation (Chan, et al., 2006). Therefore, the aims of this pilot study were (1) to determine the regular physical activity and sedentary patterns in children aged 10-13 years old across two seasons and (2) to analyze the potential seasonal differences by identifying the contexts where those differences occur.

4.2.3 Methods

Participants

The participants in this pilot study were involved in a broader activity assessment project in a school of Porto metropolitan area, Portugal. The original sample included 35 youth (10 to 13 years old) but emphasis in the present study focused on only those youth that had valid data over multiple seasons. Therefore, the sample of this study comprised 24 students, 12 boys and 12 girls (mean age = 11.04 $\pm$ 1.45 years-old). Participants were free from health problems that could affect physical activity levels and provided written informed consent prior to beginning the study. The local school Director and the Portuguese Ministry for Science and Technology also provided permission to conduct this study.

Anthropometry

Stature was measured using the Harpenden Portable Stadiometer (Holtain Ltd, UK), and the values were recorded in centimeters to the nearest mm. Body mass was measured to the nearest 0.1 kg with an electronic weighing scale (Tanita Inner Scan BC 532, UK), with the participants in T-shirt and shorts. Body mass index (BMI) (kg/m2) was calculated from the ratio of weight/height^2.

Habitual Physical Activity and Sedentary activity

Information about habitual physical activity was assessed with the MTI/CSA 7164 accelerometer – a device that has been used in the majority of accelerometer research studies and for which many validation studies are available (Troiano, 2005). Students and their parents were informed about the utility of the accelerometer and participants were asked to wear the monitor for a full week. In the summer, participants received the monitors on a Monday and returned them the following week, while in the winter the monitoring week started on a Thursday. A full week of activity monitoring has been shown to provide a reliable estimate of daily participation in MVPA in children and adolescents (Trost, Pate, Freedson, Sallis, & Taylor, 2000).

Students wore the accelerometer tightly in the hip, on the right side according to manufacturer recommendations. The MTI was set to record in 1 minute intervals (epoch) and the age-specific cut-points developed by the Freedson group and published by Trost (Trost, et al., 2002) were used to evaluate levels of physical activity. This equation has been widely used in the pediatric exercise literature and demonstrated better agreement for categorizing levels of physical activity than other alternative equations (Trost, Way, & Okely, 2006). The age specific cut-points for 10 year old youth were as follows: 1017 (3 MET); 3695 (6 MET); 6374 (9 MET). Values for the 13 year old youth were as follows: 1399 (3 MET); 4381 (6 MET); 7363 (9 MET).

The accelerometer data were analyzed by an automated data reduction program (Kinesoft) used to run quality assurance checks and summarize accelerometer data (Esliger, Copeland, Barnes, & Tremblay, 2005b). To facilitate examination of activity patterns, the minute-by-minute activity counts were processed to determine time spent in MVPA (above 3 METs) for each 60-min segment of the week days monitoring period. Two daily time periods were calculated according to time spent in MVPA (≥3 MET) by summing the minute's in-school (8:00 – 18:00) and after-school time (18:01-20:00). Emphasis was placed on capturing levels of MVPA since youth physical activity guidelines have emphasized the importance of this intensity range (Cavill, Biddle, & Sallis, 2001). There has been increased interest in capturing lightest activity and, for that reason, the sedentary behavior cut-points were defined as <50 counts, which allowed time spent in sedentary behavior to be determined (Matthews, et al., 2008).

Activities context

A weekly activity diary was used to record the periods when they didn't place the MTI, such as sleeping, bath time and swimming. The same diary was used to allow students to take note of their school schedule, a task that they are used to perform in the beginning of the school year. Information and training was given on how students should fill the remaining half-hours of the day, because the Portuguese school schedule is approximately from 8:00 to 18:00 they had to recall only a small portion of their usual day. The students were instructed to carry the diary sheet with them all week and to include the principal activity they participated in for each half-hour, between 7:00 - 24:00. The activity log provided critical information about the context of children's physical activity in both the summer and the winter seasons.

Season variables

Season has been defined as the natural periods in which the year is divided, which vary by weather conditions, daylight hours and temperature (Tucker & Gilliland, 2007). The weather variables for the present study were collected from the Portuguese Institute of Meteorology. The weather conditions in Portugal vary according to the season of the year and the geographical region. In Northern Portugal, the summer weather is temperate, with approximately 27º average daily temperatures, normally no rain and days with long sunshine exposure time, whereas, in the Winter time, the weather changes to very rainy and windy, with average temperatures dropping to around 7º and reduced sun exposure (less two hours than the summer).

Statistical Analysis

Descriptive statistics (Means and standard deviations) were calculated to describe the participant's characteristics and to summarize activity patterns in both seasons. The PA activity was analyzed in a "zooming" perspective, i.e. from the week totals and intensities, to periods of the day then by hour until the context of the activity could be scrutinized. A two-way repeated measures ANOVA (day period x season) was used to examine differences between period of the day (in school / out of school) and season (summer / winter). Data were further processed to examine average daily patterns of activity. These analyses compared average activity levels (hour by hour) by season, paired sample t-test and Wilcoxon tests were used to assess the differences between seasons in the MVPA and sedentary behavior. All analyses were performed by using Microsoft Excel (Microsoft Office 2003 for Windows) and the Statistical Package for Social Sciences (SPSS, version 17.0 for Windows; SPSS Inc, Chicago) the level of significance was set at $p \leq 0.05$.

4.2.4 Results

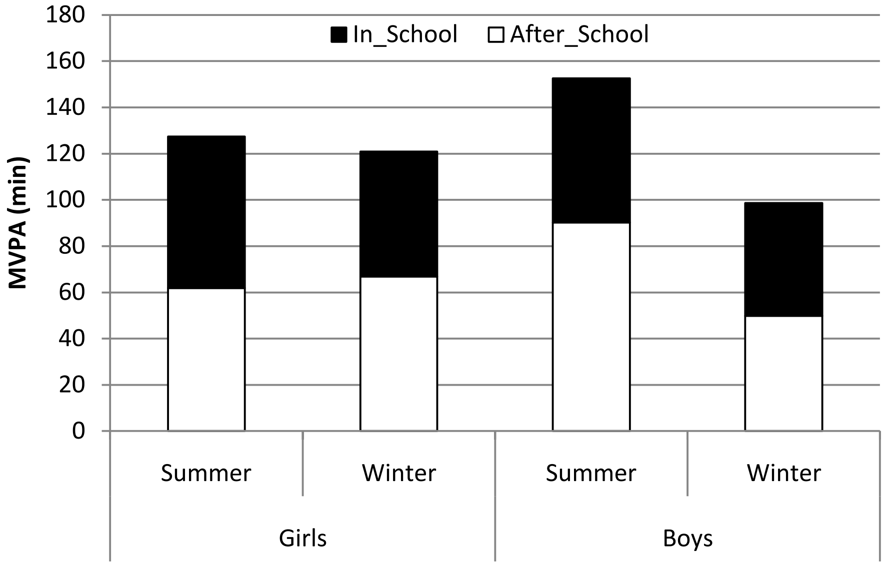
The descriptive data of the sample are shown in table 1. No statistically significant differences were found for age, height, weight and BMI, according to gender. The activity profiles for males and females, however varied considerably. Boys engaged in considerably more MVPA, during the week days, in the summer time (153 minutes/day) compared to winter time (99 minutes/day). Girls, in contrast, had similar overall levels of MVPA in summer (127 minutes/day) and winter (121 minutes/day). Statistical differences were found between genders only in the MVPA amount in the summer, with boys presenting higher values than girls. Results for sedentary behavior complemented the results for the MVPA analyses. Both genders had higher values during the winter but interestingly boys had higher levels of sedentary behavior in the winter than girls.

Table 1 – Descriptive characteristics for participants in the study, mean (SD).

	Girls	Boys	
Age (years)	11.50 (1.58)	11.20 (1.55)	
Weight (Kg)	46.84 (8.03)	50.19 (12.02)	
Height (m)	1.55 (0.08)	1.59 (0.09)	
BMI (Kg/m^2)	19.37 (3.01)	19.83 (3.38)	
PA (during week days)			***p*-value**
MVPA (Summer)	127 (36.50)	153 (32.41)	.040[a]
MVPA (Winter)	121 (60.02)	99 (52.31)	.345
Sedentary (Summer)	366 (115.33)	358 (71.02)	.842
Sedentary (Winter)	428 (148.78)	517 (251.04)	.300

[a]Mann-Whitney U

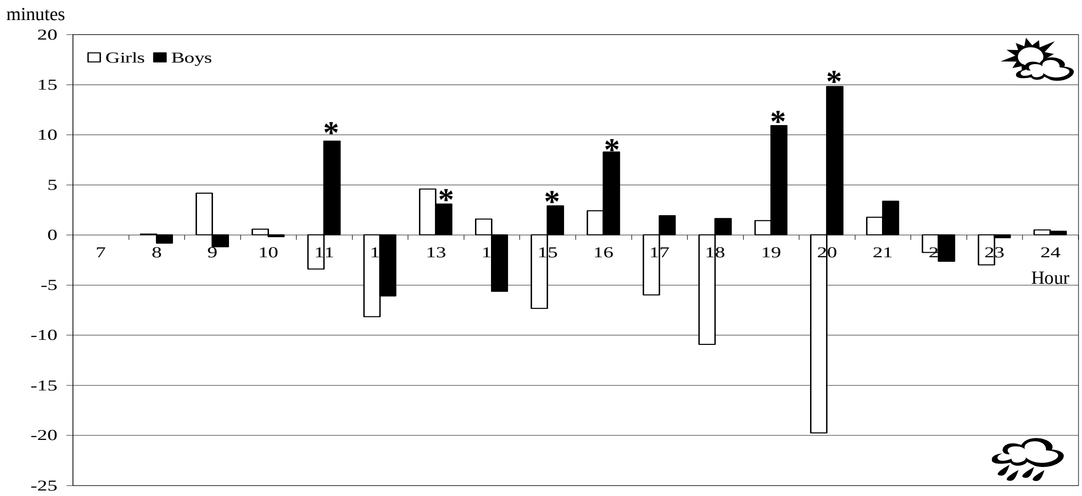
The repeated measures ANOVA revealed significant effects for season ($F = 5.98$, $p = .023$) and period ($F = 6.53$, $p = .018$). These results demonstrate that youth were more active in the summer and that activity levels were higher after school than in school. Gender differences in the patterns are apparent as boys engaged in significantly more in MVPA during summer time (compared to girls), while the opposite occurred in the winter time but without statistical significance. Boys and girls demonstrate differential patterns of activity in/out of school during the summer and winter months. The three way interaction is graphed in Figure 1 to illustrate the effect. As evident in the stacked bar graphs, out of school activity makes up a sizable part of boys activity in the summer but considerably less in the winter. This pattern is not evident in girls.



After-school period (season by gender interaction: F = 7.852, p = .010)
In-school period (season by gender interaction: F = .12, p = .915)

Figure 1 – Seasonal differences in MVPA (min) according to in-school and after-school periods (repeated measures analyses of variance).

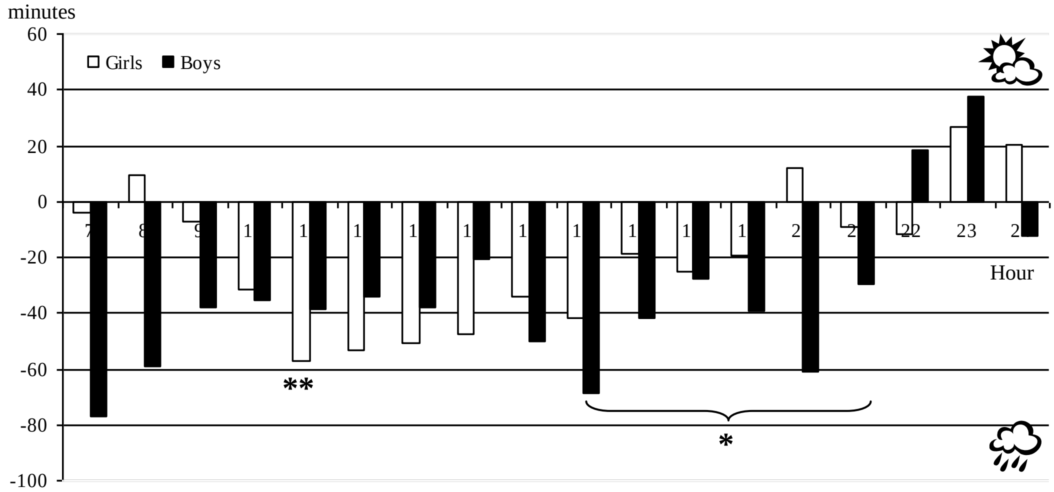
Figure 2 highlights the difference in MVPA (by hour) between the summer and winter seasons in both genders. The difference scores are computed as Summer – Winter so values above the x-axis indicate higher levels of activity for that time period in the Summer. As is evident in the figure, Boys demonstrate a larger decrease in the total week volume of MVPA amount in the winter (Boys: Summer-Winter= 330 minutes vs Girls: Summer-Winter=-57 minutes). The seasonal difference by hour presents a distinct pattern between genders. Boys had six time periods with higher MVPA amount in the summer than winter; there were several time periods (19:00 and 20:00) in which the summer-winter difference exceeded 10 minutes of MVPA. Girls, in contrast, had several periods (18:00 and 20:00) in which activity levels were higher in the winter by more than 10 minutes. It is important to point out that the main differences, for both genders, occurred during non-school hours.



***** p<0,05 difference between seasons in boys

Figure 2 – Mean differences in MVPA between seasons according to gender.

Figure 3 shows the difference in sedentary time (by hour) between the summer and winter seasons in both genders. The difference scores are computed as Summer – Winter so values below the x-axis indicate higher levels of sedentary behavior for that time period in the Winter. Girls showed only one period in their day, with significant differences between seasons (the 11:00) hour period corresponding to the morning recess. On the other hand, boys presented higher differences in sedentary time between the two seasons with the largest differences between 15:00 to 21:00 (corresponding to the afternoon and after-school periods). This differential pattern suggests that, during the winter, boys are more likely to use this after school time periods in a more sedentary way.



****** p<0,05 difference between seasons in girls

***** p<0,05 difference between seasons in boys

Figure 3 – Mean differences in sedentary activity between seasons according to gender.

Data from the activity log were processed to explain the differential gender pattern of activity in summer and winter data. The results in Table 2 summarize the frequency of different physical activities that youth reported participating in during the key after-school time period (18:00 – 20:00). This range was selected since it was the period the MVPA differed the most between seasons, in both genders. Repeated measures ANOVA was run to examine the season by gender interaction specifically during the after school time period. As expected, the season by gender interaction was significant ($F = 7.852$, $p = .010$). The contextual basis for the differences in PA can be seen in the frequency of activities reported during this time period. Boys reported lower values of outdoor PA in the winter and no walking or indoor PA. This indicates that the season may have been a significant barrier to their preferred PA context. For girls, there were little differences in the context of PA. The PA levels of girls had smaller seasonal differences because the activity contexts were not that different.

Another interesting observation is the change in reporting of

Tutoring/Homework time after school (youth in Portugal have settings available after school where students go to do their homework, to get help in the classes, or to study).

Table 2 – Mean MVPA minutes (SD) on after-school period, and the context of those activities (reported by diary), according to gender and season.

	Girls		Boys	
	Summer	**Winter**	**Summer**	**Winter**
After-School MVPA (min)	62 (25.66)	67 (40.93)	90 (29.68) *	50 (17.59)
After-School Activities (frequencies - blocks of 30 minutes)				
TV	22	26	21	11
PC-PS2	3	2	11	7
Study	6	7	0	2
Tutoring-time	0	0	7	9
Walking	12	3	7	0
Indoor PA	12	6	7	0
Outdoor PA	1	0	22	6

*** *p*<0.001**

None of the girls reported participation in this context; only boy's made reference to this particular context. They apparently increased participation in this category in the winter, which may explain their lower levels of MVPA (and higher levels of sedentary time) during the 15:00 to 21:00 hour period.

4.2.5 Discussion

The season effect on physical activity has been previously studied but the majority of studies have used subjective measures. In this study we used accelerometers to access the children's habitual PA during a typical school week in the summer and winter time, respectively. Assessing the amount of PA in different seasons of the year is pertinent because, obesity levels among children have been higher when measured in autumn and winter (December–March) than when measured in summer (May–September). This difference may result from higher levels of activity due to the increased availability of outdoor recreational facilities, and weather that supports activity behaviors (Dietz & Gortmaker, 1984).

These study findings are consistent with the extant literature on children's physical activity (Trost, et al., 2002) and (Riddoch, et al., 2007), that show that age-matched boys are generally more active than girls. Interestingly, the data from the winter showed girls with more MVPA than boys. While this finding was not statistically significant it is a noteworthy outcome deserving further comment and study. Our analyses revealed that the volume of MVPA decreased in winter by an average of 5.45 hours/week in boys but only by 1.1 hours/week in girls, which is in concordance with a study by Pate et al.(Pate, et al., 1997) that showed that boys reported weather as the most significant barrier, whereas girls indicated that time constrains due to homework were more problematic.

The time period of the day with the higher differences between genders, both in MVPA and sedentary behavior, was after school. Closer examination of this time period revealed that boys had more dramatic changes in the contexts and settings of the activity between seasons. Girls, on the other hand, tended to maintain more consistent patterns. The tendency for girls to perform more activity in indoor PA contexts may contribute to the more stable activity patterns observed across seasons.

Research on seasonality is complicated by a number of factors. One challenge is that comparisons are dependent on initial levels of physical activity. One previous study found that the more active the individuals are in the summer, the larger the reduction of activity in the winter; However, those who were inactive in the summer tend to remain inactive in the winter (Plasqui & Westerterp, 2004). Thus, there may be a ceiling effect which causes most youth to be characterized as less active in the winter. The results of this study agree with this and other studies documenting declines in activity from summer to winter. Girls may not have decreased activity as much in winter since the levels in the summer were not as high in Summer.

A previous study of 10-17 year old Portuguese students (n = 6131) reported greater participation in physical activity during the spring/summer period, reflecting a similar seasonal influence (Santos, Matos, & Mota, 2005). Many environment factors contribute to an individual's willingness to engage in PA, Chan and colleagues (Chan, et al., 2006) showed significant interactions between day of the week and month indicating that patterns of activity during the week were not independent of season. A recent review of the evidence (Tucker & Gilliland, 2007) concluded that levels of physical activity vary with seasonality and that poor or extreme weather (precipitation, cold weather and wind) are likely deterrents to physical activity in the winter.

A novel aspect of the present study is the detailed temporal profiling of the accelerometer data and the additional information provided about the context of PA. The accelerometer data revealed periods where youth tended to be more active or less active (as a group) and the activity logs provided information to explain the differences in the amount of MVPA and/or sedentary behavior. For example, in boys, three clear peaks were evident in the summer (the first context comprised the morning recess; the second the after-lunch period and the third is related to after-school activities).

In both seasons, the 19:00 to 21:00 period showed higher levels of MVPA, corresponding to after-school time. Therefore, as reported in other studies, extra-curricular activities played an important role on MVPA levels. Boys had distinctly different activity patterns in this time period with considerably less MVPA and more sedentary behavior during the winter time. Girls, in contrast, had more consistent patterns across seasons. This difference can be attributed to differential effects of weather/season on their activity preferences and patterns. Boy's preferred PA context in the summer was outdoor PA while in the winter this context was replaced by more sedentary choices.

Weather has frequently been reported to have an impact but studies to date had not quantified this effect with objective data. Time spent outdoors is an important correlate of physical activity (Baranowski, et al., 1993; Sallis, et al., 1993) but this access is clearly limited during winter months. The previously mentioned review (Tucker & Gilliland, 2007), reported that 27 of 37 articles (73%) found significant weather effects on physical activity behaviors. One study (Loucaides, Chedzoy, & Bennett, 2004) revealed that weather accounts for as much as 42% of variance in measured physical activity. Four of the 37 articles specifically acknowledged season or 'bad weather' as a perceived barrier to participation in physical activity.

If weather is preventing people from participating in physical activity, measures must be taken to help overcome this barrier. Specifically, there is a need to provide more opportunities for indoor physical activity during the cold and wet months of the year (Sallis, et al., 2000a). A review of environmental and policy interventions (Sallis, Bauman, & Pratt, 1998a) highlighted the importance of providing additional activity opportunities in the winter. Opportunities may be limited but most communities offer some options for youth to be active (gyms, fitness centers, etc.). Therefore, the burden may be on parents to find opportunities for their children to remain active in the winter. Parents have identified that the warmer seasons are more conducive to physical activity for their children and that colder seasons pose greater challenges (Irwin, He, Sangster Bouck, Tucker, & Pollett, 2005). Parents, however, have also identified the need for indoor facilities to provide the opportunity for year-round participation in physical activity (Tucker, Irwin, Sangster Bouck, He, & Pollett, 2006). Our results confirm the importance of indoor activities because it clearly explained the smaller decline in activity for girls in the winter months.

Additional research is clearly needed to better understand factors that may explain seasonal differences in activity. The seasonal patterns suggest that physical activity interventions must be modified during different seasons of the year (to specifically increase involvement in winter months). It is important to acknowledge that the findings of this pilot study are based on data taken from a relatively small sample. However, it is also important to recognize that small numbers are a common problem when measuring physical activity objectively and, indeed, should be balanced against the fact that, if used effectively, such techniques are able to provide highly detailed information. The meticulous temporal processing of accelerometer data and the linking with activity logs provide a framework for identifying the critical contexts where physical activity and sedentary behaviors occur.

4.2.6 References

Baranowski, T., Thompson, W. O., Durant, R. H., Baranowski, J. & Puhl, J. (1993) Observations on physical activity in physical locations: age, gender, ethnicity, and month effects. *Res Q Exerc Sport,* 64**,** 127-33.

Berkey, C. S., Rockett, H. R., Gillman, M. W. & Colditz, G. A. (2003) One-year changes in activity and in inactivity among 10- to 15-year-old boys and girls: relationship to change in body mass index. *Pediatrics,* 111**,** 836-43.

Bouchard, C., Shephard, R. & Stephens, T. (1994) The consensus Statement. IN Stephens, C. B. R. S. T. (Ed.) *Exercise, Fitness and Health: A Consensus of Current Knowledge.* Champaign. IL, Human Kinetics.

Cavill, N., Biddle, S. & Sallis, J. (2001) Health Enhancing Physical Activity for Young People: Statement of the United Kingdom Expert Consensus Conference. *Pediatric Exercise Science,* 13**,** 12-25.

Chan, C. B., Ryan, D. A. & Tudor-Locke, C. (2006) Relationship between objective measures of physical activity and weather: a longitudinal study. *Int J Behav Nutr Phys Act,* 3**,** 21.

Dietz, W. H., Jr. & Gortmaker, S. L. (1984) Factors within the physical environment associated with childhood obesity. *Am J Clin Nutr,* 39**,** 619-24.

Dishman, R. K., Motl, R. W., Saunders, R., Felton, G., Ward, D. S., Dowda, M. & Pate, R. R. (2004) Self-efficacy partially mediates the effect of a school-based physical-activity intervention among adolescent girls. *Prev Med,* 38**,** 628-36.

Esliger, D. W., Copeland, J. L., Barnes, J. D. & Tremblay, M. S. (2005) Standardizing and Optimizing the Use of Accelerometer Data for Free-Living Physical Activity Monitoring. *JPAH,* 2**,** 366-383.

Gordon-Larsen, P., Mcmurray, R. G. & Popkin, B. M. (2000) Determinants of adolescent physical activity and inactivity patterns. *Pediatrics,* 105**,** E83.

Hill, J. O. & Melanson, E. L. (1999) Overview of the determinants of overweight and obesity: current evidence and research issues. *Med Sci Sports Exerc,* 31**,** S515-21.

Irwin, J. D., He, M., Sangster Bouck, L. M., Tucker, P. & Pollett, G. L. (2005)

Preschoolers' physical activity behaviours: Parent's perspectives. *Canadian Journal of Public Health,* 96**,** 299-303.

Kahn, J. A., Huang, B., Gillman, M. W., Field, A. E., Austin, S. B., Colditz, G. A. & Frazier, A. L. (2008) Patterns and determinants of physical activity in U.S. adolescents. *J Adolesc Health,* 42**,** 369-77.

Loucaides, C. A., Chedzoy, S. M. & Bennett, N. (2004) Differences in physical activity levels between urban and rural school children in Cyprus. *Health Educ Res,* 19**,** 138-47.

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R. & Troiano, R. P. (2008) Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am J Epidemiol,* 167**,** 875-81.

Merrill, R. M., Shields, E. C., White, G. L., Jr. & Druce, D. (2005) Climate conditions and physical activity in the United States. *Am J Health Behav,* 29**,** 371-81.

Owen, N., Leslie, E., Salmon, J. & Fotheringham, M. J. (2000) Environmental determinants of physical activity and sedentary behavior. *Exerc Sport Sci Rev,* 28**,** 153-8.

Pate, R. R., Trost, S. G., Felton, G. M., Ward, D. S., Dowda, M. & Saunders, R. (1997) Correlates of physical activity behavior in rural youth. *Res Q Exerc Sport,* 68**,** 241-8.

Plasqui, G. & Westerterp, K. R. (2004) Seasonal variation in total energy expenditure and physical activity in Dutch young adults. *Obes Res,* 12**,** 688-94.

Riddoch, C. J., Mattocks, C., Deere, K., Saunders, J., Kirkby, J., Tilling, K., Leary, S. D., Blair, S. N. & Ness, A. R. (2007) Objective measurement of levels and patterns of physical activity. *Arch Dis Child,* 92**,** 963-9.

Sallis, Bauman, A. & Pratt, M. (1998) Environmental and policy interventions to promote physical activity. *Am J Prev Med,* 15**,** 379-397.

Sallis, Kraft, K. & Linton, L. S. (2002) How the environment shapes physical activity: a transdisciplinary research agenda. *Am J Prev Med,* 22**,** 208.

Sallis & Owen, N. (1999) *Physical Activity & Behavioral Medicine*, Sage Publications.

Sallis, Prochaska, J. J. & Taylor, W. C. (2000) A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc,* 32**,** 963-75.

Sallis, J. F., Nader, P. R., Broyles, S. L., Berry, C. C., Elder, J. P., Mckenzie, T. L. & Nelson, J. A. (1993) Correlates of physical activity at home in Mexican-American and Anglo-American preschool children. *Health Psychol,* 12**,** 390-8.

Santos, M. P., Matos, M. & Mota, J. (2005) Seasonal Variations in Portuguese Adolescents' Organized and Nonorganized Physical Activities. *Pediatric Exercise Science,* 17**,** 390-398.

Troiano, R. P. (2005) A timely meeting: objective measurement of physical activity. *Med Sci Sports Exerc,* 37**,** S487-9.

Trost, S. G., Pate, R. R., Freedson, P. S., Sallis, J. F. & Taylor, W. C. (2000) Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc,* 32**,** 426-31.

Trost, S. G., Pate, R. R., Sallis, J. F., Freedson, P. S., Taylor, W. C., Dowda, M. & Sirard, J. (2002) Age and gender differences in objectively measured physical activity in youth. *Med Sci Sports Exerc,* 34**,** 350-5.

Trost, S. G., Way, R. & Okely, A. D. (2006) Predictive validity of three ActiGraph energy expenditure equations for children. *Med Sci Sports Exerc,* 38**,** 380-7.

Trudeau, F. & Shephard, R. J. (2008) Physical education, school physical activity, school sports and academic performance. *Int J Behav Nutr Phys Act,* 5**,** 10.

Tucker, P. & Gilliland, J. (2007) The effect of season and weather on physical activity: a systematic review. *Public Health,* 121**,** 909-22.

Tucker, P., Irwin, J. D., Sangster Bouck, L. M., He, M. & Pollett, G. (2006) Preventing paediatric obesity; recommendations from a community-based qualitative investigation. *Obesity Reviews,* 7**,** 251-260.

Chapter 5

Chapter 5

5.1 Space contexts - Country, Community

Manuscript: Differences in the Physical Activity pattern between Portuguese and Spanish adolescents

5.1.1 Abstract

Objectives: Physical activity (PA) occurs in a variety of contexts and there is a need to understand the biocultural determinants of the active or inactive lifestyle. The aim of this study is to compare adolescents' PA patterns living in two different countries from south Europe, exploring gender differences.

Design: Five public schools entered the study: two in Porto (Portugal) and three in Huesca (Spain). 105 students (57% girls) from Porto aged 14.56±1.50, and 95 students (40% girls) from Huesca aged 13.66±1.15. PA was assessed with accelerometers over 7 consecutive days. Linear regression model was used to study the influence of the following factors: age, location, gender, and body mass index on the adolescents moderate to vigorous PA amount on weekdays and weekend days.

Main results: Linear regression analysis reported that when controlling for age and BMI, City was considered a significant predictor (p<0.001) of the MVPA amount on weekend days and also in the number of days the students comply with the PA guidelines (60 minutes of Moderate-to-vigorous PA (MVPA) daily). Huesca adolescents had superior values of MVPA and consequently higher rate of compliance the PA guidelines. Gender differences in MVPA were more marked in the Spanish adolescents.

Conclusions: Location of residence was found to have impact on the achievement of PA guidelines. These differences were more marked on weekends.

Key-words: Physical activity guidelines, Accelerometer, High school students**.**

5.1.2 Introduction

Physical activity (PA) patterns in youth have important public health implications because low amount of PA ad high physical inactivity behaviors have important contributions to current and future health problems, such as the early onset of Cardiovascular Disease (CHD), osteoporosis or adult obesity (Strong, et al., 2005). Several studies showed that PA activity tracks over time (Malina, 1996; Telama, et al., 2005), and physical inactivity presents an even greater tracking effect. PA occurs in a variety of contexts and there is a need to understand the biocultural determinants of the active or inactive lifestyle (Malina, 1996).

One approach to clarifying this issue is to determine the types and elements of PA that cause some youth to be more active than others, this may help identify patterns that facilitate long term involvement or, alternately, identify groups that may be at risk of dropping out from a more active lifestyle (Tammelin, 2005). The measurement of PA across the lifespan is a difficult task. Most discussions refer to an estimated level of habitual PA derived from questionnaires, interviews, diaries and heart rate monitors. Although PA is evaluated in terms of energy expenditure, it is essential to recognize that PA is a behavior that occurs in a variety of forms and contexts. Contextual factors are systemic characteristics of the community, school district, or school, and the investigation might focuses on variables such as physical plant, rules, policies, or informal norms rather than individual teachers, students, or intra-class interactions (Griffin, 1985).

In general, youth have similar exposure and opportunities at school but activity patterns and choices may be more variable, for example, a single strategy aimed at reducing sedentary behavior is unlikely to be effective across Europe as the target populations and behaviors of focus differ between countries (van Sluijs, Page, Ommundsen, & Griffin, 2008). Research is needed to confirm these findings and to examine the consistency across different populations and cultures. Therefore, the aims of this study were: 1) to describe the physical pattern of high school adolescents attending public schools in Portugal and in Spain; 2) to compare the differences between the two countries in the PA pattern. So this study offers a unique opportunity to examine contributions of different culture settings and contexts of PA in the south of Europe.

5.1.3 Methods

Participants

The sample comprised adolescents attending 2 public schools in north Portugal, Porto (Portugal) and 3 public schools in north Spain, Huesca (Spain). The students that agreed to participate were 105 (57% girls and 43% boys) from Porto, Portugal, aged 14.56±1.50, and 95 (40% girls and 60% boys) from Huesca, Spain, aged 13.66±1.15. Only the students attending school on the day of data collection were entered into the study. Each research team followed the ethical procedures of that country, the Portuguese Ministry for Science and Technology in Portugal, provided permission to conduct this study and was approved by the Ethical Committee from the University of Zaragoza. Informed written consent was also obtained from the youth's legal guardians and from individual school principals. We therefore had a convenient sample of adolescents living in two different countries from the northern part of the Iberian Peninsula with different physical and cultural environments but similar climate.

Anthropometry

Height was measured to the nearest mm in bare or stocking feet with the child standing upright against a Holtain portable stadiometer. Weight was measured to the nearest Kg, lightly dressed (underwear and tee-shirt) using a portable digital beam scale (Tanita Inner Scan BC532). The BMI was calculated from the ratio weight/height^2 (Kg/m^2).

Assessment of physical activity

PA was assessed similarly in both cities, within the closest as possible timeframe (month) of data collection. The Actigraph accelerometer (model GT1M) was used, this device is small and light weight accelerometer designed to measure and record acceleration, in the vertical axis, ranging in magnitude from 0.05 to 2.00 G, with frequency response from 0.25 to 2.50 Hz. The filtered acceleration signal is digitized and the magnitude is summed over a user-specified period of time (an epoch interval).

Adolescents wore the accelerometer in an elastic waistband on the right hip during daytime, except while bathing and during other aquatic activities. Therefore, data from swimming activities was omitted. A data sheet was given to students who were instructed to record the time when the monitor was attached in the morning and detached in the evening. The Actigraph was worn over 7 consecutive days in order to obtain a reliable picture of the habitual PA (Trost, et al., 2005), a 7-d monitoring protocol provides reliable estimates of usual PA behavior in children and adolescents and accounts for potentially important differences in weekend versus weekday activity behavior as well as differences in activity patterns within a given day (Trost, et al., 2000).

It was established 600 minutes (10 hours) as the minimum monitored time for a valid day, one study reported that a monitored period of 7 days with 10 hours/day produced high reliability (Penpraze, et al., 2006). The *epoch* (sampling period) was setup to one minute, similar to other studies (Andersen & van Mechelen, 2005; Welk, et al., 2004), and the age-specific count ranges corresponding to the intensity levels developed by Freedson (Freedson, et al., 2005) were adopted. The availability of age-specific count cutoffs that take into consideration age-related differences in economy and resting metabolism allows for the estimation of daily participation in moderate and vigorous PA (Trost, et al., 2002). Time spent in moderate and vigorous PA (>3MET) was calculated by summing the minutes of moderate, vigorous, and very vigorous PA for each day. This variable was used to verify the participant's compliance to the PA guidelines – more than 60 minutes of MVPA (moderate to vigorous PA) per day. To analyze the accelerometer data was used the Kinesoft software developed specifically for the Actical and Actigraph accelerometers. The outcome variables were expressed in time (min/d) spent at different PA-intensity categories.

Statistics

Descriptive statistics were used to describe participant's characteristics and the activity data. Independent t-tests were used to verify gender differences within the two countries, and Mann-Whitney tests were used when the variables did not present a normal distribution. Linear regression model was used to study the influence of the following factors: age (continuous variable), City (Huesca and Porto), gender, and BMI on the adolescents MVPA amount on week days, weekend, and number of days with PA guidelines compliance. All analyses were performed by using Statistical Package for Social Sciences (SPSS, version 17.0), and the level of significance was set at $P < 0.05$.

5.1.4 Results

The participant's physical characteristics are summarized in Table 1. Portuguese boys were taller and heavier ($p < 0.05$) than girls, while no statistical significant differences were found within the Spanish sample. No statistical significant differences were found between genders in BMI in both Cities. There were significant differences between the two cities within each gender in all the anthropometric variables with the exception of height in girls.

Table 1 – Descriptive characteristics for participants in the study, mean (SD).

	Huesca		Porto	
	Girls	**Boys**	**Girls**	**Boys**
Age	13.55 (1.06)**	13.73 (1.21)**	14.53 (1.59)	14.60 (1.39)
Weight (Kg)	51.38 (9.41)**	52.97 (14.05)**	58.03 (10.70)[a]	65.54 (11.67)
Height (m)	1.60 (.07)	1.62 (.11)**	1.62 (.059)[a]	1.72 (.085)
BMI (Kg/m^2)	19.82 (2.42)**	19.87 (3.30)**	22.13 (3.57)	22.20 (3.53)
PA (min/day)				
MVPA (Week days)	51.61 (14.91)[b]	92.14 (76.18)**	55.34 (21.37)	62.46 (24.35
MVPA (Weekend)	40.71 (26.05)**[b]	75.75 (94.28)**	16.88 (19.74)[a]	32.36 (28.03)
Light (Week days)	112.08 (25.43)	116.61 (43.36)	105.28 (33.25)	106.52 (34.32)
Light (Weekend)	116.34 (35.72)**	180.18 (242.28)**	72.85 (44.50)	73.19 (43.63)
Moderate (Week days)	25.16 (7.44)[a]	28.92 (10.38)	27.67 (12.33)	27.72 (12.72)
Moderate (Weekend)	20.34 (13.04)**[a]	26.35 (16.51)**	9.89 (11.86)	13.99 (12.01)
Vigorous (Week days)	18.70 (6.88)[b]	26.62 (11.44)	21.37 (11.22)	25.26 (12.26)
Vigorous (Weekend)	13.95 (11.56)**[a]	19.60 (17.14)*	5.58 (7.92)[b]	12.43 (12.94)
Number of days with >= 60 min MVPA)	2.18 (1.52)[b]	3.88 (1.63)**	2.07 (1.64)	2.56 (1.66)

PA – physical activity; MVPA – moderate to vigorous PA.

[a] Significant gender difference (within city) p<0.05;

[b] Significant gender difference (within city) p<0.01

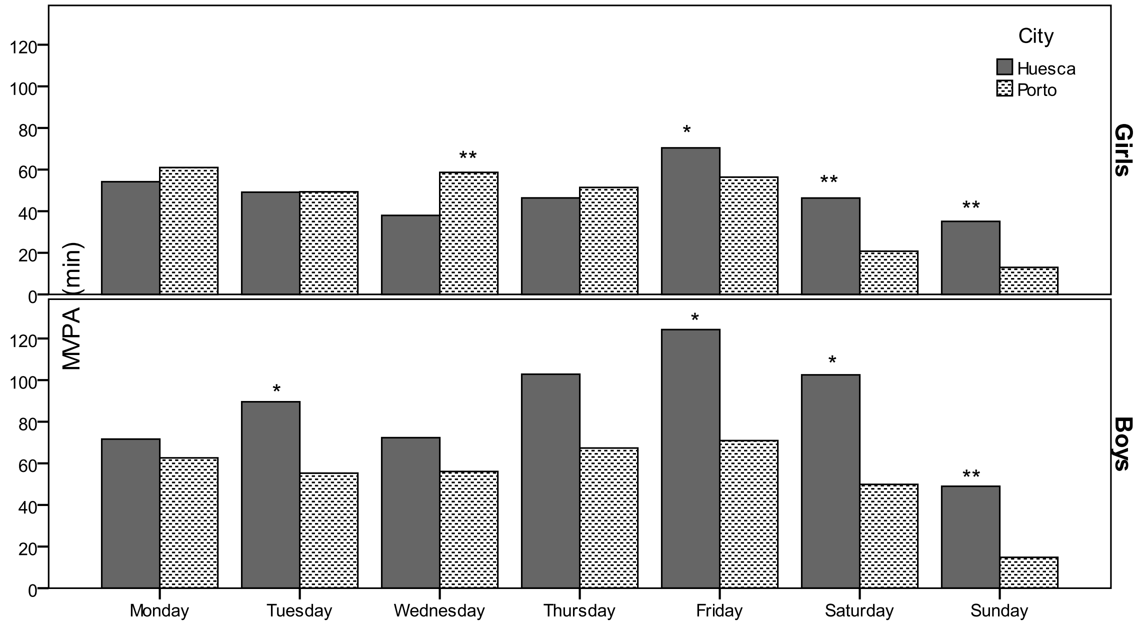
[*] Significant city difference (within gender) p<0.05;

[**] Significant city difference (within gender) p<0.01

PA intensities by day type (i.e. weekdays and weekend) are presented in table 1. In both cities boys had higher values than girls in all variables although not all reached statistical significance. Huesca boys had significantly more minutes of MVPA, Moderate PA, and Vigorous PA than Huesca girls, both on the weekdays and weekend days. The gender differences in Porto were only significant in MVPA and Vigorous on the weekend days.

Comparing differences between cities, girls from Huesca were significantly ($p<0.01$) more active than girls from Porto in all PA intensities during the weekend, the same situation occurred in boys. Moreover, boys from Huesca were also significantly ($p<0.01$) more active than boys from Porto in MVPA during the week days. Significant differences were also verified regarding the compliance with the current PA guidelines (60 minutes of MVPA per day). Huesca adolescents had superior values of MVPA and consequently higher rate of compliance the PA guidelines.

Figure 1 shows the daily MVPA values by gender between the two cities. To notice that in both genders were found significant differences in four days of the week, as stated earlier on weekend days the Huesca students had significant ($p<0.01$) higher values than the Porto students, moreover Huesca boys had almost every day (with the exception of Sunday) more than 60 minutes of MVPA. During the week days the difference wasn´t so notorious in girls, they had very similar values on Monday, Tuesday, and Thursday, with the Porto girls presenting higher values than the Huesca girls but with statistical significance only on Wednesday. On the other hand, Huesca boys had higher MVPA values on every days of the week with statistical significance ($p<0.05$) on Tuesday, Friday, Saturday, and Sunday ($p<0.01$).



* p<.05 ** p<.001

Figure 1 –Differences between the two cities in mean MVPA (min) by day of the week.

The relevance of the different variables (city, gender, age and BMI) to the MVPA amount is demonstrated in table 2. City and gender were significant predictors ($p<0.001$) of the MVPA amount on weekend days and also in the number of days the students comply with the PA guidelines (60 minutes of MVPA daily), and gender was a significant predictor of MVPA on week days ($p<0.001$).

Table 2 – Linear regression model for the PA response variables, using City, Gender, Age and BMI as explanatory variables.

Model	**MVPA Week**			**MVPA Weekend**			**Guidelines (# Days)**		
	B	**SE**	***Sig.***	***B***	**SE**	***Sig.***	***B***	**SE**	***Sig.***
(Constant)	48.60	18.19	.008	75.16	23.62	.002	2.20	1.29	.090
City	-5.72	3.65	.119	-24.06	4.74	.000*	-.720	.259	.006*
Gender	15.22	3.35	.000*	17.83	4.34	.000*	1.03	.237	.000*
Age	.918	1.26	.467	-2.76	1.63	.092	.055	.089	.537
BMI	-.197	.513	.701	.226	.670	.734	-.020	.036	.583

5.1.5 Discussion

This study examined the weekly PA patterns of two convenient samples of adolescents living in two different countries. Our findings showed that gender differences in MVPA were more marked in the Spanish adolescents group, and that Spanish Boys recorded higher values than Portuguese boys. The weekend was the period of the week when the differences between the two cities wore more pronounced.

Gender is the most studied variable in PA patterns differences (Armstrong & Welsman, 2006; Mota & Sallis, 2003). The higher values in MVPA found in boys from both cities, are similar with those reported in other studies (Andersen & van Mechelen, 2005; Ekelund, et al., 2004; Riddoch, et al., 2004; Trost, et al., 2002), as well as in studies of Portuguese youth and adolescents (Lopes, et al., 2007; Mota, et al., 2008; Mota, et al., 2005; Santos, et al., 2003). Although gender differences in PA amount were different within the two cities, they were more marked in Huesca than in Porto.

Differences in the amount of MVPA between week days and weekend days were clear. Several studies using objective measures of PA in youth have documented marked differences in weekday and weekend PA behavior (Armstrong, Balding, Gentle, & Kirby, 1990; Jago, Anderson, Baranowski, & Watson, 2005; Trost, et al., 2000), and recommendations to measure both types of days have also been established (Jago, et al., 2005; Sallis, 1991; Trost, et al., 2000). Similar to other studies, one in the United States (Trost, et al., 2000) and other in Europe – Norway (Klasson-Heggebo & Anderssen, 2003), our data showed that adolescents in both locations regardless of gender, engaged less time in MVPA during the weekend period. However, Huesca adolescents were significantly more active than Porto adolescents during this period. Weekend days are likely to offer more free time to be active than school days, but only a small proportion of youth met the current recommendations for health-enhancing PA (Biddle & Fox, 1998). Similar findings, from other European countries (Nilsson, et al., 2008), show that more Spanish and Portuguese students achieved PA guidelines on week days. This highlights the importance of considering week days when implementing PA intervention programs for youth and the need to promote more PA opportunities during the weekends.

The current PA guidelines highlight that youth should fulfill at least 60 minutes of moderate to vigorous PA daily (Biddle & Fox, 1998). Our data clearly showed that the majority of the adolescents did not reach those standards. Boys from Porto had a mean of 2.56 days with at least 60 minutes of MVPA, and boys from Huesca achieved 3.88 days. Girls had a worse scenario: girls from Porto achieved 2.07 days and girls from Huesca achieved 2.18 days. Taking into consideration each day of the week, only the Huesca boys had on average more days achieving a minimum of 60 minutes of MVPA on week and weekend days. These data are in line with other studies that show that adolescents, particularly girls, are far behind to reach the recommended daily levels of MVPA (Jago, et al., 2005; Riddoch, et al., 2004; Troiano, et al., 2008). For instance, in a study that included Portuguese students only 25.4% youngsters were engaged in at least 60 of MVPA in 5 or more days per week (Janssen, et al., 2005). Another study also found similar values of MVPA, 17.4% for boys and 12% in girls (Ekelund, et al., 2004).

In a review, Armstrong and Welsman (Armstrong & Welsman, 2006) showed the habitual PA of children and adolescents from European Union countries. They stated that boys of all ages participated in more PA than girls and this difference was more marked when vigorous activity were considered. These authors also highlighted the potential weakness in national comparisons using surveys and the difference in the season of year when the questionnaire was administered. A strong point of our study was the use of objective measures of PA and the similar season and year of data collection. However, we acknowledge that the sample size is not national representative. Efforts in using this kind of PA assessment are being put in practice at the moment worldwide and this study pretends to contribute to those efforts. Moreover, some studies with accelerometry have been published in Portugal although with small and local samples (Lopes, et al., 2007; Mota, et al., 2008), and Spanish studies with accelerometry are also scarce (Martínez-Gómez, et al., 2009).

One important study with European children and adolescents – European Youth Heart Study (Riddoch, et al., 2004) using accelerometers also showed difference in the PA amount between countries. Although, in that sample the Portuguese participants belong to a Portuguese island – Madeira, and Spanish participants weren’t included. The authors, similarly to our study, also indicated some small but statistically significant differences between countries ($p < 0.05$), but the main impression is one of consistency in activity levels between countries. Although our study showed the same consistency in relation to the gender differences in activity amount, the magnitude of the differences between genders were different within each city.

Given that Porto and Huesca differ in geography, socioeconomic circumstances, and culture, this suggests that PA habits in youth may be determined by environmental factors as much as by biological factors. Although, the detailed assessment of the environment context wasn’t an objective of this study, this study revealed that place of residence was a significant predictor to the MVPA amount. In a review study of environmental correlates of PA in youth variables of the home and school environments were especially associated with youth's PA. Most consistent positive correlates of PA were father's PA, time spent outdoors and school PA-related policies (in children), and support from significant others, mother's education level, family income, and non-vocational school attendance (in adolescents) (Ferreira, et al., 2007). Therefore, monitoring individual level and microenvironment social inequalities in PA, is crucial for evaluating the effects of programs and policies and to provide an insight into whether current efforts should be continued or modified (Lee & Cubbin, 2009).

It’s fundamental to understand the trends and contexts of youth physical activity behaviors (Welk, et al., 2007), and objective measures of PA such as the accelerometer provide an opportunity to assess patterns of PA (i.e., bouts of activity) within a given day or over several days, and can be put in context of location. We see as a future direction the complementation of this kind of data with qualitative data, such as the characterization of settings and contexts of the PA behavior.

Acknowledgments

This study was supported by FCT - SFRH/BD/23088/2005.

5.1.6 References

Strong, W.B., et al., Evidence based physical activity for school-age youth. J Pediatr, 2005. 146(6): p. 732-7.

Malina, R.M., Tracking of physical activity and physical fitness across the lifespan. Res Q Exerc Sport, 1996. 67(3 Suppl): p. S48-57.

Telama, R., et al., Physical activity from childhood to adulthood: a 21-year tracking study. Am J Prev Med, 2005. 28(3): p. 267-73.

Tammelin, T., A review of longitudinal studies on youth predictors of adulthood physical activity. Int J Adolesc Med Health, 2005. 17(1): p. 3-12.

Griffin, P.S., Teaching in an Urban, Multiracial Physical Education Program: The Power of Context QUEST, 1985. 37(2): p. 154–165.

van Sluijs, E.M., et al., Behavioural and social correlates of sedentary time in young people. Br J Sports Med, 2008.

Trost, S.G., K.L. McIver, and R.R. Pate, Conducting accelerometer-based activity assessments in field-based research. Med Sci Sports Exerc, 2005. 37(11 Suppl): p. S531-43.

Trost, S.G., et al., Using objective physical activity measures with youth: how many days of monitoring are needed? Med Sci Sports Exerc, 2000. 32(2): p. 426-31.

Penpraze, V., et al., Monitoring of Physical Activity in Young Children: How Much Is Enough? Pediatr Exerc Sci, 2006. 18(4).

Welk, G.J., J.A. Schaben, and J.R. Morrow, Jr., Reliability of accelerometry-based activity monitors: a generalizability study. Med Sci Sports Exerc, 2004. 36(9): p. 1637-45.

Andersen, L.B. and W. van Mechelen, Are children of today less active than before and is their health in danger? What can we do? Scand J Med Sci Sports, 2005. 15(5): p. 268-70.

Freedson, P., D. Pober, and K.F. Janz, Calibration of accelerometer output for children. Med Sci Sports Exerc, 2005. 37(11 Suppl): p. S523-30.

Trost, S.G., et al., Age and gender differences in objectively measured physical activity in youth. Med Sci Sports Exerc, 2002. 34(2): p. 350-5.

Mota, J. and J.F. Sallis, A actividade física e saúde. Factores de influência da

actividade física nas crianças e nos adolescentes. 2003, Porto: Campo das Letras.
Armstrong, N. and J.R. Welsman, The physical activity patterns of European youth with reference to methods of assessment. Sports Med, 2006. 36(12): p. 1067-86.
Riddoch, C.J., et al., Physical activity levels and patterns of 9- and 15-yr-old European children. Med Sci Sports Exerc, 2004. 36(1): p. 86-92.
Ekelund, U., et al., Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). Am J Clin Nutr, 2004. 80(3): p. 584-90.
Santos, P., et al., Age and gender-related physical activity. A descriptive study in children using accelerometry. J Sports Med Phys Fitness, 2003. 43(1): p. 85-9.
Mota, J., et al., Physical activity and school recess time: differences between the sexes and the relationship between children's playground physical activity and habitual physical activity. J Sports Sci, 2005. 23(3): p. 269-75.
Lopes, V.P., et al., Habitual physical activity levels in childhood and adolescence assessed with accelerometry. J Sports Med Phys Fitness, 2007. 47(2): p. 217-22.
Mota, J., et al., Differences in school-day patterns of daily physical activity in girls according to level of physical activity. J Phys Act Health, 2008. 5 Suppl 1: p. S90-7.
Armstrong, N., et al., Patterns of physical activity among 11 to 16 year old British children. BMJ, 1990. 301(6745): p. 203-5.
Jago, R., et al., Adolescent patterns of physical activity differences by gender, day, and time of day. Am J Prev Med, 2005. 28(5): p. 447-52.
Sallis, J.F., Self-report measures of children's physical activity. J Sch Health, 1991. 61(5): p. 215-9.
Klasson-Heggebo, L. and S.A. Anderssen, Gender and age differences in relation to the recommendations of physical activity among Norwegian

children and youth. Scand J Med Sci Sports, 2003. 13(5): p. 293-8.

Biddle, S.J. and K.R. Fox, Motivation for physical activity and weight management. Int J Obes Relat Metab Disord, 1998. 22 Suppl 2: p. S39-47.

Nilsson, A., et al., Between- and within-day variability in physical activity and inactivity in 9- and 15-year-old European children. Scand J Med Sci Sports, 2008.

Troiano, R.P., et al., Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc, 2008. 40(1): p. 181-8.

Janssen, I., et al., Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. Obes Rev, 2005. 6(2): p. 123-32.

Martínez-Gómez, D., et al., Preliminary evidence of physical activity levels measured by accelerometer in Spanish adolescents. The AFINOS Study. Nutr Hosp, 2009. In press.

Ferreira, I., et al., Environmental correlates of physical activity in youth - a review and update. Obes Rev, 2007. 8(2): p. 129-54.

Lee, R.E. and C. Cubbin, Striding toward social justice: the ecologic milieu of physical activity. Exerc Sport Sci Rev, 2009. 37(1): p. 10-7.

Welk, G.J., et al., Reliability and validity of questions on the youth media campaign longitudinal survey. Med Sci Sports Exerc, 2007. 39(4): p. 612-21.

5.2 School free-time

Manuscript: Physical Activity in High School during the "free-choice" periods

5.2.1 Abstract

The aim of this study is to determine the gender, age, body mass index, and school influence in the amount of PA on different "free-time" periods during the school schedule. 213 adolescents (135 girls and 78 boys), aged 14.57±1.69, from two different public schools, 69 attending an Urban School (US) (16 boys and 53 girls) and 144 attending a Rural School (RS) (62 boys and 82 girls). Physical Activity (PA) was assessed by accelerometer for 7 consecutive days (with 1 minute epochs). Patterns of PA were assessed for 5 distinct time periods: 1) morning commute (MC); 2) morning recess (MR); 3) lunch time (LT); 4) afternoon recess (AR); 5) after school (AS). Statistical procedures included multiple regressions. Boys had significantly higher values of PA (counts.min^{-1}) than girls for three of the five settings (LT $p=0.05$; AR and AS $p<0.001$). Activity levels were higher among younger students in three of the five settings despite equal opportunities for physical activity (CS $p=0.021$; MR and AR $p<0.001$). Significant differences ($p<0.001$) in activity levels were observed between the two schools in the MR, LT and AR, possibly due to environmental factors. The relevance of recess as an active opportunity is reduced with the age increase. These results emphasize the role of school to provide contexts where youth can increase PA, since it's there that they spend the most part of waking hour's day.

Key-words: Physical activity guidelines, Accelerometer, choice.

5.2.2 Introduction

It's recognized worldwide that schools provide a promising setting for promoting physical activity (PA) and other health behaviors. Schools have access to young people, from the full socioeconomic spectrum, on a regular basis, for a large proportion of their waking hours during at least ten years of development (Waring, Warburton, & Coy, 2007). During a school day there are multiple opportunities for youth to be physical active, but data indicates that few youth engage in PA across various segments of the school day (Hohepa, Scragg, Schofield, Kolt, & Schaaf, 2008).

Experiences of curricular and extracurricular opportunities in school, offered within Physical Education, sport and activity programs, are extremely important for promoting continuing involvement in PA (Waring, et al., 2007). Although, there are a number of worrying trends: declines in quality and quantity of PE (Simons-Morton, Taylor, Snider, Huang, & Fulton, 1994); restrictions and reductions in recess (Skrupskelis, 2000); and apparent widening of disparities by activity status (very active vs. very inactive) (Riddoch, et al., 2007), by gender (Riddoch, et al., 2004; Troiano, et al., 2008), and by age (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008).

From a development perspective, most children start out with a physical active identity, as evidenced by the ease and willingness with which they run and play when given a chance. As they get older, sociological, cultural, and personal factors develop, and PA becomes more of a choice among multiple options. Some youth maintain their interest and involvement; others begin withdrawing from physical activities (Welk, 1999). The role of the schools becomes increasingly important since it doesn't appear that youth, when left to their own choices, will take advantage of opportunities to exercise for one hour daily (Cale & Harris, 2001).

Physical education programs in schools have the potential to promote healthy active lifestyles (McKenzie & Lounsbery, 2009), but it may be more effective to promote activity during other portions of the school day. A systematic review conducted to identify research that evaluated the effectiveness of non-curricular interventions on the physical activity of children and adolescents, showed that children were active during school break periods and that simple interventions could further increase activity during these times (Jago & Baranowski, 2004). Free-time activities with educative goals and improvements in programming options during recess can make up for weaknesses in curriculum or school support by enabling youth to be more active during the day (Pereira & Neto, 1999). These periods of time are important opportunities for PA during the school day (McKenzie, Marshall, Sallis, & Conway, 2000; Stratton & Leonard, 2002). Studies show that youth do not compensate for activity at school by being less active at home so school-based activity promotion is important (Dale, Corbin, & Dale, 2000).

The free-time available within the school day is clearly being underutilized in the context of promoting PA. In Portugal school attendance is mandatory until the 9th grade, corresponding to the age of 15 years old. If students chose to be active during 5 “free-choice” periods in the school schedule, such as commute to school, morning recess, lunch, afternoon recess, and after-school, they would get 25 more opportunities be active per week. To better utilize these opportunities, it is important to better understand the contribution of different school settings to activity levels in youth. The aim of this study is to determine how gender, age, body mass index, and school influence the amount of PA during different “free-choice” periods during the school schedule of Portuguese students attending two high schools.

5.2.3 Methods

Participants

We recruited 213 adolescents (135 girls and 78 boys), aged 14.57±1.69, from two different public schools, 69 attending an Urban School (US) (16 boys and 53 girls) and 144 attending a Rural School (RS) (62 boys and 82 girls). The Portuguese Ministry for Science and Technology provided permission to conduct this study. Informed written consent was also obtained from the children’s legal guardians and from individual school principals.

Anthropometry

Weight was measured to the nearest Kg, lightly dressed (shorts and tee-shirt) using a portable digital beam scale (Tanita Inner Scan BC532). Height was measured to the nearest mm in bare or stocking feet with the child standing upright against a Holtain portable stadiometer. The BMI was estimated from the ratio weight/height^2 (Kg/m^2).

Assessment of physical activity

Physical activity was assessed with the MTI Actigraph accelerometer (model 7164). The adolescents wore the accelerometer in an elastic waistband on the right hip during daytime, except while bathing and during other aquatic activities. A diary was given to students who were instructed to record the time when the monitor was attached in the morning and detached in the evening. The Actigraph was worn over 7 consecutive days in order to obtain a reliable picture of the habitual PA (Trost, et al., 2005), and it was used an epoch of 1 minute (Andersen & van Mechelen, 2005; Welk, et al., 2004). The age-specific count ranges corresponding to the intensity levels developed by Freedson (Freedson, et al., 2005) were adopted. The daily time spent in moderate and vigorous physical activity (MVPA more or equal than 3MET) was calculated by summing the minutes of moderate, vigorous, and very vigorous PA for each day. A SAS-based macro (developed by Svensson Sport) was used for data reduction and further analyses, the outcome variables were daily activity counts (counts/min/d), which is an indicator of the volume of PA, and time (min/d) spent at different PA intensity categories.

"Free-time" periods

Alongside the accelerometer, students had to complete a weekly diary where they recorded their school schedule, the accelerometer wearing time, and the major physical activities and sedentary activities they performed in half-hour periods. With this diary and the school schedule, it was possible to determine the time allocation of the "free-time" periods. Accelerometry in combination with diaries offers the best option for understanding activity in different contexts and for informing intervention need and design (Fox & Riddoch, 2000).

Statistics

Descriptive statistics were used to describe the activity data and the participant's characteristics. Independent samples t-test was used to assess gender differences. Multiple regression analyses were used to examine the effects of various predictor variables (gender, age, BMI, school) on activity levels during the five different free-choice periods. All analyses were performed by using Statistical Package for Social Sciences (SPSS, version 17.0), and the level of significance was set at $P < 0.05$.

5.2.4 Results

The participant's physical characteristics are summarized in Table 1. Students from RS were older (p <0,05) than those from US, but no gender difference in age was found. In both schools boys were heavier and taller than girls (p<0,05). No significant differences in BMI were found.

Boys had more total PA amount than girls in both schools and higher values of PA in all free-choice periods with one exception – the morning recess in the US. The most relevant period, in terms of PA amount varied in boys and girls. In boys, activity levels were highest in the after-school period while in girls it was the lunch period. These behaviors were constant in both schools.

RS students, of both genders, also had higher values of total physical activity than US, despite being significantly older. A different activity pattern was evident between the two schools. In RS both recess periods had higher PA amount than US, and in the US lunch and after-school periods were both higher than RS.

The free-choice periods in RS for girls and boys correspond to 37.7 % and 40.1%, respectively, of the total PA amount. These periods in US girls and boys correspond to 42.7% and 42.1%.

Table 1 – Descriptive characteristics for adolescents participating in the study

Characteristics	Rural School		Urban School	
(Mean ± SD)	Girls	Boys	Girls	Boys
Age (years)	15.1 ± 1.6	15.1 ± 1.5	13.6 ± 1.5	13.6 ± 1.6
Weight (Kg)	55.01 ± 10.02	62.18 ± 12.62	51.43 ± 8.15	61.63 ± 17.07
Height (m)	1.60 ± .07	1.71 ± .10	1.57 ± .07	1.64 ± .12
BMI ($kg.m^2$)	21.4 ± 3.4	21.4 ± 3.4	21.4 ± 3.4	21.4 ± 3.4
Physical Activity - Mean Cpm (% of total PA)				
Total PA	11739 ± 3438	16897 ± 5893	10901 ± 2760	15349 ± 5385
Morning commute	869 (7.3 %)	1071 (6.1 %)	880 (8.4 %)	914 (5.6 %)
Morning recess	583 (4.9 %)	699 (4.0 %)	508 (4.7 %)	386 (4.2 %)
Lunch time	1248 (10.4 %)	1672 (10.1 %)	1682 (15.6 %)	2078 (12.8 %)
Afternoon recess	811 (6.7 %)	1084 (6.6 %)	434 (3.9 %)	734 (4.3 %)
After-school	984 (8.4 %)	2417 (13.3 %)	1103 (10.1 %)	2626 (15.2 %)

Table 2 shows a linear regression with the free-choice periods as dependent variables, and the gender, age, BMI, and school as the predictor factors. Girls were less likely to be active than boys in all free-choice periods ($p<0.05$). Older youth were less likely to be active than younger youth ($p<0.05$). Adolescents who attend in the rural school are more likely to use the recess periods in a more active manner. BMI was not a significant variable in any of the free-choice school periods.

Table 2 – Linear regression predicting PA (cpm) in the different free-choice periods.

	Gender		Age		BMI		School	
	B	**(95% C.I)**	***B***	**(95% C.I)**	***β***	**(95% C.I)**	***β***	**(95% C.I)**
Morning commute	157.72	(-13.86, 329.31)	-63.64 *	(-117.46, -9.83)	7.33	(-18.25, 32.91)	-130.25	(-323.73, 63.23)
Morning recess	57.71	(-40.99, 156.41)	-81.16 **	(-112.12, -50.21)	-2.81	(-17.52, 11.90)	-261.02 **	(-372.32, -149.73)
Lunch time	413.55 **	(197.12, 629.99)	-74.68 *	(-142.56, -6.81)	16.39	(-15.87, 48.65)	314.81 *	(70.77, 558.86)
Afternoon recess	277.76 **	(162.85, 392.66)	-72.74 **	(-108.78, -36.70)	11.99	(-5.14, 29.12)	-477.16 **	(-606.73, -347.59)
After-school	1452.46 **	(1014.37,1890.56)	-89.79	(-227.19, 47.61)	17.27	(-48.03, 82.58)	11.51	(-482.48, 505.50)

* $p < 0.05$; ** $p < 0.001$

The figure 1 presents the PA amount in each free-choice period by gender and school.

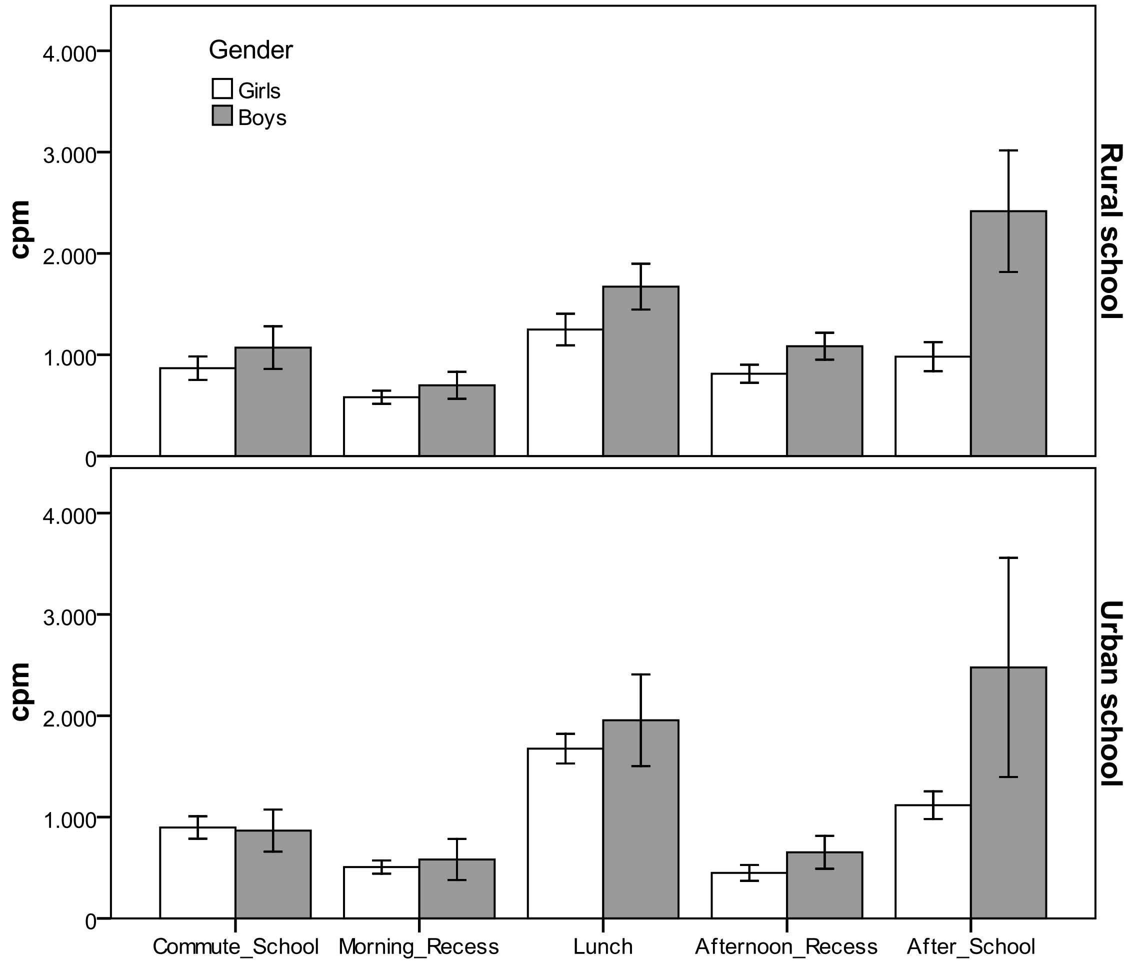


Figure 1 – Mean counts.min^{-1} during the different school free-choice periods by gender and school type.

5.2.5 Discussion

This study examined the contribution of “free-choice” periods during the school day on the amount of PA of students attending to different high schools. Our findings indicate that participation in these periods is lower in females and is lower for older youth than younger. Although this was a marked finding in both schools; students in RS were older than US and presented higher values of total PA and in the recess periods. Witch point to differences between the two schools. The students who attended the rural school use the free-choice periods in a more active manner, with the exception of the lunch-time.

A study with direct observation in 20 primary schools concluded that the school was not delivering on its potential to be a good setting to promote PA, the children spent only 11.8 percent of the available time in at least moderate activity, corresponding to 15 minutes on the day that included a PE lesson (Waring, et al., 2007). Evidence suggests that children are almost twice more likely to engage in at least moderate activity in a PE lesson than they are in the home environment (Sleap & Warburton, 1996). Numerous barriers, including limited curriculum time allocations, low subject status, and inadequate resources hinder physical education from playing a major role in providing and promoting physical activity (McKenzie & Lounsbery, 2009).

Intervention strategies should take in account the particularities of this population, and value the increase of habitual PA as a way to promote health in children and adolescents, not only to promote health but as a disease-prevention strategy (Strong, et al., 2005). Because the Portuguese school schedule is very long, finding relevant periods where youth can accumulate PA seems to us very important – particularly periods where youth have the choice to be or not to be physical active. This study showed that these free-choice periods may contribute with approximately 37.7% to 42.7% of the total PA amount.

Gender differences in activity patterns are an important consideration when studying the habitual PA of adolescents.(Armstrong & Welsman, 2006; Mota & Sallis, 2003) The higher participation by boys in a more active way in the free-choice periods, is a quite typical finding and this may be attributable to stronger social reinforcement (McKenzie, et al., 1997; Sallis, et al., 2000b). This results are in agreement with studies who also included Portuguese adolescents in the sample,(Ekelund, et al., 2004; Riddoch, et al., 2004) and with other international studies.(Andersen & van Mechelen, 2005; Trost, et al., 2002) On the other hand, some girls values of PA achieved are an important indication that the context where the PA is performed is pertinent also in this gender. Thus, it is important to refer the relevant role that schools can play in the girls PA patterns (Sarkin, McKenzie, & Sallis, 1997). It was evident a gender difference in the relevance of the lunch and after-school periods to the total PA amount. Whereas in boys the after-school was the most relevant (RS: 10.1% lunch vs. 13.3 % after-school; US: 12.8% lunch vs. 15.2 % after-school), in girls it was the lunch period (RS: 10.4% lunch vs. 8.4 % after-school; US: 15.6% vs. 10.1 % after-school). Similar results were corroborated by another Portuguese study; Mota et al. (Mota, Santos, Guerra, Ribeiro, & Duarte, 2003) reported higher proportions of daily physical activity during the morning and early afternoon period for girls, while boys were more active in the late afternoon and evening.

Age had a negative impact in the amount of MVPA, and a decrease in MVPA participation was found in older adolescents. These results are in agreement with the literature. Students in this age level present high variability in the MVPA between the days (Trost, et al., 2000), and was noticed a shift of interests when they have the chance to choose their activities during this free-choice periods. An interesting finding was the higher values of the older students (in the RS) comparing to the younger students (in the US), which points to the relevance of the school setting.

Cross-sectional data indicate that environmental and policy variables are associated with physical activity behaviors of young people and adults (Sallis, Bauman, & Pratt, 1998b). Urban residence has been suggested to be a contributing factor to a less active lifestyle (Roxane, Welk, Calabros, Nicklay, & Hensley, 2008); however, not all studies support this link (Davy, Harrell, Stewart, & King, 2004; Felton, et al., 2002; McMurray, Harrell, Bangdiwala, & Deng, 1999). Similar to our results, a study with 3416 children to examine urbanization influences on physical activity and the prevalence of being overweight, suggested that there are rural-urban differences in children’s prevalence of overweight and physical activity. Children from rural areas and small cities were more active than urban children, small cities presented a slightly greater frequency of activity during physical education time and after school compared to urban and rural children, and this likely contributed to their higher overall level of physical activity (Roxane, et al., 2008). Although in this study the schools environments weren´t characterized, it seems that the school characteristics are an important factor in the realization of physical activities (O'Malley, Johnston, Delva, Bachman, & Schulenberg, 2007).

Because all together these periods correspond to a relevant percentage of the total PA (RS: 37.7% girls, 40.1% boys; US: 42.7% girls, 42.1% boys), these results illustrate that the students who participated more in the “free-choice” periods have more opportunities to achieve the recommended amount of PA. While activity promotion is important, it is also important to try to reduce the sedentary activities during this period, since a longitudinal study showed the tracking of sedentary behavior, from adolescence to adulthood (Gordon-Larsen, et al., 2004). The results found by Wickel et al.(Wickel & Eisenmann, 2007) stress this idea, nearly 50% of the accumulated minutes of MVPA were attributed to unstructured activities (approximately 56 min), whereas PE and recess contributed almost 11 and 16% of the total MVPA.

A study with accelerometers to find the contribution of the recess time to daily PA, suggested that school recess time is an important setting to promote MVPA and contributes to daily physical activity in young children, especially in girls (Mota, et al., 2005). Another similar study (Ridgers, Stratton, & Fairclough, 2005) stated that recess can contribute with 28 min for boys and 21.5 min for girls toward the accumulation of recommended daily physical activity. However, on average, children in that study did not achieve 50% of recess time in physical activity highlighting the possibilities of this context. Consideration may be given to the lengthening of recess periods in order to increase PA levels (Zask, van Beurden, Barnett, Brooks, & Dietrich, 2001).

Lunchtime PA represented the most important source of daily PA (15-16%) obtained during school hours for both boys and girls, whereas recess accounted for 8-9% and PE class accounted for 8-11% of total steps per day. Regardless, almost half of daily steps taken are attributable to after-school activities (Tudor-Locke, Lee, Morgan, Beighle, & Pangrazi, 2006). In another study, levels of engagement in MVPA and VPA were significantly higher during lunch periods than during recess. MVPA and VPA engagement in smaller schools was significantly higher than in larger schools. Our results suggest that the lunch period can be an excellent opportunity to develop PA promotion programs targeting girls.

After-school period have been projected by the literature has the most relevant time for the PA accumulation (Fairclough, Butcher, & Stratton, 2007; Trost, Rosenkranz, & Dzewaltowski, 2008; Tudor-Locke, et al., 2006). A recent finding that use of after-school time for active versus sedentary pursuits was one of the most consistent correlates of physical activity across age and sex subgroups in a US sample of youth (Sallis, Prochaska, Taylor, Hill, & Geraci, 1999). On the other hand, this period can be worn out with sedentary activities. A study by Atkin et al. (Atkin, Gorely, Biddle, Marshall, & Cameron, 2008) showed that the most prevalent behaviors after school are technology-based sedentary behavior, homework and physical activity, and during these hours, engagement in physical activity does not appear to displace time spent doing homework. In reviewing the correlates literature, Sallis et al. (Sallis, et al., 2000b) reported that sedentary behavior after school was inversely related to adolescent physical activity. Studying behavior after school is appropriate, because during these hours adolescents have the choice how they use their time, freed from the constraints of school and parental curfews that may limit behavior later in the evening.

It is helpful to understand the pattern and distribution of behavior across the day, to indicate the most appropriate times to intervene (Atkin, et al., 2008). Therefore, PA in the school setting is important because the adolescents spend most of their day there, this has a huge impact in the Portuguese youth because of the long school schedule, which emphasizes the pertinence of studying the various school contexts where the PA is performed (Fox & Riddoch, 2000). While the school is not the only place where action is needed to address activity levels, a question should be object of reflection: Are our schools teaching students to own a physical active or inactive lifestyle? Creating active school communities is an ideal way to ensure that children and youth adopt active healthy lifestyles. Given competent providers, PA can be added to the school curriculum by taking time from other subjects without risk of hindering student academic achievement. On the other hand, adding time to "academic" or "curricular" subjects by taking time from physical education programs does not enhance grades in these subjects and may be detrimental to health (Trudeau & Shephard, 2008).

Acknowledgments

This study was supported by FCT - SFRH/BD/23088/2005.

5.2.6 References

Andersen, L. B. & Van Mechelen, W. (2005) Are children of today less active than before and is their health in danger? What can we do? *Scand J Med Sci Sports,* 15**,** 268-70.

Armstrong, N. & Welsman, J. R. (2006) The physical activity patterns of European youth with reference to methods of assessment. *Sports Med,* 36**,** 1067-86.

Atkin, A., Gorely, T., Biddle, S., Marshall, S. J. & Cameron, N. (2008) Critical Hours: Physical Activity and Sedentary Behavior of Adolescents After School. *Pediatric Exercise Science,* 20**,** 446-456.

Cale, L. & Harris, J. (2001) Exercise recommendations for young people: an update. *Health Education,* 101**,** 126 - 138.

Dale, D., Corbin, C. B. & Dale, K. S. (2000) Restricting opportunities to be active during school time: do children compensate by increasing physical activity levels after school? *Res Q Exerc Sport,* 71**,** 240-8.

Davy, B. M., Harrell, K., Stewart, J. & King, D. S. (2004) Body weight status, dietary habits, and physical activity levels of middle school-aged children in rural Mississippi. *South Med J,* 97**,** 571-7.

Ekelund, U., Sardinha, L. B., Anderssen, S. A., Harro, M., Franks, P. W., Brage, S., Cooper, A. R., Andersen, L. B., Riddoch, C. & Froberg, K. (2004) Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). *Am J Clin Nutr,* 80**,** 584-90.

Fairclough, S. J., Butcher, Z. H. & Stratton, G. (2007) Whole-day and segmented-day physical activity variability of northwest England school children. *Prev Med,* 44**,** 421-5.

Felton, G. M., Dowda, M., Ward, D. S., Dishman, R. K., Trost, S. G., Saunders, R. & Pate, R. R. (2002) Differences in physical activity between black and white girls living in rural and urban areas. *J Sch Health,* 72**,** 250-5.

Fox, K. R. & Riddoch, C. (2000) Charting the physical activity patterns of contemporary children and adolescents. *Proc Nutr Soc,* 59**,** 497-504.

Freedson, P., Pober, D. & Janz, K. F. (2005) Calibration of accelerometer output for children. *Med Sci Sports Exerc,* 37**,** S523-30.

Gordon-Larsen, P., Nelson, M. C. & Popkin, B. M. (2004) Longitudinal physical activity and sedentary behavior trends: adolescence to adulthood. *Am J Prev Med,* 27**,** 277-83.

Hohepa, M., Scragg, R., Schofield, G., Kolt, G. S. & Schaaf, D. (2008) Self-reported physical activity levels during a segmented school day in a large multiethnic sample of high school students. *J Sci Med Sport*.

Jago, R. & Baranowski, T. (2004) Non-curricular approaches for increasing physical activity in youth: a review. *Prev Med,* 39**,** 157-63.

Mckenzie, T. & Lounsbery, M. (2009) School Physical Education: The Pill Not Taken. *American Journal of Lifestyle Medicine, online first*.

Mckenzie, T. L., Marshall, S. J., Sallis, J. F. & Conway, T. L. (2000) Leisure-time physical activity in school environments: an observational study using SOPLAY. *Prev Med,* 30**,** 70-7.

Mckenzie, T. L., Sallis, J. F., Elder, J. P., Berry, C. C., Hoy, P. L., Nader, P. R., Zive, M. M. & Broyles, S. L. (1997) Physical activity levels and prompts in young children at recess: a two-year study of a bi-ethnic sample. *Res Q Exerc Sport,* 68**,** 195-202.

Mcmurray, R. G., Harrell, J. S., Bangdiwala, S. I. & Deng, S. (1999) Cardiovascular disease risk factors and obesity of rural and urban elementary school children. *J Rural Health,* 15**,** 365-74.

Mota, J. & Sallis, J. F. (2003) *A actividade física e saúde. Factores de influência da actividade física nas crianças e nos adolescentes,* Porto, Campo das Letras.

Mota, J., Santos, P., Guerra, S., Ribeiro, J. C. & Duarte, J. A. (2003) Patterns of daily physical activity during school days in children and adolescents. *Am J Hum Biol,* 15**,** 547-53.

Mota, J., Silva, P., Santos, M. P., Ribeiro, J. C., Oliveira, J. & Duarte, J. A. (2005) Physical activity and school recess time: differences between the sexes and the relationship between children's playground physical activity and habitual physical activity. *J Sports Sci,* 23**,** 269-75.

Nader, P. R., Bradley, R. H., Houts, R. M., Mcritchie, S. L. & O'brien, M. (2008) Moderate-to-vigorous physical activity from ages 9 to 15 years. *JAMA,* 300**,** 295-305.

O'malley, P. M., Johnston, L. D., Delva, J., Bachman, J. G. & Schulenberg, J. E. (2007) Variation in obesity among American secondary school students by school and school characteristics. *Am J Prev Med,* 33**,** S187-94.

Pereira, B. O. & Neto, C. (1999) *As Crianças, o Lazer e os Tempos Livres,* Braga, Universidade do Minho.

Riddoch, C. J., Bo Andersen, L., Wedderkopp, N., Harro, M., Klasson-Heggebo, L., Sardinha, L. B., Cooper, A. R. & Ekelund, U. (2004) Physical activity levels and patterns of 9- and 15-yr-old European children. *Med Sci Sports Exerc,* 36**,** 86-92.

Riddoch, C. J., Mattocks, C., Deere, K., Saunders, J., Kirkby, J., Tilling, K., Leary, S. D., Blair, S. N. & Ness, A. R. (2007) Objective measurement of levels and patterns of physical activity. *Arch Dis Child,* 92**,** 963-9.

Ridgers, N. D., Stratton, G. & Fairclough, S. J. (2005) Assessing physical activity during recess using accelerometry. *Prev Med,* 41**,** 102-7.

Roxane, R., Welk, G., Calabros, M., Nicklay, B. & Hensley, L. (2008) Rural–Urban Differences in Physical Activity, Physical Fitness, and Overweight Prevalence of Children. *The Journal of Rural Health,* 24**,** 49-54.

Sallis, J. F., Bauman, A. & Pratt, M. (1998) Environmental and policy interventions to promote physical activity. *Am J Prev Med,* 15**,** 379-397.

Sallis, J. F., Prochaska, J. J. & Taylor, W. C. (2000) A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc,* 32**,** 963-75.

Sallis, J. F., Prochaska, J. J., Taylor, W. C., Hill, J. O. & Geraci, J. C. (1999) Correlates of physical activity in a national sample of girls and boys in grades 4 through 12. *Health Psychol,* 18**,** 410-5.

Sarkin, J. A., Mckenzie, T. L. & Sallis, J. F. (1997) Gender differences in Physical activity during fifth-grade physical education and recess period. *J.Teaching Phys.Educ.,* 17:**,** 99-106.

Simons-Morton, B. G., Taylor, W. C., Snider, S. A., Huang, I. W. & Fulton, J. E.

(1994) Observed levels of elementary and middle school children's physical activity during physical education classes. *Prev Med,* 23**,** 437-41.

Skrupskelis, A. (2000) *An historical trend to eliminate recess*, American Press.

Sleap, M. & Warburton, P. (1996) Physical activity levels of 5-11-year-old children in England: cumulative evidence from three direct observation studies. *Int J Sports Med,* 17**,** 248-53.

Stratton, G. & Leonard, J. (2002) The effects of playground markings on the energy expenditure of 5-7-year-old school children. *Pediatric Exercise Science,* 14**,** 170-180.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., Hergenroeder, A. C., Must, A., Nixon, P. A., Pivarnik, J. M., Rowland, T., Trost, S. & Trudeau, F. (2005) Evidence based physical activity for school-age youth. *J Pediatr,* 146**,** 732-7.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T. & Mcdowell, M. (2008) Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc,* 40**,** 181-8.

Trost, S. G., Mciver, K. L. & Pate, R. R. (2005) Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc,* 37**,** S531-43.

Trost, S. G., Pate, R. R., Freedson, P. S., Sallis, J. F. & Taylor, W. C. (2000) Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc,* 32**,** 426-31.

Trost, S. G., Pate, R. R., Sallis, J. F., Freedson, P. S., Taylor, W. C., Dowda, M. & Sirard, J. (2002) Age and gender differences in objectively measured physical activity in youth. *Med Sci Sports Exerc,* 34**,** 350-5.

Trost, S. G., Rosenkranz, R. R. & Dzewaltowski, D. (2008) Physical activity levels among children attending after-school programs. *Med Sci Sports Exerc,* 40**,** 622-9.

Trudeau, F. & Shephard, R. J. (2008) Physical education, school physical activity, school sports and academic performance. *Int J Behav Nutr Phys Act,* 5**,** 10.

Tudor-Locke, C., Lee, S. M., Morgan, C. F., Beighle, A. & Pangrazi, R. P. (2006) Children's pedometer-determined physical activity during the segmented school day. *Med Sci Sports Exerc,* 38**,** 1732-8.

Waring, M., Warburton, P. & Coy, M. (2007) Observation of children's physical activity levels in primary school: Is the school an ideal setting for meeting government activity targets? *European Physical Education Review,* 13**,** 25-40.

Welk, G. (1999) The youth physical activity promotion model: A conceptual bridge between theory and practice. *Quest***,** 5-23.

Welk, G. J., Schaben, J. A. & Morrow, J. R., Jr. (2004) Reliability of accelerometry-based activity monitors: a generalizability study. *Med Sci Sports Exerc,* 36**,** 1637-45.

Wickel, E. E. & Eisenmann, J. C. (2007) Contribution of youth sport to total daily physical activity among 6- to 12-yr-old boys. *Med Sci Sports Exerc,* 39**,** 1493-500.

Zask, A., Van Beurden, E., Barnett, L., Brooks, L. O. & Dietrich, U. C. (2001) Active school playgrounds-myth or reality? Results of the "move it groove it" project. *Prev Med,* 33**,** 402-8.

5.3 School Sports

Manuscript: Physical activity patterns in Portuguese adolescents the contribution of extra-curricular sports

5.3.1 Abstract

In Portugal, two sports systems exist, one through schools and the other in clubs. The purpose was to determine the impact of extra-curricular sports (EC-Sports), on boys and girls moderate to vigorous physical activity (MVPA). 210 adolescents (80 boys and 130 girls), between 12 and 18 years old, wore an accelerometer over 7 days. Four EC-sport categories based on reported involvement were (no sports, school sports, club sports, both sports). Multivariable logistic regression was used to study the association of EC-sports, age, gender and BMI on the adolescent's MVPA. School sport context was more relevant in girls than clubs sports; however the opposite pattern emerged for boys. BMI was not related to adolescent's MVPA. EC-sports increase the likelihood of achieving PA guidelines. The unique social and environmental contexts of school and club sports deserve additional attention in youth activity research.

Key-words: School Physical activity, Accelerometer, organized activities.

5.3.2 Introduction

The decrease in levels of physical activity (PA) in adolescents is an important public health issue (Armstrong & Welsman, 2006). Inactivity at young ages may predispose youth to negative health consequences, such as the early onset of CHD, osteoporosis or adult obesity (Fox & Riddoch, 2000; Strong, et al., 2005). Youth PA is best described as a profile rather than as a static entity. A PA profile can be characterized as a complex matrix of behaviors that take place in a range of social contexts, each with its own set of physiological, psychological and sociological determinants and outcomes.

To enhance the effectiveness of behavioral interventions it is important to better understand the context of youth PA and to specifically determine factors that distinguish active youth from inactive youth. Research on the tracking of physical activity over the lifespan is important for determining the types and elements of PA that cause some youth to be more active than others. This work can help identify patterns that facilitate long term involvement or, alternately, identify groups that may be at risk of dropping out from a more active lifestyle (Tammelin, 2005).

A limitation of past tracking research is that little attention has been given to understanding the context of youth PA patterns. Because school is a common intervention target, most work has examined the contributions of physical education and recess to student's physical activity (Mota, et al., 2005; Ridgers, et al., 2005). Less is known about what happens during other school contexts or after the school schedule. In general, youth have similar exposure and opportunities at school but activity patterns and choices may be more variable after school. A recent study (Wickel & Eisenmann, 2007) evaluated the contribution of youth sports to children's daily physical activity level. This study demonstrated that sports contribute significantly to children's total physical activity. Additional research is needed to confirm these findings and to examine the consistency across different populations and cultures.

In Portugal, two youth sports systems coexist - one performed in schools and the other in clubs. School sports are present in the majority of high schools, although the club sports have a stronger tradition for after school programming

(Bento, 2006; Seabra, Mendonca, Thomis, Malina, & Maia, 2007). This study aims to address the contributions of extracurricular sports (EC-sports), performed in both contexts to activity profiles of Portuguese adolescents. A secondary goal is to examine possible variability in these effects by age and gender.

5.3.3 Methods

Participants

The sample comprised 210 adolescents (80 boys and 130 girls), aged 14.9 ± 1.7, from two public schools. Participants were recruited through their PE classes and were generally typical of the overall school population. The period of data collection was between October and December of 2005. The Portuguese Ministry for Science and Technology provided permission to conduct this study. Informed written consent was also obtained from the children's legal guardians and from individual school principals.

Anthropometry

Height was measured to the nearest mm in bare or stocking feet with the child standing upright against a Holtain portable stadiometer. Weight was measured to the nearest Kg, lightly dressed (underwear and tee-shirt) using a portable digital beam scale (Tanita Inner Scan BC532). The BMI was estimated from the ratio weight/height^2 (Kg/m^2).

Assessment of physical activity

Physical activity was assessed with the MTI Actigraph accelerometer (model 7164). This device is a small and light weight accelerometer designed to measure and record acceleration, in the vertical axis, ranging in magnitude from 0.05 to 2.00 G, with frequency response from 0.25 to 2.50 Hz. The filtered acceleration signal is digitized and the magnitude is summed over a user-specified period of time (an epoch interval). The recorded data was downloaded through the company Reader Interface Unit.

The adolescents wore the accelerometer in an elastic waistband on the right hip throughout the waking day, except while bathing and during other aquatic activities. A data sheet was given to students who were instructed to record the time when the monitor was attached in the morning and detached in the evening. The Actigraph was worn over 7 consecutive days in order to obtain a reliable picture of the habitual PA (Trost, et al., 2005). The monitor was initialized to record in 1 minute similar to other studies (Andersen & van Mechelen, 2005; Welk, et al., 2004), and the age-specific count ranges corresponding to the intensity levels developed by Freedson (Freedson, et al., 2005) were adopted. We established 600 minutes (10 hours) as the minimum monitored time for a valid day. A previous study reported that a monitored period of 7 days with 10 hours/day produced high reliability (Penpraze, et al., 2006).

The daily time spent in moderate and vigorous physical activity (>3MET) was calculated by summing the minutes of moderate, vigorous, and very vigorous PA for each day. A SAS-based macro (developed by Svensson Sport) was used for data reduction and further analyses. The daily activity counts (counts/min/d) were computed to provide, an indicator of the total volume of PA. The time (min/d) spent at different PA-intensity categories were computed to capture the patterns of physical activity. Participants were divided into two categories based on whether they achieved the standard youth physical activity guideline of 60 minutes per day (Less-Active (<420min/week of MVPA); Active (≥420min/week of MVPA).

Extra-curricular sports

Sport involvement was obtained using a simple self-report instrument. Participants reported their participation in both school sports and club sports. This allowed participants to be categorized into four distinct extra-curricular sport categories (no sports (NS); school sports (SS); club sports (CS); and both school and club sports (BS).

Statistics

Descriptive statistics were used to describe the activity data and the participant's characteristics. The Chi-Square test for proportions was used to reflect gender differences in EC-Sports participation, and a two-factor ANOVA tested the gender and EC-Sports participation differences. Post-hoc analyses were conducted to assess the differences between the sports contexts. Binary logistic regression model was used to determine whether EC-sports increased the likelihood of youth achieving physical activity guidelines. The model evaluated the effects of EC-sports (NS was used as the reference category) as well as age (continuous variable), gender, and BMI on the achievement of physical activity guidelines. The odds ratios (OR) and their 95% confidence intervals (CI) for each factor were adjusted for all the other factors in the model. A separate model for each gender was conducted to evaluate potential gender differences. All analyses were performed by using Statistical Package for Social Sciences (SPSS, version 15.0), and the level of significance was set at $P < 0.05$.

5.3.4 Results

The participant's physical characteristics are summarized in Table 1. Boys had higher values ($p < 0.01$) in height and weight than girls, but there were not significant differences between genders in BMI. The proportion of youth categorized as being physical active was significantly different ($p < 0.001$) between genders. 34.6% girls were considered Active whereas 68.7% boys were considered Active. Participation in EC-Sports was also significantly different between genders ($p < 0.001$). In girls, 72.1% were categorized as NS, 16.3% as SS, 7% as CS, and 4.6% as BS. In boys, 34.2% were categorized as NS, 10.1% as SS, 31.6% as CS, and 24.1% as BS.

Table 1 – Descriptive characteristics (Mean Standard deviation) for adolescents participating in the study.

Characteristics		**All**		**Girls**		**Boys**	***p* value**
Age		14.9 ± 1.7		14.5 ± 1.7		14.8 ± 1.7	.20
Weight (Kg)		56.9 ± 12.3		53.6 ± 9.5		62.4 ± 14.3	.000*
Height (m)		1.63 ± 0.1		1.6 ± 0.1		1.7 ± 0.1	.000*
BMI (Kg.m^2)		21.4 ± 3.4		21.2 ± 3.4		21.7 ± 3.6	.25
Total MVPA (min)		439 ± 206		376 ± 161		543 ± 227	.000*
EC-Sports	N		N		N		
No sports (NS)	120	332 ± 135[a]	93	319 ± 16	27	376 ± 20	
School sports (SS)	29	504 ± 148	21	522 ± 34	8	458 ± 54	
Club Sports (CS)	34	584 ± 188	9	535 ± 51	25	601 ± 31	
Both Sports (BS)	25	682 ± 216[b]	6	510 ± 63	19	737 ± 35	
ANOVA	Gender	*F*= 5.8 *p*=.016	EC-Sports	*F*= 25.8 *p*<.001	Gender*EC-Sports	*F*= 25.8 *p*=.030	

* t-test for independent samples

[ab] EC-Sports Post-hoc tests: [a] different from the other groups (*p*<0.001) ; [b] different from NS, SS (*p*<0.001)

Table 1 also shows the descriptive data for the amount of physical activity performed by youth based on the type of EC-sport involvement. The ANOVA results demonstrated significant main effects for gender (*F*= 5.8 *p*=.016), EC-Sport category (*F*= 25.8 *p*<.001), as well as the gender by Sport category (*F*= 25.8 *p*=.030), Boys had higher activity levels than girls and youth that participated in some form of sport were more active than youth that reported no involvement. The youth that participated in both sport categories (BS) generally had higher activity levels than youth that participated in either club (CS) or school sports (SS) but results were only statistically different compared with the school sport group. Examination of the data in the Table reveals that this effect is due entirely to a strong effect in boys. Boys that were in both types of sports were considerably more active than boys in one or the other group but this was not evident in girls.

Figure 1 presents the levels of MVPA by gender for each day of the week after stratification by involvement in extra-curricular sports. This figure shows the clear gender differences in activity patterns between boys and girls. In girls, the group not participating in sports averaged less than 60 minutes of MVPA on most days of the week. In contrast, the group that participated in school sports had average activity levels that exceeded 60 minutes of MVPA every day of the week, Girls who participated in club sports also had higher activity levels but they failed to achieve the threshold on the weekend. In Boys, the group who didn't participate in sports also exhibited lower activity levels on all days of the week. Also noteworthy it the fact that the group that participated in club sports had average activity levels exceeding the 60 minute guideline each day. Lower levels of activity were evident on weekends in both genders.

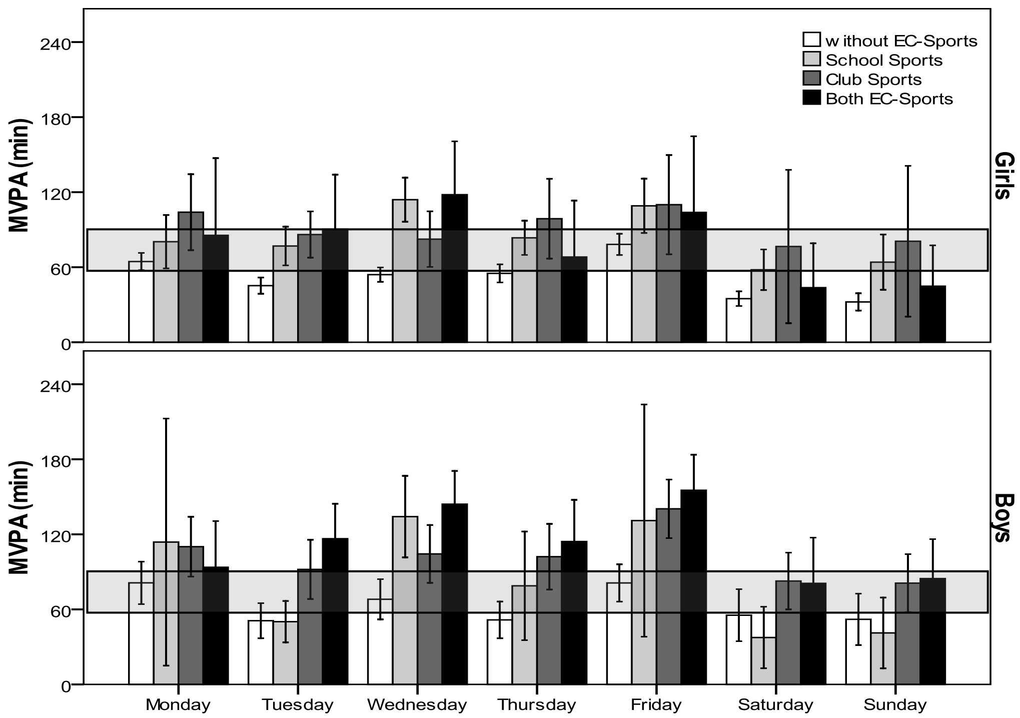


Figure 1 – Minutes of MVPA by gender, in each day of the week, for the four different groups: 1) No EC Sports; 2) School Sports; 3) Club Sports; 4) With both Sports (shaded box represents PA guidelines Zone).

Table 2 shows results from the binary logistic regression analyses with the MVPA amount as the dependent variable and gender, age, BMI, and the EC-Sports as the independent (predictor) variables. After adjustment, the variables that remained associated with the adolescent's PA were: gender, age, and EC sports. Boys were more likely to be active than girls. The likelihood of being active decreased significantly (*p* <0.001) with age. No differences in the odds of PA were detected in terms of BMI. Adolescents who participated in school sports, club sports and both sports were significantly more likely to be active than those who did not participate in EC-Sports.

Table 2 – Logistic regression model for the recommended amount of PA given the participation on EC-sports for the entire sample.

Explanatory variables	Odds Ratio	95% C. I.	p-value
Gender			.003
Girls[1]	1	1	
Boys	3.66	1.56 – 8.59	
Age	.63	.49 - .79	<.001
BMI	.93	.83 – 1.04	.211
EC-sports			<.001
No sports[1]	1	1	
School sports	4.30	1.67 – 11.06	.002
Club Sports	6.57	2.24 – 19.31	.001
Both Sports	9.65	2.45 - 38.11	.001

[1]. Reference category

Additional analyses were conduced to examine gender specificity in the predictive variables (sports contexts). Table 3 shows results for separate binary logistic regression analyses for girls and boys. The age variable exhibited different effects in girls and boys. In girls, the likelihood of being active decreased significantly with age but this pattern was not evident in boys. No gender differences were evident in the odds ratios based on BMI categories (no effects were evident in either gender). Effects based on type of EC- Sports involvement varied by gender. In girls, involvement in school sports significantly increased the likelihood of being categorized as being active (OR= 8.98, *p* <0.001) but this context was not significant in boys (OR = .79,*p* =.796). Girls and boys had similar OR for Club sports, but this context was only significant in boys (OR= 5.26, *p* =.018). Participation in Both Sports contexts was only significant in boys (OR= 15.71, *p* =.015).

Table 3 – Logistic regression model for the recommended amount of PA given the participation on EC-sports by gender.

Explanatory variables		**Odds Ratio**	**95% C. I.**	**p-value**
Age	Girls	.53	.39 - .73	<.001
	Boys	.77	.53 – 1,14	.197
BMI	Girls			
	Boys	.88	.74 – 1.05	.16
EC-sports				
No sports[1]	Girls	[1]	[1]	.001
	Boys	[1]	[1]	.010
School sports	Girls	8.98	2.72 – 29.65	<.001
	Boys	.79	.14 – 4.47	.796
Club Sports	Girls	5.40	.88 – 32.92	.068
	Boys	5.26	1.32 – 20.89	.018
Both Sports	Girls	5.38	.77 – 37.70	.090
	Boys	15.71	1.69 – 145.73	.015

[1]. Reference category

5.3.5 Discussion

This study provides new information about the unique contributions of extra-curricular sports in adolescent boys and girls. Our findings indicate that participation in extra-curricular sports increased the likelihood that students achieved the recommended PA guidelines. Boys engage more in sports in the clubs context. Although girls had less participation in sports than boys, sports in the school context were found to be a stronger predictor of total activity involvement.

Time spent doing physical activity has been proposed as the most relevant indicator for public health research because of its link to current physical activity recommendations. Because Portuguese students spend the major part of their day in the school it is important to understand the different contexts where they can achieve the recommended PA levels. The temporal nature of accelerometer data make it ideally suited for the task.

Studies in the field have shown that accelerometers are an appropriate methodology for measuring adolescent physical activity behavior. Previous studies have demonstrated significant correlations between PA recorded by accelerometer and energy expenditure assessed by indirect calorimetry (Crouter, Churilla, & Bassett, 2006), and a high degree of intra- and inter-instrument reliability (Brage, Wedderkopp, Franks, Andersen, & Froberg, 2003; Esliger & Tremblay, 2006b; Metcalf, et al., 2002; Welk, et al., 2004).

Consistent with the extant literature, the present results with accelerometers demonstrate that age had a negative impact on the likelihood of meeting the PA guidelines. Students in this age group typically exhibit high variability in the MVPA between the days (Trost, et al., 2000), but we observed that students participating in sports in both contexts (school and club) had a more stable amount of MVPA during the monitoring period.

Gender differences in activity patterns are an important consideration when studying the habitual PA of adolescents (Armstrong & Welsman, 2006; Mota & Sallis, 2003). The higher values in the amount of MVPA for boys, are similar with international studies who included Portuguese adolescents in the sample (Ekelund, et al., 2004; Riddoch, et al., 2004), and other international studies (Andersen & van Mechelen, 2005; Trost, et al., 2002). In this study, boys had higher overall sports participation than girls, and also in the club settings (after school). This is a fairly typical finding and this may be attributable to stronger social reinforcement for club sports (McKenzie, et al., 1997; Sallis, et al., 2000b). Interestingly, girls had less overall participation in sports than boys, but higher participation than boys in the school context. School sports make a strong contribution to girl's activity levels indicating that this context is particularly important for girls.

The unique gender patterns confirm that schools can play an important role in girls PA patterns (Sarkin, et al., 1997). In a prospective study, sports practice was associated with a 7-fold protection against low bone density in school-aged girls (Ford, Bass, Turner, Mauromoustakos, & Graves, 2004). A study by Vilhjalmsson et al.(Vilhjalmsson & Kristjansdottir, 2003) found that Icelandic girl's lower enrollment in sport clubs fully accounted for gender differences in frequency of overall PA. Involvement in community sport teams has also been shown to be an important variable in explaining gender differences in strenuous PA (Trost, et al., 1996). Gender-specific motivational factors are likely involved in the differential involvement and contexts. Boys may be more attracted to the competitive aspects of sports, whereas girls may be more motivated by the social opportunities that sports provide (Sirard, Pfeiffer, & Pate, 2006). There is evidence that participating on a sports team with a friend is associated with increased PA during adolescence (Voorhees, et al., 2005), friendships may increase youth's motivation to engage in PA and promote greater PA in non-overweight and overweight youth (Salvy, et al., 2009).

The current PA guidelines propose that youth achieve at least 60 minutes of moderate to vigorous PA daily, Involvement in resistance and strength activities, at least twice a week, are also recommended as desirable for improving bone health (Strong, et al., 2005). More ambitious guidelines have also been proposed, such as the accumulation of 90 minutes of MVPA (Andersen, et al., 2006) or even 60 minutes of MVPA plus 30 minutes of vigorous PA (Public.Health.Canada, 2002).Our results demonstrate that the sports setting provides a context that may help youth accomplish physical activity guidelines. Boys and girls who participate in sports are more physically active every day of the week (see Figure 1), so it's important to develop programs that children want to participate in and maximize retention (Sirard, et al., 2006). Those who have participated in sports in youth may learn skills that help them enhance and maintain their fitness later life as well (Tammelin, 2005). The unique gender patterns suggest that their may be different preferences, patterns and effects from sports in girls and boys. The contribution of these contexts factors to the stronger age-related declines in activity for girls deserves further attention (Fox & Riddoch, 2000).

It is important to emphasize the differences between the week and weekend in levels of MVPA (students had lower values on the weekend). While general activity promotion strategies are needed it may be more effective to target periods that offer the most potential for change. Weekend days and leisure-time during weekdays seem appropriate targets since youth have more available time (Nilsson, et al., 2008). Our results illustrate that the students who participated in sports were more likely to be active on weekends. Previous studies on Portuguese students, showed that only 25,4%, between 10 – 16 years-old, participate in 60 minutes or more of MVPA, in 5 or more days per week (Janssen, et al., 2005), and another study also found similar values of MVPA, 17,4% for boys and 12% in girls (Ekelund, et al., 2004).

A previous study in 6-12 years old boys to determined the contribution of organized youth sport, recess and physical education to total daily PA, found that youth sport contributed approximately 23% of the total MVPA, whereas PE and recess contributed almost 11% and 16% respectively (Wickel & Eisenmann, 2007). During a non-sport day, the participants engaged in significantly more sedentary activity, significantly less moderate and vigorous activity compared with the sport day.

Our results should be interpreted while bearing in mind the limitations of accelerometers and the process chosen to treat the accelerometer data. The intensity of activity is also an important issue, but there is uncertainty in defining cutoffs for different intensity levels with the use of an accelerometer (Ekelund, et al., 2004). We chose to use the intensity cut points proposed by Freedson et al. (Freedson, et al., 2005), because they take in account the age of the subjects. While results could vary depending on the cut-points selected, the age range of our sample population made this an appropriate choice. Another important factor is the time of the year when the PA assessment took place (November – December), while seasonal factors can influence PA patterns and amount (Chan, et al., 2006). This is less of an issue in the temperate climate in Portugal. Although, the utilization of the accelerometer with specific criteria to assess the habitual PA of children and adolescents, will allow a rigorous description of the amount of PA and will be a powerful tool in clarifying activity patterns and preferences in youth.

Physical Activities in school have important implications, individually, socially and economically. For effective activity promotion it is important to include school and community programming. Creating active school communities is an ideal way to ensure that children and youth adopt active healthy lifestyles. Education on physical activity and behavioral skills can help to increase the likelihood that youth will find opportunities to become (and remain) active (Corbin, 2002). The results of this study suggest that special attention should be given to the contributions of youth sport for facilitating physical activity in youth. The continued enhancement of sport and exercise programming for youth provides opportunities for children to be active outside of school and on the weekends. Enhanced community-based programming can also complement activity promotion strategies in schools. While evidence is still somewhat limited, current research supports the hypothesis that activity levels established during adolescence track to some degree over the lifespan (Tammelin, 2005).

Acknowledgments

This study was supported by MCTES/FCT - SFRH/BD/23088/2005 and Project PTDC/DES-72424-2006.

5.3.6 References

Andersen, L. B., Harro, M., Sardinha, L. B., Froberg, K., Ekelund, U., Brage, S. & Anderssen, S. A. (2006) Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet,* 368**,** 299-304.

Andersen, L. B. & Van Mechelen, W. (2005) Are children of today less active than before and is their health in danger? What can we do? *Scand J Med Sci Sports,* 15**,** 268-70.

Armstrong, N. & Welsman, J. R. (2006) The physical activity patterns of European youth with reference to methods of assessment. *Sports Med,* 36**,** 1067-86.

Bento, J. (2006) *Pedagogia do desporto: definições, conceitos e orientações. ,* Rio Janeiro, Guanabara-Koogan.

Brage, S., Wedderkopp, N., Franks, P. W., Andersen, L. B. & Froberg, K. (2003) Reexamination of validity and reliability of the CSA monitor in walking and running. *Med Sci Sports Exerc,* 35**,** 1447-54.

Chan, C. B., Ryan, D. A. & Tudor-Locke, C. (2006) Relationship between objective measures of physical activity and weather: a longitudinal study. *Int J Behav Nutr Phys Act,* 3**,** 21.

Corbin, C. B. (2002) Physical activity for everyone: what every physical educator should know about promoting lifelong physical activity. *J.Teach.Phys.Educ.,* 21**,** 128-144.

Crouter, S. E., Churilla, J. R. & Bassett, D. R., Jr. (2006) Estimating energy expenditure using accelerometers. *Eur J Appl Physiol,* 98**,** 601-12.

Ekelund, U., Sardinha, L. B., Anderssen, S. A., Harro, M., Franks, P. W., Brage, S., Cooper, A. R., Andersen, L. B., Riddoch, C. & Froberg, K. (2004) Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). *Am J Clin Nutr,* 80**,** 584-90.

Esliger, D. W. & Tremblay, M. S. (2006) Technical reliability assessment of three accelerometer models in a mechanical setup. *Med Sci Sports*

Exerc, 38**,** 2173-81.

Ford, M. A., Bass, M. A., Turner, L. W., Mauromoustakos, A. & Graves, B. S. (2004) Past and recent physical activity and bone mineral density in college-aged women. *J Strength Cond Res,* 18**,** 405-9.

Fox, K. R. & Riddoch, C. (2000) Charting the physical activity patterns of contemporary children and adolescents. *Proc Nutr Soc,* 59**,** 497-504.

Freedson, P., Pober, D. & Janz, K. F. (2005) Calibration of accelerometer output for children. *Med Sci Sports Exerc,* 37**,** S523-30.

Janssen, I., Katzmarzyk, P. T., Boyce, W. F., Vereecken, C., Mulvihill, C., Roberts, C., Currie, C. & Pickett, W. (2005) Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes Rev,* 6**,** 123-32.

Mckenzie, T. L., Sallis, J. F., Elder, J. P., Berry, C. C., Hoy, P. L., Nader, P. R., Zive, M. M. & Broyles, S. L. (1997) Physical activity levels and prompts in young children at recess: a two-year study of a bi-ethnic sample. *Res Q Exerc Sport,* 68**,** 195-202.

Metcalf, B. S., Curnow, J. S., Evans, C., Voss, L. D. & Wilkin, T. J. (2002) Technical reliability of the CSA activity monitor: The EarlyBird Study. *Med Sci Sports Exerc,* 34**,** 1533-7.

Mota, J. & Sallis, J. F. (2003) *A actividade física e saúde. Factores de influência da actividade física nas crianças e nos adolescentes,* Porto, Campo das Letras.

Mota, J., Silva, P., Santos, M. P., Ribeiro, J. C., Oliveira, J. & Duarte, J. A. (2005) Physical activity and school recess time: differences between the sexes and the relationship between children's playground physical activity and habitual physical activity. *J Sports Sci,* 23**,** 269-75.

Nilsson, A., Anderssen, S. A., Andersen, L. B., Froberg, K., Riddoch, C., Sardinha, L. B. & Ekelund, U. (2008) Between- and within-day variability in physical activity and inactivity in 9- and 15-year-old European children. *Scand J Med Sci Sports*.

Penpraze, V., Reilly, J., Maclean, C., Montgomery, C., Kelly, K., Paton, J., Aitchison, T. & Grant, S. (2006) Monitoring of Physical Activity in Young Children: How Much Is Enough? *Pediatr Exerc Sci,* 18.

Public.Health.Canada (2002) Family guide to physical activity for youth 10-14 years of age. Otawa, Government of Canada.

Riddoch, C. J., Bo Andersen, L., Wedderkopp, N., Harro, M., Klasson-Heggebo, L., Sardinha, L. B., Cooper, A. R. & Ekelund, U. (2004) Physical activity levels and patterns of 9- and 15-yr-old European children. *Med Sci Sports Exerc,* 36**,** 86-92.

Ridgers, N. D., Stratton, G. & Fairclough, S. J. (2005) Assessing physical activity during recess using accelerometry. *Prev Med,* 41**,** 102-7.

Sallis, J. F., Prochaska, J. J. & Taylor, W. C. (2000) A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc,* 32**,** 963-75.

Salvy, S. J., Roemmich, J. N., Bowker, J. C., Romero, N. D., Stadler, P. J. & Epstein, L. H. (2009) Effect of peers and friends on youth physical activity and motivation to be physically active. *J Pediatr Psychol,* 34**,** 217-25.

Sarkin, J. A., Mckenzie, T. L. & Sallis, J. F. (1997) Gender differences in Physical activity during fifth-grade physical education and recess period. *J.Teaching Phys.Educ.,* 17:**,** 99-106.

Seabra, A. F., Mendonca, D. M., Thomis, M. A., Malina, R. M. & Maia, J. A. (2007) Sports participation among Portuguese youth 10 to 18 years. *J Phys Act Health,* 4**,** 370-80.

Sirard, J. R., Pfeiffer, K. A. & Pate, R. R. (2006) Motivational factors associated with sports program participation in middle school students. *J Adolesc Health,* 38**,** 696-703.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., Hergenroeder, A. C., Must, A., Nixon, P. A., Pivarnik, J. M., Rowland, T., Trost, S. & Trudeau, F. (2005) Evidence based physical activity for school-age youth. *J Pediatr,* 146**,** 732-7.

Tammelin, T. (2005) A review of longitudinal studies on youth predictors of adulthood physical activity. *Int J Adolesc Med Health,* 17**,** 3-12.

Trost, S. G., Mciver, K. L. & Pate, R. R. (2005) Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc,* 37**,** S531-43.

Trost, S. G., Pate, R. R., Dowda, M., Saunders, R., Ward, D. S. & Felton, G. (1996) Gender differences in physical activity and determinants of physical activity in rural fifth grade children. *J Sch Health,* 66**,** 145-50.

Trost, S. G., Pate, R. R., Freedson, P. S., Sallis, J. F. & Taylor, W. C. (2000) Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc,* 32**,** 426-31.

Trost, S. G., Pate, R. R., Sallis, J. F., Freedson, P. S., Taylor, W. C., Dowda, M. & Sirard, J. (2002) Age and gender differences in objectively measured physical activity in youth. *Med Sci Sports Exerc,* 34**,** 350-5.

Vilhjalmsson, R. & Kristjansdottir, G. (2003) Gender differences in physical activity in older children and adolescents: the central role of organized sport. *Soc Sci Med,* 56**,** 363-74.

Voorhees, C. C., Murray, D., Welk, G., Birnbaum, A., Ribisl, K. M., Johnson, C. C., Pfeiffer, K. A., Saksvig, B. & Jobe, J. B. (2005) The role of peer social network factors and physical activity in adolescent girls. *Am J Health Behav,* 29**,** 183-90.

Welk, G. J., Schaben, J. A. & Morrow, J. R., Jr. (2004) Reliability of accelerometry-based activity monitors: a generalizability study. *Med Sci Sports Exerc,* 36**,** 1637-45.

Wickel, E. E. & Eisenmann, J. C. (2007) Contribution of youth sport to total daily physical activity among 6- to 12-yr-old boys. *Med Sci Sports Exerc,* 39**,** 1493-500.

Chapter 6

Chapter 6

6.1 Individual in Space-time - Key Findings

Space-time is the arena in which all physical events take place - an event is a point in space-time specified by its time and place. For example, the motion of planets around the sun may be described in space-time, or the motion of light around a large object such as a star. The basic elements of space-time are events, a unique position at a unique time. Examples of events include the explosion of a star or the single beat of a drum.

In physics, space-time refers to mathematical model that combines space and time into a single construct called the space-time continuum. Space-time is usually interpreted with space being three-dimensional and time playing the role of a fourth dimension that is of a different sort than the spatial dimensions. By combining space and time into a single construct, physicists have been able to describe the workings of the universe at both the super galactic and subatomic levels. Individuals are also in space-time - a person’s life is determined by events that happen in both space and time.

The series of studies presented here will be summarized using elements of the space-time concept. The epidemic of obesity has led to considerable interest in understanding how physical activity behaviors vary across the lifespan. However, it has proven difficult to accurately assess physical activity behavior. The studies presented here all make use of portable accelerometers that provide objective information about physical activity behavior. By combining detailed information from an accelerometer with qualitative information such as the “space-time” variables of where and when PA is realized, it is possible to better understand physical activity behavior.

Ideally, a physical activity measurement tool should provide valid and reliable assessments of all dimensions of activity behavior. However, due to practical considerations and unresolved methodological issues, no such measurement tool currently exists. An accelerometer only measures the acceleration of the center of mass of the human body and hence, from first principles, would need more information to determine energy expenditure. More specifically, the travel through space-time itself is not measured, only the acceleration of the body. While accelerometers have some inherent limitations they have been widely accepted as the most feasible and effective monitoring tool.

In study 3, we found the intra-instrument variability of the new GT1M accelerometer to be very low (counts overall mean CV_{intra}= 0.54%; steps overall mean CV_{intra}= 0.20%). The inter-instrument variability was six times higher than within device numbers, however these values are also quite impressive (counts overall mean CV_{inter}= 3.5%; steps overall mean CV_{intra}= 1.18%). The lack of batch effects also supports the fact that this new model from ActiGraph provides reliable information both in the "counts" and steps outputs. This information it's important to give insurance about the use of this instrument in research.

It's common knowledge that physical activity it's a multi-dimensional behavior and that it can be influenced by a large number of space-time correlates. Our first study tried to use a simple but comprehensive model to further explore these factors. The fact that we showed that the YPAPM can be applied in different cultural contexts opens the door for is broadly application in order to better understand the correlates of physical activity. This knowledge will allow the tailoring of physical activity interventions, due to a large diversity in levels of physical activity among population subgroups, social-ecological approaches to physical activity promotion may be warranted (Bergman, Grjibovski, Hagstromer, Bauman, & Sjostrom, 2008). Moreover, young peoples' physical activity was identified (Ommundsen, et al., 2006) as taking place in multiply genuine locations, and the psychosocial correlates of their physical activity seem to some extent to be location specific. These results may inform intervention efforts suggesting that targeting specific sets of psycho-social factors may prove efficient across physical activity locations, gender and age groups. Others, in contrast may prove effective in facilitating location specific physical activity, in which age may come to moderate the efficiency of intervention efforts.

The goal of study 2 was to identify groups that might be important to target in future behavioral interventions. We found that Portuguese population, more specifically the Porto residents, had low levels of physical activity. Age had a negative impact in the amount of MVPA, and was found a decrease in participation in PA with the increase of the age of the youth; these results are in agreement with the literature. An important finding of this study was the fact that Porto youth had even lower levels than young adults, which should be faced has a fact demanding intervention. This is emphasized by the fact that the use of accelerometry in all of our studies gave more confidence to the interpretation of the PA patterns, because current PA guidelines propose that youth fulfill a total of 60 minutes per day of moderate to vigorous PA (Biddle & Fox, 1998), and most of the research on PA guidelines has evolved from studies that used subjective measures to assess PA.

Studies in which included Portuguese students, only 25,4%, between 10 – 16 years-old, participate in 60 minutes or more of MVPA, in 5 or more days per week (Janssen, et al., 2005), and another study also found similar values of MVPA, 17,4% for boys and 12% in girls (Ekelund, et al., 2004). The higher values in the amount of MVPA for boys, are similar with international studies who included Portuguese adolescents in the sample (Ekelund, et al., 2004; Riddoch, et al., 2004) and other international studies (Andersen & van Mechelen, 2005; Trost, et al., 2002).

Another relevant fact brought up by our research, in study 4, was the importance of taking in consideration the effect of season when collecting data on PA and sedentary behaviors. The MVPA accomplishment during a regular school week decreased in the winter by 5.45 hours in boys and 1.1 hour in girls, which shows a more pronounced effect of season in boys compared to girls. This agrees with data using DLW, that reported a reduction of physical activity amount in the winter, as consequence of the fact that the PA differences are dependent on the initial level of activity (summer); the more active the individuals are in the summer, the larger the reduction of activity in the winter; and those who were inactive in the summer, remain inactive in the winter (Plasqui & Westerterp, 2004). The seasonal patterns suggest that physical activity interventions must be modified during different seasons of the year (to specifically increase involvement in winter months). Moreover, this seasonal difference point to the importance to studies of PA behavior state on the methods section the seasonal timing of collecting PA data. Additional research is clearly needed to better understand factors that may explain seasonal differences in activity.

In study 5, the space context was further analyzed by comparing the PA pattern between different countries – Portugal and Spain. Because a single strategy aimed at reducing sedentary behavior is unlikely to be effective across Europe as the target populations and behaviors of focus differ between countries (van Sluijs, et al., 2008). Our findings showed that gender differences in MVPA were more marked in the Spanish adolescents group, and that Spanish Boys recorded higher values than Portuguese boys. The weekend was the period of the week when the differences between the two cities wore more pronounced. Huesca adolescents were significantly more active than Porto adolescents during this period. Given that Porto and Huesca differ in geography, socioeconomic circumstances, and culture, this suggests that PA habits in youth may be determined by environmental factors as much as by biological factors. Although, the detailed assessment of the environment context wasn’t an objective of this study, this study revealed that place of residence was a significant predictor to the MVPA amount. In a review study of environmental correlates of PA in youth variables of the home and school environments were especially associated with youth's PA. Most consistent positive correlates of PA were father's PA, time spent outdoors and school PA-related policies (in children), and support from significant others, mother's education level, family income, and non-vocational school attendance (in adolescents) (Ferreira, et al., 2007). Therefore, monitoring individual level and microenvironment social inequalities in PA, is crucial for evaluating the effects of programs and policies and to provide an insight into whether current efforts should be continued or modified (Lee & Cubbin, 2009).

When studying PA behavior the context where, how and with who it occurs are key variables. School is the most present and relevant context in youth’s life, in a normal school year youth spent approximately 10 months of the 12 in school, which represents 35 weeks, more or less 245 days, and in the Portuguese school schedule context can reach 1960 hours. Therefore, within schools different opportunities for PA occur and the free-time periods are a very relevant one as our study 6 showed. Pereira e Neto (1999) refer that by analyzing several studies about the free-time concept it seems that youth voice and opinion has been neglected, and as a consequence we don't know their perspective. The individual skills and abilities shape his free-time options, but also does the school, family and community by limiting past learning opportunities. The more limited the childhood experiences are, the lower will be the choice skills.

An important contribution of this work, in study 7, was the reinforcing of a PA context often neglected in schools and extra-school (especially in girls) that is sports participation. Boys and girls who participate in sports are more physically active, so it's important to develop programs that children want to participate in and maximize retention (Sirard, et al., 2006). Those who have participated in endurance sports in youth, know how to enhance and maintain one's fitness, with may motivate them to be active in later life as well (Tammelin, 2005). Girls had less participation in sports in both contexts (school and clubs). The higher sports participation by boys (in the school and club settings), is a fairly typical finding and this may be attributable to stronger social reinforcement (McKenzie, et al., 1997; Sallis, et al., 2000b) On the other hand, some girls values of MVPA achieved are an important indication that the context where the PA is realized is pertinent also in this gender. This way, it´s important to refer the relevant role that schools can play in the girls PA patterns (Sarkin, et al., 1997).

Youth present high variability in the MVPA between the days (Trost, et al., 2000), but an interesting result that we could verify was the fact that students who participated in sports, in both contexts (school and club), had a more stable amount of MVPA. Moreover, our results illustrate that the students who participated in club sports also achieved the PA recommendations in the weekend. Thus, by implementing community programs and activities that value their free time, after-school period, and the weekends, such measures could be considered as preventive and promoters of an active lifestyle (Mota & Sallis, 2003).

6.2 Strengths and Limitations

This work demonstrates the rich information that accelerometers provide about youth activity patterns - information that might further our understanding of the relationship between physical activity and healthy lifestyles. By complementing accelerometer data with contextual information, all the physical activity dimensions can be studied and this has been the pursuit of the physical activity researchers.

By using accelerometers over several days, it is possible to determine and characterize individually the PA behavior of different age groups and genders. These characteristics are important since children typically engage in frequent, short bursts of intense activity, rather than continuous activities (Riddoch & Boreham, 1995), while adults tend to engage in sustained activity (Telama & Yang, 2000), then adult-specific measurements may not accurately quantify the activity patterns of children (Pescatello & VanHeest, 2000). Furthermore, the ability of the accelerometer to record is not affect by individual's weight, gender or emotional state while other instruments like heart rate monitors may be (Rowlands, Eston, & Ingledew, 1997), they offer considerable opportunity to provide the type of information that can isolate differences between obese and non-obese groups and also informs individual program designs (Fox & Riddoch, 2000). Because accelerometers are generally more sensitive than self-report measures, they might be also ideal for use with populations who typically engage in very light or very brief activity, such as the elderly (Shephard, 2003).

As demonstrated by this work accelerometers are one of the references to study PA behavior. Although, this instrument also has some limitations that should be taken into consideration:

a) There is no consensus yet on what cut-off points are better to assess the time spent in different PA intensities using the ActiGraph accelerometer, and significant differences between PA intensity cut points have been shown (Mota, et al., 2007). Several cut-points have been published and the considerable variability in these cut-point estimates limits the accuracy of their identification of moderate-intensity physical activity.

b) The ActiGraph was not designed to be worn in the water, and therefore, adolescents had to remove it during water activities (e.g. shower, swimming, water-polo).

c) The ActiGraph model used in our studies was set to only detect vertical accelerations. Thus, activities with important movements in the horizontal axis might be underestimated (e.g. dancing, cycling, skating) (Puyau, et al., 2002).

d) Different epochs have been used in previous studies in youth. Significant differences in vigorous PA using diverse epochs were found in children (Nilsson, Ekelund, Yngve, & Sjostrom, 2002b). Thus, epochs < 60 seconds are recommended for these ages (Ward, et al., 2005).

e) There is variability in the readings of an accelerometer among people doing a certain level of physical activity, for example 6 METS (Ekelund, Aman, & Westerterp, 2003). This variability likely reflects differences across people in numbers of steps to go a certain distance (stride length), positioning of the accelerometer, and technical issues associated with accelerometers.

f) The quality of accelerometer data is affected significantly by the degree of participant compliance, such as remembering to wear the device. This could pose a problem especially to older adults facing memory loss or lacking the visual and manual dexterity to properly attach the device in the recommended position (Wilcox, Tudor-Locke, & Ainsworth, 2001).

g) Finally, depending on the ActiGraph model used (CSA, MTI, ActiGraph 7164, ActiGraph 71256, ActiGraph GT1M) differences might exist between measurements which would limit comparison (Rothney, et al., 2008).

Accelerometers are ideally suited for measuring ambulatory activity. Although Welk (Welk, 2005) points out that there are many challenges to converting counts to meaningful outcome data. Factors that contribute to some noise in accelerometry studies is the quantity of different instruments available, and within studies using the same device, exists different protocols for the data processing, as stated in the following Table A:

Table A - Most common criteria's to process the accelerometer data.

Studies	Inclusion Criteria
(Tudor-Locke et al., 2002)	Exclusion of days with less than 720 minutes of valid data. Exclusion of subjects with less than 3 days.
(Matthews et al., 2002)	Exclusion of days with less than 720 minutes of valid data (75% of waking time, considering 8 hours of sleep). Exclusion of subjects with less than 7 days.
(Treuth et al., 2003)	Exclusion of 20 minutes of zero consecutive counts. Data divided in 4 periods of the day. Considered days with at least 70% of the day (1000 minutes). Considered participants with at least 3 days of valid data.
(Cradock et al., 2004)	Exclusion of 20 minutes of zero consecutive counts. Analyzed data in between 7 and 22 hours on the week days and in between 9 and 22 hours on weekend days.
(Riddoch et al., 2004 Ekelund et al., 2004b)	Exclusion of 10 minutes of zero consecutive counts. Exclusion of days with less than 600 minutes of valid data. Exclusion of subjects with less than 3 days, with at least one weekend day.
(Anderson et al., 2005)	Exclusion of 20 minutes of zero consecutive counts. Exclusion of days with less than 600 minutes of valid data. Exclusion of subjects with less than 4 days.
(Van et al., 2005)	Exclusion of 180 ou mais minutos de zero count's contínuos num único dia. Analyzed data in between 8 and 21 hours on the week days and in between 12 and 21 hours on weekend days.
(Masse et al., 2005)	Exclusion of 20 minutes of zero consecutive counts.

Despite all these limitations they are intrinsic to all the studies using accelerometers. A recent meeting in the United States (July, 2009), brought together experts in the physical activity assessment field to develop guidelines for future research. and the result will be in form of a supplement in the Medicine & Science in Sports & Exercise, similar what happen in the supplement of November 2005 in the same journal.

6.3 Future Directions

The intervention in PA by their one may not be sufficient, but this intervention is accepted as the one that could diminish the influence of all the modifiable health risk factors. Epidemiological studies demonstrate that regular PA is considered as “medicine” of proven efficacy in different types of morbidity, and in some circumstances, is strongly related to longevity (Fulton, McGuire, Caspersen, & Dietz, 2001). This way it becomes essential to transmit the concept that health is built, trainable and can be systematically increased. This trainability character means that the health training effects aren’t stable at long range (Bento, 1991). We don’t need to wait for the disease occurrence, we must anticipate it and the best way is through education. Behavior can be changed and new ones can take place, the maintenance of the beneficial changes is the biggest challenge. Although, short behavior changes are encouraging, it’s necessary efforts at long range in order to effectively promote health benefits (Pellmar, Brandt, & Baird, 2002).

Corbin (Corbin, 2002) gives relevance to the development in our student’s autonomy skills: in their definition of health goals; their management and commitment to a PA program; and in the choice for a healthy lifestyle. Our contemporary lifestyle has been marked by relevant technology developments that have negative effects on youth health status, for example the increase in screen time (computer games). Knowing that it’s difficult to avoid this hypo-active lifestyles changes, but not impossible (for example the Amish population), the challenge must be in using those changes to promote physical activity behavior. Therefore, the uses of recent PA monitors can and have to play an important role to motivate youth to a more PA lifestyle.

New instruments that were mainly used in research studies have been trying to overcome some limitations in the PA assessment such as the lack of tools to measure objectively the contexts and the spaces were PA happens (for example Global Positioning System and Geographic Information System). Moreover, the improvement and advances in data processing alongside with the use of internet interfaces to provide feedbacks have been key factors to the use of such PA instruments. These developments are starting a very positive trend to the increase of the use of these instruments by the general population.

Future research directions should lead to further knowledge of PA levels and contexts in free-living conditions along the lifespan. Accelerometers combined with qualitative information should be used to assess PA in cross-sectional and longitudinal studies to provide important information to future national public health policies. Books, thesis, reports destination nearly all the times is a bookshelf. Our aim is to challenge Portuguese researches and authorities to take the next step forward to use the evident information and take action in the promotion of physical activity.

References

Actigraph (2008a). Actilife Users Manual, 2008, from http://www.theactigraph.com/index.php?option=com_docman&task=cat_view&gid=53&Itemid=64

Actigraph (2008b). GT1M Specifications, 2008, from http://theactigraph.com/index.php?option=com_docman&task=cat_view&gid=70&Itemid=64

Aires, L., Silva, P., Santos, R., Santos, P., Ribeiro, J. C., & Mota, J. (2008). Association of physical fitness and body mass index in youth. *Minerva Pediatr, 60*(4), 397-405.

Allender, S., Cowburn, G., & Foster, C. (2006). Understanding participation in sport and physical activity among children and adults: a review of qualitative studies. *Health Educ Res, 21*(6), 826-835.

Allender, S., Foster, C., & Boxer, A. (2008). Occupational and nonoccupational physical activity and the social determinants of physical activity: results from the Health Survey for England. *J Phys Act Health, 5*(1), 104-116.

Allender, S., Hutchinson, L., & Foster, C. (2008). Life-change events and participation in physical activity: a systematic review. *Health Promot Int, 23*(2), 160-172.

Andersen, L. B., Harro, M., Sardinha, L. B., Froberg, K., Ekelund, U., Brage, S., et al. (2006). Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet, 368*(9532), 299-304.

Andersen, L. B., & van Mechelen, W. (2005). Are children of today less active than before and is their health in danger? What can we do? *Scand J Med Sci Sports, 15*(5), 268-270.

Armstrong, N., Balding, J., Gentle, P., & Kirby, B. (1990). Patterns of physical activity among 11 to 16 year old British children. *BMJ, 301*(6745), 203-205.

Armstrong, N., & Welsman, J. R. (2006). The physical activity patterns of European youth with reference to methods of assessment. *Sports Med, 36*(12), 1067-1086.

Atkin, A., Gorely, T., Biddle, S., Marshall, S. J., & Cameron, N. (2008). Critical Hours: Physical Activity and Sedentary Behavior of Adolescents After School. *Pediatric Exercise Science, 20*, 446-456.

Bandura, A. (2004). Health promotion by social cognitive means. *Health Educ Behav, 31*(2), 143-164.

Baranowski, T., Thompson, W. O., DuRant, R. H., Baranowski, J., & Puhl, J. (1993). Observations on physical activity in physical locations: age, gender, ethnicity, and month effects. *Res Q Exerc Sport, 64*(2), 127-133.

Barr-Anderson, D. J., Young, D. R., Sallis, J. F., Neumark-Sztainer, D. R., Gittelsohn, J., Webber, L., et al. (2007). Structured physical activity and psychosocial correlates in middle-school girls. *Prev Med, 44*(5), 404-409.

Bassett, D. R., Jr., Ainsworth, B. E., Swartz, A. M., Strath, S. J., O'Brien, W. L., & King, G. A. (2000). Validity of four motion sensors in measuring moderate intensity physical activity. *Med Sci Sports Exerc, 32*(9 Suppl), S471-480.

Beets, M. W., Vogel, R., Forlaw, L., Pitetti, K. H., & Cardinal, B. J. (2006). Social support and youth physical activity: the role of provider and type. *Am J Health Behav, 30*(3), 278-289.

Bento, J. (1991). *Desporto, Saúde, Vida. Em defesa do desporto*. Lisboa: Livros Horizonte.

Bento, J. (2006). *Pedagogia do desporto: definições, conceitos e orientações.* . Rio Janeiro: Guanabara-Koogan.

Bergman, P., Grjibovski, A. M., Hagstromer, M., Bauman, A., & Sjostrom, M. (2008). Adherence to physical activity recommendations and the influence of socio-demographic correlates - a population-based cross-sectional study. *BMC Public Health, 8*, 367.

Berkey, C. S., Rockett, H. R., Gillman, M. W., & Colditz, G. A. (2003). One-year changes in activity and in inactivity among 10- to 15-year-old boys and girls: relationship to change in body mass index. *Pediatrics, 111*(4 Pt 1), 836-843.

Biddle, S. J., & Fox, K. R. (1998). Motivation for physical activity and weight management. *Int J Obes Relat Metab Disord, 22 Suppl 2*, S39-47.

Bouchard, C., Shephard, R., & Stephens, T. (1994). The consensus Statement. In C. B. R. S. T. Stephens (Ed.), *Exercise, Fitness and Health: A Consensus of Current Knowledge*. Champaign. IL: Human Kinetics.

Brage, S., Wedderkopp, N., Franks, P. W., Andersen, L. B., & Froberg, K. (2003). Reexamination of validity and reliability of the CSA monitor in walking and running. *Med Sci Sports Exerc, 35*(8), 1447-1454.

Brage, S. r., Brage, N., Wedderkopp, N., & Froberg, K. (2003). Reliability and Validity of the Computer Science and Applications Accelerometer in a Mechanical Setting. *Measurement in Physical Education & Exercise Science, 7*(2), 101-119.

Cale, L., & Harris, J. (2001). Exercise recommendations for young people: an update. *Health Education, 101*(3), 126 - 138.

Cavill, N., Biddle, S., & Sallis, J. (2001). Health Enhancing Physical Activity for Young People: Statement of the United Kingdom Expert Consensus Conference. *Pediatric Exercise Science, 13*(1), 12-25.

Chan, C. B., Ryan, D. A., & Tudor-Locke, C. (2006). Relationship between objective measures of physical activity and weather: a longitudinal study. *Int J Behav Nutr Phys Act, 3*, 21.

Chen, K. Y., & Bassett, D. R., Jr. (2005). The technology of accelerometry-based activity monitors: current and future. *Med Sci Sports Exerc, 37*(11 Suppl), S490-500.

Cole, T. J. (2002). A chart to link child centiles of body mass index, weight and height. *Eur J Clin Nutr, 56*(12), 1194-1199.

Corbin, C. B. (2002). Physical activity for everyone: what every physical educator should know about promoting lifelong physical activity. *J.Teach.Phys.Educ., 21*, 128-144.

Corder, K., Brage, S., Ramachandran, A., Snehalatha, C., Wareham, N., & Ekelund, U. (2007). Comparison of two Actigraph models for assessing free-living physical activity in Indian adolescents. *J Sports Sci, 25*(14), 1607-1611.

Corder, K., Ekelund, U., Steele, R. M., Wareham, N. J., & Brage, S. (2008). Assessment of physical activity in youth. *J Appl Physiol, 105*(3), 977-987.

Crouter, S. E., Churilla, J. R., & Bassett, D. R., Jr. (2006). Estimating energy expenditure using accelerometers. *Eur J Appl Physiol, 98*(6), 601-612.

Crouter, S. E., Schneider, P. L., Karabulut, M., & Bassett, D. R., Jr. (2003). Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc, 35*(8), 1455-1460.

Dale, D., Corbin, C. B., & Dale, K. S. (2000). Restricting opportunities to be active during school time: do children compensate by increasing physical activity levels after school? *Res Q Exerc Sport, 71*(3), 240-248.

Davis, M. G., & Fox, K. R. (2007). Physical activity patterns assessed by accelerometry in older people. *Eur J Appl Physiol, 100*(5), 581-589.

Davy, B. M., Harrell, K., Stewart, J., & King, D. S. (2004). Body weight status, dietary habits, and physical activity levels of middle school-aged children in rural Mississippi. *South Med J, 97*(6), 571-577.

De Bourdeaudhuij, I., Philippaerts, R., Crombez, G., Matton, L., Wijndaele, K., Balduck, A. L., et al. (2005). Stages of change for physical activity in a community sample of adolescents. *Health Educ Res, 20*(3), 357-366.

Dietz, W. H., Jr., & Gortmaker, S. L. (1984). Factors within the physical environment associated with childhood obesity. *Am J Clin Nutr, 39*(4), 619-624.

Dinger, M. K., & Behrens, T. K. (2006). Accelerometer-determined physical activity of free-living college students. *Medicine and Science in Sports and Exercise, 38*(4), 774-779.

Dishman, R. K., Motl, R. W., Saunders, R., Felton, G., Ward, D. S., Dowda, M., et al. (2004). Self-efficacy partially mediates the effect of a school-based physical-activity intervention among adolescent girls. *Prev Med, 38*(5), 628-636.

Dishman, R. K., Motl, R. W., Saunders, R., Felton, G., Ward, D. S., Dowda, M., et al. (2005). Enjoyment mediates effects of a school-based physical-activity intervention. *Med Sci Sports Exerc, 37*(3), 478-487.

Dishman, R. K., Saunders, R. P., Motl, R. W., Dowda, M., & Pate, R. R. (2008). Self-Efficacy Moderates the Relation Between Declines in Physical Activity and Perceived Social Support in High School Girls. *J Pediatr*

Psychol.

do Carmo, I., Dos Santos, O., Camolas, J., Vieira, J., Carreira, M., Medina, L., et al. (2008). Overweight and obesity in Portugal: national prevalence in 2003-2005. *Obes Rev, 9*(1), 11-19.

Dowda, M., Dishman, R. K., Pfeiffer, K. A., & Pate, R. R. (2007). Family support for physical activity in girls from 8th to 12th grade in South Carolina. *Prev Med, 44*(2), 153-159.

Duncan, S. C., Duncan, T. E., & Strycker, L. A. (2005). Sources and types of social support in youth physical activity. *Health Psychol, 24*(1), 3-10.

Duncan, S. C., Duncan, T. E., Strycker, L. A., & Chaumeton, N. R. (2007). A cohort-sequential latent growth model of physical activity from ages 12 to 17 years. *Ann Behav Med, 33*(1), 80-89.

Ekelund, U., Aman, J., & Westerterp, K. (2003). Is the ArteACC index a valid indicator of free-living physical activity in adolescents? *Obes Res, 11*(6), 793-801.

Ekelund, U., Sardinha, L. B., Anderssen, S. A., Harro, M., Franks, P. W., Brage, S., et al. (2004). Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). *Am J Clin Nutr, 80*(3), 584-590.

Esliger, Copeland, J. L., Barnes, J. D., & Tremblay, M. S. (2005a). Standardizing and Optimizing the Use of Accelerometer Data for Free-Living Physical Activity Monitoring. *JPAH, 2*(3), 366-383.

Esliger, Probert, A., Gorber, S. C., Bryan, S., Laviolette, M., & Tremblay, M. S. (2007). Validity of the Actical accelerometer step-count function. *Med Sci Sports Exerc, 39*(7), 1200-1204.

Esliger, & Tremblay, M. S. (2006a). Technical reliability assessment of three accelerometer models in a mechanical setup. *Med Sci Sports Exerc, 38*(12), 2173-2181.

Esliger, & Tremblay, M. S. (2007). Physical activity and inactivity profiling: the next generation. *Can J Public Health, 98 Suppl 2*, S195-207.

Esliger, D. W., Copeland, J. L., Barnes, J. D., & Tremblay, M. S. (2005b).

Standardizing and Optimizing the Use of Accelerometer Data for Free-Living Physical Activity Monitoring. *JPAH, 2*(3), 366-383.

Esliger, D. W., & Tremblay, M. S. (2006b). Technical reliability assessment of three accelerometer models in a mechanical setup. *Med Sci Sports Exerc, 38*(12), 2173-2181.

Fairclough, S. J., Butcher, Z. H., & Stratton, G. (2007). Whole-day and segmented-day physical activity variability of northwest England school children. *Prev Med, 44*(5), 421-425.

Felton, G. M., Dowda, M., Ward, D. S., Dishman, R. K., Trost, S. G., Saunders, R., et al. (2002). Differences in physical activity between black and white girls living in rural and urban areas. *J Sch Health, 72*(6), 250-255.

Ferreira, I., van der Horst, K., Wendel-Vos, W., Kremers, S., van Lenthe, F. J., & Brug, J. (2007). Environmental correlates of physical activity in youth - a review and update. *Obes Rev, 8*(2), 129-154.

Ford, M. A., Bass, M. A., Turner, L. W., Mauromoustakos, A., & Graves, B. S. (2004). Past and recent physical activity and bone mineral density in college-aged women. *J Strength Cond Res, 18*(3), 405-409.

Fox, K. R., & Riddoch, C. (2000). Charting the physical activity patterns of contemporary children and adolescents. *Proc Nutr Soc, 59*(4), 497-504.

Freedson, P., Pober, D., & Janz, K. F. (2005). Calibration of accelerometer output for children. *Med Sci Sports Exerc, 37*(11 Suppl), S523-530.

Fulton, J. E., McGuire, M. T., Caspersen, C. J., & Dietz, W. H. (2001). Interventions for weight loss and weight gain prevention among youth: current issues. *Sports Med, 31*(3), 153-165.

Gilson, N. D., Cooke, C. B., & Mahoney, C. A. (2001). A comparison of adolescent moderate-to-vigorous physical activity participation in relation to a sustained or accumulated criterion. *Health Educ. Res., 16*(3), 335-341.

Gordon-Larsen, P., McMurray, R. G., & Popkin, B. M. (2000). Determinants of adolescent physical activity and inactivity patterns. *Pediatrics, 105*(6), E83.

Gordon-Larsen, P., Nelson, M. C., & Popkin, B. M. (2004). Longitudinal physical activity and sedentary behavior trends: adolescence to adulthood. *Am J Prev Med, 27*(4), 277-283.

Griffin, P. S. (1985). Teaching in an Urban, Multiracial Physical Education Program: The Power of Context *QUEST, 37*(2), 154–165.

Hagstromer, M., Oja, P., & Sjostrom, M. (2007). Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc, 39*(9), 1502-1508.

Haskell, W. L. (2001). What to look for in assessing responsiveness to exercise in a health context. *Med Sci Sports Exerc, 33*(6 Suppl), S454-458; discussion S493-454.

Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., et al. (2008). Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care, 31*(4), 661-666.

Hill, J. O., & Melanson, E. L. (1999). Overview of the determinants of overweight and obesity: current evidence and research issues. *Med Sci Sports Exerc, 31*(11 Suppl), S515-521.

Hohepa, M., Scragg, R., Schofield, G., Kolt, G. S., & Schaaf, D. (2008). Self-reported physical activity levels during a segmented school day in a large multiethnic sample of high school students. *J Sci Med Sport*.

Irwin, J. D., He, M., Sangster Bouck, L. M., Tucker, P., & Pollett, G. L. (2005). Preschoolers' physical activity behaviours: Parent's perspectives. *Canadian Journal of Public Health, 96*(4), 299-303.

Jago, R., Anderson, C. B., Baranowski, T., & Watson, K. (2005). Adolescent patterns of physical activity differences by gender, day, and time of day. *Am J Prev Med, 28*(5), 447-452.

Jago, R., & Baranowski, T. (2004). Non-curricular approaches for increasing physical activity in youth: a review. *Prev Med, 39*(1), 157-163.

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

Janz, K. F. (1994). Validation of the CSA accelerometer for assessing children's physical activity. *Med Sci Sports Exerc, 26*(3), 369-375.

Kahn, J. A., Huang, B., Gillman, M. W., Field, A. E., Austin, S. B., Colditz, G. A., et al. (2008). Patterns and determinants of physical activity in U.S. adolescents. *J Adolesc Health, 42*(4), 369-377.

Kendzierski, D., & DeCarlo, K. (1991). Physical activity enjoyment scale: two validation

studies. *J Sport Exerc Psychol, 13*(1), 50-64.

Klasson-Heggebo, L., & Anderssen, S. A. (2003). Gender and age differences in relation to the recommendations of physical activity among Norwegian children and youth. *Scand J Med Sci Sports, 13*(5), 293-298.

Le Masurier, G. C., & Tudor-Locke, C. (2003). Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med Sci Sports Exerc, 35*(5), 867-871.

Lee, R. E., & Cubbin, C. (2009). Striding toward social justice: the ecologic milieu of physical activity. *Exerc Sport Sci Rev, 37*(1), 10-17.

Leenders, N., Sherman, W. M., & Nagaraja, H. N. (2000). Comparisons of four methods of estimating physical activity in adult women. *Med Sci Sports Exerc, 32*(7), 1320-1326.

Livingstone, M. B., Robson, P. J., Wallace, J. M., & McKinley, M. C. (2003). How active are we? Levels of routine physical activity in children and adults. *Proc Nutr Soc, 62*(3), 681-701.

Lobstein, T., & Frelut, M. L. (2003). Prevalence of overweight among children in Europe. *Obes Rev, 4*(4), 195-200.

Lopes, V. P., Vasques, C. M., Maia, J. A., & Ferreira, J. C. (2007). Habitual physical activity levels in childhood and adolescence assessed with accelerometry. *J Sports Med Phys Fitness, 47*(2), 217-222.

Loucaides, C. A., Chedzoy, S. M., & Bennett, N. (2004). Differences in physical activity levels between urban and rural school children in Cyprus. *Health Educ Res, 19*(2), 138-147.

Lubans, D. R., Foster, C., & Biddle, S. J. (2008). A review of mediators of behavior in interventions to promote physical activity among children and adolescents. *Prev Med, 47*(5), 463-470.

Malina, R. M. (1996). Tracking of physical activity and physical fitness across the lifespan. *Res Q Exerc Sport, 67*(3 Suppl), S48-57.

Malina, R. M., & Little, B. B. (2008). Physical activity: the present in the context of the past. *Am J Hum Biol, 20*(4), 373-391.

Marsh, H. W., Balla, J. R., & McDonald, R. P. (1988). Goodness of fit indexes in confirmatory factor analysis: The effect of sample size. *Psychol Bull.*(103), 391-410.

Martínez-Gómez, D., Welk, G., Calle, M., Marcos, A., & Veiga, O. (2009). Preliminary evidence of physical activity levels measured by accelerometer in Spanish adolescents. The AFINOS Study. *Nutr Hosp, In press*.

Matthews, C. E., Ainsworth, B. E., Thompson, R. W., & Bassett, D. R., Jr. (2002). Sources of variance in daily physical activity levels as measured by an accelerometer. *Med Sci Sports Exerc, 34*(8), 1376-1381.

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., et al. (2008). Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am J Epidemiol, 167*(7), 875-881.

Mattocks, C., Ness, A., Leary, S., Tilling, K., Blair, S. N., Shield, J., et al. (2008). Use of accelerometers in a large field-based study of children: protocols, design issues, and effects on precision. *J Phys Act Health, 5 Suppl 1*, S98-111.

McClain, J. J., Sisson, S. B., & Tudor-Locke, C. (2007). Actigraph accelerometer interinstrument reliability during free-living in adults. *Med Sci Sports Exerc, 39*(9), 1509-1514.

McKenzie, T., & Lounsbery, M. (2009). School Physical Education: The Pill Not Taken. *American Journal of Lifestyle Medicine, online first*.

McKenzie, T. L., Marshall, S. J., Sallis, J. F., & Conway, T. L. (2000). Leisure-time physical activity in school environments: an observational study using SOPLAY. *Prev Med, 30*(1), 70-77.

McKenzie, T. L., Sallis, J. F., Elder, J. P., Berry, C. C., Hoy, P. L., Nader, P. R., et al. (1997). Physical activity levels and prompts in young children at recess: a two-year study of a bi-ethnic sample. *Res Q Exerc Sport, 68*(3), 195-202.

McMurray, R. G., Harrell, J. S., Bangdiwala, S. I., & Deng, S. (1999). Cardiovascular disease risk factors and obesity of rural and urban elementary school children. *J Rural Health, 15*(4), 365-374.

Merrill, R. M., Shields, E. C., White, G. L., Jr., & Druce, D. (2005). Climate conditions and physical activity in the United States. *Am J Health Behav, 29*(4), 371-381.

Metcalf, B. S., Curnow, J. S., Evans, C., Voss, L. D., & Wilkin, T. J. (2002). Technical reliability of the CSA activity monitor: The EarlyBird Study. *Med Sci Sports Exerc, 34*(9), 1533-1537.

Metzger, J. S., Catellier, D. J., Evenson, K. R., Treuth, M. S., Rosamond, W. D., & Siega-Riz, A. M. (2008). Patterns of objectively measured physical activity in the United States. *Med Sci Sports Exerc, 40*(4), 630-638.

Moeller, N. C., Korsholm, L., Kristensen, P. L., Andersen, L. B., Wedderkopp, N., & Froberg, K. (2008). Unit-specific calibration of Actigraph accelerometers in a mechanical setup - is it worth the effort? The effect on random output variation caused by technical inter-instrument variability in the laboratory and in the field. *BMC Med Res Methodol, 8*, 19.

Mota, J., & Sallis, J. F. (2003). *A actividade física e saúde. Factores de influência da actividade física nas crianças e nos adolescentes*. Porto: Campo das Letras.

Mota, J., Santos, P., Guerra, S., Ribeiro, J. C., & Duarte, J. A. (2003). Patterns of daily physical activity during school days in children and adolescents. *Am J Hum Biol, 15*(4), 547-553.

Mota, J., Silva, P., Aires, L., Santos, M. P., Oliveira, J., & Ribeiro, J. C. (2008). Differences in school-day patterns of daily physical activity in girls according to level of physical activity. *J Phys Act Health, 5 Suppl 1*, S90-97.

Mota, J., Silva, P., Santos, M. P., Ribeiro, J. C., Oliveira, J., & Duarte, J. A. (2005). Physical activity and school recess time: differences between the sexes and the relationship between children's playground physical activity and habitual physical activity. *J Sports Sci, 23*(3), 269-275.

Mota, J., Valente, M., Aires, L., Silva, P., Santos, M., & Ribeiro, J. (2007). Accelerometer cut-points and youth physical activity prevalence. *European Physical Education Review, 13*(3), 287-299.

Motl, R. W., Dishman, R. K., Saunders, R., Dowda, M., Felton, G., & Pate, R. R. (2001). Measuring enjoyment of physical activity in adolescent girls. *Am J Prev Med, 21*(2), 110-117.

Motl, R. W., Dishman, R. K., Trost, S. G., Saunders, R. P., Dowda, M., Felton, G., et al. (2000). Factorial validity and invariance of questionnaires measuring social-cognitive determinants of physical activity among adolescent girls. *Prev Med, 31*(5), 584-594.

Murphy, S. L. (2009). Review of physical activity measurement using accelerometers in older adults: considerations for research design and conduct. *Prev Med, 48*(2), 108-114.

Nader, P. R., Bradley, R. H., Houts, R. M., McRitchie, S. L., & O'Brien, M. (2008). Moderate-to-vigorous physical activity from ages 9 to 15 years. *JAMA, 300*(3), 295-305.

Nichols, J. F., Morgan, C. G., Chabot, L. E., Sallis, J. F., & Calfas, K. J. (2000). Assessment of Physical Activity with the Computer Science and Applications, Inc., Accelerometer: Laboratory Versus Field Validation. *Research Quarterly for Exercise and Sport, 71(1)*, 36-43.

Nilsson, A., Anderssen, S. A., Andersen, L. B., Froberg, K., Riddoch, C., Sardinha, L. B., et al. (2008). Between- and within-day variability in physical activity and inactivity in 9- and 15-year-old European children. *Scand J Med Sci Sports*.

Nilsson, A., Ekelund, U., Yngve, A., & Sjostrom, M. (2002a). Assessing physical activity among children with accelerometers using different time sampling intervals and placements. *Pediatr Exerc Sci, 14*(1), 87-96.

Nilsson, A., Ekelund, U., Yngve, A., & Sjostrom, M. (2002b). Assessing physical activity among children with accelerometers using different time sampling intervals and placements. *Ped.Exerc.Science, 14*(1), 87-96.

O'Malley, P. M., Johnston, L. D., Delva, J., Bachman, J. G., & Schulenberg, J. E. (2007). Variation in obesity among American secondary school students by school and school characteristics. *Am J Prev Med, 33*(4 Suppl), S187-194.

Ommundsen, Y., Klasson-Heggebo, L., & Anderssen, S. A. (2006). Psycho-social and environmental correlates of location-specific physical activity among 9- and 15- year-old Norwegian boys and girls: the European Youth Heart Study. *Int J Behav Nutr Phys Act, 3*, 32.

Owen, N., Leslie, E., Salmon, J., & Fotheringham, M. J. (2000). Environmental determinants of physical activity and sedentary behavior. *Exerc Sport Sci Rev, 28*(4), 153-158.

Padez, C., Fernandes, T., Mourao, I., Moreira, P., & Rosado, V. (2004). Prevalence of overweight and obesity in 7-9-year-old Portuguese children: trends in body mass index from 1970-2002. *Am J Hum Biol, 16*(6), 670-678.

Pate, R. R., O'Neill, J. R., & Lobelo, F. (2008). The evolving definition of "sedentary". *Exerc Sport Sci Rev, 36*(4), 173-178.

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

Pate, R. R., Trost, S. G., Felton, G. M., Ward, D. S., Dowda, M., & Saunders, R. (1997). Correlates of physical activity behavior in rural youth. *Res Q Exerc Sport, 68*(3), 241-248.

Patterson, S. M., Krantz, D. S., Montgomery, L. C., Deuster, P. A., Hedges, S. M., & Nebel, L. E. (1993). Automated physical activity monitoring: validation and comparison with physiological and self-report measures. *Psychophysiology, 30*(3), 296-305.

Paxton, R. J., Estabrooks, P. A., & Dzewaltowski, D. (2004). Attraction to physical activity mediates the relationship between perceived competence and physical activity in youth. *Res Q Exerc Sport, 75*(1), 107-111.

Pellmar, T. C., Brandt, E. N., Jr., & Baird, M. A. (2002). Health and behavior: the interplay of biological, behavioral, and social influences: summary of an Institute of Medicine report. *Am J Health Promot, 16*(4), 206-219.

Penpraze, V., Reilly, J., MacLean, C., Montgomery, C., Kelly, K., Paton, J., et al. (2006). Monitoring of Physical Activity in Young Children: How Much Is Enough? *Pediatr Exerc Sci, 18*(4).

Pereira, B. O., & Neto, C. (1999). *As Crianças, o Lazer e os Tempos Livres*. Braga: Universidade do Minho.

Pescatello, L. S., & VanHeest, J. L. (2000). Physical activity mediates a healthier body weight in the presence of obesity. *Br J Sports Med, 34*(2), 86-93.

Plasqui, G., & Westerterp, K. R. (2004). Seasonal variation in total energy expenditure and physical activity in Dutch young adults. *Obes Res, 12*(4), 688-694.

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

Pollock, M. L., Gaesser, G. A., Butcher, J. D., Després, J.-P., Dishman, R. K., Franklin, B. A., et al. (1998). ACSM Position Stand on The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in Adults. *Med Sci Sports Exerc, 30*(6), 975-991.

Public.Health.Canada (2002). *Family guide to physical activity for youth 10-14 years of age*.

Puyau, M. R., Adolph, A. L., Vohra, F. A., & Butte, N. F. (2002). Validation and calibration of physical activity monitors in children. *Obes Res, 10*(3), 150-157.

Raitakari, O. T., Porkka, K. V., Taimela, S., Telama, R., Rasanen, L., & Viikari, J. S. (1994). Effects of persistent physical activity and inactivity on coronary risk factors in children and young adults. The Cardiovascular Risk in Young Finns Study. *Am J Epidemiol, 140*(3), 195-205.

Reilly, J. J., Penpraze, V., Hislop, J., Davies, G., Grant, S., & Paton, J. Y.

(2008). Objective measurement of physical activity and sedentary behaviour: review with new data. *Arch Dis Child, 93*(7), 614-619.

Ribeiro, J., Guerra, S., Pinto, A., Oliveira, J., Duarte, J., & Mota, J. (2003). Overweight and obesity in children and adolescents: relationship with blood pressure, and physical activity. *Ann Hum Biol, 30*(2), 203-213.

Riddoch, C. J., Bo Andersen, L., Wedderkopp, N., Harro, M., Klasson-Heggebo, L., Sardinha, L. B., et al. (2004). Physical activity levels and patterns of 9- and 15-yr-old European children. *Med Sci Sports Exerc, 36*(1), 86-92.

Riddoch, C. J., & Boreham, C. A. (1995). The health-related physical activity of children. *Sports Med, 19*(2), 86-102.

Riddoch, C. J., Mattocks, C., Deere, K., Saunders, J., Kirkby, J., Tilling, K., et al. (2007). Objective measurement of levels and patterns of physical activity. *Arch Dis Child, 92*(11), 963-969.

Ridgers, N. D., Stratton, G., & Fairclough, S. J. (2005). Assessing physical activity during recess using accelerometry. *Prev Med, 41*(1), 102-107.

Rothney, M. P., Apker, G. A., Song, Y., & Chen, K. Y. (2008). Comparing the performance of three generations of ActiGraph accelerometers. *J Appl Physiol, 105*(4), 1091-1097.

Rowlands, A. V., Eston, R. G., & Ingledew, D. K. (1997). Measurement of physical activity in children with particular reference to the use of heart rate and pedometry. *Sports Med, 24*(4), 258-272.

Rowlands, A. V., Stone, M. R., & Eston, R. G. (2007). Influence of speed and step frequency during walking and running on motion sensor output. *Med Sci Sports Exerc, 39*(4), 716-727.

Roxane, R., Welk, G., Calabros, M., Nicklay, B., & Hensley, L. (2008). Rural–Urban Differences in Physical Activity, Physical Fitness, and Overweight Prevalence of Children. *The Journal of Rural Health, 24*(1), 49-54.

Sallis, Bauman, A., & Pratt, M. (1998a). Environmental and policy interventions to promote physical activity. *Am J Prev Med, 15*(4), 379-397.

Sallis, Kraft, K., & Linton, L. S. (2002a). How the environment shapes physical activity: a transdisciplinary research agenda. *Am J Prev Med, 22*(3), 208.

Sallis, & Owen, N. (1999a). *Physical Activity & Behavioral Medicine* (Vol. 3):

Sage Publications.

Sallis, Prochaska, J. J., & Taylor, W. C. (2000a). A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc, 32*(5), 963-975.

Sallis, J., & Owen, N. (1999b). *Physical Activity & Behavioral Medicine* (Vol. 3): Sage Publications.

Sallis, J. F. (1991). Self-report measures of children's physical activity. *J Sch Health, 61*(5), 215-219.

Sallis, J. F., Bauman, A., & Pratt, M. (1998b). Environmental and policy interventions to promote physical activity. *Am J Prev Med, 15*(4), 379-397.

Sallis, J. F., & Hovell, M. F. (1990). Determinants of exercise behavior. *Exerc Sport Sci Rev, 18*, 307-330.

Sallis, J. F., Kraft, K., & Linton, L. S. (2002b). How the environment shapes physical activity: a transdisciplinary research agenda. *Am J Prev Med, 22*(3), 208.

Sallis, J. F., Nader, P. R., Broyles, S. L., Berry, C. C., Elder, J. P., McKenzie, T. L., et al. (1993). Correlates of physical activity at home in Mexican-American and Anglo-American preschool children. *Health Psychol, 12*(5), 390-398.

Sallis, J. F., Prochaska, J. J., & Taylor, W. C. (2000b). A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc, 32*(5), 963-975.

Sallis, J. F., Prochaska, J. J., Taylor, W. C., Hill, J. O., & Geraci, J. C. (1999). Correlates of physical activity in a national sample of girls and boys in grades 4 through 12. *Health Psychol, 18*(4), 410-415.

Sallis, J. F., Taylor, W. C., Dowda, M., Freedson, P., & Pate, R. (2002). Correlates of Vigorous Physical Activity for Children in Grades 1 Through 12: Comparing Parent-Reported and Objectively Measured Physical Activity. *Pediatric Exercise Science, 14*, 30-44.

Salvy, S. J., Bowker, J. W., Roemmich, J. N., Romero, N., Kieffer, E., Paluch, R., et al. (2008). Peer influence on children's physical activity: an experience sampling study. *J Pediatr Psychol, 33*(1), 39-49.

Salvy, S. J., Roemmich, J. N., Bowker, J. C., Romero, N. D., Stadler, P. J., & Epstein, L. H. (2009). Effect of peers and friends on youth physical activity and motivation to be physically active. *J Pediatr Psychol, 34*(2), 217-225.

Santos, M. P., Matos, M., & Mota, J. (2005). Seasonal Variations in Portuguese Adolescents' Organized and Nonorganized Physical Activities. *Pediatric Exercise Science, 17*(4), 390-398.

Santos, P., Guerra, S., Ribeiro, J. C., Duarte, J. A., & Mota, J. (2003). Age and gender-related physical activity. A descriptive study in children using accelerometry. *J Sports Med Phys Fitness, 43*(1), 85-89.

Sardinha, L. B., Andersen, L. B., Anderssen, S. A., Quiterio, A. L., Ornelas, R., Froberg, K., et al. (2008). Objectively measured time spent sedentary is associated with insulin resistance independent of overall and central body fat in 9- to 10-year-old Portuguese children. *Diabetes Care, 31*(3), 569-575.

Sarkin, J. A., McKenzie, T. L., & Sallis, J. F. (1997). Gender differences in Physical activity during fifth-grade physical education and recess period. *J.Teaching Phys.Educ., 17:*, 99-106.

Seabra, A. F., Mendonca, D. M., Thomis, M. A., Malina, R. M., & Maia, J. A. (2007). Sports participation among Portuguese youth 10 to 18 years. *J Phys Act Health, 4*(4), 370-380.

Shephard, R. J. (2003). Limits to the measurement of habitual physical activity by questionnaires. *Br J Sports Med, 37*(3), 197-206; discussion 206.

Simons-Morton, B. G., Taylor, W. C., Snider, S. A., Huang, I. W., & Fulton, J. E. (1994). Observed levels of elementary and middle school children's physical activity during physical education classes. *Prev Med, 23*(4), 437-441.

Sirard, J. R., Melanson, E. L., Li, L., & Freedson, P. S. (2000). Field evaluation of the Computer Science and Applications, Inc. physical activity monitor. *Med Sci Sports Exerc, 32*(3), 695-700.

Sirard, J. R., Pfeiffer, K. A., & Pate, R. R. (2006). Motivational factors associated with sports program participation in middle school students. *J Adolesc Health, 38*(6), 696-703.

Skrupskelis, A. (2000). *An historical trend to eliminate recess*: American Press.

Sleap, M., & Warburton, P. (1996). Physical activity levels of 5-11-year-old children in England: cumulative evidence from three direct observation studies. *Int J Sports Med, 17*(4), 248-253.

Storti, K. L., Pettee, K. K., Brach, J. S., Talkowski, J. B., Richardson, C. R., & Kriska, A. M. (2008). Gait speed and step-count monitor accuracy in community-dwelling older adults. *Med Sci Sports Exerc, 40*(1), 59-64.

Stratton, G., & Leonard, J. (2002). The effects of playground markings on the energy expenditure of 5-7-year-old school children. *Pediatric Exercise Science, 14*(2), 170-180.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., et al. (2005). Evidence based physical activity for school-age youth. *J Pediatr, 146*(6), 732-737.

Tammelin, T. (2005). A review of longitudinal studies on youth predictors of adulthood physical activity. *Int J Adolesc Med Health, 17*(1), 3-12.

Teixeira e Seabra, A. F., Maia, J. A., Mendonca, D. M., Thomis, M., Caspersen, C. J., & Fulton, J. E. (2008). Age and sex differences in physical activity of Portuguese adolescents. *Med Sci Sports Exerc, 40*(1), 65-70.

Telama, R., & Yang, X. (2000). Decline of physical activity from youth to young adulthood in Finland. *Med Sci Sports Exerc, 32*(9), 1617-1622.

Telama, R., Yang, X., Viikari, J., Valimaki, I., Wanne, O., & Raitakari, O. (2005). Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med, 28*(3), 267-273.

Toschke, J. A., von Kries, R., Rosenfeld, E., & Toschke, A. M. (2007). Reliability of physical activity measures from accelerometry among preschoolers in free-living conditions. *Clin Nutr, 26*(4), 416-420.

Troiano, R. P. (2005). A timely meeting: objective measurement of physical activity. *Med Sci Sports Exerc, 37*(11 Suppl), S487-489.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc, 40*(1), 181-188.

Trost, S. G., McIver, K. L., & Pate, R. R. (2005). Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc, 37*(11 Suppl), S531-543.

Trost, S. G., Pate, R. R., Dowda, M., Saunders, R., Ward, D. S., & Felton, G. (1996). Gender differences in physical activity and determinants of physical activity in rural fifth grade children. *J Sch Health, 66*(4), 145-150.

Trost, S. G., Pate, R. R., Freedson, P. S., Sallis, J. F., & Taylor, W. C. (2000). Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc, 32*(2), 426-431.

Trost, S. G., Pate, R. R., Sallis, J. F., Freedson, P. S., Taylor, W. C., Dowda, M., et al. (2002). Age and gender differences in objectively measured physical activity in youth. *Med Sci Sports Exerc, 34*(2), 350-355.

Trost, S. G., Rosenkranz, R. R., & Dzewaltowski, D. (2008). Physical activity levels among children attending after-school programs. *Med Sci Sports Exerc, 40*(4), 622-629.

Trost, S. G., Ward, D. S., Moorehead, S. M., Watson, P. D., Riner, W., & Burke, J. R. (1998). Validity of the computer science and applications (CSA) activity monitor in children. *Med Sci Sports Exerc, 30*(4), 629-633.

Trost, S. G., Way, R., & Okely, A. D. (2006). Predictive validity of three ActiGraph energy expenditure equations for children. *Med Sci Sports Exerc, 38*(2), 380-387.

Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *Int J Behav Nutr Phys Act, 5*, 10.

Tucker, P., & Gilliland, J. (2007). The effect of season and weather on physical activity: a systematic review. *Public Health, 121*(12), 909-922.

Tucker, P., Irwin, J. D., Sangster Bouck, L. M., He, M., & Pollett, G. (2006). Preventing paediatric obesity; recommendations from a community-based qualitative investigation. *Obesity Reviews, 7*(3), 251-260.

Tudor-Locke, C., Ainsworth, B. E., Adair, L. S., & Popkin, B. M. (2003). Physical activity in Filipino youth: the Cebu Longitudinal Health and Nutrition

Survey. *International Journal of Obesity, 27*(2), 181-190.

Tudor-Locke, C., Lee, S. M., Morgan, C. F., Beighle, A., & Pangrazi, R. P. (2006). Children's pedometer-determined physical activity during the segmented school day. *Med Sci Sports Exerc, 38*(10), 1732-1738.

Van Der Horst, K., Paw, M. J., Twisk, J. W., & Van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Med Sci Sports Exerc, 39*(8), 1241-1250.

van Sluijs, E. M., Page, A., Ommundsen, Y., & Griffin, S. J. (2008). Behavioural and social correlates of sedentary time in young people. *Br J Sports Med*.

Vaz de Almeida, M. D., Graca, P., Afonso, C., D'Amicis, A., Lappalainen, R., & Damkjaer, S. (1999). Physical activity levels and body weight in a nationally representative sample in the European Union. *Public Health Nutr, 2*(1A), 105-113.

Vilhjalmsson, R., & Kristjansdottir, G. (2003). Gender differences in physical activity in older children and adolescents: the central role of organized sport. *Soc Sci Med, 56*(2), 363-374.

Voorhees, C. C., Murray, D., Welk, G., Birnbaum, A., Ribisl, K. M., Johnson, C. C., et al. (2005). The role of peer social network factors and physical activity in adolescent girls. *Am J Health Behav, 29*(2), 183-190.

Ward, D. S., Dowda, M., Trost, S. G., Felton, G. M., Dishman, R. K., & Pate, R. R. (2006). Physical activity correlates in adolescent girls who differ by weight status. *Obesity (Silver Spring), 14*(1), 97-105.

Ward, D. S., Evenson, K. R., Vaughn, A., Rodgers, A. B., & Troiano, R. P. (2005). Accelerometer use in physical activity: best practices and research recommendations. *Med Sci Sports Exerc, 37*(11 Suppl), S582-588.

Ward, D. S., Saunders, R., & Pate, R. (2007). *Physical Activity Interventions in Children and Adolescents*. Champaign, IL: Human Kinetics.

Waring, M., Warburton, P., & Coy, M. (2007). Observation of children's physical activity levels in primary school: Is the school an ideal setting for meeting government activity targets? *European Physical Education Review,* *13*(1), 25-40.

Waxman, A. (2004). WHO global strategy on diet, physical activity and health. *Food Nutr Bull, 25*(3), 292-302.

Weiss, M. R., Smith, A. L., & Theeboom, M. (1996). "That's What Friends Are For": Children's and Teenagers' Perceptions of Peer Relationships in the Sport Domain. *Journal of Sport & Exercise Psychology, 18*(4), 347-379.

Welk, G. (1999). The youth physical activity promotion model: A conceptual bridge between theory and practice. *Quest*(51), 5-23.

Welk, G., Babke, M., & Brustad, R. (1998). Casual links among determinants of physical activity in children: A structural equation model. *Med Sci Sports Exerc, 30*(5), S182.

Welk, G., Wood, K., & Morss, G. (2003). Parental influences on physical activity in children: An exploration of potential mechanisms. *Pediatric Exercise Science*(15), 19-33.

Welk, G. J. (2005). Principles of design and analyses for the calibration of accelerometry-based activity monitors. *Med Sci Sports Exerc, 37*(11 Suppl), S501-511.

Welk, G. J., Blair, S. N., Wood, K., Jones, S., & Thompson, R. W. (2000). A comparative evaluation of three accelerometry-based physical activity monitors. *Med Sci Sports Exerc, 32*(9 Suppl), S489-497.

Welk, G. J., Schaben, J. A., & Morrow, J. R., Jr. (2004). Reliability of accelerometry-based activity monitors: a generalizability study. *Med Sci Sports Exerc, 36*(9), 1637-1645.

Welk, G. J., Wickel, E., Peterson, M., Heitzler, C. D., Fulton, J. E., & Potter, L. D. (2007). Reliability and validity of questions on the youth media campaign longitudinal survey. *Med Sci Sports Exerc, 39*(4), 612-621.

Westerterp, K. R. (1999). Physical activity assessment with accelerometers. *Int J Obes Relat Metab Disord, 23 Suppl 3*, S45-49.

Wickel, E. E., & Eisenmann, J. C. (2007). Contribution of youth sport to total daily physical activity among 6- to 12-yr-old boys. *Med Sci Sports Exerc, 39*(9), 1493-1500.

Wilcox, S., Tudor-Locke, C., & Ainsworth, B. E. (2001). Physical activity patterns, assessment and motivation in older adults. In R. Shephard (Ed.), *Gender, physical activity, and aging* (pp. 13-39). Boca Raton: CRC Press.

Williams, H. G., Pfeiffer, K. A., O'Neill, J. R., Dowda, M., McIver, K. L., Brown, W. H., et al. (2008). Motor skill performance and physical activity in preschool children. *Obesity (Silver Spring), 16*(6), 1421-1426.

Yang, X., Telama, R., Hirvensalo, M., Mattsson, N., Viikari, J. S., & Raitakari, O. T. (2008). The longitudinal effects of physical activity history on metabolic syndrome. *Med Sci Sports Exerc, 40*(8), 1424-1431.

Yang, X., Telama, R., Leino, M., & Viikari, J. (1999). Factors explaining the physical activity of young adults: the importance of early socialization. *Scand J Med Sci Sports, 9*(2), 120-127.

Zask, A., van Beurden, E., Barnett, L., Brooks, L. O., & Dietrich, U. C. (2001). Active school playgrounds-myth or reality? Results of the "move it groove it" project. *Prev Med, 33*(5), 402-408.

List of Publications

- Mota,J.; **Silva, P.**; Santos M.P.; Ribeiro, JC.; Oliveira, J.; Duarte, J.A. (2005): Physical activity and school recess time. Gender differences and relationship between children's playground physical activity and habitual physical activity. *Journal of Sport Sciences*, 23(3):269-275.
- Aires, L., Santos, R., **Silva, P.**, Santos, P., Oliveira, J., Ribeiro, J. C., Mota, J. (2007). Daily differences in patterns of physical activity among overweight/obese children engaged in a physical activity program. *American Journal of Human Biology*, 19(6), 871-877.
- Mota J, Valente M, Aires L, **Silva P**, Santos MP, Ribeiro JC. (2007). Accelerometer cut-points and youth physical activity prevalence. *European Physical Education Review* 13(3):287–299.
- Mota J, **Silva P**, Aires L, Santos MP, Oliveira J, Ribeiro JC. (2008). Differences in school-day patterns of daily physical activity in girls according to level of physical activity. *Journal of physical activity & health* 5 Suppl 1:S90-7.
- Aires, L., **Silva, P.**, Santos, R., Santos, P., Ribeiro, J. C., & Mota, J. (2008). Association of physical fitness and body mass index in youth. *Minerva Pediatrica, 60*(4), 397-405.
- Santos, R.; **Silva, P.**; Santos, P.; Ribeiro, J.C.; Mota, J. (2008). Physical activity and perceived environmental attributes in a sample of Portuguese adults: results from the Azorean Physical Activity and Health study. *Preventive Medicine*. 47(1):83-8.
- J. C. Ribeiro, M. Sousa, C. Sa, P. Santos, **P. Silva**, L. Aires, J. Mota (2009). Patterns of Moderate to Vigorous Physical Activities and daily Compliance with Guidelines for Youth. *The Open Sports Sciences Journal* (2) pp.71-75.
- Aires, L., **Silva, P.**, Silva, G; Santos, P., Ribeiro, J. C., & Mota, J. Intensity of Physical Activity, Cardiorespiratory Fitness and Body Mass Index in Youth. *Journal of physical activity & health (in Press)*