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SEDENTARY BEHAVIOUR, PHYSICAL ACTIVITY AND ENERGY EXPENDITURE IN ADOLESCENTS:

Assessment and correlates

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RESUMO

Objectivos: A presente tese de doutoramento teve como principais objectivos: a) analisar a associação entre o dispêndio energético diário avaliado por um diário de actividade física de 3 dias (Bouchard et al., 1983) e um acelerómetro uniaxial; b) estudar a influência da maturação somática na magnitude das diferenças associadas ao género, tanto no comportamento sedentário como na actividade física habitual; c) determinar o impacto do desporto organizado no dispêndio energético diário e na sua porção de intensidade moderada a vigorosa; d) examinar os factores correlatos à aptidão cardio-respiratória em adolescentes de proveniência rural e urbana; e) estudar a associação entre o estatuto nutricional e o sedentarismo, a actividade física e a aptidão cardio-repiratória, bem como comparar estes construtos em adolescentes de diferente proveniência geográfica. **Material e métodos:** A amostra foi constituída por 403 adolescentes com idades compreendidas entre os 13 e os 16 anos. A aptidão cardio-respiratória foi avaliada com o recurso ao *Progressive Aerobic Cardiovascular Endurance Run test* (PACER) e a actividade física habitual foi determinada com o recurso a um diário de 3 dias e à acelerometria uniaxial. O sedentarismo foi igualmente estudado recorrendo não apenas ao instrumento de auto-resposta, na determinação do consumo televisivo e uso das demais tecnologias de ecrã, como pela sua avaliação objectiva com o recurso à acelerometria. Os gráficos de *Bland-Altman* foram utilizados para analisar a concordância entre as duas metodologias de avaliação da actividade física. Diferentes técnicas de estatística inferencial foram utilizadas para testar os objectivos supra-mencionados. **Resultados:** A magnitude da associação entre o dispêndio energético diário providenciado pelos dois instrumentos de avaliação da actividade física foi moderada. O diário de 3 dias tende a subestimar a determinação do dispêndio energético diário nos adolescentes estudados, particularmente entre os mais velhos e com excesso de peso. Os adolescentes do sexo masculino de proveniência urbana despenderam menos tempo em actividades de natureza sedentária comparativamente aos seus pares de proveniência rural. Os rapazes urbanos foram mais activos durante o fim-de-semana do que os rapazes rurais, enquanto que as raparigas urbanas revelaram ser significativamente menos activas do que as raparigas de proveniência rural nos dias de semana e no total dos cinco dias avaliados. Contudo, tanto os rapazes como as raparigas de contextos rurais obtiveram melhores resultados na prova de aptidão cardio-respiratória. Os resultados da presente pesquisa mostraram igualmente que o desporto organizado tem um impacto de cerca de 11%-13% e de cerca de 35-42%, respectivamente, no dispêndio energético diário e na sua porção moderada a vigorosa dos adolescentes masculinos. Adicionalmente, tanto o estatuto nutricional como a actividade física de intensidade moderada a vigorosa revelaram ser importantes preditores da aptidão cardio-respiratória entre os adolescentes de ambos os sexos; as habilitações literárias da mãe foram um importante preditor da capacidade aeróbia apenas entre as raparigas. **Conclusões:** A complexidade da avaliação do dispêndio energético e actividade física apela para desenhos de pesquisa multi-método. O desporto organizado aparenta ser uma componente importante do dispêndio energético diário dos adolescentes masculinos, e que poderá ter um papel relevante na promoção de estilos de vida activos entre a população juvenil. Existe uma associação importante entre a aptidão cardiorespiratória e a adiposidade tanto nos adolescentes de proveniência rural como urbana. Adicionalmente, o sedentarismo parece ser influenciado pelo contexto geográfico onde os adolescentes residem.

Palavras-chave: *Sedentarismo, accelerometria, diário de 3 dias, avaliação da actividade física, aptidão aeróbia, contexto geográfico*

ABSTRACT

Purpose: *The present PhD thesis aimed: a) to examine the relationship between activity energy expenditure (AEE) based on the 3-day diary and accelerometry; b) to investigate the contribution of somatic maturation to sex differences in objective assessment of sedentary behaviour (SB) and physical activity (PA); c) to determine the contribution of organized sport to estimated daily energy expenditure (DEE) and to moderate-to-vigorous energy expenditure (MVEE); d) to examine the correlates of cardiorespiratory fitness (CRF) among adolescents from different areas of residence (i.e. rural and urban communities); e) to compare PA, SB, screen time and CRF in rural and urban adolescents and to analyse the relationships between those previously mentioned variables and weight status.* ***Methods:*** *The sample comprised 403 adolescents aged 13-16 years. CRF was assessed by the Progressive Aerobic Cardiovascular Endurance Run test. A GT1M uniaxial accelerometer and the 3-day diary were used to obtain PA data. Screen time and objective sedentary behaviour were also assessed. Bland-Altman procedures were used to analyse concordance between the self-reported and objective estimates of AEE. Different statistical procedures were conducted to analyze associations among aforementioned variables.* ***Results:*** *The relationship between AEE assessed by both instruments was no more than moderate. Furthermore, the 3-day diary markedly underestimated AEE in overweight/obese and older adolescents. Male adolescents from urban communities spent less time in sedentary activities than rural male youth. Urban males were also more active than their rural peers at the weekend, whereas urban females were significantly less active than rural females on week days and across total assessed days. Rural boys and girls demonstrated higher levels of CRF than urban youth. Male adolescents spent 11%-13% of DEE in organized sports which corresponded to 35%-42% of the MVEE. Moderate-to-vigorous physical activity and weight status were important predictors of CRF in Portuguese adolescents 13-16 years of age. Maternal education was an additional predictor among female adolescents.* ***Conclusions:*** *The assessment of AEE is complex and may require a combination of methods. In addition, organized sport appears to be a relevant component of daily AEE to promote healthy lifestyles among adolescents. Observations in Portuguese youth indicate an important association between BMI and CRF in both rural and urban settings. Place of residence also has an important impact on time spent sedentary of adolescents.*

Keywords: *sedentary behaviour, accelerometry, 3-day diary, physical activity assessment, aerobic fitness, geographic context*

TABLE OF CONTENTS

Page Number

Acknowledgements.. III
Resumo V
Abstract.. VII
List of tables.. XIII
List of figures XV
List of abbreviations...XVI

CHAPTER I – INTRODUCTION.. 1

1.1. Obesity concern and active lifestyles promotion 3
1.2. Sedentary behaviour exposure in youth 4
1.3. Level of physical activity in youth.. 5
1.4. Sport participation during adolescence... 6
1.5. Physical activity assessment and methodological issues.................................. 7
1.6. Physical fitness, physical activity, sedentary behaviour and BMI in different geographic contexts 8
1.7. Objectives of the thesis... 9
References... 11

CHAPTER II – LITERATURE REVIEW 15

2.1. Physical activity and related concepts 18
2.2. Measurement of physical activity in youth 20
2.2.1. Subjective measures of physical activity... 21
Direct observation instruments 21
Self-report instruments 21
2.2.2. Objective measures of physical activity 27
Heart rate monitoring 27
Pedometry 28
Accelerometry 28
Combined methods.. 31
2.3. Recommended levels of physical activity and sedentary behaviour for youth 32

2.4. Habitual physical activity in youth 34
Age-related variation of physical activity in youth 34
Sex-related variation of physical activity in youth 35
Compliance with physical activity guidelines: prevalence in children and adolescents........ 38
2.5. Sport participation during adolescence 39
Age and sex differences in organized sport 40
Contribution of organized sport to active lifestyles 41
2.6. Sedentary behaviour in young people 42
Screen time........ 42
Screen time and health markers........ 44
Time spent sedentary objectively measured 44
2.7. Biological maturation as a confounding factor 46
2.8. Physical activity and socio-economic status........ 47
2.9. Physical fitness, physical activity, and BMI in youth 49
Cardiorespiratory fitness level concern 50
Cardiorespiratory fitness, physical activity, and BMI 50
2.10. Geographic context, physical activity, cardiorespiratory fitness, sedentary behaviour and BMI in young people........ 52
Definition of rural vs. urban........ 52
Rural-urban contrast on physical activity, cardiorespiratory fitness, sedentary behaviour, and obesity in young people 54
References........ 59

CHAPTER III – METHODS 71
3.1. Study design and sampling........ 73
3.2. Anthropometry 74
3.3. Physical activity 75
3.4. Time spent sedentary 76
3.5. Cardiorespiratory fitness........ 77
3.6. Area of residence........ 77
3.7. Parental education........ 77
3.8. Data analysis 78
3.9. Reliability of measures........ 79
3.10. Statistical procedures 79
References........ 80

CHAPTER IV – Concurrent validation of estimated activity energy expenditure using a 3-day diary and accelerometry in adolescents 83

Abstract 86
Introduction 87
Methods 88
Results 90
Discussion 93
Conclusion 95
References 96

CHAPTER V – Agreement in activity energy expenditure assessed by accelerometer and self-report measures in adolescents: variation by sex, age and weight status 99

Abstract 102
Introduction 103
Methods 104
Results 107
Discussion 117
Conclusion 120
References 120

CHAPTER VI – Confounding effect of biologic maturation on sex differences in physical activity and sedentary behavior in Portuguese adolescents aged 13 to 16 years 125

Abstract 128
Introduction 129
Methods 131
Results 132
Discussion 137
Conclusion 139
References 140

CHAPTER VII – Urban-rural contrasts in cardio-respiratory fitness, physical activity, and sedentary behaviour in Portuguese adolescents 143

Abstract 146
Introduction 147
Methods 148
Results 151
Discussion 155
Conclusion 157
References 158

CHAPTER VIII – Physical activity and energy expenditure in adolescent male sport participants and non-participants 13-16 years 161

Abstract 164
Introduction 165
Methods 165
Results 168
Discussion 172
Conclusion 176
References 176

CHAPTER IX – Correlates of aerobic fitness in urban and rural Portuguese adolescents 179

Abstract 182
Introduction 183
Methods 184
Results 187
Discussion 189
Conclusion 192
References 193

CHAPTER X – Relationships between obesity, cardiorespiratory fitness, sedentary behaviour and objective intensity levels of physical activity in rural and urban Portuguese adolescents 197

Abstract 200
Introduction 201
Methods 203
Results 206
Discussion 209
Conclusion 212
References 212

CHAPTER XI – Main findings and recommendations for future research 215

11.1. Main findings and conclusions 217

11.2. Limitations and recommendations for future research 225

References 228

Appendix A - Example of the 3-day diary.

Appendix B - Questionnaire (familial data).

Appendix C - Information letter (parent and adolescents), parental consent form, and child assent form.

Appendix D - Dissemination of the project to date with the support of *Fundação para a Ciência e a Tecnologia* [SRFH/BD/38988/2007].

LIST OF TABLES

Table 2.1. Studies using the 3-day diary protocol proposed by Bouchard et al. (1983) in youth 24

Table 2.2. Physical activity measured by accelerometer of males and females youth in recent studies 37

Table 2.3. Overview of the rural-urban contrast on physical activity, aerobic fitness and obesity in youth 55

Table 3.1. Basic characteristics of each study 74

Table 3.2. Statistical procedures used in each study 80

Table 4.1. Descriptive statistics for the total sample 91

Table 4.2. Correlations between energy expenditure (kcal/min) estimated from accelerometry and the 3-day diary by day and the three days combined and partial correlations controlling for body mass for males and females separately 92

Table 5.1. Means and standard deviations for males and females and results of ANOVA testing the effect of sex on chronological age, body size, daily activity energy expenditure and accelerometer counts/min 108

Table 5.2. Descriptive statistics by sex and age-group and results of ANOVA testing the effect of age on chronological age, body size, daily activity energy expenditure and accelerometer counts/min in males and females separately 109

Table 5.3. Descriptive statistics for normal-weight and overweight/obese adolescents and results of ANOVA testing the effect of weight status on chronological age, body size, daily activity energy expenditure and accelerometer counts/min in males and females separately 110

Table 5.4. Partial correlations (controlling for body mass) between estimates of activity energy expenditure by the diary and accelerometry, bias ant its limits of agreement between two AEE estimates by sex, age group, and weight status 111

Table 5.5. The log transformed (ln) measurement means and differences, the "ratio limits of agreement", together with the correlation between the absolute differences and the mean (log transformed) by sex, age group, and weight status 116

Table 6.1. Means (standard deviations) for chronological age, percentage of predicted mature height, body size, and time spent in sedentary behaviors and in physical activities by age group and sex 133

Table 6.2. Adjusted means (and standard errors) and results of analyses of covariance (controlling for maturation) to test the effect of sex on time spent in sedentary behaviors and physical activities of different intensities... 134

Table 6.3. Significant predictors of sedentary behavior and physical activities of different intensities by sex 136

Table 7.1. Descriptive statistics and results of ANCOVAs (chronological age as co-variable) testing the effect of age group on body size, sedentary behaviour, physical activity and aerobic endurance for males and females separately... 153

Table 7.2. Descriptive statistics and results of ANOVAs testing the effect of degree of urbanization on body size, sedentary behaviour, physical activity and aerobic endurance for males and females separately............... 154

Table 8.1. Results of the independent sample *t*-tests for differences between adolescents who participate in organized youth sports and who do not, for males aged 13-14 years.. 170

Table 8.2. Results of the independent sample *t*-tests for differences between adolescents who participate in organized youth sports and who do not, for males aged 15-16 years.. 171

Table 9.1. Demographic characteristics of unfit and fit adolescents 13-16 years of age... 188

Table 9.2. The association between CRF and area of residence in adolescents......... 189

Table 10.1. Descriptive characteristics of adolescents by area of residence................ 206

Table 10.2. Bivariate correlations between CRF, BMI, and physical activity in its different intensity portions by geographic contexts..................................... 207

Table 10.3. Logistic regression analysis for variables predicting overweight/ obesity adjusted for chronological age and gender 208

LIST OF FIGURES

Figure 4.1. Bland–Altman plot of differences between estimated activity energy expenditure (AEE, kcal/min) from the 3-day diary and accelerometry protocols (accelerometry minus diary) relative to mean estimated AEE based on the two protocols (kcal/min). The solid line represents the mean difference and the dashed lines are the upper and lower limits of agreement (1.96 standard deviations).. 93

Figure 5.1. Bland-Altman plot for AEE of adolescent males showing the difference between the diary and accelerometer estimates plotted against the mean of the two estimates.. 112

Figure 5.2. Bland-Altman plot for AEE of female adolescents showing the difference between the diary and accelerometer estimates plotted against the mean of the two estimates.. 113

Figure 5.3. Bland-Altman plot for AEE of adolescents 13-14 years of age showing the difference between the diary and accelerometer estimated plotted against the mean of the two estimates 113

Figure 5.4. Bland-Altman plot for AEE of adolescents 15-16 years of age showing the difference between the diary and accelerometer estimates plotted against the mean of the two estimates 114

Figure 5.5. Bland-Altman plot for AEE of normal weight adolescents showing the difference between the diary and accelerometer estimates plotted against the mean of the estimates.. 114

Figure 5.6. Bland-Altman plot for AEE of overweight/obese adolescents showing the difference between the diary and accelerometer estimates plotted against the mean of the two estimates.. 115

LIST OF ABBREVIATIONS

AEE – Activity Energy Expenditure;

BMI – Body Mass Index;

CDC – Centers for Disease Control and Prevention;

CHD – Cardiovascular Disease;

CRF – Cardiorespiratory Fitness;

CSA – Computer Science Application Accelerometer;

DEE – Daily Energy Expenditure;

EE – Energy Expenditure;

EYHS – European Youth Heart Study;

HELENA – *Healthy Lifestyle in Europe by Nutrition in Adolescence;*

Km – Kilometre;

LPA – Light Physical Activity;

m – metre;

min – minute;

MALS – *Midlands Adolescent Lifestyle Study;*

MET – Metabolic Equivalent;

MPA – Moderate Physical Activity;

mph – miles per hour;

MTI – Manufacturing Technology Inc.;

MVPA – Moderate-to-Vigorous Physical Activity;

MVEE – Moderate-to-Vigorous Energy Expenditure;

NHANES - *National Health and Nutrition Examination Survey*;

NSTT – Non-Screen Sedentary Time;

NW – Normalweight;

OB – Obese;

OW – Overweight;

PA – Physical Activity;

PACER – *Progressive Aerobic Cardiovascular Endurance Run test;*

PAEE – Physical Activity Energy Expenditure;

SB – Sedentary Behaviour;

SES – Socio-economic Status;

SPSS – Statistical Package for the Social Sciences;

SP – Sport Participation;

TDEE – Total Daily Energy Expenditure;

VPA – Vigorous Physical Activity;

VVPA – Very Vigorous Physical Activity;

CHAPTER I

Introduction

1. INTRODUCTION

1.1. Obesity concern and active lifestyles promotion

The World Health Organization (WHO) has estimated that every year 1.9 million people die as a result of physical inactivity while 2.6 million people die as the result of being overweight or obese (WHO 2005). The ubiquitous nature of the worldwide increases in, and excessive prevalences of, physical inactivity and obesity has gathered international attention. Even among adolescents, the prevalence of overweight and obesity has substantially increased in many countries during the past two decades. Recent studies estimate that more than 30% of children and adolescents in North America, 21%-25% in Australia and, approximately 20% in Europe were overweight or obese (Lobstein 2010; Padez et al. 2004). Further research indicates that about 18% of European school children (25 EU member states) were overweight, with an annual rise in prevalence between 0.55% and 1.65%, i.e. more than 400,000 new cases every year (Lobstein 2010; Padez et al. 2004; Sardinha et al. 2010). Effectiveness of interventions or prevention strategies strongly depends upon an understanding of the causes and correlates of obesity.

The aetiology of obesity is complex and believed to be linked with environment factors that contribute to the increasing adoption of sedentary behaviours. However, it is not totally clear whether the global increase in weight problems in children is the result of excessive energy intake or decreasing energy expenditure. There is evidence that at least part of the problem may lie with increasing energy consumption, but it is also important to examine the other side of the energy equation. Therefore, in light of the increasing prevalence of obesity among the world's children and youth, the need to promote regular involvement in physical activity and aerobic fitness in young people has been recognized by numerous public and private health agencies targeting public health (Strong et al. 2005). In fact, children and adolescents who are overweight or obese are at a increased risk of several co-morbidities including type 2 diabetes, endocrine and orthopaedic disorders, and reduced health-related quality of life (Cumming and Riddoch 2008). Consequently, active behaviours play an important role in weight control and prevention of unhealthy weight gain; evidence indicates an inverse relationship between physical activity and adiposity and aerobic fitness (Malina et al. 2004).

1.2. Sedentary behaviour exposure in youth

Contemporary lifestyles have been blamed for the epidemic of “diseases of Western civilization”, since young children and adolescents are seen as particularly vulnerable to the influence of electronic media. From the point of view of clinical and educational intervention design, screen time assessment is an attractive target for several reasons. On one hand, increased screen time is known to be associated with excessive adiposity in young people (Eisenmann and Malina 2002; Ekelund et al. 2006; Hume et al. 2010; Mark and Janssen 2008; Tremblay et al. 2010) and, therefore, reducing that sedentary behaviour may help address the issue of youth overweight and obesity. On the other hand, TV viewing and computer use are relatively easy to assess among children and adolescents. Data from the WHO revealed that 70% of 13-year-old boys and 69% of girls watched TV 2 or more hours per day, while these were 69% and 67% among 15-year-old boys and girls, respectively (WHO 2005). Complementary research revealed that children and adolescents who watched television less than 1 hour, 1-2 hours, 2-3 hours and more than 3 hours daily had a prevalence of obesity of 10.9%, 11.8%, 13.2% and 15.1%, respectively (Ma et al. 2002).

However, TV viewing and computer use are not the only form of sedentary behaviour in adolescents who also spend substantial amounts of time sitting in school classes, riding in cars, eating, socialising, reading and studying. This non-screen sedentary time has been relatively understudied (Biddle et al. 2009). Recently, Olds and colleagues (Olds et al. 2010) described the magnitude and composition of screen sedentary time and non-screen sedentary time (NSST) in Australian adolescents. These youth spent a mean of 345 minutes per day in NSST, which constituted 60% of total sedentary time. School activities contributed 42% of NSST, socialising 19%, self-care (mainly eating) 16%, and passive transport 15%. In addition, results from the *Healthy Lifestyle in Europe by Nutrition in Adolescence Study* (Ruiz et al. 2011) show adolescents spent most of the registered time in sedentary behaviours (9 hours/day, or 71% of the registered time), and boys were less sedentary than girls. Furthermore, sedentary time was higher in older adolescent boys and girls and it was lower in adolescent boys and girls from Central-Northern Europe (2.5% and 2.9%, respectively) in comparison to their North of Europe counterparts.

Sedentary behaviours track at moderate levels from childhood or adolescence. Data from a recent review suggest that sedentary behaviours may form the foundation for such behaviours in the future and some may track slightly better than physical activity (Biddle et al. 2010). It should be noted, however, that the interaction of social, geographic and educational factors play an important role on leisure activity choices, and it has been responsible of perpetuating specific stereotypes among children and adolescents (Ramirez et al. 2011). In addition, technological changes have also led to an increase of opportunities to undertake convenient and attractive sedentary behaviours as part of a contemporary lifestyle.

1.3. Level of physical activity in youth

Moreover, the decline in physical activity from late childhood through adolescence, a period of physical, physiological and psychological transition, is well documented in both sexes. Although the adolescent decline in physical activity is evident in both sexes, several studies indicate that males are, on average, more physically active and more likely to engage in exercise than females of the same chronological age (Malina et al. 2004). Sex differences in physical activity are reasonably consistent across cultures and are independent of research design (cross-sectional or longitudinal) and methods of assessing physical activity (self-report, accelerometry). Two examples suffice to illustrate the magnitude of the sex difference. Among 15 year-old youth in the *European Youth Heart Study*, boys spent 36% more time in daily moderate physical activity than girls (Riddoch et al. 2004). Similarly, in a representative sample of American youth 12-15 years, boys were more likely to engage in moderate-to-vigorous physical activity (MVPA) than girls [boys: 41 minutes/day (non-hispanic white), 54 minutes/day (non-hispanic black), 51 minutes/day (Mexican-American); girls: 22 minutes/day (non-hispanic white), 26 minutes/day (non-hispanic black), 27 minutes/day (Mexican-American)] (Troiano et al. 2008).

Although sex differences in physical activity are well documented, the potential confounding effects of sex differences in biological maturity status on estimates of physical activity have not received much attention. Most studies have compared boys and girls of the same chronological age without considering sex differences in biological age which could contribute to sex differences in activity (Baxter-Jones et al. 2005). It is thus not unreasonable to assume that sex differences in biological maturation may contribute to sex-differences in physical activity, especially during adolescent years.

Given the variation in the timing of the growth spurt and sexual maturation, one may expect that sex differences in physical activity would be attenuated when maturation is controlled for in statistical analyses. This was indeed noted in surveys of physical activity based on questionnaires among Canadian (Thompson et al. 2003) and British adolescents (Cumming et al. 2008) and based on objective assessment of physical activity in Canadian youth 8-13 years (Sherar et al. 2007).

A recent review paper, performed by Sherar and colleagues (Sherar et al. 2010), revealed that the influence of biological maturity on the decline process of physical activity during adolescent years has been largely overlooked. Moreover, results from the available research are generally inconsistent among studies, and associations, when noted, are generally low. In general, data are limited by small sample sizes, lack of consideration of interacting and/or mediating influences, and quality of assessments of maturity and physical activity.

1.4. Sport participation during adolescence

Sport has high social valence and is a primary context for physical activity for the majority of youth. Furthermore, youth sports have been more recently invoked as a potentially important means to combat the worldwide epidemic of childhood overweight and obesity through the provision of regular physical activity (Malina 2009). Moreover, the number of youth competing in sports at national and international levels continues to increase in several countries around the world. Approximately 40 million of U.S. youth participated in organized sport in 2008 (National Council of Youth Sports 2010). This number approximates about 76% of the kindergarten through grade 12 (high school) enrolments in the U.S. In Australia, almost two-thirds of youth aged 5–14 years participate in organised sports outside of school hours (Hardy et al. 2010). Corresponding estimates for other countries vary due in part to differences in estimation strategies and to differences in program structure, accessibility and cost. Nevertheless, reasonably regular participation in sport is characteristic of youth in many European countries (Adelino et al. 2005; Seabra et al. 2007a; Telama and Yang 2000).

Given the seemingly central role of organized sport in the lives of youth, a question of relevance is the habitual physical activity of youth sport participants and non-participants. Evidence based on three day diary records in boys and girls aged 12-14 years (Katzmarzyk and Malina 1998), accelerometry in 119 boys aged 6-12 years (Wickel and Eisenmann 2007), questionnaires in U.S. boys and girls 11-12 years (Trost et al. 1997) and also in Finnish twins aged 16-18 years (Aarnio et al. 2002a; Aarnio et al. 2002b) indicate higher levels of physical activity in sport participants compared to non-participants.

In Portugal, participants who engaged in organized physical activity reported more moderate-intensity, and particularly in team activities, whereas adolescents in non-organized physical activities reported more low-intensity, and participation in individual activities (Santos et al. 2004). Complementary results based on the national representative study of Portuguese adolescent performed by Seabra and colleagues (Seabra et al. 2007b) revealing that high intensity sports were more prevalent among males, while sports of mid-level intensity were more prevalent among females.

1.5. Physical activity assessment and methodological issues

Physical activity is particularly complex to assess in children and adolescents, mainly by its sporadic nature, making it more difficult to draw conclusions about the impact of regular involvement in physical activity upon current and future health status. Furthermore, it is also generally assumed that no single measurement technique accurately reflects all dimensions of physical activity (Armstrong and Welsman 2006; Trost 2001; Welk 2002). Objective measures of physical activity (i.e., heart rate monitors, accelerometers, pedometers) provide reliable and valid information, while subjective protocols (i.e., questionnaires, diaries) provide less accurate alternatives but are more suitable for large samples (Eston et al. 1998; Montoye 1996; Welk 2002) and to assess the context where physical activity occurs.

Adequate and comprehensive physical activity assessment techniques are needed to evaluate relationships between physical activity and indicators of health status, fitness and behaviour (Rush et al. 2008; Schutz et al. 2001; Trost 2001; Wickel et al. 2006). Moreover, methods of physical activity assessment should be socially acceptable, should not burden the participant with cumbersome equipment, and should minimally influence normal physical activity patterns (Armstrong and Welsman 2006).

Self-report physical activity protocols, such as questionnaires and diaries, provide a low cost alternative to objective assessments, but rely on the ability to recall and/or record information and may be influenced by social desirability. Commonly used questionnaires for assessing physical activity in large samples include the *Leisure-Time Exercise Questionnaire* (Godin and Shephard 1985a; Godin and Shephard 1985b) and *Physical Activity Questionnaires* for children (Crocker et al. 1997) and adolescents

(Martinez-Gomez et al. 2010). In contrast to questionnaires, several studies have derived estimates of daily energy expenditure (DEE) and activity energy expenditure (AEE) from a 3-day diary (Bouchard et al. 1983). That diary protocol has been used with adolescents in Canada (Katzmarzyk et al. 1999; Katzmarzyk et al. 1998), United States (Katzmarzyk and Malina 1998), Taiwan (Huang and Malina 1996; Huang and Malina 2002), Australia (Lee and Trost 2006) and United Kingdom (Atkin et al. 2008; Biddle et al. 2009; Gorely et al. 2007). However, accuracy of that instrument is still a research challenge for lack of abundant evidence among children and adolescents.

1.6. Physical fitness, physical activity, sedentary behaviour and BMI in different geographic contexts

Urbanization is periodically highlighted as a factor that influences physical activity, sedentary behaviour, weight status, and cardiovascular fitness in youth (Liu et al. 2008; Spring et al. 2006; Albarwani et al. 2009; Ismailov and Leatherdale 2010). Urbanization refers to the concentration of people in towns/cities and associated changes – migration, transformation of economic and physical organization of the city, and changes in behaviours of the population (Ezzati et al. 2005). It has been intuitively assumed that individuals living in urban centres would be less active, and by inference would have lower levels of cardiorespiratory fitness and higher levels of overweight and obesity.

Physical activity occurs in social contexts that have specific demands and constraints such as opportunities for walking, access to playgrounds, proximity to shopping centres, among others. These factors interact with social autonomy and of course with rearing style among children. However, the impact of urbanization on physical activity, cardiorespiratory fitness and health is somewhat unclear (Cicognani et al. 2008). Potential confounders include local cultural factors, climate and methods of assessment so that socio-geographic variation in physical activity, cardiorespiratory and health outcomes may not generalize across countries. It is also possible that urban-rural contrasts may be associated with different heath outcomes across relatively geographic regions (i.e., North Europe, Mediterranean countries, US, Asia or in Mexico).

Previous research has documented higher levels of overweight and obesity among rural school youth compared to their urban counterparts in the United States (Liu et al. 2008; Lutfiyya et al. 2007), Canada (Ismailov and Leatherdale 2010), and Spain (Moreno et al. 2001). In contrast, adolescents from urban communities were more likely to be classified as overweight and obese than rural peers in China (Xu et al. 2007), and

Oman (Albarwani et al. 2009). Other research has shown that rural adolescents of both sexes were less physically active than urban youth in the U.S. (Liu et al. 2008; Lutfiyya et al. 2007) and Iceland (Kristjansdottir and Vilhjalmsson 2001), while the opposite trend was noted in Oman (Albarwani et al. 2009). Urban youth in the U.S. were more likely to be sedentary than rural youth (Liu et al. 2008). Within the U.S. school youth resident in the South reported the lowest prevalence of physical activity and highest prevalence of TV viewing in contrast with adolescents from the Western region (Springer et al. 2006). On the other hand, youth from different regions of Sweden did not differ in active behaviours (Sjolie and Thuen 2002).

Trends in physical fitness show variable contrasts. Youth from rural communities were more likely to be classified as physically fit, especially in its cardio-respiratory component, compared to urban youth in Spain (Chillon et al. 2011) and Oman (Albarwani et al. 2009). On the other hand, differences in several motor fitness and somatic characteristics between rural and urban Belgian youth were negligible, an observation which the authors attributed to an ongoing process of conurbation in this relatively small country (Taks et al. 1991) and, relatively impoverished Mexican youth resident in an urban colonia had somewhat better endurance performance compared to peers from an impoverished indigenous rural community (Reyes et al. 2003).

Given the aforementioned issues associated with physical activity, sedentary behaviour and physical fitness which are seemingly variable among and within specific countries and regions, it would seem logical to examine specific behaviours and aerobic attributes in adolescents from diverse geographic regions and its relations with different biological and social factors with obvious advantages for interventions.

1.7. Objectives of the thesis

The overall aim of this thesis was to analyse the habitual physical activity, time spent sedentary, and cardio-respiratory fitness in a sample of adolescents from Portuguese Midlands. This thesis is presented in manuscripts format, and each of the seven manuscripts addresses a specific component of the overall purpose of the study.

Manuscript one - The first objective was to examine the relationship between estimated AEE based on the 3-day diary protocol proposed by Bouchard and colleagues (Bouchard et al. 1983) and on objective measure of physical activity provided by uniaxial accelerometry in a sample of Portuguese adolescents.

Machado-Rodrigues AM, Figueiredo AJ, Mota J, Cumming SP, Eisenmann J, Malina RM, Coelho e Silva MJ (2010). Concurrent validation of estimated activity energy expenditure using a 3-day diary and accelerometry in adolescents. *Scandinavian Journal of Medicine & Science in Sports*. [*in press*, Epub ahead of print, Jun 16].

Manuscript two - Further, as a second objective, it was interesting to extend that examination to know how several concomitant variables, such as weight status, age and gender, could explain the variability of activity energy expenditure between subjective and objective measures of physical activity.

Machado-Rodrigues AM, Coelho e Silva MJ, Mota J, Cyrino E, Cumming SP, Riddoch C, Beunen G, Malina RM (2011). Agreement in activity energy expenditure assessed by accelerometer and self-report measures in adolescents: variation by sex, age and weight status. *Journal of Sport Sciences*. [accepted for publication].

Manuscript three - The third objective of this thesis was to investigate the contribution of somatic maturation, given by the percentage of estimated mature stature attained at a given age, to sex differences in objective assessment of sedentary behaviour and physical activity in adolescents 13-16 years.

Machado-Rodrigues AM, Coelho e Silva MJ, Mota J, Neville H, Sherar LB, Cumming SP, Malina RM (2010). Confounding effect of biologic maturation on sex differences in physical activity and sedentary behavior in Portuguese adolescents. *Pediatric Exercise Science*, Vol. 22; (3): 442-453.

Manuscript four - The fourth purpose of this PhD project was to compare physical activity, time spent sedentary, screen time and cardiorespiratory fitness in rural and urban adolescents from Portuguese Midland communities.

Machado-Rodrigues AM, Coelho e Silva MJ, Mota J, Padez C, Cumming SP, Riddoch C, Malina RM (2011). Urban-rural contrasts in cardio-respiratory fitness, physical activity, and sedentary behaviour in Portuguese adolescents. *Health Promotion International*. [under review after revision].

Manuscript five - Taking into account that sport has high social valence and is a primary context for physical activity for the majority of youth, the fifth objective was to compare the level of physical activity between participants and non-participants in organized sport, and afterwards, to analyze the contribution of organized sport to estimated daily energy expenditure and to energy expenditure in moderate-to-vigorous physical activity.

> Machado-Rodrigues AM, Coelho e Silva MJ, Mota J, Santos R, Cumming SP, Malina RM (2011). Physical activity and energy expenditure in adolescent male sport participants and non-participants 13-16 years. *Journal of Physical Activity and Health*. [accepted for publication].

Manuscript six - The sixth purpose of this thesis was to examine the association between cardio-respiratory fitness and the area of residence (i.e. rural and urban communities) among Portuguese adolescents, controlling for several potential correlates including gender, age, weight status, type of housing, parental education, sedentary behaviour and physical activity.

> Machado-Rodrigues AM, Coelho e Silva MJ, Mota J, Cumming SP, Riddoch C, Malina RM (2011). Correlates of aerobic fitness in urban and rural Portuguese adolescents. *Annals of Human Biology*, Vol. 38(4): 479-484.

Manuscript seven - The final objective was to investigate relationships between BMI, cardiorespiratory fitness, intensity portions of physical activity, and sedentary behaviour in a sample of adolescents from different areas of residence.

> Machado-Rodrigues AM, Coelho e Silva MJ, Ronque ER, Mota J, Cumming SP, Malina RM (2011). Relationships between obesity, cardiorespiratory fitness, sedentary behaviour and objective intensity levels of physical activity in rural and urban Portuguese adolescents. *Journal of Child Health Care*. [under review].

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CHAPTER II

Literature review

2. LITERATURE REVIEW

In the nineteenth century, the public health effort in the United States was focused on controlling the spread of infectious disease, and advances in sanitation and the provision of clear water contributed to improvements in the health of the population (WHO 2005). At the turn of the century, urban reformers adopted zoning laws and building codes to reduce the spread of disease from overcrowded conditions in the central cities by lowering housing densities, as well as to separate residences from noxious commercial and industrial enterprises (Institute of Medicine of the National Academies 2005). Furthermore, during the last century, the technological progress achieved in industrialized countries had an important impact on the amount of energy expended by individuals to ensure sustained food supply, decent housing, safe and rapid transportation, personal and collective security, and diversified and abundant leisure activities. Nowadays, international public health efforts are particularly focused on the prevention of chronic diseases, and the question has arisen of whether the decentralized and largely automobile-dependent development patterns that emerged in part in response to earlier public health concerns are contributing to the increasingly sedentary lifestyle of the populations around the world.

Obesity corresponds to an excess of body adiposity derived from an imbalance between energy intake and expenditure. The aetiology of obesity is complex and believed to be linked with environment factors that contribute to the adoption of increasing sedentary behaviours. Not surprisingly, the prevalence of overweight and obesity among adolescents has substantially increased in many countries during the last two decades (Malina and Katzmarzyk 2006). In more developed economies, youth obesity prevalence levels have risen particularly strongly among lower-income households and minority ethnic groups while in less developed economies, those obesity levels have also risen, specially in urban areas and among better-off households (Lobstein 2010).

Recent studies estimate that more than 30% of children and adolescents in North America (Hedley et al. 2004), 21%-25% in Australia (Olds et al. 2010b) and, approximately 20% in Europe are overweight or obese (Lobstein 2010; Lobstein et al. 2004; Padez et al. 2004; Sardinha et al. 2010). Further research indicates that about

18% of European school children (in the 25 EU member states) are overweight, with an annual rise in prevalence between 0.55% and 1.65%, i.e. more than 400 000 new cases every year (Lobstein et al. 2004; Lobstein and Baur 2005). The ubiquitous nature of the worldwide increases in, and excessive prevalences of, physical inactivity and obesity has gathered international attention (WHO 2005). In light of the dramatic increasing prevalence of obesity among children and youth, the development of scientifically based community intervention approaches to reduce the incidence of youth obesity through increasing physical activity and sport participation assumes a crucial role.

The need to promote regular involvement of physical activity in young people has been recognized by numerous government health agencies and private organizations targeting public health (Strong et al. 2005), in part because overweight and obese youth are at increased risk of co-morbidities including type 2 diabetes, endocrine and orthopaedic disorders, and low health-related quality of life (Cumming and Riddoch 2008). Physical activity also plays an important role in weight control and, in general, studies indicate an inverse relationship between physical activity and adiposity (Ara et al. 2007; Gutin et al. 2005; Ness et al. 2007; Riddoch et al. 2009; Roman et al. 2009). In addition, physical activity was the leading health indicator in Healthy People 2010, an U.S. agenda for reducing the most significant preventable threats to health. Among adults, there is strong scientific evidence that regular physical activity reduces the risk of premature mortality and the development of numerous chronic diseases, improves psychological well-being, and helps to prevent weight gain and obesity by keeping caloric intake in balance with energy expenditure. Evidence about the effects of daily physical activity in adolescents is strongly dependent on difficulties related to methodological assessments of physical activity.

2.1. Physical activity and related concepts

Physical activity is a complex behaviour since it can vary within a range of dimensions (e.g., type of activity, duration, intensity, or even the frequency of sessions). When considering the health benefits of physical activity, it is essential to have clear understanding of various components of this multi-dimensional variable. Specifically, it should be recognized that there is a continuum of behaviour ranging from being inactive to being very physically active (Warburton 2010).

Physical activity is typically defined to all leisure or non-leisure body movements produced by the contraction of skeletal muscle that increases energy expenditure above the basal level (Malina et al. 2004; Montoye 1996; Shephard and Bouchard 1994; Welk 2002). It is often categorized by the context in which it occurs, such as leisure time (recreational time for physical activity, sport, exercise, and hobbies), transportation (bicycling or walking), household (housework, yard work, child care, chores), and occupation (work related). In children and adolescents, in-school physical activity (including recess and physical education), out-of-school physical activity, and physical activity in specific behavioural settings (e.g., after-school programs) may also be considered important domains.

Typically defined, exercise refers to structured and repetitive leisure-time physical activity whose main objective is to maintain or improve physical fitness, exercise performance, or health status (Warburton 2010).

Sport participation is a component of physical activity that involves variations in level, frequency and duration associated with training and competition. Sport participation takes place in leisure and organized sports and in physical education classes. It is generally accepted that physical education classes are sport education (Seabra et al. 2008). On the other hand, some authors refer to sport participation as just the competitive and supervised component of physical activity (Katzmarzyk and Malina 1998; Wickel and Eisenmann 2007). In addition, and with more detail, sport practice during leisure time was assessed in Brazilian adolescents and the authors considered regular engaging if they had participated in moderate to vigorous activities for more than four hours per week in the four months prior to the study (Fernandes et al. 2010).

Physical activity is associated with an increase in energy expenditure above a resting (basal) level and can therefore be defined as a continuum composed of several stages. Physical activity and physical inactivity represent opposite ends of that energy expenditure continuum. Actually, at the lower end of this continuum, sedentary behaviour refers to a number of activities that have energy expenditure levels that approximate resting (Tremblay 2010). Watching television, working on a computer, or playing video games - that is time spent in front of a screen (i.e., screen time) - is a commonly used indicator of sedentary behaviour. Low accelerometer counts also represent an objective measure of the sedentary behaviour (Katzmarzyk et al. 2008). It is important to emphasise that in many situations, sedentary behaviours are independent from (not correlated with) physical activity behaviours (Ekelund et al. 2006; Mark and Janssen 2008), and therefore, this dichotomy highlights the need to assess the complete activity-inactivity profile of the individual across the day.

2.2. Measurement of physical activity in youth

Quantifying physical activity behaviour of children and adolescents in free-living settings is an extremely difficult undertaking, particularly due to the sporadic nature of the movement patterns of youth. Factors such as ease of use, reliability/validity, choice of output measure, burden on participant, and cost are just some of the factors that must be considered when comparing different techniques. Further, if assessments are needed for research purposes, the reliability and validity of the assessments may be more important factors.

Although limitations still exist, measures of physical activity have improved over time (Armstrong and Welsman 2006; Cumming and Riddoch 2008). More than 30 different methods have been used for the assessment of physical activity and energy expenditure. Despite this variety, there is compelling evidence that no single method can fully reflect a person's activity behaviour and the energy cost - mechanical and or physiological - of such activity (Malina et al. 2004; Trost 2007; Welk 2002), particularly due to practical considerations and unresolved methodological issues. Until recently, our understanding of children's activity levels and patterns, and especially the associations between physical activity and health, had been severally restricted by the lack of accurate measurement tools. However, technology advances on objective measures provided a crucial opportunity to improve its levels of accuracy, and therefore, the possibility of studying the influence of numerous factors on physical activity among children and adolescents (Riddoch 2010).

Physical activity assessment techniques must be socially acceptable, should not burden the child with cumbersome equipment and should only minimally influence the person's normal physical activity pattern (Armstrong and Welsman 2006; Montoye 1996). Ideally, if a true picture of habitual physical activity is required, it should be assessed several dimensions of this behaviour, such as intensity, duration, frequency and mode of activity. In addition, one of the main concerns regarding any method that assesses spontaneous behaviour is that the substantial act of measuring may induce changes in these behaviours (i.e. reactivity). This observable fact may occur when the subject becomes aware of the presence of an observer or the subject must wear an instrument to monitor the activity (Malina et al. 2004).

Measures of physical activity/inactivity can be classified into two distinct categories: subjective and objective measures. Subjective measures depend on the ability of participants to recall and/or report their own behaviour while the objective ones provide concrete data generally less affected by participant and/or researcher bias.

2.2.1. Subjective measures of physical activity

Direct observation

One of the earliest methods employed to access physical activity entailed an observer's recording observations while watching a subject. The cost of observation is often prohibitive, particularly if it is necessary to employ one observer for each subject (Montoye 1996). Another problem is related to the aforementioned reactivity, in other words, subjects may change their habitual activity when they know they are being observed. In addition, as observing and recording requires high levels of practice among observers and is also tedious, the accuracy decreases as the observation period lengthens. However, the main advantage of this technique is that it enables researchers to accurately describe what is taking place in the physical activity environment, generating both qualitative and quantitative information. Observers may make note of various data, such as behavioural information, types of activity, time per activity, and frequency of performance. Since physical activity categories are determined before data collection occurs, specific targeting of physical activity behaviours is possible (Welk 2002).

Self-report instruments

A number of different self-report methods have been used to measure physical activity in youth. These include self-administered recalls, interviewer-administered recalls, diaries, and proxy reports completed by parents or teachers. The selection of self-report measures always depend heavily on the scope and aims of a project or study, and instruments vary considerably in the specificity with which type, duration, frequency, and intensity are evaluated. Furthermore, recall time frames range from as little as one day to as much as one year (Corder et al. 2008; Montoye 1996; Welk 2002). Several advantages and disadvantages can be found in the literature associated with each specific technique, however, the most frequently cited advantages of self-report measures are ease of administration and their facility to collect data from a large number of people, the ability to characterize activity in the past, and low cost. In addition, it is possible to record activity type and the context in which physical activity is performed capturing qualitative and quantitative information which is very important for describing physical activity behaviour in children and adolescents.

Although convenient, self-report methods are subject to considerable recall bias and may not be suitable for use among young children (Riddoch 2010). These instruments rely on the ability of the participant to recall behaviour information accurately and this is particularly challenging for children due to a lower cognitive ability relative to adults (Baranowski 1988; Sallis 1991). Children are less time-conscious than adults and tend to engage in physical activities at sporadic times and intensities rather than consistent bouts (Bailey et al. 1995; Baquet et al. 2007). They may misinterpret questions posed to them or may deliberately misrepresent information, creating content validity problems (Sallis and Saelens 2000; Welk 2002). There is an additional problem related to the recall of leisure time activity, which is considerably more difficult to report than occupational activity, making up a substantial proportion of total physical activity in children and adolescents. In fact, youth are frequently unable to quantify the time frame of activity, and it is often assumed that younger children may not fully understand the concept of physical activity (Trost 2007). Extreme caution must be exercised when attempting to use self-report instruments in children aged 10 years or younger (Corder et al. 2008; Sallis and Saelens 2000). Consequently, the self-recall of duration, intensity, and frequency of bouts of activity by children is even more difficult than with adults.

The validity and reliability of self-report measures for children and adolescents have been continually studied and results are consistent. For example, Corder and co-workers (Corder et al. 2008) summarized the validity characteristics of 21 self-report instruments used to assess physical activity in children and adolescents. When accelerometry was used as a criterion measure of physical activity, concurrent validity coefficients ranged from 0.09 to 0.73. All self-report instruments demonstrated no more than moderate evidence of validity. In general, validity coefficients were age dependent, with younger children (0.20-0.37) exhibiting poorer concurrent validity than adolescent youth (0.33-0.63). The literature had previously reported similar magnitude of results on youth physical activity assessment by self-report (Sallis and Saelens 2000). Validity coefficients were also generally higher among adolescents than children.

Questionnaires are specifically valuable for the assessment of activity setting and mode of activity behaviours, in other words, qualitative information, which may be more difficult to assess objectively. Commonly used questionnaires for assessing physical activity in large samples of youth include the *Leisure-Time Exercise Questionnaire* (Godin and Shephard 1985a; Godin and Shephard 1985b), the *Physical Activity Questionnaires* for children (Crocker et al. 1997) and adolescents (Martinez-Gomez et al. 2010), *weekly checklist* (Sallis et al. 1996), and the *Baecke questionnaire* (Baecke et al.

1982). These instruments differentiate themselves by the dimensions of physical activity that they are able to assess and also by the sort and number of questions they collect.

Diary. The diary method of assessing habitual physical activity consists of logging one's own activities periodically. Recording has been done as often as every minute (Riumallo et al. 1989), and as infrequently as 30-min (Pate et al. 2003) or 15-min periods (Biddle et al. 2009b; Biddle et al. 2009c; Bouchard et al. 1983; Gorely et al. 2009a; Gorely et al. 2007). Further, it has been used for assessing physical activity from just one day (Wickel et al. 2006) until seven days (Bratteby et al. 1997), however, the most widely used frame/structure refers to the 3-day-diary proposed by Bouchard and colleagues (Bouchard et al. 1983).

On one hand, there are several advantages of the diary method on physical activity or energy expenditure assessment. Data collection involves little expense and does not require an observer, and data can be collected by many subjects simultaneously (Montoye 1996). On the other hand, processing a large volume of data can be time-consuming and this is an important disadvantage of this technique. Complete cooperation and conscientiousness on the part of the subjects is crucial if accurate data is to be obtained. Even so, the subject may forget to log all entries or might make recording errors (Montoye 1996; Wickel et al. 2006). The literature is clear by stating that the longer the period of data collection, the less accurate the results might be. In addition, it is generally assumed that this protocol is inappropriate with children below the age of 10 and perhaps even in older children (Bouchard et al. 1983; Corder et al. 2008; Sallis and Saelens 2000). The greater source of error is possibly the conversion of data into energy expenditure, since it is well know that less fit participants will rate activities at higher intensities than will more fit subjects. However, diary measures were found to be reliable ($r = 0.91$) and valid ($r = 0.80$ with physical work capacity) among youth old enough to record their physical activity behaviour (Bouchard et al. 1983).

The 3-day diary protocol has been widely used with adolescents in Canada (Katzmarzyk et al. 1999; Katzmarzyk et al. 1998a), United States (Katzmarzyk and Malina 1998), Taiwan (Huang and Malina 1996; Huang and Malina 2002), Australia (Lee and Trost 2006), and United Kingdom (Atkin et al. 2008; Biddle et al. 2009c; Gorely et al. 2009a; Gorely et al. 2009b). That instrument permits an estimation of daily energy expenditure and also of the type, intensity, frequency and duration of specific activities including sedentary behaviours (Katzmarzyk and Malina 1998). Table 2.1. presents an overview of the 3-day diary use.

Table 2.1. Studies using the 3-day diary protocol proposed by Bouchard et al (1983) in youth.

Reference	Country	Purpose	Participants	Main results
Bouchard et al. (1983)	Canada	To describe a method for the assessment of habitual energy expenditure and to report the reliability of the procedure.	150 children and 150 adults; aged 10 to 50 years.	Results of the present study suggest that the procedures described can be useful in population studies in which current energy expenditure in human subjects who are at least 10 yr old must be quantified.
Huang & Malina (1996)	Taiwan	(1) To estimate the total daily EE and EE in moderate-to-vigorous physical activity of Taiwanese adolescents 12-14 years of age; (2) to evaluate the relationship between socio-demographic variables and estimated EE.	The sample included 138 boys and 144 girls, 12-14 years of age.	Estimated total daily EE and EE in moderate-to-vigorous physical activity are higher in boys than girls, and on weekend days than week days. Results of multiple and stepwise regression analyses indicate that age, sex, area of residence, and SES account for only about 15-17% of the variance in estimated daily EE and EE in moderate-to-vigorous activity.
Katzmarzyk & Malina (1998)	U.S.	To examine the contribution of participation in organized sports to estimated total daily energy expenditure in youth.	90 males and 93 females, 12 to 14 years of age.	Males expended 20.4% of TDEE in youth sports; the corresponding estimate for females was 16.3%. Males and females expended 55% and 64.6%, respectively, of MVEE in youth sports. Youth who participated in organized sports had greater TDEE and MVEE, and spent less time watching television than those who did not participate.
Katzmarzyk et al. (1998)	Canada	To evaluate the relationship between indicators of physical activity and health-related fitness in youth 9-18 yrs.	356 boys and 284 girls 9-18 yr of age.	There is a significant relationship between activity and health-related physical fitness, but a large part of the variability (80-90%) in fitness is not accounted for by physical activity as measured in this study.
Katzmarzyk et al. (1998)	Canada	To evaluate the relationships among television viewing time (TVTIME), physical activity, and health-related fitness in youth 9–18 years of age from the Québec Family Study.	The sample included 423 males and 361 females.	Correlations between TVTIME and EE and MVPA were low, with no pattern by age group and gender. Those between TVTIME and fitness variables were also low, with no pattern by age and gender. Adolescents in the highest and lowest quartiles of TVTIME showed no consistent differences in EE, MVPA, and the four fitness items. Similarly, adolescents in the highest and lowest quartiles of EE, MVPA, and each fitness item did not consistently differ in TVTIME.
Ekelund et al. (1999)	Sweden	The activity diary method has been compared to minute-by-minute HR-monitoring in estimating TDEE and its components and in determining time spent at different activity levels.	Thirty-six 14-16 year-old adolescents.	The activity diary underestimated time spent in moderate and vigorous physical activity for inactive subjects and consequently overestimated highly active subjects.

Table 2.1. (*continued*).

Reference	Country	Purpose	Participants	Main results
Katzmarzyk et al. (1999)	Canada	To analyse the relationships between physical activity, fitness, and CHD risk factors in adolescents.	342 males and 268 females 9–18 years of age.	Canonical correlations between activity and risk factor profiles range from 0.22 to 0.45, while those between fitness and risk factor profiles range from 0.34 to 0.55, indicating that 5 to 20% and 11 to 30% of the variance in the risk profile is explained by activity and fitness, respectively.
Hunag & Malina (2002)	Taiwan	To analyse the relationship between physical activity and health-related physical fitness in adolescents.	282 Taiwanese adolescents 12-14 years of age.	Overall, the strength of the relationship between estimated EE and specific items in the total sample varied from low to moderate, with only 1% to12% of the variance in fitness variables were explained by estimated EE. The most active (highest quartile) were also the most fit in cardio-respiratory endurance.
Gorely et al. (2007)	UK	To investigate the patterning of physical activity and sedentary behaviours in UK adolescents and to examine if different lifestyle groups differ on key explanatory variables.	1371 (38% boys, mean age 14.7 years) adolescents.	Active adolescents spend more time outside and more time with their friends.
Eisennman & Wickel (2007)	U.S.	To examine the estimated total energy expenditure (TEE) and physical activity patterns of adolescent distance runners.	Twenty-eight (20 male, 8 female) adolescent.	Mean values for TEE, 57.4±11.6 and 51.0±9.8 kcal.kg$^{(-1)}$.d$^{(-1)}$, and activity energy expenditure (AEE), 26.7±10.4 and 21.0±8.8 kcal.kg$^{(-1)}$.d$^{(-1)}$, when expressed per kilogram body mass were not significantly different between males and females, respectively (P = 0.18). When expressed in absolute terms, TEE, 3609±927 and 2467±426 kcal/d, and AEE, 1688±746 and 977±269 kcal/d, were significantly higher in males than in females, respectively.
Atkin et al. (2008)	UK	To examine physical activity and sedentary behavior patterns of adolescents between 15:30h and 18:30h.	1484 (boys: n=561; girls: n=923): mean age 14.7 years.	The most prevalent behaviors after school are technology-based sedentary behavior, homework and physical activity. During these hours, engagement in physical activity does not appear to displace time spent doing homework.
Gorely et al. (2009)	UK	To examine the relationships between family circumstances (e.g. socio-economic status, single vs. dual parent household, presence/absence of siblings) and leisure-time physical activity and sedentary behaviours in adolescents.	1171 adolescents (40% male; mean age 14.8 years).	Boys from single parent households and girls from low socio-economic families may be at increased risk of high sedentary behaviour. Those living in low socioeconomic neighbourhoods may be at increased risk of reduced participation in sports and exercise.

Table 2.1. (*continued*).

Reference	Country	Purpose	Participants	Main results
Gorely et al. (2009)	United Kingdom	To describe how adolescent boys in the United Kingdom spend their leisure time.	561 boys with a mean age of 14.6 years (range 12.7-16.7 years).	Television viewing occupied the most leisure time on both week days (131 minutes) and weekend (202.5 minutes) days. On week days the five most time consuming sedentary activities (television viewing, homework, motorised travel, playing computer/video games and shopping/hanging out) occupied on average 272.2 minutes. On weekend days, the five most time consuming sedentary activities (television viewing, shopping/hanging out, motorised travel, sitting and talking and playing computer/video games) occupied 405.5 minutes.
Biddle et al. (2009)	England	To describe sedentary and active leisure-time behaviours of adolescents across the day and setting.	Adolescents (male n=579, female n=967; aged 13-16 years).	TV viewing and sports/exercise peaked at different times in the day, although TV viewing was two to three times more likely to occur than sports/exercise. TV viewing was most likely to occur during the middle to late evening. The playing of computer games was low, particularly for girls. Weekend data showed TV viewing was the most reported activity throughout the day. For boys, "being in the garden" was highly predictive of engaging in sports/exercise, but this declined rapidly with age. Motorized travel to school was reported twice as often as active travel.
Biddle et al. (2009)	Scotland	To report time and prevalence of leisure time sedentary and active behaviours in adolescents.	n=385 boys, 606 girls; mean age 14.1 years; range 12.6-16.7 years.	Television viewing occupied the most leisure time. The five most time consuming sedentary activities occupied 228 min per week day and 396 min per weekend day for boys, and 244 min per week day and 400 min per weekend day for girls, with TV occupying one-third to one-half of this time. In contrast, 62 min was occupied by active transport and sports/exercise per week day and 91 min per weekend day for boys, with 55 min per week day and 47 min per weekend day for girls. A minority watched more than 4 h of TV per day, with more at the weekends. Other main sedentary behaviours for boys were homework, playing computer/video games, and motorised transport and, for girls, homework, motorised transport, and sitting and talking.
Bringolf-Isler et al. (2009)	Switzerland	To determine activity type/mode and to quantify intensity and duration of children's everyday PA by combining information of a time activity diary with accelerometer measurements and to assess differences by gender and age.	n = 189, aged 6/7 years, 9/10 years and 13/14 years.	Adolescents spent significantly more time in high intensity sports activities than younger children but this increase was compensated by a reduction in time spent playing vigorously ($p = 0.04$). In addition, adolescents spent significantly more time in sedentary activities and accumulated less counts/min during these activities than younger children. Among moderate to vigorous activities, children spent most time with vigorous play (43 min/day) and active transportation (56 min/day).

2.2.2. Objective measures of physical activity

Developments in technology over the past two decades have resulted in an increase in the use of objective methods to assess habitual physical activity. During the 1990's, heart rate monitoring was extensively used by Armstrong and colleagues (Armstrong et al. 1990; Armstrong and Bray 1991; Welsman and Armstrong 1992) and was the preferred method of assessing physical activity among youth. However, over the last decade pedometry and accelerometry (Duncan et al. 2008; Hohepa et al. 2008; Mattocks et al. 2008a; Nader et al. 2008; Ness et al. 2007; Riddoch et al. 2004; Riddoch et al. 2007; Rowlands et al. 1999; Trost et al. 2002a; Trost et al. 2002b) have become more popular and widely used among youth. The accelerometer is currently the objective method of choice, and is being used increasingly for the quantification of the amount of physical activity, intensity of physical activity and amount of sedentary behaviour in children and adolescents (Reilly et al. 2008). Therefore one question, perhaps among others, surfaces in this context. Why is accelerometry so often the tool of choice for assessing youth's activity?

Heart rate monitoring. Heart-rate monitoring provides an objective estimate of physical activity that is based on the assumption that children who spend longer periods of time with elevated heart rates are generally more active than those whose heart rate (HR) remains in the lower ranges (Armstrong and Welsman 2006). The widespread use of heart rate monitoring is due to its ease of measurement, its ability to record values over a week, and its reflection of the relative stress placed on the cardiopulmonary system due to physical activity (Welsman and Armstrong 1992). Further, heart-rate monitors are becoming smaller and now have the ability to internally store data while not displaying HR and, therefore, reducing the chance of altered behaviour by reactivity.

Despite this, the measurement of physical activity is based on the linear relationship between oxygen uptake and heart rate, this relationship between HR and EE is not linear at low intensity of physical activity and while sedentary (Corder et al. 2008). Heart rate is frequently used to predict EE or to determine time spent when physically active, with heart beats per minute above a certain level. For the assessment of physical activity, HR data theoretically require more processing than movement data. In addition, some kind of individual calibration is usually necessary due to individual variation in resting HRs and fitness levels which influence the slope and intercept of the regression line between HR and energy expenditure (Mattocks et al. 2008c; Rowlands et al. 1997). This may be impractical in free-living studies, and validation studies of HR monitoring for assessing physical activity in youth have not been developed as in the motion sensors field. An additional problem of the heart rate as a measure of physical activity is that it can be increased by stimuli other than physical activity (Armstrong and Welsman 2006; Corder et al. 2008; Rowlands et al. 1997), reducing therefore its accuracy. In other words, the relationship between heart rate and physical activity may also be influenced by emotional stress or type of activity undertaken and fitness levels.

Pedometry. Pedometers count the number of times a certain acceleration threshold is exceeded (mechanical pedometers) or the number of zero crossings in the acceleration waveform and sum this to give an overall estimate of steps taken (Corder et al. 2008). An accumulated step count can be used as an indicator of total activity. These instruments are usually cheaper than accelerometers and no calibration equations are needed to interpret pedometer data and therefore more practical for use in large epidemiological studies.

Despite their ease of use, there are well-documented disadvantages of this method, particularly the pedometer's inability to measure intensity of physical activity (Mattocks et al. 2008c), record counts during cycling and record increases in energy expenditure due to carrying objects or walking/running uphill (Rowlands et al. 2007). Youth may also react to pedometers by checking their step counts.

Following the last assessment recommendation (Corder et al. 2008; Rowlands et al. 2007), pedometer output should be expressed as steps per day without any further inference of distance or energy expenditure because the level of uncertainty in these predictions may be unacceptably high.

Accelerometry. Acceleration is defined as the change in velocity over time, and, as such, it quantifies the volume and intensity of movement. Accelerometers measure acceleration in several orthogonal planes. The sensitive axis of the uniaxial accelerometers is normally oriented in the vertical plane. Triaxial accelerometers consist of three orthogonal accelerometer units and provide an output for each plane as well as a composite measure. The signal from an accelerometer is integrated over a given time interval, or epoch, then summed and stored. Data are usually reported as accelerometer counts per minute (cpm) averaged over the defined measured time, and the number of minutes, often per day, of moderate-to-vigorous physical activity.

The use of accelerometers enables researchers to record all intensities of every movement of youth, particularly not just the more memorable bouts of physical activity that the child or the adolescent may recall. As a non-invasive technique, often associated to low-burden in the subject, accelerometry can provide insights of the physical activity levels and patterns with far higher levels of precision (Mattocks et al. 2008b; Mattocks et al. 2008c; Riddoch 2010). In addition, movement sensors are usually related to marginal reactivity among youth, especially after short adaptation periods. Mattocks and co-workers (Mattocks et al. 2008b) demonstrated that accelerometer counts were just 3% higher during the first day of measurement than subsequent days in 11-years-old children, and the problem is not apparent on subsequent days.

Although these methods are increasingly being used in large studies (Nader et al. 2008; Ness et al. 2007; Riddoch et al. 2004; Riddoch et al. 2007; Troiano et al. 2008) there are still uncertainties about their use. These include, among others, the number of hours per day and total number of days of measurement required to better characterize usual activity, the likely compliance in large studies (potential bias introduced by non-response), and the potential for bias resulting from differences in number of days of measurement (Mattocks et al. 2008b). Another fundamental question, which is essential to understanding the meaning of physical activity assessed by accelerometry, is how to translate and interpret the accelerometer signal into meaningful data linked to physiological outcomes or, in some cases, behavioural patterns (Freedson et al. 2005; Rowlands 2007).

At the beginning of the century, some of the protocol decisions were made based on the experience of other research groups. However, there have been made an essential effort to standardized criteria among studies to better manage data from this objective measure. The first practical issue facing users of accelerometry is which accelerometer to use. Recent systematic reviews found that the device most widely used, the *MTI Actigraph* (MTI, Florida), is also the device that has the greatest body of consistent and high-quality evidence to support its use (e.g. reliable and valid) (de Vries et al. 2006; Reilly et al. 2008). In addition, there is a large body of evidence on ‘‘calibration’’ of the *Actigraph*. The *Actigraph* (uniaxial) has been calibrated in both children and adolescents against heart-rate telemetry (Janz 1994), indirect calorimetry (Melanson and Freedson 1995), observational techniques (Fairweather et al. 1999), and energy expenditure measured by doubly labeled water (Ekelund et al. 2001). A correlation coefficient of 0.58 between counts per minute from the *7164 Actigraph* and physical activity level assessed by using doubly labelled water as the criterion measure was reported in free-living settings (Ekelund et al. 2001). The same accelerometer has been shown to be valid and reliable in children, with a between instrument correlation of 0.87 being reported (Trost et al. 1998). Furthermore, the relationships between activity counts from the *ActiGraph* and energy expenditure (EE) was evaluated by Puyau and co-workers (Puyau et al. 2002) in 26 children aged 6-16 years. The participants performed a variety of free-living physical activities in a whole room calorimeter and correlations with EE ranged from r =0.66 to 0.73.

Depending on the accelerometer model, the epoch can be set as low as one second or as high as several minutes. In the past, the vast majority of studies have set the epoch at one minute, although this is known that could underestimate vigorous and very vigorous intensity activity. Few empirical studies have addressed this issue, and the evidence is particularly based on children aged 7-11 years old (Nilsson et al. 2002; Rowlands et al. 2006) and preschoolers (Vale et al. 2009). Despite a widespread perception that shorter epochs are essential to measure physical activity in children, the empirical evidence on the topic is limited and does not support the notion that ‘‘short’’ epochs are essential. One exception to this conclusion might be in circumstances where the outcome of interest is vigorous intensity physical activity (Reilly et al. 2008).

To provide a reliable measurement of habitual physical activity, the representativeness of the monitored period also plays an important role. Most studies rely on a single period of measurement to characterize habitual physical activity in youth, that is, the average level of physical activity over time. This specified period is typically between 3 and 7 days, with 3-4 days of valid recording considered the minimum needed to characterize habitual physical activity, including at least one weekend day (Mattocks et al. 2008b; Riddoch et al. 2004; Trost et al. 2000). Some studies have provided an overview of the accelerometry processing and compliance patterns in large samples of children. For example, Mattocks and colleagues (Mattocks et al. 2008b) demonstrated that the use of 3 days of physical activity measurement provide good reliability (r=.7). Although it has been previously suggested that a minimum of 4 days of measurement is required to give a .8 reliability coefficient and 11 days were needed to achieve a reliability coefficient of .9 (Trost et al. 2000).

The lack of a standardized procedure for handing out and summarizing data from accelerometry has led to the use of a variety of strategies on physical activity assessment among youth. Consequently, it has been difficult to decide whether a given day constitutes a valid day to the data set or whether it is likely that the accelerometer has been removed or contains spurious data. Decisions about 10 hours of registered time as a minimum for inclusion were done in different studies (Andersen et al. 2006; Nader et al. 2008; Riddoch et al. 2004; Sardinha et al. 2008). In contrast, Eiberg and colleagues (Eiberg et al. 2005) adopted 8 hours as the criterion corroborating the recent *Healthy Lifestyle in Europe by Nutrition in Adolescence Study* performed in nine European countries (Ruiz et al. 2011). The decisions about the inclusion criteria seem to be somewhat arbitrary, since they can be found in the literature studies that assumed 13 hours for the week-days and only nine hours for the weekend days (Van Coervering et al. 2005).

An issue of equal importance is related to cut-points to estimate the amount of time spent in moderate-to-vigorous physical activity. These cut-points are defined by calibration studies where counts/minute, a dimensionless unit, from the accelerometer is compared with a criterion measure such as energy expenditure, and they vary between studies that can lead to substantial under or over-estimation of the amount of moderate-to-vigorous physical activity accumulated by adolescents (Guinhouya et al. 2006; Mattocks et al. 2008b; Mattocks et al. 2008c). For example, the *National Health and Nutrition Examination* study (Troiano et al. 2008) and *European Youth Heart Study* (Riddoch et al. 2004) adopted relatively low thresholds for MVPA (906–2020 counts/min), whereas *Avon Longitudinal Study of Parents and Children* (Riddoch et al. 2007) used 3000–3600 counts/minute.

Despite few disparities on methodological issues that can lead to a less comparability of results between studies, accelerometers represent an important advance in measurement of physical activity that have greatly increased our understanding of the nature of the relationship between physical activity and obesity and cardiovascular disease risk factors that have their origins in childhood.

Combined methods. There are new technologies that have been developed to more accurately measure physical activity and energy expenditure, which are often able to combine accelerometry measures with physiological parameters using one device. These emerging methods are expected to enhance the validity and comprehensiveness of physical activity measurement.

The *ActiHeart* is a physical activity instrument that combines HR monitoring and sensing using simultaneously. This combination seems to be more accurate than either method used alone in controlled environment in children (Corder et al. 2007). However, free-living studies using combined and separate HR and motion sensing are necessary to determine weather the accuracy of the prediction is increased enough relative to the increased cost and complexity of analyse of the combined method (Corder et al. 2008).

In order to study the physical environment and its association with physical activity, several researchers have used a combination of global position system (GPS) and accelerometer (Maddison et al. 2010; Oliver et al. 2010). These devices are able to provide information of the duration, frequency, and location of activity, which can be used to identify the most common environments in which physical activity occurs. It is therefore logical that combined parameters would capture more variance in activity than a singe instrument alone. On the other hand, a GPS system is associated with several concerns such as the individual privacy of the subject or the lack of research among children (Pate 2010). In addition, the high cost of some of these methods inhibits their use for large-scale epidemiological studies.

2.3. Recommended levels of physical activity and sedentary behaviour for youth

A number of international organizations have put forward physical activity guidelines for optimizing health and functional capacity of youth. Guidelines are typically population-targeted consensus statements on the general course of actions and strategies that inform how best to implement successful interventions to realise the health potential of physical activity. These guidelines have been adapted over time and continue to change as new information is discovered on the relationship between physical activity and health, communicating the necessary dose of physical activity required for specific and general health gains. It should be noted that recommendations are usually specific to a population group (e.g. adults, older adults, and young people) and can be either aimed at primary prevention or secondary prevention.

The earliest recommendation was presented by the *American College of Sports Medicine* (ACSM 1988). On the basis of the adult recommendations, it was suggested that children should be involved in at least 20 minutes of vigorous physical activity per day (ACSM 1988). Later, and taking into account that children and adolescents are not small adults, the *International Conference on Physical Activity Guidelines for Adolescents* performed a systematic review of the available knowledge to establish empirically based guidelines for physical activity (Sallis and Patrick 1994). This panel recommended that all adolescents should (i) be active on a daily basis (i.e. at work, playing, on physical education, sport, or active transportation), and (ii) engage in at least 20 minutes of sustained moderate to vigorous physical activity at least three times per week. Later on, the *Health Education Authority* of England specially made guidelines for activity in children (Biddle 1998). Recognizing individual differences in fitness and activity levels, the guidelines were based on a minimum of 60 minutes of moderate to vigorous physical activity each day for active children, whereas less active youth should achieve at least 30 minutes of moderate activity. In addition, youth should also engage at least twice per week in activities designed to promote bone growth, strength, and flexibility. Afterwards, a systematic review conducted in United States by Strong and colleagues (Strong et al. 2005) concluded that school children should engage in at least 60 minutes of moderate to vigorous activity each day, highlighting that activities should be enjoyable and developmentally appropriate. More recently, the *British Association of Sport and Exercise Sciences* (O'Donovan et al. 2010) and the *Canadian Society for Exercise Physiology* (Tremblay et al. 2011a) provided the same recommendation related to the daily amount of physical activity for children and adolescents.

Specific guidelines for children and adolescents were internationally varying over the time, and they are often used for determining the percentage of youth who meet the criteria for adequate habitual physical activity. For example, several international organizations, including the U.S. *Centre for Disease Control and Prevention* (Centers for Disease Control and Prevention 1997) have recommended that children and adolescents should get 60 minutes of physical activity of at least moderate intensity most days of the week, preferably daily. However, the exception to this statement would be the Canadian guidelines which suggest children should progress to 90 minutes or more moderate to vigorous intensity activity per day (Health Canada and the Canadian Society for Exercise Physiology 2002a; Health Canada and the Canadian Society for Exercise Physiology 2002b).

On the other hand, few published reports present specific guidelines for the amount of sedentary behaviour that is recommended for children and adolescents. However, most experts on behavioural sciences agree that young people, particularly those in elementary or primary school, should avoid prolonged periods of inactivity altogether, especially during daylight hours (Corbin and Pangrazi 2004). Nevertheless, it is difficult to know what constitutes a prolonged period. Furthermore, several sedentary behaviours are important for healthy social and cognitive development, such as talking with friends and doing homework. Therefore, the most widely cited and scientifically accepted recommendation is based mainly on TV viewing and was stated by the *American Academy of Pediatrics* (APP) (American Academy of Pediatrics 2001). The

AAP recommends that parents should limit youth's total entertainment media time to no more than two hours of quality programmes per day.

To date, the published guidelines about the time young people should spend engaged in sedentary behaviour was just formally adopted in Australia and Canada. The most recent guideline recommendations adopted in Canada (Tremblay et al. 2011b) state that for health benefits, children (aged 5–11 years) and youth (aged 12–17 years) should minimize the time that they spend being sedentary each day. This may be achieved by (*i*) limiting recreational screen time to no more than 2 hours per day - lower levels are associated with additional health benefits; and (*ii*) limiting sedentary (motorized) transport, extended sitting time, and time spent indoors throughout the day. This is the first evidence-based on *Canadian Sedentary Behaviour Guidelines for Children and Youth* and provide important and timely recommendations for the advancement of public health based on a systematic synthesis, interpretation, and application of the current scientific evidence.

2.4. Habitual physical activity in youth

Youth physical activity trends in different European countries are very similar and males appear to participate in more physical activity than their female counterparts, with the gender difference being particularly marked in comparisons of vigorous physical activity portions. The physical activity levels of both genders decline as they move through adolescence. Furthermore, the patterns of physical activity that are developed during childhood are also important because levels of physical activity tend to track from childhood into adolescence and adulthood (Malina 2001; Malina et al. 2004). Recently, Blaes and co-workers (Blaes et al. 2011) demonstrated that changes in physical activity patterns across adolescent years were associated with an increase of LPA and a concomitant decrease of MPA, while changes were more pronounced during free days than during school days.

Age-related variation of physical activity in youth

The decline of physical activity from late childhood is well documented in males and females (Malina et al. 2004; Nader et al. 2008; Sallis 2000; van Mechelen et al. 2000). Several studies have assessed tracking of physical activity, and, in general, results have shown low to moderate stability of physical activity through childhood and adolescent years (Janz et al. 2005; Kristensen et al. 2008; Malina 2001; McMurray et al. 2003; Pate et al. 1996). It should be noted, however, physical activity is a very complex behaviour to quantify, and most studies have made use of methods with some degree of subjectivity and the apparent decline in physical activity during adolescence varies among contexts and studies.

For example, data from the *Norwegian Longitudinal Health Behaviour Study* (Kjonniksen et al. 2008) indicate low associations between participation in specific types of activities during adolescence and global leisure-time physical activity in young adulthood, while participation in several adolescent physical activities simultaneously was moderately related to later activity. In addition, longitudinal descriptive analyses of the 1032 participants of the *National Institute of Child Health and Human Development Study of Early Child Care and Youth Development* birth cohort that had accelerometer-determined minutes of MVPA (Nader et al. 2008) revealed a significant decrease of physical activity between ages 9 and 15 years. By age 15 years, adolescents were only engaging in moderate-to-vigorous physical activity for 49 minutes per week day and 35 minutes per weekend day. Boys were more active than girls, spending 18 and 13 more minutes per day in moderate-to-vigorous physical activity on week days and weekend days, respectively.

The physical activity decline is particularly marked during the adolescence that is recognized as a period of great physical, psychological, cognitive and emotional changes, which may be linked to physical activity, and influence adolescent participation in physical activity (Sallis 2000).

Sex-related variation of physical activity in youth

Although a decline in physical activity is evident in both genders, mainly on leisure-time activities, results from several investigations have shown adolescent males to be, on average, more physically active and more likely to engage in exercise than females of the same chronological age (Malina et al. 2004; Riddoch et al. 2004; Riddoch et al. 2007; Ruiz et al. 2011; Trost et al. 2002a; van Mechelen et al. 2000). Sex differences in physical activity are reasonably consistent across cultures and are independent of research design (i.e., cross-sectional or longitudinal) and methods used to assess physical activity (i.e., self-report instruments, accelerometry). For example, an investigation of accelerometer-assessed physical activity in 2185 participants from the *European Youth Heart Study* revealed that 15-year-old boys spend 36% more time in daily moderate physical activity than their same age female peers (Riddoch et al. 2004). In fact, gender differences were apparent at age 9 (192±66 vs. 160±54 $min \cdot d^{-1}$) and age

15 (99±45 vs. 73±32 min·day^{-1}). Similarly, evidence using a large youth sample from the United States (n=4867) demonstrated that between 12 and 15 years of age, boys were more likely to engage in moderate-to-vigorous physical activity than girls [boys: 41 minutes per day (non-hispanic white), 54 minutes per day (non-hispanic black), 51 minutes per day (Mexican-American); girls: 22 minutes per day (non-hispanic white), 26 minutes per day (non-hispanic black), 27 minutes per day (Mexican-American)] (Troiano et al. 2008). More recently, in a representative sample of Norwegian youth (Kolle et al. 2010), on a daily basis, nine-year-old boys spent more time in moderate-to-vigorous physical activity and in vigorous physical activity than their same age female counterparts [boys: 95 minutes per day of MVPA, and 56 minutes per day of VPA; girls: 76 minutes per day of MVPA, and 44 minutes per day of VPA]. A similar pattern was found among 15-year-old adolescents, but the sex difference was smaller [boys: 68 minutes per day of MVPA, and 45 minutes per day of VPA; girls: 62 minutes per day of MVPA, and 40 minutes per day of VPA].

Additional sources of variation in physical activity among youth are week days vs. weekend days. Studies have consistently shown a decrease of physical activity from week days to the weekend, primarily in physical activity of high intensity levels (Nader et al. 2008; Rowlands et al. 2008). Using also objective measures to assess moderate-to-vigorous physical activity in a Norwegian nationally representative cohort, Kolle and colleagues (Kolle et al. 2010) revealed, in all age and sex groups, a higher physical activity level during week days than during weekends. Nine-year-old boys were 14.9% and 11.9% more physically active than the girls during the week days and at the weekend, respectively. Fifteen-year-old boys were 16.0% more physically active than the girls during week days; however, no sex differences in the activity level were found during weekend days.

The following brief review (Table 2.2.) focuses especially on some of the largest studies that utilize accurate measurements and, in some of them, that it might consider representative large and diverse populations of youth of both genders across countries. As those studies have used similar methods, the results are broadly comparable. Thus, in general, table 2.2. shows that total physical activity of youth (counts per minute) markedly decrease with increasing age and consistent gender differences, with females generally 20%-30% less active than male youth. These data can provide great insight regarding whether children and adolescents are achieving the physical activity guidelines promoted by several international health institutions focused on public health promotion.

Table 2.2. Physical activity measured by accelerometer of males and females youth in recent studies.

Study	Country/location	Participants	Age or grade	Total physical activity (counts/minute)		MVPA (min/day)				MVPA cut point	References
				Males	Females	Males		Females			
EYHS[1]	Portugal, Estonia, Noeway, Denmark	2185 boys and girls	9 years	784 (282)	649 (204)	192 (66)		160 (54)		9yrs, 906	Riddoch et al. (2004)
			15 years	615 (228)	491 (163)	99 (45)		73 (32)		15yrs, 1706	
ALSPAC[2]	England	5595 boys and girls	11 years	644 (528-772)	529 (444-638)	25 (16-38)		16 (10-25)		3600	Riddoch et al. (2007)
NHANES[3]	United States	1778 boys and girls	6-11 yrs	647 (21)	568 (12)	95 (5)		75 (2)		1400-2020	Troiano et al. (2008)
			12-15 yrs	521 (24)	328 (14)	45 (3)		25 (2)			
			16-19 yrs	429 (11)	328 (12)	33 (2)		20 (2)			
						week	weekend	week	weekend		
NICHD Study [4]	United States	839	9 years			191 (53)	184 (69)	173 (46)	173 (64)	9yrs, 906	Nader et al. (2008)
		850	11 years			133 (43)	127 (60)	116 (36)	113 (53)	11yrs, 1135	
		699	12 years			105 (40)	93 (55)	86 (33)	74 (46)	12yrs, 1263	
		604	15 years			58 (32)	43 (38)	39 (24)	26 (23)	15yrs, 1706	
HELENA Study[5]	Greece, Italy, Germany, Hungary, Spain, France, Sweden, Austria Belgium	431	13 years	504	396	68		51		≥ 2000	Ruiz et al. (2011)
		559	14 years	501	379	68		49			
		577	15 years	481	384	66		51			
		460	16 years	466	390	65		53			
Canadian Health Measures Survey[6]	Canada	504	11-14 yrs			59		47			Colley et al. (2011)
		395	15-19 yrs			53		39			

[1] *European Youth Heart Study*. Data are mean (SD).
[2] *Avon Longitudinal Study of Parents and Children*. Data are medians (IQR). MVPA (moderate-to-vigorous physical activity).
[3] *National Health and Nutrition Examination*. Data are means (SEM).
[4] *National Institute of Child Health and Human Development Study of Early Child Care and Youth Development.* Data are means (SD).
[5] *Healthy Lifestyle in Europe by Nutrition in Adolescence Study (HELENA Study).* Data are means.
[6] *Canadian Health Measures Survey.* Data are means (SD).

Compliance with physical activity guidelines: prevalence in children and adolescents

As previously mentioned, physical activity recommendations for health benefits in children vary slightly according to each organizational definition. Moreover, the obvious challenges that are linked to physical activity measurement in children and adolescents make difficult the determination of whether youth meet the guidelines. The proportion of youth meeting physical activity guidelines can substantially vary across studies which are based on differing methodologies and/or analytical techniques.

Studies from different geographic contexts have reported worrying rates of the compliance with physical activity guidelines. On one hand, based on self-report instruments, 48% of Spanish youth aged 6–18 years were shown to engage in at least 60 minutes of physical activity a day (Roman et al. 2008), while in Finland only 23% of males and 10% of female adolescents aged 15-16 years did so (Tammelin et al. 2007). On the other hand, youth seem appropriate targets when promoting physical activity in order to increase the proportion meeting the recommendations. As such, based on objective measures (i.e. accelerometry), among 9-year-olds, 75.2% of the girls and 90.5% of the boys met the Norwegian physical activity guidelines of 60 minutes of moderate-intensity physical activity every day (Kolle et al. 2010). The corresponding value among the 15-year-olds was 49.9% among females and 54.1% among male adolescents. In contrast, in the USA, only 42% of children and an alarming 6–8% of adolescents achieved the recommended levels of physical activity objectively assessed (Troiano et al. 2008). However, in a different sample of U.S. adolescents aged 14–17 years (n= 6125), but surveyed by phone, approximately 40% of the females and 57% of the males complied with the national physical activity guidelines (Butcher et al. 2008).

Recently, in the *Healthy Lifestyle in Europe by Nutrition in Adolescence Study* (Ruiz et al. 2011), a higher proportion of European males (56.8% of boys vs. 27.5% of girls) met the physical activity recommendations of at least 60 minutes/day of MVPA. The *Canadian Health Measures Survey* (CHMS) shows 7% of adolescents attain this level of activity (>60 minutes of MVPA every day). Much higher percentage (44%) has 60 minutes of MVPA at least 3 days a week (Colley et al. 2011).

According to the afore-mentioned data, one crucial question surfaces in this context. Are youth “active enough”? In other words, are these levels of physical activity low enough to be contributing to the youth obesity epidemic? For example, a cross sectional analysis of the *European Youth Heart Study* data showed that 116 minutes per day and 88 minutes per day of MVPA were necessary in 9- and 15-year-olds, respectively, to avoid increased risk of a cluster of cardiovascular disease risk factors, including obesity (Andersen et al. 2006). On the other hand, in a cross-sectional study of 11-year-old children in the *Avon Longitudinal Study of Parents and Children*, 35 minutes per day (boys) and 23 minutes per day (girls) of MVPA were insufficient to avoid increased risk of obesity compared to that in children who participated in MVPA 55 minutes per day (boys) and 37 minutes per day (girls). Therefore, it appears that only youth currently in the top quintile of MVPA are likely to avoid obesity and other elevated cardiovascular disease risk factors (Riddoch et al. 2007). It should be noted, however, those two studies applied different analytical techniques for moderate-to-vigorous physical activity assessment.

Extra-curricular sports participation is probably one of the best ways to attain the recommendations for physical activity (Seabra et al. 2007), and may even be the only way to attain a vigorous level of exercise. These physical activities are performed systematically in schools and sporting clubs. They usually involve 3 hours per week plus weekend competition. Therefore, it is important to investigate which sports are practised most, the different participation of males and females, and the factors that affect their participation.

2.5. Sport participation during adolescence

Sport has high social valence and is a primary context for physical activity for the majority of youth. Moreover, the number of youth competing in sports at national and international levels continues to increase in several countries around the world. Approximately 40 million of U.S. youth participated in organized sport in 2008 (National Council of Youth Sports 2010). This number approximates about 76% of the kindergarten through grade 12 (high school) enrolments in the United States. In Australia, almost two-thirds of youth aged 5–14 years participate in organised sports outside of school hours (Hardy et al. 2010). Corresponding estimates for other countries vary due in part to differences in estimation strategies and to differences in program structure, accessibility and cost. In Portugal, programs for systematic training and organized competition in sport are widespread and apparently increasing (e.g., the number of participants in the practice of sport increased by 24.3% (116759 to 145148) from 1998 to 2004 (Adelino et al. 2005).

There are numerous objectives of youth sport programs that are typically stated in general terms and emphasize the enjoyment, wellbeing, health, fitness and social development of participants. Youth sports have been more recently invoked as a potentially important means to combat the worldwide epidemic of childhood overweight and obesity through the provision of regular physical activity (Malina 2009). Given the seemingly central role of organized sport in the lives of youth, a question of relevance is the habitual physical activity of youth sport participants and non-participants. Evidence based on three day diary records in boys and girls 12-14 years (Katzmarzyk and Malina 1998), accelerometry in 119 boys 6-12 years (Wickel and Eisenmann 2007), questionnaires in U.S. boys and girls 11-12 years (Trost et al. 1997) and also in Finnish twins 16-18 years (Aarnio et al. 2002a; Aarnio et al. 2002b) indicate higher levels of physical activity in sport participants compared to non-participants. In addition, Portuguese participants who engaged in organized physical activity reported more moderate-intensity and moderate-frequency team activities, whereas adolescents in non-organized physical activities reported more low-intensity and moderate-frequency individual activities (Santos et al. 2004).

Age and sex differences in organized sport

The national representative study of Portuguese adolescents performed by Seabra and colleagues (Seabra et al. 2007) revealed that high intensity sports were more prevalent among males, while sports of mid-level intensity were more prevalent among females, and the majority of youth participate in sport more than 9 months of the year. That study pointed out soccer as the most practiced sport among males, while swimming and soccer were the most practiced sports among females. In the *Avena Study* (Gracia-Marco et al. 2010), the five most prevalent sports were soccer, indoor soccer, basketball, cycling, swimming or tennis for Spanish males; and swimming, aerobics, basketball, cycling, and light gymnastics for Spanish females. According to Katzmarzyk and Malina (Katzmarzyk and Malina 1998), participation rates for sport teams (not sponsored by the school) in a sample of U.S. adolescents were 30% and 29% for males and females, respectively. Gender differences in sport participation are usually explained by the less available activities for females. Gender roles may also still be part of the explanation because the male role implies instrumental activities involving physical strength and exertion, and competitive sport activities whereas the female role implies care-dominated activities involving social and emotional skills (Malina 2009).

In general, participation in sports seems to increase with educational attainment both as a result of the longer time period in which one has been familiarized with sports in the framework of compulsory sports lessons and as a result of better insights into the connection between sporting activity and health (Van Tuyckom et al. 2010). In addition, trends in youth's participation in organized physical activity over the course of childhood and adolescence have been investigated both cross-sectionally and longitudinally, and results have generally shown a decline in sports participation over the life-course. For example, data from the *National Longitudinal Survey of Children and Youth in Canada* suggest that children's organized physical activity tend to peak in middle childhood and decline into adolescence (Findlay and Bowker 2009). A prospective investigation of 1293 adolescents initially aged 12-13 years from Montreal (Belanger et al. 2009) was conducted for 5 years and shows that participation in almost all physical activities declined during adolescence. Further, sustained participation in a specific activity related both to its intensity (90%, 73%, and 40% of girls and 77%, 86%, and 60% of boys sustained participation in light-, moderate-, and vigorous-intensity activities, respectively) and its format (41% and 89% of girls and 69% and 90% of boys sustained participation in team and individual physical activities, respectively). Specifically on organized sports, the *Norwegian Longitudinal Health Behavior Study* (Kjonniksen et al. 2008), a 10-year longitudinal study of 630 adolescents surveyed eight times from age 13 years, revealed that organized youth sports during childhood and adolescence was positively related to frequency of leisure-time physical activity in young adulthood. However, the correlation coefficients tended to be higher among males and decreased over time both in females and males. Results from the *Youth, Education, and Society* study of U.S. youth (Johnston et al. 2007) revealed only a fraction of all students participate in varsity sports during the school year, with girls participating only slightly less than boys (33% vs 37%). Furthermore, participation rates in intramural sports were even lower, declined in higher grades, and were lower among low-SES and Hispanic students (Johnston et al. 2007). Despite a decline in participation into adolescence for the majority of children, some boys (26%) and girls (24%) maintain a stable level of participation from early childhood through adolescence (Findlay and Bowker 2009).

Contribution of organized sport to active lifestyles

Sports participation as a component of health enhancing physical activity is an important public health issue and the benefits of an active and sporting lifestyle in relation to well-being and health have been strongly emphasized worldwide. The literature, however, currently lacks an examination of the impact of sport participation on daily energy expenditure of youth and, accordingly, reflecting of sufficient duration and intensity to prevent overweight and obesity. Studies strictly conducted in U.S. demonstrated that organized sports contributed to 23% of time spent in MVPA in boys 6-12 years (Wickel and Eisenmann 2007) and to about 65% of the daily EE in MVPA in boys 12-14 years (Katzmarzyk and Malina 1998). In addition, among Australia youth, participation in organised sports at school and at clubs/associations is an important part of their total physical activity, contributing between 50–70% and 40–50%, respectively, of their total physical activity (Hardy et al. 2010).

On the other hand, studies have also revealed that during a non-sport day, participants engaged in significantly more sedentary activity and significantly less moderate and vigorous activity compared with the sport day (Wickel and Eisenmann 2007). It is usually accepted that time spent on media-based sedentary behaviours such as screen time (e.g. time spent playing video games, TV viewing or internet surfing) might otherwise be spent in active behaviours. Given the limited amount of "free time" students have during the school year, those students who chose to participate in organized sports likely had limited time to devote to less active pursuits such as television viewing (Katzmarzyk and Malina 1998). As such, organized sport participation might be a significant outlet for energy expenditure among youth since it is also related to less physical inactivity in the form of television viewing (Katzmarzyk and Malina 1998), However, results are somewhat inconsistent. In Brazil, for example, regular participation in sports was positively associated with a higher frequency of walking and cycling during leisure time, while the frequency of TV viewing was not associated with participation in sports (Fernandes et al. 2010).

2.6. Sedentary behaviour among young people

An issue of equal importance, that has received comparatively less attention, is the potential sex and age differences in physical inactivity or sedentary behaviour. The most common approach to the study of inactive lifestyles has been examining on highly visible and prevalent sedentary behaviours such as television viewing and use of other screen based media.

Screen time

TV viewing is a common pastime among young people, with, for example, 65% of US youth watching TV for two or more hours per day and 25% watching TV for more than four hours per day (Eisenmann et al. 2002). It is important to highlight that the survey responses indicate an inordinately high amount of time spent watching TV with, for example, an exposure of 2.8 hours per day in Italian adolescents aged 11 to 16 years (Patriarca et al. 2009), and 3.1 hours in youth aged 12 to 13 years in the United States (Jordan et al. 2006). However, substantially lower exposure was reported by the *European Youth Heart Study* with 1.9 hours per day in boys and girls aged 15-16 years from three regions in Europe (Ekelund et al. 2006), and 2.2 hours per day in children aged 11–14 years in France (Lioret et al. 2007). Television viewing hours per week were similar between genders in the *Avon Longitudinal Study of Parents and Children* (Mitchell et al. 2009). However, the *Healthy Lifestyle in Europe by Nutrition in Adolescence Study* (Rey-Lopez et al. 2010) showed that males spent more hours on TV viewing (for ≥15 years, at the weekend), playing computer games and console games, while females spent more time studying and surfing for non-study reasons. During week days, one third of adolescents exceeded the screen time guidelines (>2 hours/day) based solely on TV viewing, whereas around 60% exceeded it at the weekend. In addition, having a TV or a console in the bedroom was associated with higher TV viewing (OR=2.66; 95% CI 2.23–3.18; and OR=1.92; 95% CI 1.61–2.28, respectively) whereas the presence of computer reduced it (OR=0.57; 95% CI 0.48–0.68) (Rey-Lopez et al. 2010). This study also revealed that adolescents living in Europe are not meeting media recommendations, especially at the weekend. The authors agree that the absence of a TV in the adolescents' bedroom, for example, might reduce TV viewing. International comparisons, however, should be taken with caution mainly because of differences across the studies such as, for example, the characteristics of the sample and the study's methodology.

Results from a systematic review (Marshall et al. 2006) revealed that most young people watch approximately 2 - 2.5 hours of television each day, and of those with access to computers and video games, a further 0.5 and 0.75 hours respectively, is spent using these technologies. In addition, while the majority of young people may be considered “low users” of TV (≤2 hours/day), 28% watch more than 4 hours/day, which is double the maximum dose recommended by the *American Academy of Pediatrics* (American Academy of Pediatrics 2001). “High users” (>4 hours/day) of both television and video games are more likely to be male which suggests that behavioural preferences are gender specific (Marshall et al. 2006). Age-specific data suggest TV viewing decreases during adolescence, but those considered “high users” at young ages are likely to remain “high users” when older. Although trends show small declines in absolute values of TV viewing during mid-to-late adolescence and across cohorts (Marshall et al.

2006), a recent review data suggest that TV viewing is a relatively stable behaviour (Biddle et al. 2010).

Screen time and health markers

Nevertheless, there is a wide agreement that a sedentary lifestyle is related to negative health outcomes such as heart disease, diabetes, and obesity (Hume et al. 2010; Ekelund et al. 2006). Furthermore, it has been shown that high level of TV viewing during adolescence is a strong predictor of risk of obesity in adulthood (Boone et al. 2007). Extensive television viewing and computer use are consistently associated with overweight and obesity in North American (Mark and Janssen 2008), Canadian (Tremblay et al. 2010) and in European (Ekelund et al. 2006; Hume et al. 2010) youth. Therefore, reducing screen-related sedentary behaviour is essential to prevent and treat youth obesity. Several health professional organizations, including the *Canadian Pediatric Society* and the *American Academy of Pediatrics* recommend that children spend no more than 2 hours per day in screen-related sedentary activities.

It seems consensual the relationship between screen time, as an independent factor, with health markers. For example, data from the *National Health and Nutrition Examination Surveys* showed that screen time was associated with an increased likelihood of the metabolic syndrome in a dose-dependent manner independent of physical activity (Mark and Janssen 2008). Furthermore, results from the *European Youth Heart Study* also revealed that television viewing time was independent correlated to the body weight and level of fatness in youth (Andersen et al. 2006). The observation that physical activity had little or no impact on the relation between screen time and metabolic syndrome is consistent with findings that physical activity and screen time behaviours are poorly or unrelated in youth (Ekelund et al. 2006; Mark and Janssen 2008). Data from the *European Youth Heart Study* showed that television viewing time was correlated to metabolic syndrome components after adjustment for physical activity (Ekelund et al. 2006). It should be noted, however, that some studies only considered television time and did not measure neither other important components of screen time such as computer and video game use nor sedentary behaviour objectively. Sedentary behaviour assessment is also an essential issue to understanding the meaning of those behaviours on health of young people.

Time spent sedentary objectively measured

The literature has been highlighted, not only among adults (Healy et al. 2008) but also among youth (Olds et al. 2010a), that sedentary behaviour is clearly more than screen activities. Objective data from a recent research performed by Healy and co-workers (Healy and Owen 2010) showed the average proportion of waking hours spent sedentary differed among age groups, with children as the least sedentary (44%), followed by adults (56%), adolescents (58%), and older adults (65%). These data reveal a problematic concern among adolescent people in terms of time spent sedentary. Among youth, it has been recognized that much attention has been paid to youth's screen time and very few studies have examined non-screen sedentary time. Assessment of television viewing, computer games, internet use provide only a partial picture of overall levels of sedentary behaviour in a typical day.

From the point of view of clinical and educational intervention design, screen time assessment is an attractive target for several reasons. As previously mentioned, increased screen time is known to be associated with excessive adiposity in young people (Ekelund et al. 2006; Mark and Janssen 2008; Tremblay et al. 2010) and, therefore, reducing that sedentary behaviour may help address the issue of youth overweight and obesity. However, TV viewing and computer use are not the only form of sedentary behaviour in adolescents, who also spend substantial amounts of time sitting in school classes, riding in cars, eating, socialising, reading and studying. This non-screen sedentary time has been relatively understudied (Biddle et al. 2010). For example, television time was negatively associated with other leisure time sedentary behaviours (comprising computer use, sitting and talking, listening to music, reading, behavioural hobbies and homework), revealing that television viewing did not reflect additional time in other sedentary behaviours among UK adolescents (Biddle et al. 2009a). More recently, Olds and colleagues (Olds et al. 2010a) described the magnitude and composition of screen sedentary time and non-screen sedentary time (NSST) in Australian adolescents. Youth spent a mean of 345 minutes per day in NSST, which constituted 60% of total sedentary time. School activities contributed 42% of NSST, socialising 19%, self-care (mainly eating) 16%, and passive transport 15%. Because screen time was negatively correlated with NSST (r=-0.58), and exhibited a moderate correlation (r=0.53) with total sedentary time, screen time was only a moderately effective surrogate for total sedentary time.

The average amount of daily sedentary time in European adolescents from nine countries was objectively assessed in the *Healthy Lifestyle in Europe by Nutrition in Adolescence Study (HELENA Study)* (Ruiz et al. 2011). Results show adolescents spent most of the registered time in sedentary behaviours (9 hours/day, or 71% of the registered time), and boys were less sedentary than girls. Furthermore, sedentary time was higher in older adolescent boys and girls (2.3% and 1% per age group increase, respectively). It should be also highlighted that sedentary time also differed between European regions; it was significantly lower in adolescent boys and girls from Central-Northern Europe (2.5% and 2.9%, respectively). Adolescent boys from Southern Europe and Central-Northern Europe spent 69.8% and 68.4% of their registered time in sedentary behaviours, respectively, whereas adolescent girls spent 72.9% and 71.0% of their registered time, respectively. These findings persisted after further adjustment for age, and BMI (Ruiz et al. 2011).

2.7. Biological maturation as a confounding factor

Although sex differences in physical activity are well documented, the potential confounding effects of sex differences in biological maturity status on estimates of physical activity have not received much attention. Most studies have compared boys and girls of the same chronological age without considering sex differences in biological age which could contribute to sex differences in activity (Baxter-Jones et al. 2005). Biological maturation is a factor that may contribute to sex differences in physical activity and refers to progress toward the mature state, which can be discussed in terms of variation in timing - when events occur, and tempo - rate (Beunen et al. 2006; Malina et al. 2004). Age for age, females are, on average, advanced in biological maturity status when compared to males. Indeed, girls generally enter puberty and reach adulthood two years in advance of boys. As physical activity in males and females decrease with chronological age, at least beyond the age of 7 years, it is reasonable to assume that sex-differences in physical activity or sedentary behavior might be attributable to the fact that girls mature earlier than boys (Malina et al. 2004).

Indeed, sex differences in self-reported physical activity were eliminated when adolescents were grouped by biological rather than chronological age in a longitudinal sample of Canadian youth (Thompson et al. 2003) and attenuated and non-significant when biological age was statistically controlled in a sample of British adolescents (Cumming et al. 2008). Both studies utilized non-invasive estimates of maturity status, predicted years from age at peak height velocity (APHV) and percentage of predicted mature height attained, respectively. Employing an objective measure of physical activity, sex differences in MVPA in Canadian youth 8-13 years were apparent emerged when participants were grouped by chronological age but not apparent when grouped by biological age, years from predicted APHV (Sherar et al. 2007).

A recent review paper, performed by Sherar and colleagues (Sherar et al. 2010), revealed that the influence of biological maturity on the decline process of physical activity during adolescent years has been largely overlooked. Moreover, results from the available research are generally inconsistent among studies, and associations, when noted, are generally low. In general, data are limited by small sample sizes, lack of consideration of interacting and/or mediating influences, and quality of assessments of maturity and physical activity. Therefore, future research needs to adopt a more sophisticated study design and analytical approach (such as structured equation modeling) to unravel underlying mechanisms that have an impact on physical activity behaviour.

In contrast to physical activity, potential sex differences in physical inactivity or sedentary behaviour have received less attention. Among a large cohort of 11-years-old children from the *Avon Longitudinal Study of Parents and Children* (Riddoch et al. 2007) and adolescents from the *Canadian Health Measures Survey* (Colley et al. 2011) have shown that girls are more sedentary than boys who spent more time in light activities. In addition, these sex-differences in sedentary activities are especially evident on week days (448 minutes/day for females and 425 minutes/day for males) (Mitchell et al. 2009). However, both of these above-mentioned studies did not examine the potential confounding effect of biological maturity on sex differences in sedentary behavior.

To date, the potential confounding effect of maturation on sex differences in sedentary behaviour has not been addressed during the pubertal years. In one of the few studies that included measures of sedentary behaviour and biological maturation, sedentary habits increased with stage of self-reported (questionnaire) pubertal status between 10 and 15 years (Murdey et al. 2005). Given the limited research examining the role of maturation relative to sex differences in sedentary behaviours, and since recent advances of objective technological systems for measuring physical activity (such as accelerometry) allow monitoring a wide range of intensities of the activity variables with considerable precision, further research is needed to examine the contribution of somatic maturation to sex differences of sedentary behaviour and physical activity in adolescents.

2.8. Physical activity and socio-economic status

Societies develop and maintain systems of social stratification along multiple dimensions, where socioeconomic conditions are one of the most important. Unequal distribution of resources and social goods lead to different degrees of economic, political, social and cultural advantage among groups, which may then be translated into differences in health (Galobardes et al. 2007). Substantial research usually shows that healthy lifestyles and quality of life are associated with socioeconomic status (SES), with more well-off people experiencing better health outcomes than less well-off individuals and groups (Gauvin 2010).

The literature on SES and physical activity relationships is somewhat scarce, however there is growing recognition that SES disparities as they relate to both physical activity and health it has been considered in programs of health promotion and disease prevention. As such, the focus of intervention has been particularly emphasised among low SES people.

Education and income have been the most commonly criteria used to represent SES (Gidlow et al. 2006). Data derived from the *Italian National Health Interview Survey* (15216 individuals aged 6–17 years) showed children and adolescents whose parents held a middle or high educational title were 80% more likely to practice moderate or vigorous physical activity than subjects whose parents had a lower level of education (OR=1.80, 95% CI: 1.40–2.33), while subjects with unemployed parents had an odds of practicing moderate or vigorous physical activity 0.43 times that of those children whose parents belonged to the top job occupation category (administrative/professionals) (Federico et al. 2009). Data from the *Canadian Community Health Survey* also show that adolescents from low income families were less physically active (odds ratio=1.30, 95% CI=1.29-1.32) than those from high income families (Mo et al. 2005). Additional research confirms the a positive relationship between youth physical activity and their families' SES, particularly, in extra-curricular physical activity (La Torre et al. 2006).

More specifically, mothers with higher levels of education are more likely to engage in health-promoting behaviour; thus, it is intuitive that a child's physical activity would be positively related to maternal education (Desai and Alva 1998). Parents serve as the most important behavioural role models from early childhood through to the teen years (Sherar et al. 2009). The literature on this area, however, is somewhat inconclusive with some studies showing a positive relationship between maternal and youth's physical activity (Butcher et al. 2008; Gordon-Larsen et al. 2000; Hesketh et al. 2006; Lasheras et al. 2001), and others showing no relationship (Riddoch et al. 2007; Sallis et al. 2002). Potential factors on that disagreement between studies may be linked to the methods used to assess physical activity (i.e. the use of aggregated and self-reported physical activity that may not reflect the true and detailed variation of physical activity).

In Portugal, mainly in the North, studies have demonstrated controversial impact of SES on physical activity (Mota and Silva 1999; Santos et al. 2004). In a sample of 498 adolescents aged 14 years, no evidence was found regarding the influence of socio-economic status on adolescents' self-reported physical activity (Mota and Silva 1999). In contrast, Santos and co-workers (Santos et al. 2004) showed that adolescents from Portuguese families of higher socioeconomic status chose significantly more organized activities. Furthermore, in sub-groups by weight status, educational status of father (r=0.23) and mother (r=0.18) was positively and significantly associated with active obese girls (Mota et al. 2009b). Complementarily, girls assigned to the higher SES group were more likely (OR=2.4; 95% CI = 1.3-4.5) to belong to the active group than their low SES peers. In general, Portuguese data show that lower SES is associated with less active adolescent people, and knowing the impact of the health education on active lifestyles could be an important way to promote physical activity among youth.

In summary, it should be noted that diverse and often crude physical activity and socio-economic measurement made it difficult to distinguish between artefact and true effect in a relationship with so many potential confounding influences. However, there was consistent evidence of a higher prevalence or higher levels of leisure-time or moderate–vigorous intensity physical activity in those at the top of the socio-economic strata compared with those at the bottom.

2.9. Physical fitness, physical activity, and BMI in youth

Physical fitness is generally viewed as having morphological, muscular, motor, cardiovascular and metabolic components (Shephard and Bouchard 1994). Cardiorespiratory fitness (CRF), the capacity of the cardiovascular and respiratory systems to carry out prolonged strenuous exercise, is often considered the most important health indicator (Ortega et al. 2008), although it is related to and influenced by other components of fitness. Cardiorespiratory fitness as reflected in absolute maximal oxygen uptake (peak VO2) improves, on average, with age during childhood and adolescence in males and during childhood females, and tends to reach a plateau or decline slightly during adolescence in females. Per unit mass, however, cardiorespiratory fitness is stable from childhood through adolescence in males, and declines with age in females (Malina et al. 2004).

Cardiorespiratory fitness level concern

Of significant concern regarding parameters of fitness is the notable trend, in almost 130000 6- to 19-year-old youth of both genders from 11 developed countries, in the overall decline of aerobic performance (Tomkinson et al. 2003). The rate of decline was similar for both boys and girls and was most evident in older age groups. Evidence based primarily on distance runs suggests that the aerobic fitness of youth has declined by 0.36% to 0.43% per year over the past 40 years (Olds et al. 2006; Tomkinson et al. 2007). This comprehensive review (Olds et al. 2006) revealed wide variation in fitness levels; children in Northern European countries (Estonia, Iceland, Lithuania, and Finland) were the most fit, whereas children from Singapore, Brazil, the United States, Italy, Portugal, and Greece were the least fit. Gender differences in the final completed stage of the 20 metres shuttle run tests reveal the increasing differences in aerobic performance as boys and girls move through puberty. There was evidence that performance for boys and girls was negatively related to fatness.

Data from a recent survey (Sandercock et al. 2010) indicates a larger decline in cardiorespiratory fitness in British males (7%) and females (9%) over a 10 year period. This represents a significant public health problem because low physical fitness during adolescence tends to track into adulthood, and unfit adults are at increased risk for chronic disease morbidity and mortality (Pate et al. 2006). The secular decline in cardiorespiratory fitness is attributed, in part, to a reduction in habitual physical activity and the increased prevalence of overweight and obesity among youth (Malina and Katzmarzyk 2006; Pate et al. 2006).

Cardiorespiratory fitness, physical activity, and BMI

Examining research on active lifestyles and fitness over the past decade revealed that the most commonly studied aspect of this topic focused on the relationships of physical activity, aerobic fitness, sedentary behaviour and the development of obesity in youth. Associations between aerobic fitness and indicators of fatness with some risk factors have been found in childhood and adolescence (Ortega et al. 2008). Recent epidemiologic studies suggest high levels of cardiorespiratory fitness may offset much of the excess mortality risk, and is negatively associated with body fatness (Hussey et al. 2007; LaMonte and Blair 2006; Lohman et al. 2008; McGavock et al. 2009). However, the effect of overweight on health-related physical fitness varies with the component of fitness being analyzed. In spite of having poorer muscular strength and CRF, overweight adolescents tend to have similar flexibility and even better isometric strength compared with normal-weight adolescents (Mak et al. 2010). Previous studies in Portuguese youth (Mota et al. 2006; Mota et al. 2002) suggested that cardiorespiratory fitness assessed by no laboratory test was inversely and significantly associated with BMI. These findings also agree with other studies of US (Pate et al. 2006), Canadian (Katzmarzyk et al. 1998a; McGavock et al. 2009), and European (Ara et al. 2007; Hussey et al. 2007) adolescents. Further, by following a cohort in studies with longitudinal design it has been shown that reductions in cardio-respiratory fitness over time were positively associated with weight gain (Mota et al. 2009a).

On the other hand, physical activity and physical inactivity are also correlates of cardiorespiratory fitness among youth. Correlations between cardiorespiratory fitness and habitual physical activity (based largely on questionnaires) are moderate at best (Gutin et al. 2005; Katzmarzyk et al. 1999; Katzmarzyk et al. 1998a), while the relationship of cardiorespiratory fitness and physical inactivity has received less attention (Hussey et al. 2007; Katzmarzyk et al. 1998b). Although using objective measure of physical activity, Dencker and colleagues (Dencker et al. 2006) showed a weak, but positive, relationship established between daily physical activity and VO_{2PEAK}, while a stronger relationship was found when aerobic fitness was related to time spent performing vigorous physical activity (r=0.32 for males, r=0.30 for females). Gutin and co-workers had already noted that more variance is explained by vigorous than moderate physical activity (Gutin et al. 2005). In the *Quebéc Family Study*, only 11-21% of variance in fitness items was explained by physical activity variables (Katzmarzyk et al. 1998a). Socio-economic factors related to parental education and occupation and living conditions may also play an important role to understanding cardiorespiratory fitness and health-related behaviours of adolescents, although the literature in this area is equivocal (Riddoch et al. 2007).

Allowing for limitations of secular comparisons of cardiorespiratory fitness, weight status, especially excess weight-for-height, is an important factor affecting CRF in youth (Malina et al. 2004). The prevalence of overweight in youth worldwide has substantially increased (Lobstein 2010; Lobstein et al. 2004), and it is often assumed that the increase in the prevalence of obesity is associated with decreased levels of physical activity and cardiorespiratory fitness in youth (Pate et al. 2006). Obese children tend to be less fit than their non-obese peers (Chatrath et al. 2002). In addition, cardiorespiratory fitness is associated with total and abdominal adiposity (Ortega et al. 2008) and other indicators of obesity (Kim et al. 2005) in youth. Variation in associations among physical activity, adiposity and health outcomes, including CRF are dependent, in part, on methods of assessments of the respective parameters.

2.10. Geographic context, physical activity, cardiorespiratory fitness, sedentary behaviour and BMI in young people

In the past several years, the interest has grown in rural health issues by the acknowledgement that, in general and compared to urban communities, rural communities have limited access to health care, suffer more preventable morbidity and mortality and have lower numbers and diversity in specialty of health professionals per population (Muula 2007).

Demographic statistics show an evident concentration of the Portuguese population in the metropolitan areas combined with a shift from an agriculture-based economy into services (Barreto 2000). In the past decades, the proportion of the world's population living in urban areas has grown from 14% to over 50% (Ezzati et al. 2005). A similar trend has been verified in Portugal for the last four decades where over 45% of people are living nowadays in both biggest metropolitan areas of Lisbon and Oporto (Barreto 2000; INE 2001).

Knowledge about the distinctive patterns and risks that may exist in rural and urban environments/communities is somewhat scarce and controversial. While in rural areas health status is poorer than in metropolitan areas (Dixon and Welch 2000), it is unclear how much of this differential results from biological factors, structural determinants of health or lifestyle behaviours. Rural life does not necessarily encompass physically demanding tasks anymore and may be a factor in the higher incidence of obesity in rural areas.

Definition of rural vs. urban

There is no one universal definition of a rural area. This makes comparisons of data from differently defined areas problematic. Definitions of rural area have been particularly based on population size, access to health care and socioeconomic variables. The literature strongly suggests that the appropriate definition should be determined by the question being addressed. For national level analysis in Canada (Plessis et al. 2001), for example, several alternative definitions of "rural" are available: (1) rural refers to individuals in towns or municipalities outside the commuting zone of larger urban centres (with 10000 or more population); (2) rural communities refer to individuals in communities with less than 150 people per square kilometre. This includes people living in the countryside, towns and small cities; (3) non-metropolitan regions refer to individuals living outside metropolitan regions with urban centres of 50000 or more population.

In U.S., the Oregon system for classification of counties, for example, has the following definitions: (1) urban areas: counties within *Metropolitan Statistical Area*, with population of 1000 inhabitants or more per square mile; (b) Mixed urban-rural: emerging urban areas with a population density of 60 to 99 inhabitants per square mile; (c) rural: a population between 10 and 59.9 per square mile; (d) frontier: 0.5 to 9.9 inhabitants per square mile; (e) remote: counties with 0.4 or less inhabitants per square mile (The Association of Maternal Health Programs 2004). In addition, even within Oregon State, another categorization scheme presented by Crandall and Weber (Crandall and Weber 2005) is in use. It identifies the urban area: an area with 50 000 or more residents and the surrounding areas within 10 miles; (b) urban-rural: a community at least 10 miles from an urban area; (c) rural: a community located at least 30 miles from an urban community, there are some commercial activities, and reasonable but not immediate access to health care; (d) isolated rural: an area at least 100 miles from a community of 3000 or more individuals; (e) frontier-rural: a rural area that is at least 75 miles from a community of less than 2000 individuals. The *US National Rural Health Association*, however, defines frontier counties as counties with less than six persons per square mile (Crandall and Weber 2005; Rourke 1997).

The *European Commission* describes rural areas as complex economic, natural and cultural locations, which cannot be characterized by a one-dimensional criterion such as population density, agriculture or natural resources (European Commission 1999). However, rural typology of EU is less strict and regions are classified into 3 types: (1) *Densely Populated Zones*: these are groups of contiguous municipalities, each with a population density above 500 inhabitants/km², and a total population for the zone of at least 50,000 inhabitants; (2) *Intermediate Zones*: these are groups of municipalities, each with a density above 100 inhabitants/km², not belonging to a densely populated zone. The total population of the zone must be at least 50,000 inhabitants, or it must be adjacent to a densely populated zone. (3) *Sparsely Populated Zones*: these are groups of municipalities not classified as either densely populated or intermediate (Politechnico di Milano 1999).

In Portugal, *Statistical National Institute* (INE) commonly classify urban or rural settings as following: (1) urban area is defined as a city with more than 500 inhabitants/Km^2 or more than 50000 inhabitants; (2) rural area is defined as villages with no more than100 inhabitants/Km^2 or with total population under 2000 people (Monteiro 2000). The same criterion has been used in other studies of adolescents (Coelho e Silva et al. 2003).

A variety of definitions of the terms “urban”, “rural” and “remote” are in use in the literature. In most instances, the authors assume readers have specific knowledge of what is being referred to their definition of rural and remote areas. Comparing rural with urban across different countries is potentially problematic as area designation can vary from country to country, but also within countries, based on the question being addressed.

Rural-urban contrast of physical activity, cardiorespiratory fitness, sedentary behaviour, and obesity in young people

Although the association between physical activity and demographic/social factors such as gender, chronological age, race/ethnicity and educational and professional level of families has been commonly examined, geographical factors have received less attention. In fact, a factor that has been identified as a potential contributor to physical activity, sedentary behaviour, weight status, and cardiovascular fitness in youth is urbanization. This term relates to concentration of populations into towns/cities and the corresponding changes associated with this – migration, transformation of the economic and physical organization of the city, and changes in behaviour of populations due to “urban-living” (Lake et al. 2010). It has been intuitively assumed that individuals living in urban contexts would be less active, with lower levels of cardio-respiratory fitness and, therefore, would be associated to higher levels of overweight and obesity (Liu et al. 2008; Spring et al. 2006; Albarwani et al. 2009; Ismailov and Leatherdale 2010). Children and adolescents from some communities have little opportunities for walking, limited access to playgrounds and their behaviour is often associated with a lack of social autonomy in rearing style. However, the impact of urbanization on afore-mentioned variables and health is somewhat unclear (Cicognani et al. 2008; Yousefian et al. 2009). This is may be related to cultural factors, and methods of assessment and, consequently, the urban-rural contrast of physical activity, cardiorespiratory fitness and obesity may result in different heath outcomes across geographic regions (i.e., North Europe, Mediterranean countries, US, Asia or in Mexico).

Table 2.3 presents an overview of the rural-urban contrast on physical activity, aerobic fitness and obesity, and describes the criterion of geographic contexts used in each study.

Table 2.3. Overview of the rural-urban contrast on physical activity, aerobic fitness and obesity in youth.

Reference	Country	Participants	Methods	Criteria of rural vs. urban	Main results
Moreno et al. (2001)	Spain	106284 youth; 52772 males and 53512 females (aged 13–14 years).	Obesity: WHO cutoffs were used.	It was considered 10000 inhabitants as cutoff value for the analysis (urban vs rural communities).	The probability to be overweight was higher in the rural than in the urban areas.
Kristjansdottir & Vilhjalmsson (2001)	Iceland	1642 boys; 1608 girls, (n= 3270) aged 11–16-years-old.	Physical activity: self-report measure.	Residence was a trichotomous variable: (a) Reykjavík metropolitan area (49%); (b) other small- or medium-sized towns around the country (45%); or (c) in rural areas (village or farm) (6%).	Rural students were more sedentary during leisure time, and less physically active than students from urban areas.
Sjolie et al. (2002)	Norway	n=105 (14.7±0.7 years); 8th and 9th grades.	Physical activity: self-report (questionnaire of daily life activities).	(1) A rural municipality, Rendalen. School authorities informed that most pupils used school bus, due to lack of walking trails and to school centralisation; (2) An urban area within a distance of 4 km from Hanstad primary and junior secondary school in Elverum community, 120 km from Rendalen.	1. No differences were observed between the two groups in regard to activity patterns. 2. The median distance the urban adolescents walked or cycled to school was three times larger than the median distance the rural adolescents walked or cycled to bus stop or to school. 3. The urban adolescents also walked or cycled more to regular activities than the rural counterparts.
Constantinos et al. (2004)	Cyprus	256 youth (11-12 years); urban youth (n= 144, boys=73 and girls=71) and rural youth (n=112, boys=56 and girls =56).	Physical activity: pedometer (Yamax Digiwalker).	Urban schools came from the capital of Cyprus, Nicosia. Rural students came from three village schools.	1. Youth in urban schools were more active in the winter and children in rural schools were more active in the summer. 2. Students in urban schools had more exercise equipment available at home, and were more frequently transported to places where they could be physically active in both summer and winter. 3. No differences were found between the two locations on time spent watching television, frequency of sports club attendance and the frequency that parents exercised with their child.

Table 2.3. *(continued).*

Reference	Country	Participants	Methods	Criteria of rural vs. urban	Main results
Facchini et al. (2007)	Kazakh and Russian	2616 children aged ≥ 12 years.	Obesity: CDC 2000 US reference values.	Participants resided either in Almaty or in Chilik. Almaty is the biggest city of Kazakhstan, numbering 1200000 inhabitants. Chilik is a village of about 20000 inhabitants.	The authors conclude that overweight and cardiovascular risk factors are less prevalent in children living in Kazakhstan than in those living in Western countries.
Lutfiyya et al. (2007)	U.S.	Rural=2589 and Urban=5383 children and adolescents aged 5-18 yrs.	BMI: underweight, <5th percentile; normal weight, ≥5th percentile to <85th percentile; overweight, ≥85th to <95th percentile; obese, ≥95th percentile. PA: Telephone Survey (Liu et al., 2008).	Metropolitan or Micropolitan Statistical Area (MSA); This suppression occurred whenever the sum total population for all MSA areas in a given state was <500000 people or whenever the sum total population for all of the non-MSA areas in a given state was <500000 people.	Rural U.S. children ≥5 years of age of age were more likely than their metropolitan counterparts to: have no health insurance, have not received preventive health care in the past 12 months, be female, use a computer for non-school work >3 hours a day, and watch television for >3 hours a day. Living in rural areas is a risk factor for children being overweight or obese.
Constantinos et al. (2007)	Canada	Youth aged 15.6 ± 1.3 years; urban (n = 1398, boys=674, girls= 724) and rural (n = 1290, boys= 568, girls = 722).	Physical activity: self-report (*Godin Leisure-Time Exercise Questionnaire*).	Four schools in urban Ontario (i.e., suburban Toronto area) and 4 schools in rural central Alberta (within a 300-km radius of Edmonton).	1. Active commuting to school and taking a physical education class were unique correlates of physical activity at the multivariate level in urban and rural students, respectively. 2. Variance explained in physical activity ranged from 43% for urban school students to 38% for rural school students.
Xu et al. (2007)	China	6848 youth, aged 12–18 years.	TV viewing by self-report instrument.	Not available.	The proportion of overweight was significantly lower among rural students than urban students (4.5% vs. 8.9%; OR 0.49, 95% CI 0.40, 0.60). Those students who watched TV for more than 7 hours/week had a 1.5 times greater odds of being overweight relative to their counterparts who watched TV for 7 hours/week or less.

Table 2.3. *(continued).*

Reference	Country	Participants	Methods	Criteria of rural vs. urban	Main results
Liu et al. (2008).	U.S.	47757 youth aged 10-17 years.	Obesity: The 2000 CDC BMI charts as a reference. Physical activity: telephone Survey.	The 2003 Urban Influence Codes (UICs) of the Economic Research Service of the US Department of Agriculture (REF). UICs of 1 and 2, metropolitan areas, were classified as *urban*, while all other UICs were classified as *rural*.	1. Overweight status was more prevalent among rural (16.5%) than urban children (14.3%). 2. Rural children had higher odds of being overweight than urban children (OR: 1.13; 95% CI: 1.01-1.25). 3. Minorities, children from families with lower socioeconomic status, and children living in the South experienced higher odds of being overweight. More urban children (29.1%) were physically inactive than rural children (25.2%).
Bruner et al. (2009)	Canada	4851 adolescents from 169 schools, aged 11-15 years.	BMI cut-points endorsed by the International Obesity Task Force were used Physical activity: self-report measure.	Urban/rural status was coded on five categories: 1) Large metropolitan regions with a population greater than one million; 2) Medium metropolitan regions (medium metro) with a population between 250000 and 999999; (3) Small metropolitan regions (small metro) with a population between 50000 and 249000; (4) Nonmetro-adjacent regions that has a population greater than 50000; (5) Nonmetro-nonadjacent (rural) regions has a population lower than 50000.	1. After adjusting for age, sex, socioeconomic status, and Region of Canada, there was a trend for increasing overweight and obesity among adolescents as the level of ‘‘rurality’’ increased. 2. There were no strong or statistically significant associations observed between physical activity or unhealthy diet with geographic location after adjustment for age, sex and SES. 3. Findings suggest that obesity prevention interventions should be particularly aggressive in rural areas.
Albarwani et al. (2009)	Oman	245 males 284 females (15-16 years).	Physical activity: Self-report (IPAQ). CRF: 20-m shuttle run test.	Ministry of Planning criteria Urban schools: part of the inner-city capital, Muscat, with transportation, internet, fast-food amenities; Rural schools: from small villages (over a mountainous terrain or in coastal areas), without paved road, telephones, and piped water and have intermittent electricity supply and one channel of national television.	1. Urban boys and girls had significantly higher BMI than their rural peers. 2. Urban boys and girls spent significantly less weekly hours on sports activities and significantly more weekly hours on TV/computer games than their rural counterparts. 3. Urban boys and girls achieved significantly less VO2max than rural boys and girls.

Table 2.3. *(continued).*

Reference	Country	Participants	Methods	Criteria of rural vs. urban	Main results
Constantinos et al. (2009)	Cyprus	N = 676 7th to 9th grade class.	Physical activity: self-report measure.	Rural schools (4) were located outside the towns in smaller communities; Urban schools were located in 4 towns in Cyprus (2 schools in Nicosia, 2 schools in Limassol, 1 in Paphos, and 1 in Larnaca).	Children from rural schools reported higher friend support for physical activity and more ease of walk to a bus station from their home. Urban school children reported higher presence of sidewalks in their neighbourhood.
Luo et al. 2009	China	24194 urban youths and 7130 rural youth aged 12–18 years.	BMI was used without cutoffs.	Rural area: it is a typical mountain area with little industry and almost all the people living by agriculture. Urban area: the largest urban area in Hunan province.	Both male and female youth from urban areas were significantly taller than youth from rural areas in both the 1990s and 2000s, except for the female 15–18 years subset from rural areas. Similar results were obtained for BMI.
Roman et al. (2009)	Spain	819 male and 856 female children and youth aged 6 and 18 years.	Physical activity: self-report measure. BMI by following cutoff points: 85th percentile for overweight and 97th percentile for obesity.	Geographical area of Spain was analyzed; size of the population of residence as follows: <10,000; 10–50,000; 50–350,000; >350,000.	Low energy expenditure due to physical activity at school was related to obesity among boys from a high socioeconomic level and among boys living in cities of 50000–300000 inhabitants. No significant relationships were found in females.
Ismailov & Leatherdale (2010)	Canada	N=25416; 50.8% males; 49.2% females.	(BMI) was calculated using self-report measures of eight (kg) and height (m) and classified with CDC guidelines and growth charts. Physical activity: self-report measure.	Not available.	1. The prevalence of overweight in urban, suburban and rural areas was 14.6%, 13.8% and 15.1%, respectively, while the prevalence of obesity was 6.3%, 6.0% and 6.7%. 2. There was a larger proportion of those male adolescents who watched TV for 3 hours and more in urban (37.0%) and suburban (36.9%) areas, while among females, this number was highest among those living in the suburban (27.0%) area and lowest in the rural (25.2%) area.

The literature have often documented higher levels of overweight and obesity among rural school youth of both genders than among their urban peers in the United States (Liu et al. 2008; Lutfiyya et al. 2007), Canada (Bruner et al. 2008; Ismailov and Leatherdale 2010), and in Spain (Moreno et al. 2001). In contrast, adolescents of both genders from urban communities were more likely to be classified as overweight and obese than their rural peers in China (Xu et al. 2008), in Kazakhs and Russia (Facchini et al. 2007), and in Oman (Albarwani et al. 2009). Other studies showed that male and female rural adolescents were less physically active than their urban peers in U.S. (Liu et al. 2008; Lutfiyya et al. 2007) and Iceland (Kristjansdottir and Vilhjalmsson 2001), while studies from other contexts revealed opposite results in Oman (Albarwani et al. 2009). Further research in U.S. also revealed urban youth of both sexes were more likely to be sedentary than rural youth (Liu et al. 2008), while other studies revealed that U.S. students from the South reported the lowest prevalence of physical activity and the highest prevalence of TV watching in contrast with adolescents from the West region (Springer et al. 2006). Complementary research revealed no differences among active behaviours between youth of both genders from different geographic contexts in Sweden (Sjolie and Thuen 2002).

Contrasting results were also found in physical fitness among urban and rural contexts, particularly in its cardiorespiratory component, where youth from rural were more likely to be classified as fit than their urban counterparts in Spain (Chillon et al. 2011), Oman (Albarwani et al. 2009) and Australia (Dollman et al. 2002). In contrast, Mexican youth from urban areas revealed better performance in the endurance run test than their counterparts from rural areas (Reyes et al. 2003). Further, in Belgian (Taks et al. 1991) small motor and somatic differences were noted between rural and urban youngsters. Therefore, more research is needed to improve our understanding of how CRF and active lifestyles relate to weight status in specific socio-geographic contexts to define educational and clinical interventions.

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CHAPTER III

Methods

3. METHODS

3.1. Study design and sampling

The *Midlands Adolescent Lifestyle Study* (MALS) was part of a cross-sectional survey of the prevalence of overweight/obesity in Portugal (Sardinha et al. 2010). All administrative regions of mainland Portugal (Alentejo, Allgarve, Midlands, Lisbon and North) were surveyed. The population was selected by proportionate stratified random sampling taking into account the location (region) and the number of students by age and gender in each school. *MALS* is a school-based survey that comprised 492 adolescents (264 girls and 227 boys aged 13-16 years) resident in the Portuguese Midlands, in grades 7 through 9, from seven secondary schools where accelerometer-based data were specifically collected.

The first visit to the schools occurred on a Wednesday and was used to explain objectives of the study; to measure height and weight; and to distribute the diary and accelerometers with specific directions for each one. In addition, a familial questionnaire was used to collect information about parents´ morphology (e.g., height and weight) and various types of socio-economic variables, such as educational background of parents or type of residence. Each school had a master's level graduate student who was in charge of monitoring the protocol. Participants were contacted at school on Thursdays and Fridays to ensure adequate completion/application of the diary and accelerometer and/or to address potential problems. The instruments were collected for analysis on the following Tuesday.

The study was approved by the *Scientific Committee* of the *University of Coimbra* and by the *Regional Education Office* that required the registration of the initiative in the *Portuguese Commission for Protection of Personal Data* [Process #3132006] which requires anonymity and non-transmissibility of the data. Informed written consent and assent was obtained from the participants and their parents or guardians, respectively, before participants entered into the study.

Table 3.1. shows basic information of each study including sample size and analysed variables.

Table 3.1. Basic characteristics of each study.

Study	Sample	Gender	Age	Studied Variables
I	403	Males and females	13-16 years	Activity Energy Expenditure provided by an multi-method approach
II	403	Males and females	13-16 years	Activity Energy Expenditure provided by an multi-method approach (age, gender and BMI variation)
III	302	Males and females	13-16 years	PA intensity levels, Time Spent Sedentary by gender (maturation as confounding factor)
IV	362	Males and females	13-16 years	PA (intensity levels) and CRF by geographic context
V	165	Males	13-16 years	Intensity levels of PA: sport participants vs. non-sport participants
VI	362	Males and females	13-16 years	CRF Geographic context Potential confounders
VII	362	Males and females	13-16 years	Intensity levels of PA CRF BMI

PA (Physical Activity); BMI (Body Mass Index); MVPA (Moderate-to-Vigorous Physical Activity);
CRF (Cardiorespiratory fitness).

3.2. Anthropometry

Height (0.1 cm) and weight (0.1 kg) were measured at school in the morning using a portable stadiometer (Harpenden model 98.603, Holtain Ltd, Crosswell, UK) and scale (Seca model 770, Hanover, MD, USA) respectively, with participants wearing a t-shirt and shorts, and without shoes.

The body mass index (BMI, Kg/m^2) was calculated and categorized using age and sex-adjusted cut-off points described by Cole and colleagues (Cole et al. 2000). According to the present sample of adolescents and the purpose of this study, adolescents were assigned into two weight-status groups (i.e., normal weight and overweight/obese).

3.3. Physical activity

Physical activity was assessed by a multi-method procedure using the 3-day diary proposed by Bouchard and colleagues (Bouchard et al. 1983) and an uniaxial accelerometer. It was also assessed the time devoted on organized sport using the 3-day diary.

Three-day diary. The 3-day diary protocol (Bouchard et al. 1983) partitions each day into 96 periods of 15 minutes and requires the subject to record activities over three complete days, two week days and one week-end day. Participants were asked to rate the intensity of the primary activity performed in each 15-minute period using a numeric code ranging one to nine. Energy expenditure was subsequently estimated from equivalents for each activity: [1] sleeping or resting: 0.26 kcal/Kg/15min; [2] sitting: 0.38 Kcal/Kg/15min; [3] light activity standing: 0.57 Kcal/kg/15min); [4] slow walking ~ 4 km/hr: 0.69 Kcal/Kg/15min; [5] light manual tasks: 0.84 Kcal/Kg/15min; [6] leisure and recreational sports: 1.2 Kcal/kg/15min; [7] manual tasks at a moderate pace: 1.4 Kcal/Kg/15min; [8] leisure and sport activities of higher intensity – not competitive: 1.5 Kcal/Kg/15min; [9] very intensive activities – competitive sports: 2.0 Kcal/Kg/15min. Based on the 24-hour record, daily energy expenditure (DEE) was estimated for each day. According to the original protocol provided by Bouchard and co-workers (Bouchard et al. 1983), intensity categories 1-3 represent sedentary behaviours and 6-9 categories represent moderate-to-vigorous physical activities. This diary protocol has been widely used with adolescents in Canada (Katzmarzyk et al. 1999; Katzmarzyk et al. 1998a), United States (Katzmarzyk and Malina 1998), Taiwan (Huang and Malina 1996; Huang and Malina 2002), Australia (Lee and Trost 2006), and United Kingdom (Atkin et al. 2008; Biddle et al. 2009; Gorely et al. 2009a; Gorely et al. 2009b).

Accelerometry. The *ActiGraph GT1M* accelerometer (ActiGraph^{TM}, LLC, Fort Walton Beach, FL, USA) was used for directly assessment physical activity and sedentary behaviour. This small (3.8 cm x 3.7 cm x 1.8 cm) and light (27g) uniaxial accelerometer was designed to detect vertical accelerations ranges in magnitude from 0.05 to 2.00g with a frequency of response of 0.25-2.50 Hz that allows normal human motion assessment. The filtered acceleration signal is digitized and the magnitude is summed over a user-specified period of time (an epoch interval). At the end of each epoch, the summed value is stored in the memory. This device has been widely validated in laboratory and free-living conditions with children and adolescents (Freedson et al. 2005).

The accelerometer was firmly placed at waist level using an elastic belt. Participants were instructed to remove the monitor while showering or participating in swimming activities. The sampling period was set at one minute as in other studies of adolescents (Mota et al. 2002; Nader et al. 2008; Pate et al. 2003; Riddoch et al. 2004; Troiano et al. 2008; Trost et al. 2002). Although most studies have used an epoch of 60 seconds, some evidence suggests underestimation of vigorous and high intensity activity in children (Nilsson et al. 2002; Rowlands et al. 2006; Stone et al. 2009). The current study was done with adolescents where corresponding comparisons of epoch length are scarce. The accelerometer was worn for 5 consecutive days [Thursday to Tuesday].

Sport participation (SP). Organized sports in Portugal are voluntary programmes offered during discretionary or free time and have defined competitive seasons. In general, the annual season corresponds to 9-month supervised participation, with 3/4 training sessions per week and a competition game at the weekend.

SP was estimated with the 3-day diary (Bouchard et al. 1983) previously described. Participants were asked to mark the categorical number (e.g. cells of 15 min periods) that corresponded to organized sports practice. This practice was defined as the training period and the competition games undertaken under supervision of a certified coach at the club affiliated in the national federations. Total amount of time and intensity levels of SP was given by the sum of categorical number pointed out.

3.4. Time spent sedentary

Sedentarism has often been conceptualized as reflecting the low end of physical activity continuum (Katzmarzyk et al. 2008). For the purpose of this project, sedentary behaviour was defined as purposeful and extended engagement in behaviours characterized by minimal movement, low energy expenditure, and rest. Therefore, the amount of time spent on screen activities (TV-viewing and computer use) was estimated from an activity diary (Katzmarzyk et al. 1998b) and was expressed as minutes/day. Respondents were grouped as watching TV and using a computer ≤2 hours/day and >2 hours/day according to the protocol suggested by the *American Academy of Pediatrics* (American Academy of

Pediatrics 2001). In addition, the aforementioned uniaxial accelerometer was used to assess sedentary behaviour objectively.

3.5. Cardiorespiratory fitness (CRF)

CRF was assessed by the *Progressive Aerobic Cardiovascular Endurance Run* test (PACER). This multistage running test is a 20 metres endurance shuttle run test (Leger et al. 1988) that was scored as the number of "laps" completed at volitional exhaustion. Participants were required to run between 2 lines 20 metres apart using the cadence dictated by a CD emitting audible signals at prescribed intervals. Initial speed was set at 8.5 km/hour for the first minute and then was increased 0.5 km/hour each subsequent minute. When participants could no longer keep up with the pace by reaching the line at the time of the tone, their participation was finished (at the second fault) and the number of laps completed was recorded. The test provides a valid and reliable field measure of VO_{2max} in children and adolescents (Leger et al. 1988; van Mechelen et al. 1986). The test is also frequently incorporated into Physical Education (PE) curricula to track CRF levels among youth. The test protocol was explained in full before the start and all testing was done in PE classes under dry weather conditions.

3.6. Area of residence

Participants were classified by residence as urban or rural according criteria of the Portuguese Statistical System (Monteiro 2000). Urban areas were defined as a city with more than 500 inhabitants/Km^2 or more than 50000 inhabitants. Rural areas were defined as villages with no more than100 inhabitants/Km^2 or with total population under 2000 people. The same criterion has been used in other studies of adolescents (Coelho e Silva et al. 2003). Participants were also classified according to the type of housing: flat (apartment) or house.

3.7. Parental education

Educational background of parents was based on the Portuguese Educational System [(1) 9 years or less – sub-secondary; (2) 10-12 years – secondary, and (3) higher education)]. The three educational levels defined three categories: 1 = Low Education; 2=Middle Education and 3=High Education. Similar procedures have been applied in Portuguese studies (Mota et al. 2007; Santos et al. 2003).

3.8. Data analysis

Accelerometer data were electronically downloaded using the *ActiLife software*. The *MAHUffe program* (www.mrc-epid.cam. ac.uk) was used to reduce the data in a file containing minute-by-minute movement counts. The output also included the total time that the accelerometer was worn (minutes) on each day. The total amount of daily physical activity was expressed as total counts divided by registered time (counts.min^{-1}). Participants who did not complete a minimum of 600 minutes of accelerometer data per day [after removing sequences of 20 or more consecutive zero counts (Anderson et al. 2005; Bringolf-Isler et al. 2009)] were excluded from subsequent analyses. This inclusion criterion was the same as in the *European Youth Heart Study* (Riddoch et al. 2004), the *Avon Longitudinal Study of Parents and Children* (Riddoch et al. 2007), and the *National Health and Nutrition Examination* (Troiano et al. 2008). Data for 403 youth (82% of the initial sample) met the criteria for inclusion and were used for subsequent analyses. The records of 89 students of the total sample (n=492) failed to achieve 10 hours of registered time. There were no significant differences in the distributions of included and excluded participants by sex [$\chi_{(1)}^2$=1.49; p=0.22], age [$\chi_{(1)}^2$=2.35 p=0.13], and weight status [$\chi_{(1)}^2$=0.38 p=0.54].

An inclusion record for the 3-day diary corresponded to the completion of all (96) 15-minutes episodes per day with a categorical value from 1 to 9. The original version of the protocol (Bouchard et al. 1983) assumes a standard energy equivalent for all activity codes, including code 1 which represents sleeping or resting activities (resting energy expenditure, REE). Activity energy expenditure (AEE) was derived by subtracting REE (0.26 kcal·kg^{-1}·15 min^{-1} or approximately 25 kcal·kg^{-1}·d^{-1}) from daily energy expenditure. For accelerometry, average counts per minute were converted to AEE using the equation proposed by Trost and co-workers (Trost et al. 1998). This equation was developed in 20 subjects aged 10-14 years during treadmill walking and running at 3, 4 and 6 mph. Activity counts were strongly correlated with indirect calorimetry energy expenditure (r=0.86).

The threshold of sedentary activity (minimal body movements in the sitting or reclining position) was established at 800 counts.min^{-1} (Puyau et al. 2002) and intensity levels of physical activity were determined using age-specific regression equation (Freedson et al. 1997) that were published by Trost and colleagues (Trost et al. 2002). The latter criterion has been previously used in epidemiological studies of youth (Riddoch et al. 2004; Nader et al. 2008).

3.9. Reliability of measures

Anthropometry

Technical errors of measurement (σ_e) and reliability (R) based on replicate measurements of 23 subjects indicated acceptable quality for both measurements: σ_e=0.34 cm, R=1.00 for height; σ_e=0.58 kg, R=1.00 for weight. The body mass index (BMI, kg/m^2) was calculated; age- and gender-specific *International Obesity Task Force* cut-offs (Cole et al. 2000) were used to classify youth as normal weight, overweight and obese. Adolescents were grouped into two weight-status groups: normal weight (NW) and overweight/obese (OW/OB).

Physical activity

Twenty-three subjects completed the 3-day diary protocol twice, one week apart. The technical error and reliability coefficient were 146.3 kcal (0.10 kcal/min) and 0.91, respectively. Intra-individual correlations were 0.93 ($p<0.01$) for week days and 0.70 ($p<0.01$) for weekend days. The correlation for week days, 0.93, was similar to those in the development of the diary protocol, 0.95 and 0.90 for two week days, while that for the weekend day was lower, 0.70 compared to 0.86 (Bouchard et al. 1983).

Cardiorespiratory fitness

Replicate measurements of the PACER were taken on 23 students, one week apart, and technical errors of measurement (σ_e) and reliability (R) were calculated (Mueller and Martorell 1988). Technical error and reliability coefficient were 2.6 “laps” (51.6 m) and 0.97, respectively. Participants were divided into fit and unfit groups based on 20m endurance shuttle run times according to the age and sex-specific cut-off points defined by the *Prudential Fitnessgram Battery* (Cooper Institute 1999).

3.10. Statistical procedures

Different statistical procedures were using according to the aims of each specific study (Table 3.2.). The level of significance was set at 5%. Every statistical analysis was performed using the SPSS 15.0 (SPSS Inc., Chicago, Illinois, USA), exception to the Bland Altman plots that were performed by the *GraphPad software*.

Table 3.2. Statistical procedures used in each study.

Analyses	Study I	Study II	Study III	Study IV	Study V	Study VI	Study VII
Pearson correlations	X						X
Partial correlation	X	X					
Fisher r-to-z transformations		X					X
Bland-Altman plot	X	X					
Ratio limits of agreement		X					
Independent t-test					X		
ANOVA – Oneway		X		X			X
ANCOVA			X				
Factorial Analysis of the Variance			X				
Multiple linear regression			X				
Logistic regression						X	X

ANOVA (Univariate Analysis of the Variance); ANCOVA (Univariate Analysis of the Co-Variance).

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CHAPTER IV

Concurrent validation of estimated activity energy expenditure using a 3-day diary and accelerometry in adolescents [1]

[1] Machado-Rodrigues AM, Figueiredo AJ, Mota J, Cumming SP, Eisenmann J, Malina RM, Coelho e Silva MJ (2010). Concurrent validation of estimated activity energy expenditure using a 3-day diary and accelerometry in adolescents. *Scandinavian Journal of Medicine & Science in Sports*. [in press; Epub ahead of print, Jun 16].

CONCURRENT VALIDATION OF ESTIMATED ACTIVITY ENERGY EXPENDITURE USING A 3-DAY DIARY AND ACCELEROMETRY IN ADOLESCENTS

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ABSTRACT

Estimates of daily energy expenditure are important to studies of physical activity and energy balance. Objective measures are not always feasible and further research is needed to validate survey instruments and diaries. The study validates estimated activity energy expenditure (AEE) based on a 3-day diary protocol relative to AEE derived from uniaxial accelerometry in adolescents, 265 girls and 227 boys (12.5-16.4 years). Participants completed the diary and wore a GT1M Actigraph accelerometer on the same days. Height and weight were measured. Correlations between protocols were significant but moderate, $r = 0.65$ in males and $r = 0.69$ in females. The highest correlation occurred among males on Friday, $r = 0.74$ ($p<.01$). Controlling for body mass, partial correlations between protocols decreased to 0.44 and 0.35 in males and females, respectively. About 97% of the cases fell within the limits of agreement in a Bland-Altman plot. Criterion of inclusion for the accelerometer excluded 18% of the initial sample. In summary, the 3-day diary was completed without any major problems and provided a reasonably valid alternative for assessing AEE. Concordance between methods was slightly lower for individuals with higher values of AEE.

Keywords: *activity energy expenditure, 3-day diary, accelerometer, adolescents*

INTRODUCTION

Quantification of habitual physical activity is relatively complex and it is also generally accepted that no single measurement technique accurately reflects all dimensions of physical activity (Armstrong & Welsman 2006; Trost 2001; Welk 2002). Objective measures of physical activity (heart rate monitors, accelerometers, pedometers) provide reliable and valid information whereas subjective protocols (questionnaires, diaries) provide less accurate alternatives but are more suitable for large samples (Eston et al. 1998; Janz et al. 1995; Montoye 1996; Welk 2002).

Estimates of daily energy expenditure (DEE) are an important component in studies of physical activity. The 3-day diary protocol of Bouchard and colleagues (Bouchard et al. 1983) permits an estimate of DEE and of the type, intensity, frequency and duration of specific activities including sedentary behaviours (Katzmarzyk & Malina 1998). The 3-day diary has been used with adolescents in Canada (Katzmarzyk et al. 1999; Katzmarzyk et al. 1998), United States (Katzmarzyk & Malina 1998), Taiwan (Huang & Malina 1996; Huang & Malina 2002) and Australia (Lee & Trost 2006).

The initial validation of the 3-day diary (Bouchard et al. 1983) was established using interclass correlations between estimated DEE and body fat and physical working capacity (i.e., predictive validity). Based on 300 subjects of both sexes, 10-50 years of age, there was a significant relationship between mean DEE per unit body mass and physical working capacity expressed per kg of body weight. Estimates of activity energy expenditure (AEE) based on a single day of the diary showed a strong linear relationship with counts derived from Tritrac activity monitors in young adults of both sexes (Wickel et al. 2006).

With advances in technology accelerometers are increasingly used in physical activity research and permit an estimate of AEE. Accelerometers, however, have limitations, specifically the exclusion of subjects due to non-compliance with wear time. Costs remain prohibitive for some research groups and also others, including practitioners interested in quantifying physical activity and estimating AEE. Further studies of the validity of physical activity assessment tools such as the 3-day diary are thus warranted.

The purpose of the present study is to examine the relationship between estimated AEE based on the 3-day diary protocol (Bouchard et al. 1983) and AEE derived from uniaxial accelerometry in adolescents of both sexes. It was hypothesized that the diary protocol is an alternative to accelerometers in the assessment of DEE and provides a valid estimate of AEE, specifically if the amount of vigorous physical activity (which often occurs in episodes less than the 15-minute periods of the diary) is not the central question of the research.

METHODS

Participants

The sample comprised 265 girls and 227 boys, 12.5 to 16.4 years of age (14.2±1.0 years) from public schools in the Midlands of Portugal. The study was approved by the *Scientific Committee* of the *University of Coimbra* and by the *Regional Education Office* that required the registration of the initiative in the *Portuguese Commission for Protection of Personal Data* [Process #3132006]. Students and their parents provided assent and informed consent, respectively.

Anthropometry

Height (0.1 cm) and weight (0.1 kg) were measured at school in the morning, with participants in t-shirt and shorts, and without shoes. A portable stadiometer (Harpenden model 98.603, Holtain Ltd, Crosswell, UK) and a portable scale (Seca model 770, Hanover, MD, USA) were used. Replicate measurements of height and weight were taken on 23 students, one week apart. Technical errors of measurement (σ_e) and reliability (R) based on replicate measurements of 23 subjects indicated acceptable quality for both measurements: σ_e=0.34 cm, R=1.00 for height; σ_e=0.58 kg, R=1.00 for weight. The body mass index (BMI, kg/m^2) was calculated.

Three-day diary

The 3-day diary protocol (Bouchard et al. 1983) partitions each day into 96 periods of 15 minutes and requires the subject to record activities over three complete days, two week days and one weekend day. Participants were asked to rate the intensity of the primary activity performed in each 15-minute period using a numeric code ranging one to nine. According to the original report (Bouchard et al. 1983) energy expenditure was subsequently estimated for each activity: [1] sleeping or resting: 0.26 kcal/Kg/15min; [2] sitting: 0.38 Kcal/Kg/15min; [3] light activity standing: 0.57 Kcal/kg/15min); [4] slow walking ~ 4 km/hr: 0.69 Kcal/Kg/15min; [5] light manual tasks: 0.84 Kcal/Kg/15min; [6] leisure and recreational sports: 1.2 Kcal/kg/15min; [7] manual tasks at a moderate pace: 1.4 Kcal/Kg/15min; [8] leisure and sport activities of higher intensity – not competitive: 1.5 Kcal/Kg/15min; [9] very intensive activities – competitive sports: 2.0 Kcal/Kg/15min. Daily energy expenditure (DEE) was estimated for each day.

Twenty-three subjects completed the diary protocol twice, one week apart. The technical error and reliability coefficient were 146.3 kcal (0.10 kcal/min) and 0.91, respectively. Intra-individual correlations were 0.93 ($p<0.01$) for week days and 0.70 ($p<0.01$) for weekend days. The correlation for week days, 0.93, was similar to those in the development of the diary protocol, 0.95 and 0.90 for two week days, while that for the weekend day was lower, 0.70 compared to 0.86 (Bouchard et al. 1983).

Accelerometry

The *GT1M Actigraph* accelerometer incorporated an uniaxial motion sensor that was firmly placed at waist level using an elastic belt. The sampling period was set at one minute as in other studies of adolescents (Mota et al. 2002; Pate et al. 2003; Riddoch et al. 2004; Trost et al. 2002). Although most studies have used an epoch of 60 seconds, some evidence suggests underestimation of vigorous and high intensity activity in youth (Nilsson et al. 2002; Rowlands et al. 2006; Stone et al. 2009). The accelerometer was worn on the same days that the diary protocol was completed [Thursday, Friday, Saturday].

Accelerometer monitors were downloaded following procedures indicated by the manufacturer and imported to a personal computer. Activity data were analyzed and processed with a special program (MAHUffe, www.mrc-epid.cam.ac.uk). Inclusion criteria were those of the *European Youth Heart Study* (Riddoch et al. 2004; Sardinha et al. 2008). The output also included the total amount of time (minutes) registered each day. Subjects were excluded if they failed to provide a minimum of 600 minutes (10 hrs) of valid data after removing sequences of 20 or more consecutive zero counts. Valid accelerometer records were provided for 403 subjects (82% of the initial sample).

Field procedures

The first visit to the schools occurred on a Wednesday and was used to explain the objectives of the study; to measure height and weight; and to distribute the diary and accelerometers with specific directions for each instrument. A master's level graduate student was assigned to each school and was charged with monitoring the protocol. Participants were contacted at school on Thursdays and Fridays to ensure adequate completion/application of the diary and accelerometer, and/or to address potential problems. The instruments were collected for analysis on the following Tuesday.

Analysis

The analysis was based on the total sample of boys and girls combined, consistent with the analytical approach in the original development of the diary protocol (Bouchard et al. 1983). Descriptive statistics were calculated for chronological age, height, weight, and measures derived from the diary and accelerometer.

The diary protocol assumes a standard energy equivalent for all activity codes, including code 1 (resting energy expenditure - REE). Activity energy expenditure (AEE) was calculated by subtracting REE from estimated daily energy expenditure (DEE). Values for each period different from category 1 were summed across the whole day to provide the estimate of total AEE in the diary. For accelerometry, average counts per minute were converted to AEE using the equation of Trost and colleagues (Trost et al. 1998):

$$-2.23 + 0.0008\ (\text{counts} \ .\ \text{min}^{-1}) + 0.08\ (\text{body weight, kg}).$$

Agreement between estimated EE in activity (kcal/min) based on the diary and accelerometry was examined using the Bland-Altman procedure (Bland & Altman 1986). Prior to analysis, tests for normality were conducted on the measures of physical activity (AEE) provided by accelerometer and the 3-day diary. The tests suggested that both measures were not normality distributed (Diary: skewness=1.79, Kolmogorov-Smirnov value=.09, $p<.001$; Accelerometer: skewness=0.89, Kolmogorov-Smirnov value=.06, $p<.001$). Log transformation (Log10) of the variables substantially improved normality for the diary (skewness = 0.40, Kolmogorov-Smirnov value = .03; $p=.059$), but not the accelerometer data. As such, only the diary data were transformed. Day-specific Pearson product moment correlations were calculated between AEE estimated from the diary and accelerometer. Relationships between methods were determined by gender for each day (Thursday, Friday, and Saturday) and within different intervals of validly measured time using the accelerometer. Partial correlations between methods controlling for body mass were also calculated. The association between AEE and adiposity was also computed.

RESULTS

Descriptive statistics for age, body size and AEE are summarized in Table 4.1. Estimated AEE differs between protocols, 2.47±0.89 and 2.22±0.75 kcal per minute for accelerometry and the diary, respectively.

Table 4.1. Descriptive statistics for the total sample.

Variable		Mean	SD
Chronological age	years	14.18	1.03
Height	cm	161.2	8.5
Weight	kg	54.3	10.9
Accelerometry			
Habitual physical activity	counts/min	452.6	224.4
Valid activity measured time	min	857.5	97.5
Estimated activity energy expenditure	kcal/min [a]	2.47	0.89
Diary			
15-minute episodes in category 1	(f)	45.5	11.3
15-minute episodes in category 2	(f)	32.7	12.5
15-minute episodes in category 3	(f)	3.1	4.1
15-minute episodes in category 4	(f)	4.8	4.7
15-minute episodes in category 5	(f)	3.1	5.4
15-minute episodes in category 6	(f)	2.2	3.8
15-minute episodes in category 7	(f)	1.0	2.6
15-minute episodes in category 8	(f)	0.8	2.5
15-minute episodes in category 9	(f)	2.8	4.2
Estimated activity energy expenditure	kcal /min	2.22	0.75

[a] EE using the equation of Trost et al. (1998).

Correlations between AEE (kcal/min) based on accelerometry and the diary by day and all days combined are given in Table 4.2 for males and females, separately. Overall correlations between protocols are significant but moderate and similar in magnitude in males (r=0.65) and females (r=0.69). Correlations for single days range from 0.61 to 0.74 in males and from 0.67 to 0.73 in females. Partial correlations between estimates of AEE based on the diary and accelerometry for the three days combined, controlling for body mass, are 0.44 and 0.35 in males and females, respectively. Partial correlations for individual days among males are 0.41, 0.46 and 0.46 for Thursday, Friday and Saturday, respectively; corresponding partial correlations among females are 0.34, 0.35 and 0.39, respectively.

Table 4.2. Correlations between energy expenditure (kcal/min) estimated from accelerometry and the 3-day diary by day and the three days combined and partial correlations controlling for body mass for males and females separately.

		Bivariate correlation			Partial correlations (controlling for body mass)		
		r	p	N	r	p	df
Males (n=186)	Day 1 - Thursdays	0.62	<.001	186	0.41	<.001	183
	Day 2 - Fridays	0.74	<.001	186	0.46	<.001	183
	Day 3 - Saturdays	0.61	<.001	186	0.46	<.001	183
	All days	0.65	<.001	558	0.44	<.001	555
Females (n=217)	Day 1 - Thursdays	0.67	<.001	217	0.34	<.001	214
	Day 2 - Fridays	0.68	<.001	217	0.35	<.001	214
	Day 3 - Saturdays	0.73	<.001	217	0.39	<.001	214
	All days	0.69	<.001	651	0.35	<.001	648
Total (n=403)	Day 1 - Thursdays	0.65	<.001	403	0.40	<.001	400
	Day 2 - Fridays	0.71	<.001	403	0.43	<.001	400
	Day 3 - Saturdays	0.68	<.001	403	0.45	<.001	400
	All days	0.67	<.001	1209	0.42	<.001	1206

The Bland-Altman plot of differences between estimated AEE based on the diary and accelerometry relative to mean estimated AEE based on the two protocols (kcal . min^{-1}) is shown in Figure 4.1. About 97% of cases fall within the upper and lower limits of agreement. The mean difference between methods is 0.25 kcal/min, suggesting that AEE estimated with the diary tends to be lower than the estimate with accelerometry. Compared to the objective measurement, the diary yields higher estimates for 429 days, equal values for 10 days and lower estimates for 770 days.

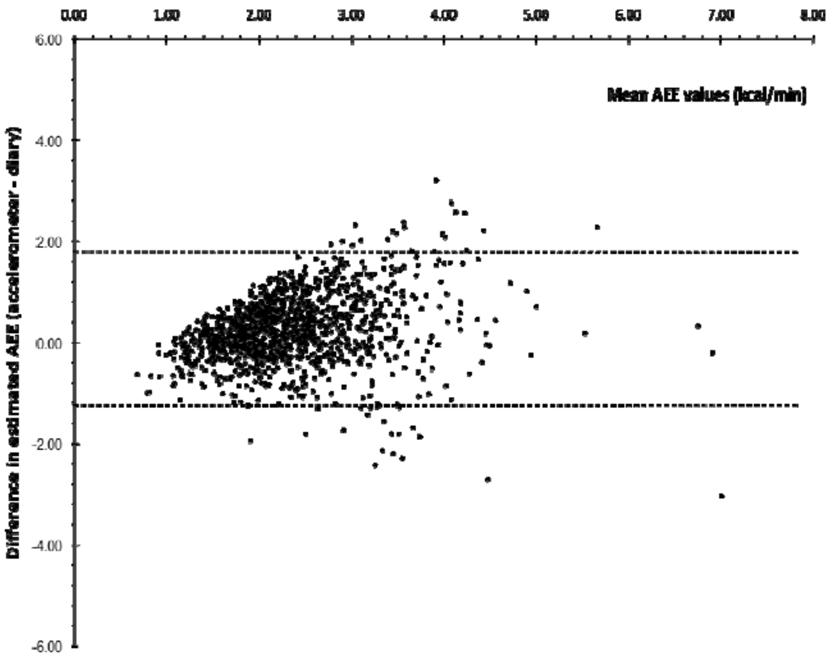

Figure 4.1. Bland–Altman plot of differences between estimated activity energy expenditure (AEE, kcal/min) from the 3-day diary and accelerometry protocols (accelerometry minus diary) relative to mean estimated AEE based on the two protocols (kcal/min). The solid line represents the mean difference and the dashed lines are the upper and lower limits of agreement (±1.96 standard deviations).

DISCUSSION

Objective assessment of EE (accelerometry, heart rate counters, etc.) in large epidemiological studies is often limited due to the costs of the instruments, trained personnel to deal with a large sample and the accelerometer-related software. As such, reliable and valid questionnaires and diaries may provide reasonable alternatives. Although information about the reliability and validity of the 3-day diary in young people is limited, the protocol has been used in a several studies of youth, including the relationship between sociogeographic variables and estimated EE in Taiwanese adolescents (Huang & Malina 1996), a comparison of the health-related physical fitness of adolescents at the extremes of activity and inactivity (Huang & Malina 2002), the contribution of organized youth sports to estimated daily EE (Katzmarzyk & Malina 1998), and relationships among physical activity, fitness and coronary heart disease risk factors in youth from the *Québec Family Study* (Katzmarzyk, Malina 1999). Results of the present study indicated that DEE estimated with the diary was quite reproducible and valid in a large sample of adolescents of both sexes.

Actigraph accelerometers have become one of the more commonly used tools for assessing physical activity in free-living youth, and the equation of Trost and co-workers (Trost et al. 1998) is commonly used to convert Actigraph "counts" to units of moderate-to-vigorous physical activity (Eisenmann et al. 2004). The equation was developed on 20 subjects 10 to 14 years of age during treadmill walking and running at 3, 4 and 6 mph (Trost et al. 1998). Activity counts were strongly correlated with energy expenditure estimated with indirect calorimetry (r=0.86). The equation was then cross-validated on 10 subjects. The predicted mean EE was within 0.01 kcal/min of measured EE, and the correlation between actual and predicted EE was 0.93. However, a subsequent study indicated that the equation underestimated EE during walking and overestimated EE during fast running (Trost et al., 2006). However, when expressed as time spent in MVPA, the equation exhibited high classification accuracy. Moderate correlations between EE estimated with Trost equation and indirect calorimetry were reported for sweeping, bowling and basketball, 0.50 to 0.68, but the correlation for the pooled data was higher, 0.78 (Eisenmann et al., 2004).

The correlation between estimates of AEE (kcal/minute) over three days based on accelerometry and the diary was 0.65 in males and 0.69 in females (Table 4.2.). Among young adults 18-23 years, the correlation for estimated AEE based on the Tritrac and diary protocols was higher, 0.72 (Wickel et al., 2006). The latter study, however, did not consider variation in body mass. In the current sample of Portuguese adolescents, the strength of the association between estimated AEE based on accelerometry and the diary was reduced when variation in body mass was statistically controlled, 0.44 in males and 0.35 in females (Table 4.2.).

A large and significant difference in estimated AEE (576±381 kcal) between the accelerometry and diary protocols was noted in young adults (Wickel et al., 2006). The 3-day diary provided higher estimates of AEE than the Tritrac. In the present study, the diary protocol produced higher estimates of AEE (kcal/min) for only 36% of the measured days in the Portuguese adolescents, but mean estimated AEE assessed by the diary was 0.25 kcal/min lower than mean AEE estimated from accelerometry.

Failure to wear the accelerometer is a potential source of error in estimates of AEE. The literature recommends searching for extended blocks of data with zero counts to identify cases in which a person may have removed the accelerometer (Rowlands 2007; Welk 2002). In the current study, valid measured time was 858±98 minutes which were substantially higher than the sum of minutes spent in diary categories 2 to 9, 758±170 minutes. The relationship between the two protocols was also examined within different intervals of valid measured time using accelerometry. Correlations for AEE (kcal/min) were quite similar among tertiles of valid epochs: 0.62 for days with valid measured time between 600 and 826 minutes, 0.60 for days between 826 and 901 minutes of valid measured time, and 0.63 for days with more than 901 minutes of valid measured time.

Energy expenditure is not entirely constant from day to day and many studies have considered variation between week and weekend days. Correlations between protocols for individual days were, respectively, 0.62, 0.74 and 0.61 for Thursdays, Fridays and Saturdays among males. The corresponding correlations for females were 0.67, 0.68 and 0.69, respectively (Table 4.2.). The correlations varied by day among males, but were somewhat higher and stable across the three days among females. However, the intra-individual correlation for repeated assessments was lower on Saturdays (0.70) compared to Thursdays or Fridays (0.93). The trend in the Bland-Altman plot showed a tendency for smaller differences between protocols for lower levels of estimated AEE and larger differences between protocols as estimated AEE increased.

The 3-day diary with 288 entries (ninety six 15-minute periods per day over 3 days) with a defined coding system was not as accurate as the 60-second epochs provided by accelerometry. The diary procedure relied on approximation; the energy cost assigned to each categorical value approximated the median energy expended in the dominant activity of each 15-minute period. On the other hand, the 60-second epoch of accelerometry data used in the current study tends to underestimate the portion of time spent in activities of vigorous and very vigorous intensity (Baquet et al. 2007; Rowlands 2007; Troiano et al. 2008; Welk 2002). These methodological factors probably contribute to the observation that the difference between methods was higher for cases with mean AEE >2.00 kcal/min.

CONCLUSION

In summary, the 3-diary protocol (Bouchard et al. 1983) was used without any major technical problems in 403 subjects comprising a span of 1209 days. The criterion of inclusion for the accelerometer, a minimum of 600 minutes of valid data, excluded 18% of the sample. Further studies of the activity level of excluded subjects are needed.

Relationships between estimates of AEE based on the diary and accelerometry protocols indicated that the 3-day diary method was quite reliable and reasonably valid. The 3-day diary thus is a valid supplement for assessing DEE and its AEE component in adolescents. The diary appears to be especially useful for studies with interest in the amount of time spent in sedentary activities.

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CHAPTER V

Agreement in activity energy expenditure assessed by accelerometer and self-report measures in adolescents: variation by sex, age and weight status [2]

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AGREEMENT IN ACTIVITY ENERGY EXPENDITURE ASSESSED BY ACCELEROMETER AND SELF-REPORT MEASURES IN ADOLESCENTS: variation by sex, age and weight status

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ABSTRACT

The agreement between self-reported and objective estimates of activity energy expenditure (AEE) was evaluated in adolescents by age, sex and weight-status. Participants (n=403; 217 females, 186 males, 13-16 years) completed a 3-day physical activity diary and wore a GT1M accelerometer on the same days. Partial correlations (controlling for body mass) were used to determine associations between estimated AEE ($kcal.min^{-1}$) from the diary and accelerometry. Differences in the magnitude of the correlations were examined using Fisher's r to z transformations. Bland-Altman procedures were used to determine concordance between the self-reported and objective estimates. Partial correlations between assessments of AEE ($kcal.min^{-1}$) did not significantly differ by age (13-14yrs: r=0.41; 15-16yrs: r=0.42) and weight status (normal weight: r=0.42; overweight: r=0.39). The magnitude of the association was significantly affected by sex ($\Delta r=0.11$; $p<0.05$). The agreement was significantly higher in males than in females. The relationship between AEE assessed by the objective method and the 3-day diary was moderate (controlling for weight correlations ranged between 0.33 and 0.44). However, the 3-day diary revealed less agreement in specific group analyses; it markedly underestimated AEE in overweight/obese and older adolescents. The assessment of AEE is complex and may require a combination of methods.

Keywords: *Physical activity, 3-day diary, accelerometry, weight-status, adolescence*

INTRODUCTION

Beneficial effects of physical activity (PA) on indicators of health, fitness and behavior appear to differentiate between "healthy" and "unhealthy" youth (Cumming & Riddoch, 2008; Strong et al., 2005). Among "healthy" children and adolescents (normal weight, normotensive blood pressure), the evidence for beneficial effects of PA is strongest for aerobic fitness, and muscular strength and endurance, whereas effects are relatively small for lipids, adiposity and blood pressures (Strong et al., 2005). Beneficial effects of systematic PA are generally more apparent among "unhealthy" youth (the obese, hypertensive, and those with features of the metabolic syndrome) (Flynn et al., 2006; Hallal, Victora, Azevedo, & Wells, 2006). Among "unhealthy youth," interventional PA programs have a beneficial effect on adiposity in the obese, blood pressures in the hypertensive, and insulin, triglycerides and adiposity in obese youth with the metabolic syndrome (McMurray & Andersen, 2010). Evidence for beneficial effects of PA programs in conjunction with cognitive behavioral modification on anxiety and depression is also suggestive (Strong et al., 2005).

Adequate and comprehensive PA assessment techniques are needed to evaluate relationships between PA and indicators of health status, fitness and behaviour (Rush, Valencia, & Plank, 2008; Schutz, Weinsier, & Hunter, 2001; Trost, 2001; Wickel, Welk, & Eisenmann, 2006). Moreover, methods of PA assessment should be socially acceptable, should not burden the participant with cumbersome equipment, and should minimally influence normal PA patterns (Armstrong & Welsman, 2006). It is also generally accepted that no single measurement accurately reflects all dimensions of PA, i.e., type, frequency, intensity, and duration (Armstrong & Welsman, 2006; Trost, 2001). Although commonly used objective measures of PA provide valid and reliable information about frequency, intensity and duration (P. S. Freedson, Melanson, & Sirard, 1998; Janz, Witt, & Mahoney, 1995; Montoye, 1996), they provide limited information about context and type of PA, and are less practical for use with large samples. Self-report PA protocols, such as questionnaires and diaries, provide a low cost alternative to objective assessments, but rely on the ability to recall and/or record information and may be influenced by social desirability. Commonly used questionnaires for assessing PA in large samples include the *Leisure-Time Exercise Questionnaire* (Godin & Shephard, 1985a, 1985b) and *Physical Activity Questionnaires* for children (Crocker, Bailey, Faulkner, Kowalski, & McGrath, 1997) and adolescents (Martinez-Gomez et al., 2010). In contrast to questionnaires, several studies have derived estimates of daily energy expenditure (DEE) and activity energy expenditure (AEE) from a 3-day diary (Y. Huang & Malina, 1996; Y. C. Huang & Malina, 2002; P.T. Katzmarzyk & Malina, 1998; P. T. Katzmarzyk, Malina, & Bouchard, 1999; P. T. Katzmarzyk, Malina, Song, & Bouchard, 1998a, 1998b). Current recommendations for the assessment of PA call for a combination of methods (Welk, 2002).

Physical activity tends to decrease, on average, with age (Malina & Katzmarzyk, 2006). This decline is more apparent at high-intensity levels of PA. The decline in PA with age may be influenced by differences between younger and older adolescents to recall information. Older adolescents are more capable of processing, retaining, and recalling information compared to younger adolescents (Baranowski, 1988). This may predispose older adolescents and young adults to provide more accurate information of PA. In addition, evidence for adults suggests that weight status of individuals influences the accuracy of self-reported PA (Irwin, Ainsworth, & Conway, 2001; Lichtman et al., 1992; Walsh, Hunter, Sirikul, & Gower, 2004). Overweight and obese adults tend to overestimate involvement in PA compared to normal weight adults, although not all studies note such differences (Lee, Cook, & Henneckens, 1993). Differences between actual and reported involvement in physical activity of normal weight and obese/overweight youth are less well documented, though McMurray and colleagues (McMurray et al., 2008) reported that overweight and obese girls aged 11-14 years were also more likely to overestimate involvement in moderate-to-vigorous PA (McMurray et al., 2008).

The agreement between self-reported and objective assessment protocols may thus be affected by age, weight status and gender. In addition, there is a clear need in advanced valid assessments of PA in adolescents (Slootmaker, Schuit, Chinapaw, Seidell, & van Mechelen, 2009). Therefore, the purpose of this study was to evaluate the concordance between self-reported and objective estimates of activity energy expenditure (AEE) among adolescents by gender, age and weight status. Relationships between estimated AEE derived from a 3-day diary and accelerometry were separately evaluated in male and female adolescents, in two age groups (13-14 and 15-16 years), and by weight status (normal weight and overweight/obese).

METHODS

Study design and sampling

The study was school-based and was part of a cross-sectional research project with Portuguese adolescents (*Midlands Adolescents Lifestyle Study* - MALS). The sample comprised 492 students, 265 girls and 227 boys, 12.5 to 16.4 years of age, from public schools in the Portuguese Midlands. The project was approved by the *Scientific Committee* of the *University of Coimbra*, and the *Portuguese Commission for Data Protection* [Process #3132006] which requires anonymity and non-transmissibility of data. Informed consent was provided by parents and pupils.

Anthropometry

Height and weight were measured at school in the morning using a portable stadiometer (Harpenden model 98.603, Holtain Ltd, Crosswell, UK) and a portable scale (Seca model 770, Hanover, MD, USA) to the nearest 0.1 cm and 0.1 kg, respectively, with participants in t-shirt and shorts, and without shoes. Technical errors of measurement (σ_e) and reliability (R) based on replicate measurements of 23 subjects indicated acceptable quality for both measurements: σ_e=0.34 cm, R=1.00 for height; σ_e=0.58 kg, R=1.00 for weight. The body mass index (BMI, kg/m^2) was calculated; age- and gender-specific *International Obesity Task Force* cut-offs (Cole, Bellizzi, Flegal, & Dietz, 2000) were used to classify youth as normal weight, overweight and obese. Adolescents were grouped into two weight-status groups: normal weight (NW) and overweight/obese (OW/OB).

Three-day diary

The diary protocol (Bouchard et al., 1983) divided each day into 96 periods of 15 minutes and required the subject to record activities over three complete days (Thursday, Friday and Saturday). Participants were required to rate the intensity of the primary activity performed in each 15-minute period using a numeric code ranging from one to nine. Energy expenditure (EE) was subsequently estimated from equivalents for each: [1] sleeping or resting: 0.26 Kcal/kg/15min; [2] sitting: 0.38 Kcal/kg/15min; [3] light activity standing: 0.57 Kcal/kg/15min); [4] slow walking $\simeq$ 4 km/hr: 0.69 Kcal/kg/15min; [5] light manual tasks: 0.84 Kcal/kg/15min; [6] leisure and recreational sports: 1.2 Kcal/kg/15min; [7] manual tasks at a moderate pace: 1.4 Kcal/kg/15min; [8] leisure and sport activities of higher intensity – not competitive: 1.5 Kcal/kg/15min; [9] very intensive activities – competitive sports: 2.0 Kcal/kg/15min. Total daily energy expenditure (TDEE) was estimated for each of the three days based on definitions of categories in the original report (Bouchard et al., 1983). Twenty-three subjects completed the 3-day diary protocol twice (one week apart). The technical errors and reliability coefficients were 146.3 kcal (0.10 kcal/min) and 0.91, respectively. Intra-individual correlations were 0.93 ($p<0.01$) for week days and 0.70 ($p<0.01$) for weekend days. Further details are available elsewhere (Machado-Rodrigues et al., 2010).

Accelerometry

The *GT1M Actigraph* accelerometer was used. It is a uniaxial accelerometer designed to detect vertical accelerations ranging in magnitude from 0.05 to 2.00g with a frequency of response of 0.25-2.50 Hz that allows assessment of normal human motion. The filtered acceleration signal is digitized and the magnitude is summed over a user-specified period of time (an epoch interval). The sampling period was set at one minute as in other studies of adolescents (Anderson, Hagstromer, & Yngve, 2005; Bringolf-Isler et al., 2009; Mota et al., 2002; Riddoch et al., 2004; Troiano et al., 2008; Trost, 2001).

Procedures and data reduction

The first visit to schools occurred on Wednesdays and was used to explain the objectives of the study and to collect anthropometric data. Adolescents were instructed on application of the accelerometer and to remove the monitor while showering or participating in water activities. The accelerometer was placed over the hip for three consecutive school days (Thursdays, Fridays, and Saturdays), the same days that diary protocol was completed. Accelerometer data were electronically downloaded using the *ActiLife software*. The *MAHUffe program* (www.mrc-epid.cam. ac.uk) was used to reduce the data in a file containing minute-by-minute movement counts. The output also included the total time (minutes) that the accelerometer was worn in each day. The total amount of daily PA was expressed as total counts divided by registered time (counts.min^{-1}). Participants who did not complete a minimum of 600 minutes of accelerometer data per day [after removing sequences of 20 or more consecutive zero counts (Anderson et al., 2005; Bringolf-Isler et al., 2009)] were excluded from subsequent analyses. This inclusion criterion was the same as in the *European Youth Heart Study* (Riddoch et al., 2004), the *Avon Longitudinal Study of Parents and Children* (Riddoch et al., 2007), and the *National Health and Nutrition Examination* (Troiano et al., 2008). Data for 403 youth (82% of the initial sample) met the criteria for inclusion and were used for subsequent analyses. The records of 89 students of the total sample (n=492) failed to achieve 10 hours of registered time. There were no significant differences in the distributions of included and excluded participants by sex [$\chi_{(1)}^2$=1.49; p=0.22], age [$\chi_{(1)}^2$=2.35 p=0.13], and weight status [$\chi_{(1)}^2$=0.38 p=0.54].

An inclusion record for the 3-day diary corresponds to the completion of all (96) 15-min episodes per day with a categorical value from 1 to 9. The original version of the protocol (Bouchard et al., 1983) assumes a standard energy equivalent for all activity codes, including code 1 which represents sleeping or resting activities (resting energy expenditure, REE). Activity energy expenditure (AEE) was derived by subtracting REE ($0.26\ kcal \cdot kg^{-1} \cdot 15\ min^{-1}$ or approximately $25\ kcal \cdot kg^{-1} \cdot d^{-1}$) from daily energy expenditure (DEE). For accelerometry, average counts per minute were converted to AEE using the equation proposed by Trost and co-workers (Trost et al., 1998). This equation was developed in 20 subjects aged 10-14 years during treadmill walking and running at 3, 4 and 6 mph. Activity counts were strongly correlated with indirect calorimetry energy expenditure (r=0.86).

Statistical analysis

Descriptive statistics were calculated for age, height, weight, BMI, AEE and accelerometer counts by gender, age-group and weight status. One-way analysis of variance (ANOVA) was performed to test the effect of gender on body size, counts of physical activity and AEE. The effects of age and weight status were subsequently tested using ANOVA separately for males and females. Alpha level was set at 0.05. Partial eta squared was used to determine the magnitude of the differences between groups. F values of 0.10, 0.25, and 0.40 were interpreted as small, medium and large effects, respectively (Cohen, 1998). Translated into partial eta squared, values of 0.01, 0.06, and 0.14 were considered small, moderate and large effects, respectively.

Agreement between estimated AEE derived from the diary and accelerometry was examined using the Bland-Aldman procedure (Bland & Altman, 1986). Partial correlations between methods controlling for body mass were calculated by gender, age and weight status. Fisher's r to z transformation procedure (Ramseyer, 1979; Fisher, 1925) was used to determine the variability in magnitude of correlations by gender, age-group, weight status. According to Nevill and Atkinson (Nevill & Atkinson, 1997), and assuming a relation exists between the measurement differences (errors) and the mean, an analysis was conducted to determine the ratio limits of agreement using natural log transformed measurements. These "limits of agreement" were expressed as a dimensionless ratio, multiplied or divided by the second ratio as a measure of agreement having already taken antilogs (Nevill & Atkinson, 1997). SPSS 15.0 (SPSS Inc., Chicago, Illinois, USA) was used for all the analyses.

RESULTS

Descriptive statistics for chronological age, stature, weight, BMI, AEE and daily physical activity (counts/min) are summarized in Table 5.1. On average, boys were 1.5 kg heavier [$F=5.45$, $p<0.05$] and 6.1 cm taller [$F=205.87$, $p<0.01$] than girls. Based on the estimates of AEE, males expended more $kcal.min^{-1}$ than females [diary: sex difference= 0.19, F=23.26, p<0.01; accelerometry: sex difference=0.20, F=15.06, p<0.01]. The magnitude of the significant effects was small.

As expected, boys 15-16 years were taller [F=202.30, p<0.01] and heavier [F=178.84, p<0.01] with a higher BMI [F=53.72, p<0.01] than boys aged 13-14 years (Table 5.2.). Older girls were taller [F=13.59, p<0.01] and heavier [F=6.86, p<0.01] than girls aged 13-14 years, but the age groups did not differ in the BMI. AEE was higher in older than younger boys [diary: difference=0.40 kcal.min^{-1}, F=36.13, p<0.01; accelerometry: difference=0.90 kcam-min^{-1}, F=160.99, p<0.01]. Corresponding age group comparisons for girls were significant only for AEE estimated by accelerometry; older girls spent 0.17 kcal.min^{-1} more than younger female participants [F=6.12, p<.01]. The magnitude of the effects ranged from small to moderate, except for differences in AEE between younger and older boys by accelerometry (large effects: partial eta between 0.21 and 0.24).

Table 5.1. Means and standard deviations for males and females and results of ANOVA testing the effect of sex on chronological age, body size, daily activity energy expenditure and accelerometer counts/minute.

		Males (n=186)	Females (n=217)	F	p	η^2
Anthropometry	Age, yrs	14.2±1.1	14.2±1.0	0.51	0.48	0.00
	Height, cm	164.5±9.6	158.4±8.5	205.87	0.00	0.15
	Weight, Kg	55.1±11.6	53.6±10.2	5.45	0.02	0.01
	BMI, Kg/m^2	20.19±3.15	21.29±3.59	33.48	0.00	0.03
Diary	AEE (kcal..min^{-1})	2.34±0.81	2.13±0.69	23.26	0.00	0.02
Accelerometer	AEE (kcal..min^{-1})	2.58±0.93	2.38±0.84	15.06	0.00	0.01
	Counts.min^{-1}	504.3±255.2	408.3±183.2	58.68	0.00	0.05

BMI (Body Mass Index); AEE (Activity Energy Expenditure).

Results by weight status are summarized in Table 5.3. Weight status was a significant source of variation in AEE in both diary [boys: F=94.31, p<0.01; girls: F=172.50, p<0.01] and accelerometry [boys: F=460.80, p<0.01; girls: F=667.96, p<0.01]. Overweight and obese adolescents presented high values of AEE. When daily physical activity is expressed in counts.min^{-1} the effect of weight status was still significant for girls [normal weight: 398 counts.min^{-1}; overweight: 441 counts.min^{-1}, F=6.00, p<0.01], but not for boys. The magnitude of the significant effects ranged from moderate to large.

Table 5.2. Descriptive statistics by sex and age-group and results of ANOVA testing the effect of age on chronological age, body size, daily activity energy expenditure and accelerometer counts/minute in males and females separately.

		Males (n=186)					Females (n=217)				
		13-14 yrs (n=112)	15-16 yrs (n=74)	F	p	η^2	13-14 yrs (n=130)	15-16 yrs (n=87)	F	p	η^2
Anthropometry	Age, yrs	13.5±0.6	15.3±0.6	1214.75	0.00	0.69	13.5±0.58	15.2±0.53	1455.18	0.00	0.69
	Height, cm	160.5±8.9	170.6±7.1	202.30	0.00	0.27	157.7±6.4	159.5±5.8	13.59	0.00	0.02
	Weight, Kg	50.4±10.4	62.1±9.7	178.84	0.00	0.24	52.7±10.8	54.8±9.1	6.86	0.01	0.01
	BMI, Kg/m^2	19.44±2.92	21.34±3.13	53.72	0.00	0.09	21.13±3.82	21.53±3.21	1.98	0.16	0.00
Diary	AEE (kcal.min^{-1})	2.18±0.71	2.58±0.88	36.13	0.00	0.06	2.12±0.76	2.14±0.57	0.06	0.81	0.00
Accelerometer	AEE (kcal.min^{-1})	2.22±0.83	3.12±0.80	160.99	0.00	0.23	2.31±0.89	2.48±0.76	6.12	0.01	0.01
	Counts.min^{-1}	522.2±262.1	477.2±242.3	4.17	0.04	0.01	410.6±167.1	404.8±205.2	0.15	0.70	0.00

BMI (Body Mass Index); AEE (Activity Energy Expenditure).

Table 5.3. Descriptive statistics for normal-weight and overweight/obese adolescents and results of ANOVA testing the effect of weight status on chronological age, body size, daily activity energy expenditure and accelerometer counts/min in males and females separately.

		Males					Females				
		Nw (n=151)	Ow/Ob (n=35)	F	p	η^2	Nw (n=165)	Ow/Ob (n=52)	F	p	η^2
Anthropometry	Age, yrs	14.2±1.1	14.2±1.0	0.00	0.97	0.00	14.1±1.0	14.0±1.0	14.56	0.00	0.02
	Height, cm	164.2±9.5	165.7±9.8	3.27	0.07	0.01	158.3±6.4	158.7±5.4	2.29	0.13	0.00
	Weight, Kg	51.8±9.2	69.1±10.8	497.62	0.00	0.47	49.6±6.3	66.1±10.1	689.09	0.00	0.52
	BMI, Kg/m^2	19.06±1.89	25.07±2.83	877.06	0.00	0.61	19.76±1.92	26.17±3.27	996.98	0.00	0.61
Diary	AEE (kcal.min^{-1})	2.19±0.68	2.95±0.99	94.31	0.00	0.15	1.95±0.52	2.68±0.83	172.50	0.00	0.21
Accelerometer	AEE (kcal.min^{-1})	2.32±0.73	3.69±0.88	460.80	0.00	0.45	2.06±0.52	3.41±0.83	667.96	0.00	0.51
	Counts.min^{-1}	505.4±254.1	499.6±260.7	0.05	0.83	0.00	397.8±160.5	441.4±239.1	6.00	0.02	0.01

Nw (normal-weight); Ow/Ob (overweight + obese participants); BMI (Body Mass Index); AEE (Activity Energy Expenditure).

Table 5.4. Partial correlations (controlling for body mass) between estimates of activity energy expenditure by the diary and accelerometry, bias ant its limits of agreement between two AEE estimates by sex, age group, and weight status.

		# observed days	Partial		Agreement [1]			
			r	p	Bias	Limits Lower	Limits Upper	Trend
Sex	Males	558	0.44	p<0.01	-0.24	-1.75	1.26	-0.18**
	Females	651	0.33	p<0.01	-0.25	-1.46	0.95	-0.28**
			Δr=0.11	p<0.05				
Age-group	13-14 years	726	0.41	p<0.01	-0.12	-1.42	1.17	-0.21**
	15-16 years	483	0.42	p<0.01	-0.43	-1.79	0.92	-0.13**
			Δr=0.01	n.s.				
Weight status	Nw	948	0.42	p<0.01	-0.11	-1.25	1.02	-0.05
	Ow/Ob	261	0.39	p<0.01	-0.74	-2.36	0.89	0.07
			Δr=0.03	n.s.				

Nw (Normal-weight); Ow/Ob (Overweight + Obese participants); [1] Diary – Accelerometry; ** (p<0.01).

Partial correlations between the diary and accelerometry, controlling for body mass, ranged between 0.33 and 0.44 (Table 5.4.). The magnitude of the relationship was significantly higher in males compared to females ($\Delta r=0.11$, $p<0.05$). Coefficients did not differ by age-group and weight status.

Concordance between self-reported and objective methods was assessed according to the 95% limits of agreement determined by the procedures of Bland-Altman (Bland & Altman, 1986). The upper and lower bounds of the 95% confidence intervals represent the largest error that could be expected for the diary method (Table 5.4.).

Agreements between the diary and accelerometry estimates of AEE are illustrated on Figures 5.1. to 5.6. The 3-day diary revealed less agreement in the specific group analyses. It markedly underestimates AEE in overweight/obese and older adolescents of both genders. The bias tends to be stronger at high intensity levels of PA, especially when the data are plotted by gender and age groups. A trend line (association between the difference and the average of the two protocols) is apparent in both genders (males: $r=-0.18$, $p<0.01$; females: $r=-0.28$, $p<0.01$) and also in the two age groups (13-14 years: $r=-0.21$, $p<0.01$; 15-16 years: $r=-0.13$; $p<0.01$), but is not apparent for weight status groups.

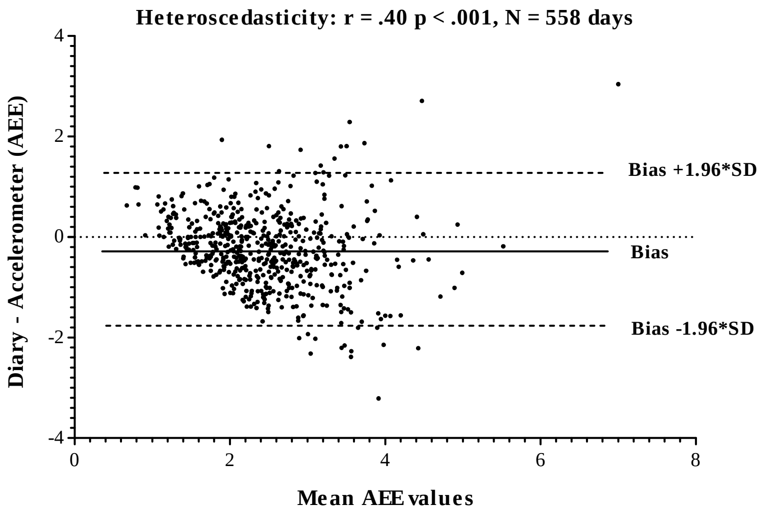

Figure 5.1. Bland-Altman plot for AEE of male adolescents showing the difference between the diary and accelerometer estimates plotted against the mean of the two estimates.

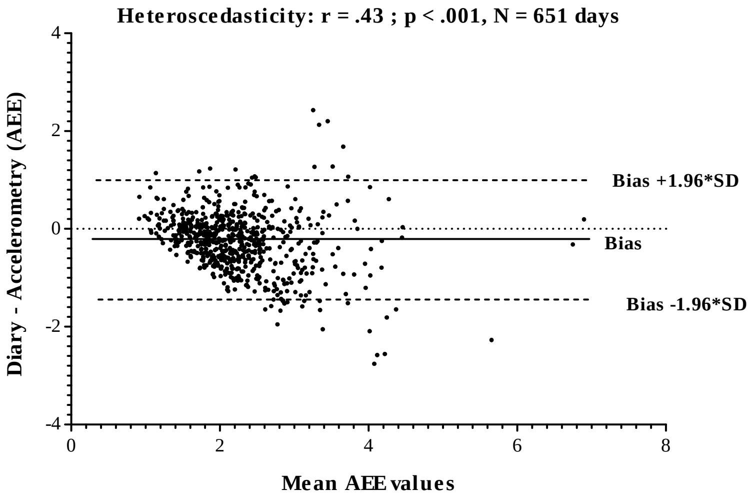

Figure 5.2. Bland-Altman plot for AEE of female adolescents showing the difference between the diary and accelerometer estimates plotted against the mean of the two estimates.

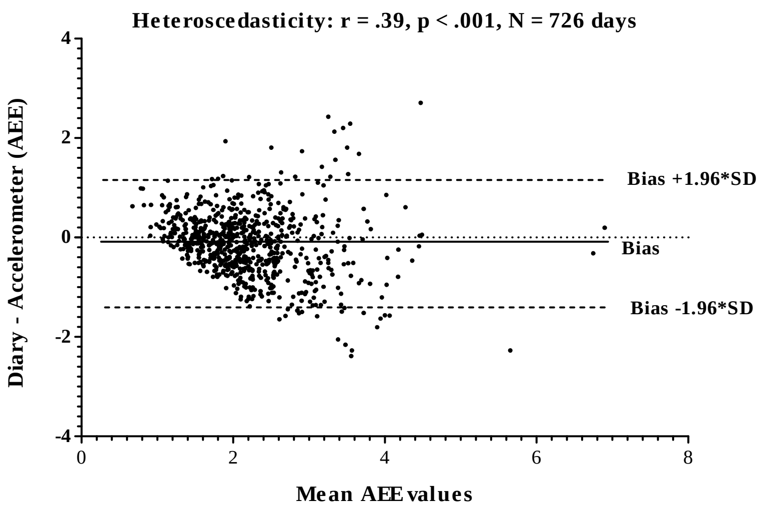

Figure 5.3. Bland-Altman plot for AEE of adolescents 13-14 years of age showing the difference between the diary and accelerometer estimated plotted against the mean of the two estimates.

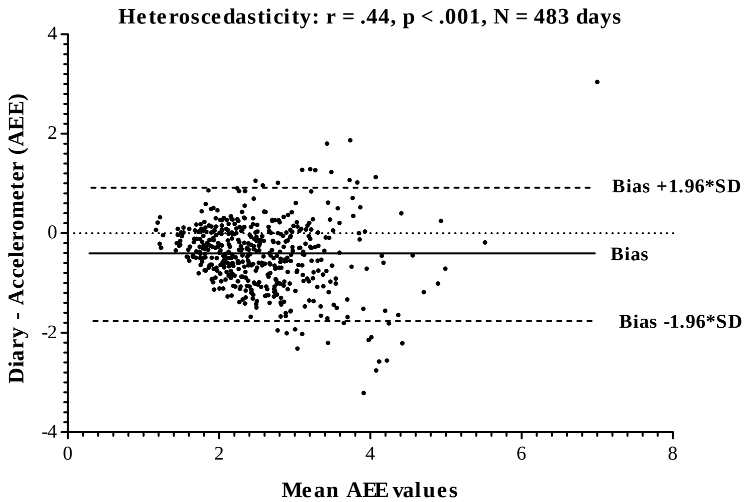

Figure 5.4. Bland-Altman plot for AEE of adolescents 15-16 years of age showing the difference between the diary and accelerometer estimates plotted against the mean of the two estimates.

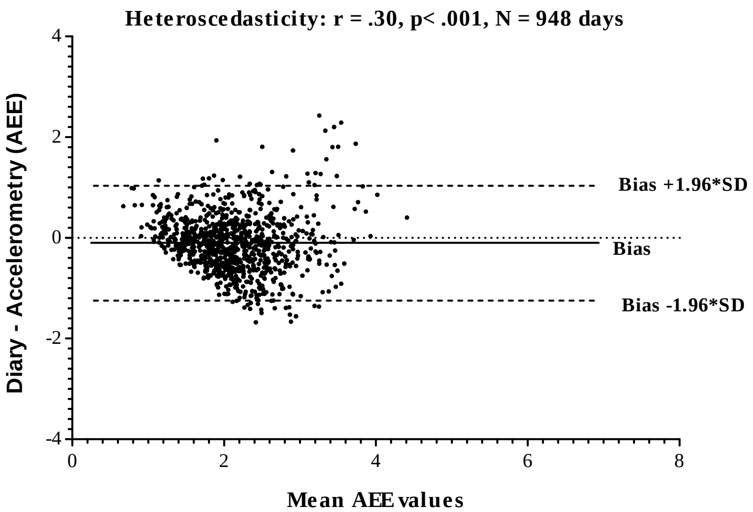

Figure 5.5. Bland-Altman plot for AEE of normal weight adolescents showing the difference between the diary and accelerometer estimates plotted against the mean of the estimates.

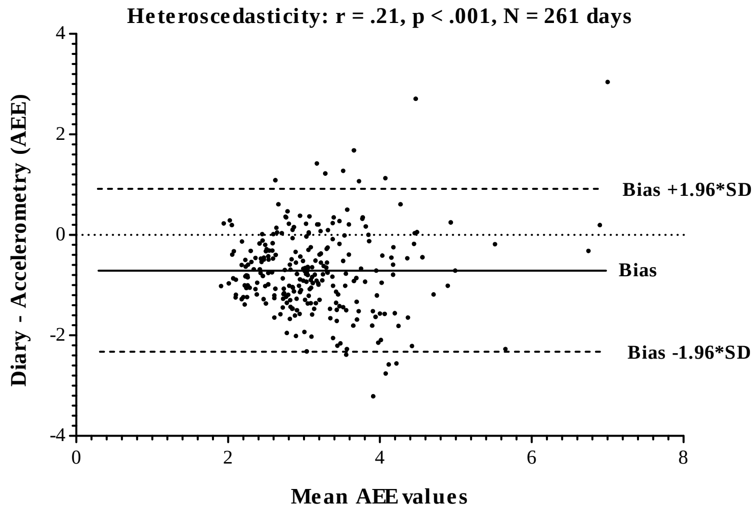

Figure 5.6. Bland-Altman plot for AEE of overweight/obese adolescents showing the difference between the diary and accelerometer estimates plotted against the mean of the two estimates.

Table 5.5. summarises the mean of the log transformed measurement, and their mean differences, and the "limits of agreement". The table also gives the correlation between the absolute differences and the mean (using the log transformed data). By observing the agreement ratios, the sub-group of older adolescents shows the greatest agreement, with a bias of 0.84 and an agreement ratio of */÷ 1.61. The worst agreement was found on male adolescents group, where two methods of measuring AEE were compared. Although the bias ratio is not great, given as 0.90, the agreement ratio (*/÷ 1.87) implies that 95% of ratios will lie between 187% of the mean bias (Table 5.5.).

Table 5.5. The log transformed (ln) measurement means and differences, the “ratio limits of agreement”, together with the correlation between the absolute differences and the mean (log transformed) by sex, age group, and weight status.

		Log transformed measurements					
		# observed days	Mean 1 Diary	Mean 2 Accelerometry	Difference (SD)	Ratio limits	Correlation *(abs(diff) v mean)*
Sex	Males	558	0.798	0.934	-0.107 (0.318)	0.90 (*/÷ 1.87)	-0.23**
	Females	651	0.698	0.820	-0.102 (0.258)	0.90 (*/÷ 1.66)	-0.30**
Age-group	13-14 yrs	726	0.698	0.779	-0.058 (0.301)	0.94 (*/÷ 1.80)	-0.24**
	15-16 yrs	483	0.779	0.971	-0.169 (0.243)	0.84 (*/÷ 1.61)	-0.16**
Weight status	Nw	948	0.673	0.772	-0.065 (0.280)	0.94 (*/÷ 1.73)	-0.11**
	Ow/Ob	261	0.975	1.230	-0.259 (0.253)	0.77 (*/÷ 1.64)	0.03

Nw (normal-weight); Ow/Ob (overweight + obese participants); ** (p<0.01).

DISCUSSION

This study examined the concordance of AEE derived from a 3-day diary and accelerometry relative to age, gender and weight status in adolescents 13-16 years of age. Partial correlations between protocols were significantly higher in males than in females and did not vary with age group. Bias ranged between -0.12 and -0.74. The diary underestimated AEE, especially among overweight/obese adolescents (-0.74 $kcal.min^{-1}$) and participants 15-16 years of age (-0.43 $kcal.min^{-1}$). Since self-reported PA is prone to misreporting and the correlations between the 3-day diary and accelerometer were no more than moderate, results should be interpreted with caution.

A decline in daily PA and AEE is often assumed across adolescent years, although not all studies support this trend. For example, in a large sample of Portuguese youth 10-18 years, school- and sport-related activities declined in females while both school- and sport-related physical activities increased with age in males (Teixeira e Seabra et al., 2008). In the present study, PA objectively assessed (counts per minute) did not differ among younger and older girls but younger boys revealed significantly higher levels of PA that their older counterparts. Note, however, discussions of the adolescent decline in PA consider a broader age range that spans early through late adolescence, while the present study compared two-year age groups across a relatively narrower age span.

The relationship between the 3-day diary and objective estimates of AEE varied by gender but not by age group. Leisure PA, in particular sports, is a more salient feature of daily life in males than in females (Chase & Dummer, 1992) and given the trend for a stronger association between instruments in males, it is perhaps likely that males face fewer choices in selecting categorical values for each 15-minutes segment of the diary, particularly for more structured activities. In addition, and contrary to expectation, the present study showed less concordance between protocols for older adolescents. From a cognitive perspective, one would expect that older adolescents were more capable to process and recall information pertaining to daily involvement in PA (Baranowski, 1988; Montoye, 1996). However, changes in the nature of PA, as result of the increasing of social autonomy, independence from family-based routines and probably sport engagement or dropout, are potential contributors in explaining the increased bias in the agreement between protocols among adolescents 15-16 years.

The Bland-Altman plots point out that the observed bias between the 3-day diary and the accelerometer is systemic by gender and age groups, and may be related to the amount of activity that is reported. In the present study, adolescents who reported lower amounts of PA had estimates of AEE values that were closer to those from the objective measure. However, participants who have reported high amounts of activity had estimated AEE values that were much lower than those from the accelerometer, particularly among older age group. The bias could result from the inaccuracy in the diary entries or from the accelerometer limitations previously mentioned. However, it should be clearly emphasised that the accuracy of the 3-day diary depends on the adolescents' willingness to adhere to the instruction as well as their ability to correctly identify the appropriate activity code, as previously noted in adults (Wickel et al., 2006).

The concordance of the 3-day diary and accelerometry estimates of AEE varied by weight status. At higher intensity levels of AEE, overweight/obese adolescents tended to overestimate PA while the opposite tendency was observed among normal weight youth (Table 5.4. and Figures 5.5. and 5.6). Previous research suggested that overweight and obese adolescents provided less accurate self-assessments of PA (McMurray et al., 2008; Slootmaker et al., 2009). American girls classified as overweight and obese, for example, had 17.7% and 19.4% fewer minutes of MVPA based on a self-instrument compared to normal weight girls (McMurray et al., 2008). In contrast, European adolescents 12 to 18 years self-reported more time on moderate and vigorous PA compared to objective accelerometry data, and results significantly differed in all subgroups (i.e. gender, weight status, and education) (Slootmaker et al., 2009). The current study suggests that the overweight/obese participants underestimated their AEE. Accordingly, further investigation is needed to examine the agreement between self-reported and objective measures at high intensity levels of PA.

Social and cultural factors not assessed in the current study may contribute to the validity of self-reported PA. Over-reporting PA may be related to social desirability issues (Klesges et al., 2004). Adolescent girls and boys from families with higher parental education over-report time spent in moderate and vigorous levels of PA, respectively, relative to accelerometer registered time (Slootmaker et al., 2009). Additional factors that may affect the relationships between self-report and objective measures of PA and AEE assessment might be the socio-geographical location. Perceptions of occupational activities (helping the family at home or in agriculture) may differ from ratings and duration of unstructured leisure activities and games. Variation in biological maturity status among adolescents is an additional concern since it relates to physical activity and sedentary behaviour (Machado Rodrigues et al., 2010) and probably mediates the perceived tiredness of intense activities. However, findings are inconsistent among studies which examine the relationship between biological maturity and PA, and associations, when noted, are generally low (Sherar, Cumming, Eisenmann, Baxter-Jones, & Malina, 2010).

Although accelerometry is often mentioned as the reference in studies of validation (Welk, 2002), it does not capture all types of PA (e.g., sports/activities that involve water or when wearing the accelerometer presents physical risk). On the other hand, self-report protocols may be affected by the nature of the behavior recalled. Most daily activities are intermittent and may involve substantial rest periods, which may lead to significant overestimation of time spent on daily activities (Slootmaker et al., 2009; Trost et al., 2002). The use of PA diaries in children and adolescents presents additional challenges. Compared to adults, youth were less time-conscious, were less able to process and recall information, and were more likely to engage in sporadic activities (Bailey et al., 1995; Baquet, Stratton, Van Praagh, & Berthoin, 2007). Such intermittent activities are probably more difficult to define or quantify than occupational activities or structured exercises (Armstrong & Welsman, 2006). Since the accelerometer is not a gold standard for assessment activity energy expenditure, the disagreement between instruments is a result of weaknesses of both instruments. Thus, research using a multi-method design to provide quantitative and qualitative data of PA is recommended in young people.

In the present study, the compliance for wearing the accelerometer was 82% (three consecutive days). Corresponding rates in previous research were 71% (days with valid accelerometer recording and corresponding diary entries) in a study of European adolescents (Bringolf-Isler et al., 2009) and 62%-75% in US youth (Anderson et al., 2005; Sallis et al., 1998). However, results of the current study are limited to Portuguese youth 13 to 16 years of age living in Midlands. Cultural and social factors specific to this region of Portugal were not considered, e.g., parental education of participants, perceptions of physical activities, spatial incentives for physical activity and sports. It is also possible that relationships between estimates of AEE may vary with season of the year. The current data were collected in the spring when youth were likely to be engaged in outdoor activities. On the other hand, the present study adopted an epoch of 60 seconds which tends to underestimate moderate, vigorous and very vigorous physical activities, especially in children (Nilsson, Ekelund, Yngve, & Sjostrom, 2002; Rowlands, Powell, Humphries, & Eston, 2006; Stone, Rowlands, & Eston, 2009). However, the time spent in activities of different intensities was not considered in the present study of adolescents. Finally, Trost equation (Trost et al., 1998) has revealed a systematic error on physical activity energy expenditure (PAEE) estimates (Corder et al., 2007) that might also influence the agreement between the 3-day diary and accelerometry in the present study. Nevertheless, Corder and colleagues (Corder et al., 2007) also demonstrated that equation was the most accurate on PAEE estimates when compared to others, such as Corder et al. (Corder, Brage, Wareham, & Ekelund, 2005) and Puyau et al. (Puyau, Adolph, Vohra, & Butte, 2002) equations.

CONCLUSION

The results of the present study showed a moderate relationship between AEE assessed by accelerometry and a 3-day diary. However, the diary protocol revealed less agreement in specific group analyses. The diary markedly underestimated AEE in overweight/ obese and older adolescent. Accordingly, those working to improve PA levels of youth should be aware of these and other factors in order to better develop future educational and clinical interventions/strategies for health promotion.

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CHAPTER VI

Confounding effect of biologic maturation on sex differences in physical activity and sedentary behavior in Portuguese adolescents [3]

[3] Machado-Rodrigues AM, Coelho e Silva MJ, Mota J, Neville H, Sherar LB, Cumming SP, Malina RM (2010). Confounding effect of biologic maturation on sex differences in physical activity and sedentary behavior in Portuguese adolescents. *Pediatric Exercise Science*, Vol. 22; (3): 442-453.

CONFOUNDING EFFECT OF BIOLOGIC MATURATION ON SEX DIFFERENCES IN PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR IN ADOLESCENTS

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ABSTRACT

Sex differences in physical activity (PA) through pubertal maturation and the growth spurt are often attributed to changing interests. The contribution of sex differences in biological maturation to the adolescent decline has received limited attention. This study examined the contribution of somatic maturation to sex differences in objective assessments of sedentary behavior and PA in Portuguese adolescents (N=302, aged 13-16 years). Maturation was estimated from the percentage of predicted mature stature and physically active and inactive behaviors assessed with Actigraph GT1M accelerometers. The influence of age, sex and their interaction on body size, maturation and physical behaviors were examined using factorial ANOVA and, subsequently, ANCOVA (controlling for maturation) tested the effect of sex. Males spent more time in MVPA and less time in sedentary behavior than females. However, sex differences were attenuated when maturation was controlled; thus suggesting that maturity may play an important role in adolescent behaviors.

***Keywords**: adolescence, somatic maturation, sedentary behavior, accelerometry*

INTRODUCTION

From the perspective of public health, physical activity is defined as "any bodily movement produced by skeletal muscles that results in a substantial increase in energy expenditure above resting metabolic rate and includes leisure time physical activity, exercise, sport, occupational work, and household and other chores" (Caspersen et al. 1985). Habitual physical activity, on the other hand, is a complex behavior that is influenced by interactions between biological and psychosocial characteristics of the individual and the physical and social environments in which the adolescent lives. Although daily energy expenditure and activity energy expenditure decline with age from early childhood onward, level of physical activity is generally stable during childhood but declines with the transition into adolescence and continues through the period of physical, physiological and psychological transition into adulthood (Malina et al. 2004).

Boys are, on average, more physically active than girls during childhood and through adolescence. The sex difference is generally attributed to differences in rearing, social expectations and other cultural factors. However, sex differences in estimated maturity status accounts for a small but significant portion of the variation in activity level in children 5-9 years of age (Eaton and Yu 1989). Sex differences in activity at older ages may also be influenced by maturity status, especially in the context of the earlier growth spurt and sexual maturation in girls compared to boys (Malina et al. 2004). Most studies comparing physical activity in boys and girls focus on chronological age to the exclusion of differences in the timing of maturation (Baxter-Jones et al. 2005). It is thus not unreasonable to assume that sex differences in biological maturation may contribute to sex-differences in physical activity, especially during adolescent years. Given the variation in the timing of the growth spurt and sexual maturation, one may expect that sex differences in physical activity would be attenuated when maturation is controlled for in statistical analyses. This was indeed noted in surveys of physical activity based on questionnaires among Canadian (Thompson et al. 2003) and British adolescents (Cumming et al. 2008) and based on objective assessment of physical activity in Canadian youth 8-13 years (Sherar et al. 2007).

Assessment of maturity status is a potentially important factor in studies of youth in the transition into and during adolescence. Indicators commonly used in growth studies tend to be invasive, e.g., skeletal and sexual maturation, or require longitudinal data, e.g., age at peak height velocity (Malina et al. 2004). Self-assessment of pubertal status is commonly used, but in some cultures this too may be considered invasive. Stages of puberty, though valuable, are also limited in the information provided. They simply indicate the stage of puberty and provide no indication of when the youngster entered the stage or how long he/she has been in the stage. Moreover, youth in the same stage of puberty but of different chronological ages are confounded by age, per se. A protocol for the estimation of age at peak height velocity is also available (Mirwald et al. 2002) and increasingly used in studies of physical activity (Sherar et al. 2007; Wickel and Eisenmann 2007). An alternative maturity indicator is the percentage of predicted mature stature attained at a given age (Khamis and Roche 1994). Two children may have the same height at a given chronological age, but one may have already attained a greater percentage of mature height than the other and is, therefore, closer to mature state (Malina et al. 2004). Percentage of predicted mature stature has been used in a study focused on sex differences in leisure-time activity assessed by questionnaire (Cumming et al. 2008) and also as a risk factor for injury in youth sport (Malina et al. 2005a; Malina et al. 2005b).

Studies of the effects of sedentary and physically active behaviors on health outcomes should be supported by evidence in which all levels of activity are differentiated clearly and measured independently (Pate et al. 2008). Research pertaining to sex differences sedentary behavior is not as abundant as for physical activity. Results from a large cohort of British youth demonstrated that girls tend to be more sedentary than boys and that sex differences were especially evident on week days (Mitchell et al. 2009; Riddoch et al. 2007). To date, the potential confounding effect of maturation on sex differences in sedentary behavior has not been addressed during the pubertal years. In one of the few studies that included measures of sedentary behavior and biological maturation, sedentary habits increased with stage of self-reported (questionnaire) pubertal status between 10 and 15 years (Murdey et al. 2005).

Given the limited research examining the role of maturation relative to sex differences in physically activity and inactive behaviors, the purpose of the present study was to examine the contribution of somatic maturation, given by the percentage of estimated mature stature attained at a given age, to sex differences in objective assessment of sedentary behavior and physical activity in adolescents.

METHODS

The sample included 135 males and 167 females (14.2±1.0 years) from seven schools in the Portuguese Midlands. The study was approved by the *Scientific Committee* of the *University of Coimbra* and the *Regional Education Office,* which required registration of the study in the *Portuguese Commission for the Protection of Personal Data* [Process #3132006]. Written consent was obtained from both parents and students.

Height and weight were measured at school in the morning using a portable stadiometer (Harpenden model 98.603, Holtain Ltd, Crosswell, UK) and a portable scale (Seca model 770, Hanover, MD, USA) to the nearest 0.1 cm and 0.1 kg, respectively.

Percentage of predicted mature (adult) height attained at the time measurement was used as an estimate of biological maturity status. The method assumes that among youth of the same chronological age, individuals closer to predicted mature height are advanced in biological maturation compared to individuals who are further from predicted mature height (Malina et al. 2004). The Khamis-Roche method (Khamis and Roche 1994) was used to predict mature height from current age, height and weight of the adolescent and midparent height (average height of biological parents). The mean error bound (median absolute deviation) between actual and predicted mature height at 18 years of age was 2.2 cm in males and 1.7 cm in females (Khamis and Roche 1994).

Physical activity and sedentary behavior were measured for five consecutive days using an ActiGraph GT1M accelerometer (ActiGraph^{TM}, LLC, Fort Walton Beach, FL, USA). Subjects were instructed to remove the sensor while showering or participating in swimming activities. The uniaxial accelerometer was designed to detect vertical accelerations ranging in magnitude from 0.05 to 2.00g with a frequency of response of 0.25-2.50 Hz that allows assessment of normal human motion. The ActiGraph uniaxial accelerometer (previously known as MTI 7164 model and CSA) is compact (3.8 cm x 3.7 cm x 1.8 cm) and light (27g) and has been validated in laboratory and free-living children and adolescents (Freedson et al. 2005). The data were electronically downloaded using the *ActiLife software*. The *MAHUffe program* was used to reduce the data in a file containing minute-by-minute counts. Participants who did not have 10 hours of valid measured data for each of the five days were excluded from subsequent analyses. The threshold of sedentary activity (minimal body movements in the sitting or reclining position) was established at 800 counts.min^{-1} (Puyau et al. 2002) and intensity levels of physical activity were determined using age-specific regression equation (Freedson et al.

1997) that were published by Trost and colleagues (Trost et al. 2002). These criteria have been previously used in epidemiological studies of youth (Riddoch et al. 2004; Nader et al. 2008).

Chronological age was calculated as the difference between date of birth and date of measurements. Participants were divided in two age-groups, 13-14 and 15-16 years. Factorial analyses of variance were used to examine the effect of age, sex and their interaction in height, weight, percentage of predicted mature stature attained as the time of study, and minutes spent in each category of physical activity and sedentary behavior. Subsequently, analyses of covariance, controlling for estimated maturity status, were conducted to determine whether sex differences in sedentary and physically active behaviors were attenuated. Statistical significance was set at 5%. In addition, multiple linear regression (backward elimination method with the stepping criteria for removal of $p<0.10$) was used to estimate the contribution of chronological age, height, weight, and percentage of estimated mature height to variation in each intensity level of physically active behaviors. This process reduces collinearity among independent variables in the final regression model by eliminating those variables do not predict a significant proportion of variance in the outcome measures.

RESULTS

Descriptive statistics by age and sex are summarized in Table 6.1. As expected, chronological age, sex and their interaction had a significant effect on body size. With few exceptions, minutes in sedentary behaviors and physical activities of two intensities were significantly affected by chronological age, sex and their interaction.

In the younger group, girls were, on average, 3.7 cm shorter than boys but did not differ in body mass. In contrast, older boys were, on average, 12.0 cm taller and 8.1 kg heavier than females. Percentage of predicted mature stature attained at the time of study was significantly affected by age [$F_{(1,302)}=187.83$, $p<.01$ $\eta^2=0.39$], sex [$F_{(1,302)}=155.14$, $p<.01$ $\eta^2=0.34$] and the age x sex interaction [$F_{(1,302)}=38.72$, $p<.01$ $\eta^2=0.12$].

Table 6.1. Means (standard deviations) for chronological age, percentage of predicted mature height, body size, and time spent in sedentary behaviors and in physical activities by age group and sex.

	13-14 years		15-16 years		Effect of age		Effect of sex		Effect of age x sex	
	Males (n=81)	Females (n=105)	Males (n=54)	Females (n=62)	F (p)	η^2	F (p)	η^2	F (p)	η^2
Chronological age, years	13.5 (0.6)	13.4 (0.6)	15.3 (0.6)	15.2 (0.5)						
Percentage of mature height, %	91.8 (3.6)	97.0 (2.0)	97.4 (1.8)	99.1 (0.5)	187.83 (.00)	.39	155.14 (.00)	.34	38.72 (.00)	.12
Height, cm	160.9 (9.6)	157.2 (6.2)	171.2 (7.4)	159.2 (5.4)	50.06 (.00)	.14	81.25 (.00)	.21	23.19 (.00)	.07
Weight, Kg	51.1 (11.5)	51.7 (9.7)	63.1 (10.1)	55.0 (9.3)	39.49 (.00)	.12	9.68 (.00)	.03	13.19 (.00)	.04
SED (week days), min/day	704.5 (68.3)	738.3 (67.1)	733.3 (55.2)	753.4 (50.2)	8.76 (.00)	.03	13.26 (.00)	.04	0.85 (.36)	.00
SED (weekend), min/day	662.3 (88.8)	650.8 (71.7)	663.0 (71.5)	701.3 (83.8)	7.39 (.01)	.02	2.03 (.16)	.01	7.03 (.01)	.02
SED (total of 5 days), min/day	687.5 (60.9)	703.2 (55.3)	705.1 (52.7)	732.4 (52.5)	12.38 (.00)	.04	10.50 (.00)	.03	0.77 (.38)	.00
Light PA (week days), min/day	64.2 (19.1)	64.2 (24.2)	74.5 (22.3)	68.4 (22.6)	7.54 (.01)	.03	1.35 (.25)	.00	1.35 (.25)	.01
Light PA (weekend), min/day	64.6 (29.1)	61.9 (29.2)	72.2 (30.9)	58.5 (24.6)	.38 (.54)	.00	5.80 (.02)	.02	2.59 (.11)	.01
Light PA (total of 5 days), min/day	64.2 (20.1)	63.2 (24.7)	73.5 (21.7)	64.3 (20.7)	3.90 (.05)	.01	3.80 (.05)	.01	2.38 (.12)	.01
MVPA (week days), min/day	109.5 (39.8)	78.6 (27.3)	70.7 (30.0)	60.0 (26.6)	59.50 (.00)	.17	31.21 (.00)	.10	7.29 (.01)	.02
MVPA (weekend), min/day	67.7 (39.4)	47.3 (30.5)	49.7 (33.3)	32.5 (23.8)	18.07 (.00)	.06	23.68 (.00)	.07	0.16 (.69)	.00
MVPA (total of 5 days), min/day	92.6 (33.4)	66.1 (25.5)	62.3 (25.0)	48.9 (22.6)	53.89 (.00)	.15	38.08 (.00)	.11	4.16 (.04)	.01

SED (minutes spent sedentary); PA (Physical Activity); MVPA (Moderate to Vigorous Physical Activity).

Table 6.2. Adjusted means (and standard errors) and results of analyses of covariance (controlling for maturation) to test the effect of sex on time spent in sedentary behaviors and physical activities of different intensities.

	13-16 years		F	η^2
	Males (n=135)	Females (n=167)	(p)	
SED (week days), min/day	720.0 (6.2)	740.7 (5.4)	5.17 (.02)	.02
SED (weekend), min/day	664.0 (8.0)	668.4 (7.0)	0.14 (.71)	.00
SED (total of 5 days), min/day	697.5 (5.6)	711.7 (4.9)	2.99 (.08)	.01
Light PA (week days), min/day	69.2 (2.2)	65.0 (1.9)	1.65 (.20)	.01
Light PA (weekend), min/day	67.9 (2.9)	60.4 (2.5)	3.24 (.07)	.01
Light PA (total of 5 days), min/day	68.6 (2.2)	63.0 (1.9)	2.91 (.09)	.01
MVPA (week days), min/day	88.4 (3.1)	76.2 (2.7)	7.25 (.01)	.03
MVPA (weekend), min/day	55.0 (3.2)	46.2 (2.8)	3.59 (.06)	.01
MVPA (total of 5 days), min/day	75.0 (2.6)	64.1 (2.3)	7.78 (.01)	.03

SED (minutes spent sedentary); PA (Physical Activity); MVPA (Moderate to Vigorous Physical Activity).

The results of the factorial ANOVA revealed a significant main effect of sex in sedentary behavior for the five days [$F_{(1,302)}$=10.50, p<.01, η^2=0.03]. Compared to boys, girls spent more time in sedentary activities. The sex-related variation in sedentary behavior was more evident during week days in the younger group, but on weekend days in the older group. However, the main effect of sex on sedentary behavior was attenuated and non-significant when biological maturation was statistically controlled (Table 6.2.).

Significant main effects for sex in LPA were observed for the five consecutive days [$F_{(1,302)}$=3.80, p<.05, η^2=0.01] in part due to significant differences on weekend days [$F_{(1,302)}$=5.80, p<.05, η^2=0.02]; no differences were noted for week days. Among 13-14 year old youth, boys spent more than 2.7 minutes per day in LPA than girls during weekends. The corresponding sex difference in the older group was 13.7 minutes. After controlling for differences in maturity status, sex differences were no longer significant for either week days or weekend days.

A significant main effect of sex of the individual on MVPA was observed on week days [$F_{(1,302)}$=31.21, p<.01, η^2=0.10], weekend days [$F_{(1,302)}$=23.68, p<.01, η^2=0.07] and consequently across all days [$F_{(1,302)}$=38.08, p<.01, η^2=0.11] (Table 6.1.). The age x sex interaction also produced a significant effect for week days [$F_{(1,302)}$=7.29, p<.01, η^2=0.02] and total days [$F_{(1,302)}$=4.16, p<.05, η^2=0.01]. Results of analyses of covariance (Table 6.2.) suggested that the sex differences were no longer significant for weekend days and that the effect size was attenuated for the other days.

Results of the regression analyses are summarized in Table 6.3. The predictor variables explained 5%-12% of the variance in sedentary behavior, 0%-8% in LPA and 20%-30% in MVPA. Chronological age was a significant predictor for LPA and MVPA in males, while age and body mass were significant predictors of the variance in sedentary behavior and MVPA in females. Percentage of predicted mature stature attained at the time of study was a significant predictor of the sedentary behavior, LPA and MVPA in boys but not in girls.

Table 6.3. Significant predictors of sedentary behavior and physical activities of different intensities by sex.

Group	Behavior	R^2	Adjusted R^2	Model	Predictor	Unstandardized coefficients		95% CI for Beta		Standardized beta coefficient
						Beta	St. error	Lower	Upper	
Males	Sedentary	5%	4%	$F_{(1,133)}$=6.207; p<.01	% EMS	3.03	1.22	0.63	5.44	+0.21
	LPA	8%	6%	$F_{(2,132)}$=5.353; p<.01	CA	9.32	3.09	3.20	15.44	+0.46
					% EMS	-1.45	0.80	-3.03	-0.13	-0.28
	MVPA	30%	30%	$F_{(2,132)}$=28.132; p<.01	CA	-7.90	4.29	-16.39	-0.58	-0.46
					% EMS	-2.70	1.10	-4.89	-0.52	-0.33
Females	Sedentary	12%	11%	$F_{(2,164)}$=10.750; p<.01	CA	17.92	4.01	10.01	25.83	+0.33
					Body mass	0.88	0.42	0.02	1.72	+0.15
	LPA	-	-	-	-	-	-	-	-	-
	MVPA	20%	19%	$F_{(2,164)}$=19.962; p<.01	CA	-10.76	1.76	-14.23	-7.28	-0.44
					Body mass	-0.51	0.19	-0.89	-0.14	-0.19

LPA (light physical activity); MVPA (moderate to vigorous physical activity); %EMS (percentage of estimated mature stature); CA (chronological age).

DISCUSSION

The results are largely consistent with previous research (Cumming et al. 2008; Eaton and Yu 1989; Sherar et al. 2007; Thompson et al. 2003) identifying biological maturation as a source of variation in sex differences in physical activity and sedentary behavior during adolescence. The use of percentage of predicted mature stature attained at the time of study as an indicator of maturity status and the objective assessment of sedentary behaviors are unique contributions in the study. The observations are particularly relevant as the decline in physical activity becomes more marked as adolescence progresses. Longitudinal data indicate that correlations between maturity indicators which occur closer in time during adolescence were higher than those more separated in time (Hauspie et al. 1991). Consequently, as adolescent growth proceeded skeletal age was more strongly related to percentage of mature stature than years from peak height velocity (Malina et al. 2004).

Predicted mature height as used in the present study has a limitation. It was based on an equation developed for a middle class of American youth in the *Fels Longitudinal Study*. The validation of the age- and sex-prediction equations for Portuguese youth needs to be examined.

Mean time spent in MVPA decreased by 28.8 and 18.6 $min.day^{-1}$, respectively, in boys and girls, from the younger to the older adolescent age groups. On the other hand, average daily time spent in sedentary behaviors increased with age in boys by 28.8 $min.day^{-1}$ and in girls 15.1 $min.day^{-1}$. The cross-sectional design did not permit individuals to be followed as they progressed through adolescence. Nevertheless, the results were consistent with other cross-sectional data (Romon et al. 2004). Reported pedometer steps per day were greater among boys in stage 1 (10509 $steps.day^{-1}$) than in stage 5 (8103 $steps.day^{-1}$) of puberty. However, subjects in stage 5 were chronologically older so that the difference in physical activity could have been age- rather than maturity-related. The influence of biological maturity status on physical activity were also examined in longitudinal samples of 70 boys and 68 girls 9–18 years (Thompson et al. 2003). Although physical activity declined when plotted relative to both chronological and biological ages, the significant sex differences observed with chronological age were eliminated when the data were aligned by years before and after peak height velocity. Of note, both studies that examined maturity-related variation were not based on objectively assessed physical activity or activities of different intensities.

In general, boys spent more time in MVPA than girls. The sex difference in this level of physical activity was consistent with previous research using accelerometry with youth spanning the adolescent years (Martinez-Gomez et al. 2009; Riddoch et al. 2004; Troiano et al. 2008). However, individual differences in maturity status were not considered in these studies. In a study that included an indicator of maturity status, level of PA decreased with increasing chronological age in both sexes 8-13 years and boys had higher MVPA at 10-13 yr; however, when aligned on biological age, sex differences disappeared (Sherar et al. 2007).

Not all studies show a decline in physical activity across adolescence. In a large sample of Portuguese youth 10-18 years, school- and sport-related activities (Baecke questionnaire) declined in females only after 16 years while both school- and sport-related physical activities increased with age in males (Teixeira e Seabra et al. 2008). Of relevance, Portuguese national statistics also showed that more males than females participated in organized sports (Adelino et al. 2005; IDP 2005). Among Canadian youth, organized sport participation appeared to be a significant component of daily energy expenditure (DEE); males expended 20.4% of DEE in organized sports compared to 16.3% in females (Katzmarzyk and Malina 1998).

The observation that sex differences in biological maturation influence sex differences in physical activity adds to our understanding of adolescent variation (Cumming et al. 2008; Sherar et al. 2007). Of interest, early-maturing youth had higher rates of both sedentary behaviors and vigorous physical activity than their "on-time" or average peers. The combination of higher rates of vigorous activity and sedentary behavior though seemingly contradictory, highlights the independence of physical activity and inactivity (Brodersen et al. 2005) and the need for further assessment of sedentary behaviors among youth.

Differences between males and females tend to be less marked in light forms of physical activity (Sherar et al. 2007; Trost et al. 2000). Results of the current study also suggest that girls spent significantly more time in sedentary behaviors than boys, especially on week days. The tendency also surfaced at the weekend but only in the older age-group. Of relevance, observations of immediate after school hours noted that technology-based sedentary behavior was higher in boys than girls (Atkin et al. 2008).

Although differences in the timing and tempo of biological maturation may contribute to sex differences in physically active and sedentary behaviors, it is likely that a combination of the social, psychological, physical and physiological changes associated with biological maturation rather than maturity status per se underlie the observations. In the current study, body size, chronological age and somatic maturation explained 5-12% of the variance in sedentary behaviors and 20-30% in MVPA. Although complex, physical and physiological changes associated with growth and maturation per se, interacting with psychosocial and other factors in the social environments of youth probably contribute to sex differences in adolescent lifestyles, including physical active and sedentary behaviors.

A role for psychosocial factors on the reduction in physical activity among girls during the transition into puberty and sexual maturation has been postulated (Malina et al. 2004). Psychosocial factors prominent at this time include decline in self-esteem (more so in early than later maturing girls) and changing interests (including interest in risk taking behaviors associated with alcohol and smoking) and social demands (homework, employment, dating, parental pressures). The decline in physical activity in adolescent females may also be related to physical and physiological changes associated with puberty and the growth spurt. These include changes in body composition (relatively more fatness) and proportions (relative broadening of the hips), discomfort associated with the establishment of regular menstrual cycles and reduction in blood haemoglobin levels (Malina et al. 2004). Advanced maturation in females is associated with somewhat less proficiency in motor skills, especially weight bearing and endurance tasks (Malina et al. 2004).

CONCLUSION

In summary, the contribution of biological maturation to sex differences in physically active and sedentary behaviors has potential implications for the promotion of active lifestyles during adolescence. Needless to say, intervention targeting boys and girls of the same chronological ages may have limitations.

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CHAPTER VII

Urban-rural contrasts in cardio-respiratory fitness, physical activity, and sedentary behaviour in Portuguese adolescents [4]

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URBAN-RURAL CONTRASTS IN CARDIO-RESPIRATORY FITNESS, PHYSICAL ACTIVITY, AND SEDENTARY BEHAVIOUR IN PORTUGUESE ADOLESCENTS

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ABSTRACT

Background: Research examining differences in the physical activity (PA) and health outcomes among urban and rural youth has produced equivocal findings. This study examined sedentary behaviours, PA and cardiorespiratory fitness (CRF) in adolescents from urban and rural communities of the Portuguese Midlands.

Methods: The sample comprised 362 adolescents (165 males and 197 females aged 13 to 16 years). CRF was assessed by the PACER test. A GT1M accelerometer was used to record five consecutive days of PA, including time spent sedentary. Analyses of variance were performed to test the effect of the area of residence on sedentary behaviour, PA and CRF. Analyses of covariance (chronological age as co-variable) were performed to test the effect of the area of residence on sedentary behaviour, PA and CRF.

Results: Male adolescents from urban communities spent less time in sedentary activities than rural male adolescents. Urban males were also more active than their rural peers at the weekend, whereas urban females were significantly less active than rural females on week days and across total assessed days. In addition, urban males were more active at the weekend than their rural peers. Rural boys and girls demonstrated higher levels of CRF than urban youth.

Conclusion: Area of residence is related to aerobic fitness, PA and time spent in sedentary among Portuguese youth. Interventions seeking to enhance health and active lifestyle in Portuguese youth should consider the potential impact of socio-geographic factors.

Keywords: *Cardiorespiratory fitness, urbanization, accelerometry, screen time, adolescence*

INTRODUCTION

Urbanization is periodically highlighted as a factor that influences PA, sedentary behaviour, weight status, and cardiovascular fitness (CRF) in youth (Liu et al. 2008; Spring et al. 2006; Albarwani et al. 2009; Ismailov and Leatherdale 2010). Urbanization refers to the concentration of people in towns/cities and associated changes – migration, transformation of economic and physical organization of the city, and changes in behaviours of the population (Ezzati et al. 2005). It has been intuitively assumed that individuals living in urban centres would be less active (Liu et al. 2008; Spring et al. 2006), and by inference would have lower levels of CRF and higher levels of overweight and obesity.

Physical activity occurs in social contexts that have specific demands and constraints such as opportunities for walking, access to playgrounds, proximity to shopping centres, and so on. These factors interact with social autonomy and of course with rearing style among children. However, the impact of urbanization on PA, CRF and health is somewhat unclear (Cicognani et al. 2008). Potential confounders include local cultural factors, climate and methods of assessment so that socio-geographic variation in PA, CRF and health outcomes may not generalize across countries. It is also possible that urban-rural contrasts may be associated with different heath outcomes across relatively different geographic regions (i.e., North Europe, Mediterranean countries, US, Asia or in Mexico).

Previous research has documented higher levels of overweight and obesity among rural school youth compared to their urban counterparts in United States (Liu et al. 2008; Lutfiyya et al. 2007), Canada (Ismailov and Leatherdale 2010), and Spain (Moreno et al. 2001). In contrast, adolescents from urban communities were more likely to be classified as overweight and obese than rural peers in China (Xu et al. 2007), and Oman (Albarwani et al. 2009). Other research has shown that rural adolescents of both sexes were less physically active than urban youth in the U.S. (Liu et al. 2008; Lutfiyya et al. 2007) and Iceland (Kristjansdottir and Vilhjalmsson 2001; Lutfiyya et al. 2007), while the opposite trend was noted in Oman (Albarwani et al. 2009). Urban youth in U.S. were more likely to be sedentary than rural youth (Liu et al. 2008). Within U.S. school youth resident in the South reported the lowest prevalence of PA and highest prevalence of TV viewing in contrast with adolescents from the Western region (Springer et al. 2006). On the other hand, youth from different regions of Sweden did not differ in active behaviours (Sjolie and Thuen 2002).

Trends in physical fitness show variable contrasts. Youth from rural were more likely to be classified as physically fit, especially in CRF, compared to urban youth in Oman (Albarwani et al. 2009). On the other hand, differences in several motor fitness and somatic characteristics between rural and urban Belgian youth were negligible, an observation which the authors attributed to an ongoing process of conurbation in this relatively small country (Taks et al. 1991) and, relatively impoverished Mexican youth resident in an urban colonia had somewhat better endurance performance compared to peers from an impoverished indigenous rural community (Reyes et al. 2003).

The proportion of the world population living in urban areas has dramatically grown over the past few decades (Ezzati et al. 2005). A similar trend has been evident in Portugal over the last four decades where over 45% of people presently live in the metropolitan areas of Lisbon and Oporto, reflecting a shift from an agricultural- to a services-based economy (Barreto 2000). Information considering rural-urban contrasts of youth lifestyles among Portuguese youth is limited, especially for the population in the Midland region of Portugal. This region, between the major urban centres of Lisbon and Porto, contains a mixture of mid-size urban centres and rural communities. Social inequalities between urban and rural communities are evident in the form of health and educational resources (Barreto 2000). According to the *National Statistics* (INE 2001), the population of the most important urban centre of Portuguese Midlands (city of Coimbra) increased 6.75% between 1991 and 2001, which was more than the proportional increase of the total population of Portugal over the same period (4.08%).

Given that the effects of urbanization on PA, sedentary behaviour and physical fitness are seemingly variable among and within specific countries and regions, the purpose of this study was to compare PA, total time being sedentary, screen time and CRF in rural and urban adolescents resident in the Portuguese Midlands. Indeed, the rationale of this study still remains more interesting once youth from Southern countries have the highest overweight and obesity rates in Europe (Padez et al. 2004).

METHODS

Sample

The study was part of a cross-sectional school-based survey of prevalence of overweight/obesity in Portugal (Sardinha et al. 2010). All administrative regions of mainland Portugal (Alentejo, Allgarve, Midlands, Lisbon and North) were surveyed. The population was selected by proportionate stratified random sampling taking into account the location (region) and the number of students by age and gender in each school. Details of the study are described elsewhere (Sardinha et al. 2010). The present study included 362 adolescents resident in the Portuguese Midlands (165 males, 197 females; 14.2±1.1 years) in grades 7th through 10th, with valid accelerometer-based data according to later mentioned criteria.

The project was registered at the *Portuguese Commission for Data Protection* [Process #3132006] and approved by the *Scientific Committee* of the *University of Coimbra*. Informed written assent was obtained from participants and informed consent was obtained from parents or guardians. The Portuguese Midlands include five districts (Aveiro: 752,867 inhabitants, km²; Leiria: 477,967 inhabitants, km²; Viseu: 394,844 inhabitants, km²; Castelo Branco: 208,069 inhabitants, km²; Guarda: 173,831 inhabitants, km²). The city of Coimbra is the primary urban centre, with a population of 148.443 in 319 km². Coimbra is located approximately midway between the two largest urban regions in the country, Lisbon and Porto, with populations of 2.7 and 1.7 million, respectively.

Anthropometry

Height and weight were measured at school in the morning using a portable stadiometer (Harpenden model 98.603, Holtain Ltd, Crosswell, UK) and a portable scale (Seca model 770, Hanover, MD, USA) to the nearest 0.1 cm and 0.1 kg, respectively, with participants in t-shirt and shorts, and without shoes. The body mass index (BMI, kg/m^2) was calculated. Students were classified into two weight status groups, normal weight vs. overweight/obese, using the age- and sex-specific BMI cut-offs of the International Obesity Task Force (Cole et al. 2000).

Physical activity and sedentary behaviour

The *ActiGraph GT1M* accelerometer (ActiGraph™, LLC, Fort Walton Beach, FL, USA) was used for direct assessment of PA and sedentary behaviour. The small uniaxial accelerometer (3.8 cm x 3.7 cm x 1.8 cm) and light (27g) detects vertical accelerations ranging in magnitude from 0.05 to 2.00g with a frequency of response of 0.25-2.50 Hz that permits normal human motion assessment. The filtered acceleration signal is digitized and the magnitude is summed over a user-specified period of time (epoch interval). At the end of each epoch, the summed value is stored in the memory. The device was validated in laboratory and under free-living conditions with children and adolescents (Freedson et al. 2005). Participants wore the accelerometer over the hip for five consecutive days (Thursday through Monday). Data were registered as counts per minute, consistent with previous studies in Europe (Riddoch et al. 2004) and the U.S. (Troiano et al. 2008), and the output was expressed as the average number of minutes spent in different physical activities of different intensities. Students were instructed to remove the monitor while showering and performing aquatic activities. The data were electronically downloaded using the *ActiLife software*. The *MAHUffe program* was used to reduce the data into a file containing minute-by-minute movement counts for each subject. Of the initial sample, 130 students failed to achieve 600 minutes (after removing sequences of 20 or more consecutive zero counts) of valid accelerometer data per day and were excluded. There were no significant differences in the distributions of included and excluded participants by sex [$\chi_{(1)}^2$=1.22; p=0.27], age [$\chi_{(1)}^2$=2.88 p=0.09], and weight status [$\chi_{(1)}^2$=0.48 p=0.49].

Sedentary behaviour was estimated using specific cut-points established against continuous measurement of energy expenditure (EE) by respiration calorimetry in a sample of children and adolescents 6 to 16 years of age (Puyau et al. 2002). Intensity-levels of PA were determined using an age-specific regression equation (Trost et al. 2002). The inclusion criteria and cut-points were previously used in pediatric epidemiological studies (Riddoch et al. 2004; Nader et al. 2008).

Cardiorespiratory Fitness (CRF)

CRF was assessed by the *Progressive Aerobic Cardiovascular Endurance Run* test (PACER), a multistage 20-m endurance shuttle run test (Leger et al. 1988). The PACER was scored as the number of “laps” completed at volitional exhaustion. Participants were required to run between 2 lines 20 m apart using a cadence dictated by a CD emitting audible signals at prescribed intervals. Initial speed was set at 8.5 km/h for the first minute and then was increased 0.5 km/h each subsequent minute. When the subject could no longer keep the pace by reaching the line at the sound of the tone, the test was finished (at the second fault) and the number of laps completed was recorded. The test provides a valid and reliable field measure of VO_{2max} in children and adolescents (Leger et al. 1988; van Mechelen et al. 1986). The test is also frequently incorporated into physical education (PE) curricula to track CRF levels among youth. The test protocol was explained in full before the start and all testing was done in PE classes under dry weather conditions. Replicate PACER tests were done on 23 students, one week apart. The technical error and reliability coefficient were 2.6 “laps” (51.6 m) and 0.97, respectively.

Screen time

Screen time, including TV viewing, computer use and video games) is a commonly used indicator of sedentariness (Tremblay 2010). The amount of time spent on screen activities was determined from an activity diary (Bouchard et al. 1983) and expressed as min/day. Respondents were grouped as watching TV and using a computer ≤2 h/day and >2 h/day according to guidelines suggested by the *American Academy of Pediatrics* (American Academy of Pediatrics 2001).

Area of residence

Participants were classified by residence as urban or rural according criteria of the *Portuguese Statistical System* (Monteiro 2000). Urban areas were defined as a city with more than 500 inhabitants/Km^2 or more than 50,000 inhabitants. Rural areas were defined as villages with no more than100 inhabitants/Km^2 or with total population under 2000 people. Participants were also classified by residence in a flat (apartment) or house.

Statistical analysis

Chronological age was calculated as the difference between date of birth and date on which height and weight of the participants was measured. Participants were categorized by sex (male, female) and age group (i.e.,13-14 and 15-16 years). Descriptive statistics included means and standard deviations for intensity levels of PA, time spent sedentary, CRF, and screen time. A series of sex-specific one-way analyses of variance (ANOVA) were conducted to test age differences in each variable. As a number of differences were observed between younger and older-age groups, mainly in MVPA for both genders and time spent sedentary in females, analysis of co-variance (controlling for chronological age) were performed to test urban-rural contrasts in CRF, physical activity and time spent sedentary by males and females separately. SPSS 15.0 (SPSS Inc., Chicago, Illinois, USA) was used for all analyses. Level of significance was set at 5%.

RESULTS

Descriptive statistics for chronological age, body size, screen time, time spent sedentary and PA by intensity level are summarized by sex and age in Table 7.1. As expected, 15-16 year old boys were, on average, significantly heavier and taller, presented higher BMI and had higher CRF compared to younger peers. The 13-14 year old boys, however, spent significantly more minutes in moderate-to-vigorous physical activities (MVPA) on week days, at the weekend, and across all days monitored (week days and weekend days combined), and spent less time in light activities than boys aged 15-16 years on week days, weekend days, and total days.

Among girls, 15-16 year olds were heavier and taller than younger peers. The BMI and CRF did not differ between age groups of girls. Girls 13-14 years were more physically active than older peers in MVPA on week days, at the weekend, and across all days. Older girls spent more time in sedentary activities than younger peers on total days, but the differences on week and weekend days were of marginal statistical significance.

Results for comparisons of urban and rural youth are summarized in Table 7.2. Urban and rural boys did not differ in age, height, weight and BMI. Urban boys spent significantly less time in sedentary activities than rural boys on week days and across total days, but did not differ at the weekend. Urban boys also spent significantly less time on screen activities than rural peers on week days and across total days. Furthermore, rural boys spent significantly more time in light physical activities than urban boys on week days. In contrast, urban boys spent significantly more time in MVPA than rural boys over the weekend. On the other hand, rural boys demonstrated significantly higher levels of CRF than urban peers.

Urban and rural girls did not differ in age, height, weight and BMI. Urban girls spent significantly less time on screen activities than rural girls on week days, and spent significantly less time in light physical activities than rural girls on week days, at the weekend, and across all days. However, urban females also spent significantly less time in MVPA on week days and across total days. As with males, rural females had significantly higher levels of CRF than their urban peers (Table 7.2.).

Table 7.1. Descriptive statistics and results of ANOVAs testing the effect of age group on body size, sedentary behaviour, physical activity and aerobic endurance separately for males (left) and females (right).

	Males (n=165)				Females (n=197)			
	13-14 (n=100)	15-16 (n=65)	F	p	13-14 (n=115)	15-16 (n=82)	F	p
Chronological age, years	13.5±0.6	15.3±0.6	344.30	0.00	13.5±0.6	15.2±0.5	454.33	0.00
Height, cm	160.7±9.0	170.6±7.4	55.54	0.00	157.5±6.2	159.4±5.8	4.62	0.03
Weight, Kg	50.6±10.8	62.6±10.1	51.89	0.00	52.0±9.5	54.6±9.3	3.78	0.05
BMI, kg . m^{-2}	19.44±3.01	21.51±3.28	17.45	0.00	20.90±3.42	21.47±3.24	1.37	0.24
Screen time: week, hours/day	2.57±1.52	2.79±1.77	0.72	0.40	2.27±1.29	2.51±1.52	1.37	0.24
Screen time: weekend, hours/day	4.87±3.30	3.94±3.46	2.99	0.09	3.36±2.35	3.41±2.72	0.02	0.88
Screen time: all days, hours/day	3.34±1.79	3.17±2.06	0.29	0.59	2.63±1.39	2.81±1.67	0.64	0.43
Sedentary: week, min/day	710.6±65.2	727.9±61.0	2.90	0.09	741.4±64.9	751.4±52.8	1.34	0.25
Sedentary: weekend, min/day	667.0±87.0	659.7±79.23	0.30	0.59	652.7±71.6	696.8±81.8	16.11	0.00
Sedentary: all days, min/day	693.0±58.7	700.5±57.9	0.65	0.42	705.8±53.8	729.4±54.4	9.18	0.00
Light PA: week, min/day	63.5±18.1	76.3±22.1	16.54	0.00	64.7±23.6	71.5±21.6	4.25	0.04
Light PA: weekend, min/day	61.5±28.3	72.8±29.8	5.97	0.02	62.3±28.8	60.5±25.6	0.20	0.66
Light PA: all days, min/day	62.6±19.1	74.8±21.5	14.59	0.00	63.7±24.1	67.0±20.3	1.04	0.31
MVPA: week, min/day	106.3±37.4	73.7±31.1	34.10	0.00	80.1±28.4	64.6±29.1	14.08	0.00
MVPA: weekend, min/day	63.5±39.1	49.4±31.7	5.90	0.02	48.8±30.9	35.2±26.9	10.27	0.00
MVPA: all days, min/day	89.1±32.2	63.9±25.7	28.09	0.00	67.5±26.3	52.7±24.9	15.82	0.00
Aerobic endurance, metres	1253±411	1464±486	9.03	0.00	743±286	805±311	2.05	0.15

BMI (Body Mass Index); PA (Physical Activity); SED (minutes spent sedentary); MVPA (Moderate-to-Vigorous Physical Activity).

Table 7.2. Descriptive statistics and results of ANCOVAs (chronological age as co-variable) testing the effect of degree of urbanization on body size, sedentary behaviour, physical activity and aerobic endurance for males and females separately.

	Males (n=165)				Females (n=197)			
	Rural (n=116)	Urban (n=49)	F	p	Rural (n=141)	Urban (n=56)	F	p
Height, cm	164.7±9.4	164.5±10.5	0.28	0.60	158.1±6.4	158.7±5.01	1.30	0.26
Weight, Kg	56.1±12.0	53.5±12.0	0.94	0.34	53.4±10.0	52.2±7.9	0.21	0.65
BMI, kg . m^{-2}	20.52±3.25	19.62±3.26	2.06	0.15	21.31±3.53	20.70±2.84	0.98	0.32
Screen time: week, hours/day	2.83±1.61	2.26±1.60	4.15	0.04	2.51±1.39	2.01±1.34	4.03	0.04
Screen time: weekend, hours/day	4.72±3.43	3.99±3.25	2.16	0.14	3.46±2.48	3.17±2.59	0.39	0.54
Screen time: all days, hours/day	3.46±1.91	2.84±1.82	4.14	0.04	2.83±1.49	2.40±1.53	2.48	0.12
Sedentary: week, min/day	724.7±61.1	700.2±67.8	4.65	0.03	743.3±60.5	751.2±59.6	1.41	0.24
Sedentary: weekend, min/day	670.5±84.5	649.2±81.3	2.21	0.14	676.4±80.0	657.5±75.1	0.68	0.41
Sedentary: all days, min/day	702.9±58.2	679.7±55.9	5.18	0.02	716.5±55.5	713.6±54.7	0.10	0.75
Light PA: week, min/day	71.8±21.1	60.7±17.4	9.65	0.00	70.7±21.4	59.6±20.0	7.14	0.01
Light PA: weekend, min/day	66.4±28.9	64.9±30.4	0.01	0.93	64.1±29.1	55.1±21.8	4.56	0.03
Light PA: all days, min/day	69.6±21.3	62.3±19.1	3.53	0.06	68.0±22.6	57.7±21.0	7.08	0.01
MVPA: week, min/day	91.6±36.7	97.9±42.4	0.38	0.54	76.0±29.2	67.7±30.0	9.00	0.00
MVPA: weekend, min/day	53.6±35.9	68.2±37.7	4.79	0.03	43.0±28.1	43.5±34.4	0.48	0.49
MVPA: all days, min/day	76.3±31.3	85.9±33.6	2.34	0.13	62.7±26.1	57.9±28.0	5.37	0.02
Aerobic endurance, metres	1407±455	1169±405	9.17	0.00	821±310	639±217	14.77	0.00

BMI (Body Mass Index); PA (Physical Activity); SED (minutes spent sedentary); MVPA (Moderate-to-Vigorous Physical Activity).

DISCUSSION

The study considered differences in time in sedentary behaviour and PA at different intensities, screen time and CRF in adolescents from urban and rural communities in the Portuguese Midlands. Rural boys and girls showed higher levels of CRF than their respective urban peers. Similar results were previously noted among youth in Spain (Chillon et al. 2011) and Oman (Albarwani et al. 2009). Although rural boys had a higher level of CRF, they tended to be less active in MVPA than urban boys, particularly at the weekend (urban= 68 min.day^{-1}; rural= 54 min.day^{-1}). These findings are consistent with previous studies by showing rural adolescents less physically active than their urban peers in U.S. (Liu et al. 2008; Lutfiyya et al. 2007) and Iceland (Kristjansdottir and Vilhjalmsson 2001). Furthermore, greater time spent in MVPA among 13-14 in contrast to 15-16 year olds of both sexes is consistent with the decline in MVPA generally observed with age as youth transition through adolescence (van Mechelen et al. 2000). The results are also consistent with changes in the nature of PA during adolescence. PA tends to become less structured and less intense in both sexes across adolescence and girls more so than boys tend to focus their interests on social activities (Coelho e Silva et al. 2003). On the other hand, CRF was greater in older compared to younger boys, but did not differ between the age groups of girls. This also is consistent with trends in aerobic fitness across age in adolescence (Malina et al. 2004).

The interaction of several environmental factors may explain why rural Portuguese youth were more likely to be classified as physically fit on the PACER test of CRF. Time spent outdoors is positively related to physical activity in youth *(*Sallis et al., 2000), thus perceived safety of the environment may be a factor. Portuguese female adolescents living in high-crime neighbourhoods, which are more frequent in urban communities, were less active outdoors (Mota et al., 2007). It possible that rural adolescents resided in safer neighbourhoods and were more likely to be physically active, which increased the likelihood of being classified as aerobically fit.

Urban boys also spent less time on sedentary activities than rural boys, while rural adolescents of both sexes spent more time on screen activities than urban youth. These findings contrast with U.S. studies that suggest that urban youth of both sexes are more sedentary than rural youth (Liu et al. 2008; Springer et al. 2006). It should be noted, however, the latter U.S. studies used electronic media as a proxy for sedentary behaviours. Of relevance, TV viewing and computer use are not the only form of sedentary behaviour in adolescents, who also spend substantial amounts of time sitting in school classes, riding in cars, eating, socialising, reading and studying.

Social and cultural discrepancies between rural and urban areas are reasonably well documented, but they likely vary within and between countries and regions (Barreto 2000; INE 2001; Reyes et al. 2003). Among urban youth, low income neighbourhoods generally have a negative influence on health, academic achievement and behavioural outcomes (Cicognani et al. 2008). Young people living in neighbourhoods with good access to shops tend to have healthier diets and were less likely to be overweight (Veugelers et al. 2008). The economic status of area of residence may also influence access to recreational facilities and playing sports and active leisure. This is especially relevant because participation in organized sports is related to MVPA. In two studies of American youth, organized sports contributed to 23% of time in MVPA in boys 6-12 years (Wickel and Eisenmann 2007) and to about 65% of the daily EE in MVPA in boys 12-14 years (Katzmarzyk and Malina 1998). In the present study, differences in MVPA between rural and urban groups were only apparent for boys, specifically over the weekend. Urban boys were more active than rural boys, and it may be suggested, perhaps, that sport participation is a more likely feature among urban boys.

In contrast to males, urban adolescent girls spent significantly less time in MVPA than their rural counterparts. Indeed, the nature of PA required and social and familial influences among rural adolescents might explain the larger amount of time in MVPA by rural female girls of the present study. Rural girls were more likely to be involved in domestic activities and at times in agricultural activities that may require more energy expenditure while urban girls tend to focus their interests on social activities such as sitting and talking with friends (Coelho e Silva et al. 2003). It is difficult to compare results of the present study to urban-rural contrasts in other countries as the data are not strictly comparable. For example, urban Icelandic adolescents walked or cycled to school about three times a larger distance than rural peers (Kristjansdottir and Vilhjalmsson 2001), while U.S. urban youth were more likely to meet recommended PA levels (Lutfiyya et al. 2007). In addition, other studies (Ismailov and Leatherdale 2010; Liu et al. 2008; Lutfiyya et al. 2007; Moreno et al. 2001) have reported geographic differences in the BMI with rural adolescents more often having an elevated BMI compared to urban youth. Such differences were not apparent among the adolescents resident in rural and urban areas of the Portuguese Midlands.

The present study has several limitations that should be recognized. The study is cross-sectional so that cause-effect relationships cannot be assumed. The results are limited to Portuguese youth 13 to 16 years of age living in Midlands region. Although accelerometers provide an objective and reasonably accurate measure of PA, they probably do not capture all dimensions of PA (sports/activities in the water or where the accelerometer may present a risk). Finally, the built environment assessment among those communities was not considered in this study. Therefore, research using built environment variables is recommended to enhance the understanding of how further factors (e.g., distance from home to school, availability of physical activity facilities, perception of the area of residence, and perhaps attitudes towards physical activity and cardiorespiratory fitness) relate to that urban-rural contrast in order to define educational and clinical interventions.

In summary, rural youth of both sexes had higher levels of CRF than their urban peers. Rural boys, however, tended to have less MVPA than urban boys, particularly at the weekend, while urban girls spent significantly less time in MVPA than their rural counterparts on week days and across total days. Urban residence was thus related to lower level in a test requiring CRF and associated to lower levels of MVPA among females. Therefore, urban Portuguese youth should perhaps be targeted as a priority for the promotion of aerobic endurance, and also the level of MVPA among female adolescents. On the other hand, urban boys spent less time on sedentary activities than rural boys and rural adolescents of both sexes spent more time on screen activities than urban youth.

CONCLUSION

Area of residence is thus related to PA, CRF and time in sedentary behaviour among rural and urban youth. Although the results suggest a potential impact of socio-geographic factors on PA, CRF and sedentary behaviour of Portuguese youth, they also highlight a need to better understand the details daily life in urban and rural settings. In addition, the current study highlights the need to enhance active behaviours and reduce sedentary one at the weekend during adolescence. Therefore, health-related behaviours may not be similarly programmed in different socio-geographic contexts.

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CHAPTER VIII

Physical activity and energy expenditure in adolescent male sport participants and non-participants 13-16 years [5]

[5] Machado-Rodrigues AM, Coelho e Silva MJ, Mota J, Santos R, Cumming SP, Malina RM (2011). Physical activity and energy expenditure in adolescent male sport participants and non-participants 13-16 years. *Journal of Physical Activity and Health*. [accepted].

PHYSICAL ACTIVITY AND ENERGY EXPENDITURE IN ADOLESCENT MALE SPORT PARTICIPANTS AND NON-PARTICIPANTS 13-16 YEARS

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ABSTRACT

Background: Sport has high social valence and is a primary context for physical activity for the majority of youth. The aim of this study was to estimate the contribution of participation in organized sport to the total daily energy expenditure and also to its moderate-to-vigorous portion in male adolescents. **Methods:** The sample comprised 165 Portuguese male youth, aged 13-16 years. Physical activity was assessed with a multi-method approach (Actigraph GT1M accelerometer plus 3-day diary record). Differences in the intensities of physical activity and sedentary behavior of male sport participants and non-sport participants were compared using univariate analyses of variance. **Results:** Male participants in organized sports spent significantly more time in moderate-to-vigorous activities than non-participants, although the p value for the 15-16 years age-group was marginal (p=0.08) at the weekend. In addition, male adolescents spent 11%-13% of total daily energy expenditure in organized sports which corresponded to 35%-42% of the moderate-to-vigorous portion of daily energy expenditure. **Conclusion**: Organized sport appears to be a relevant component of daily activity energy expenditure to promote healthy lifestyles among male adolescents.

Keywords: *Public health, accelerometry, health behavior, physical activity assessment*

INTRODUCTION

Regular participation in sport is a feature of the daily lives of youth in many countries of the world. Approximately 40 million of U.S. youth participated in organized sport in 2008 (NCYS 2010). This number approximates about 76% of the kindergarten through grade 12 (high school) enrolments in the U.S. Corresponding estimates for other countries vary due in part to differences in estimation strategies and to differences in program structure, accessibility and cost. Nevertheless, reasonably regular participation in sport is characteristic of youth in many European countries (Adelino et al. 2005a; Seabra et al. 2007; Telama and Yang 2000). Corresponding statistics for informal in contrast to organized sport are not available. This is of relevance for informal or “street” sports are often described as being more characteristic of developing countries and lower SES neighbourhoods of large cities.

Given the seemingly central role of organized sport in the lives of youth, a question of relevance is the habitual physical activity of youth sport participants and non-participants. Evidence based on three day diary records in boys and girls 12-14 years (Katzmarzyk and Malina 1998), accelerometry in 119 boys 6-12 years (Wickel and Eisenmann 2007), questionnaires in U.S. boys and girls 11-12 years (Trost et al. 1997) and also in Finnish twins 16-18 years (Aarnio et al. 2002a; Aarnio et al. 2002b) indicates higher levels of physical activity in sport participants compared to non-participants. The present study extends these observations to Portuguese male youth since the contribution of organized sport to daily physical activity and energy expenditure may be influenced by cultural facets. The purpose of this study was twofold, first to estimate the intensity physical activity among male participants and non-participants in organized sport, and second, to determine the contribution of organized sport to estimated daily energy expenditure (DEE) and to energy expenditure in moderate-to-vigorous activity (MVEE).

METHODS

Participants

The *Midlands Adolescent Lifestyle Study* (MALS) was part of a random cross-sectional survey of the prevalence of overweight/obesity in Portugal (Sardinha et al., 2010). Details of the study are described elsewhere (Sardinha et al., 2010). *MALS* is a school-based survey that included 492 adolescents resident in the Portuguese Midlands (aged 13-16 years), in grades 7 through 9, from seven secondary schools where accelerometer-based data were specifically collected. The project was registered at the *Portuguese Commission for Data Protection* [Process #3132006] and approved by the *Scientific Committee* of the *University of Coimbra*. Informed written assent was obtained from participants and informed consent was obtained from parents or guardians.

The present study included 165 male adolescents. Participants were divided in two age-groups, 13-14 and 15-16 years. Chronological age was calculated as the difference between date of birth and date of measurements. Among those who participated in the current study, 19% were overweight or obese, and 33% were from urban communities. Fathers of 28% of the participants had a college or university degree (highest educational level), and 15% had the lowest education level (i.e., nine compulsory years). Mothers of 33% of participants had the highest education level, and 11% had the lowest level.

Anthropometry

Height and weight were measured at school in the morning using a portable stadiometer (Harpenden model 98.603, Holtain Ltd, Crosswell, UK) and a portable scale (Seca model 770, Hanover, MD, USA) to the nearest 0.1 cm and 0.1 kg, respectively, with participants in t-shirt and shorts. Body mass index (BMI, kg/m^2) was calculated.

Physical Activity (PA)

Physical activity and energy expenditure were estimated using an uniaxial accelerometer and a 3-day diary protocol.

Accelerometry. Participants wore the *GT1M ActiGraph* uniaxial accelerometer (ActiGraph™, LLC, Fort Walton Beach, FL, USA) over the hip for five consecutive days (Thursday until Monday). Subjects were instructed to remove the sensor while showering or participating in swimming activities. The ActiGraph uniaxial accelerometer (previously known as MTI 7164 model and CSA) is compact (3.8 cm x 3.7 cm x 1.8 cm) and light (27g) and has been validated in laboratory and free-living children and adolescents (Freedson et al. 2005). The data were electronically downloaded using the *ActiLife software*. The *MAHUffe program* was used to reduce the data in a file containing minute-by-minute counts. Participants who did not have 10 hours of valid measured data for each of the five days were excluded from subsequent analyses. The threshold of sedentary activity (minimal body movements in the sitting or reclining position) was established at 800 counts.min^{-1} (Puyau et al. 2002). Intensity levels of PA were determined using age-specific regression equations (Trost et al. 2002). The criteria have been previously used in epidemiological studies of youth (Riddoch et al. 2004; Nader et al. 2008).

Data for 165 youth (75% of the initial sample) met the criteria for inclusion and were used for subsequent analyses. The records of 54 participants of the total sample (n=219) failed to achieve 10 hours of registered time in each of the 5 measured days. There were no significant differences in the distributions of included and excluded participants by age-group [$\chi_{(1)}^2$=0.02; p=0.90], weight status [$\chi_{(1)}^2$=2.15 p=0.142] and geographic context [$\chi_{(1)}^2$=2.19 p=0.139].

Diary. The diary protocol (Bouchard et al. 1983) partitioned each day into 96 periods of 15 minutes and required the subject to record activities over three complete days, two week days and one weekend day. Participants were asked to rate the intensity of the primary activity performed in each 15-minute period using a numeric code ranging from one to nine. Energy expenditure was subsequently estimated from equivalents for each activity: (1) sleeping or resting: 0.26 kcal/Kg/15min; (2) sitting: 0.38 Kcal/Kg/15min; (3) light activity standing: 0.57 Kcal/kg/15min; (4) slow walking ~ 4 km/hr: 0.69 Kcal/Kg/15min; (5) light manual tasks: 0.84 Kcal/Kg/15min; (6) leisure and recreational sports: 1.2 Kcal/kg/15min; (7) manual tasks at a moderate pace: 1.4 Kcal/Kg/15min; (8) leisure and sport activities of higher intensity – not competitive: 1.5 Kcal/Kg/15min; (9) very intensive activities – competitive sports: 2.0 Kcal/Kg/15min. Total daily energy expenditure (TDEE) was estimated for each of the three days. Intensity categories 1-3 represented sedentary behaviours and categories 6-9 represented moderate-to-vigorous physical activities based on definitions of the original report (Bouchard et al., 1983).

The diary protocol has been used with adolescents in Canada (Katzmarzyk et al. 1999; Katzmarzyk et al. 1998), United States (Katzmarzyk and Malina 1998), Taiwan (Huang and Malina 1996; Huang and Malina 2002; Lobstein et al. 2004) and Australia (Lee and Trost 2006). The instrument was recently accepted as reliable and valid among Portuguese adolescents (Machado-Rodrigues et al. 2010).

Sport participation (SP)

Organized sports in Portugal are voluntary programmes offered during discretionary or free time and have defined competitive seasons. In general, the annual season corresponds to 9-month supervised participation, with 3/4 training sessions per week and a competition game at the weekend.

SP was estimated with the 3-day diary (Bouchard et al. 1983) above described. Participants were asked to mark the categorical number (e.g. cells of 15 min periods) that corresponded to organized sports practice. This practice was defined as the training period and the competition games undertaken under supervision of a certified coach at the club affiliated in the national federations. Total amount of time and intensity levels of SP was given by the sum of categorical number pointed out.

Data analysis

Descriptive statistics for anthropometry, accelerometry and 3-day diary were calculated for the two age groups, 13-14 and 15-16 years. Prior to analysis, tests for normality were conducted for the habitual PA measures (counts per minute) and for its intensity portions [i.e. light PA and MVPA]. Tests suggested that PA measures [accelerometry: total PA on week days and across 5 days (counts per minute); MVPA on week days; 3-day diary: absolute DEE on MVPA] were not normality distributed. Log transformations (Log10) of the variables were thus calculated to proceed with the parametric analysis. Independent sample *t*-tests were used to test the effect of sport participation in the two age groups for body size, chronological age, and the diary and accelerometry estimates of PA. SPSS 15.0 (SPSS Inc., Chicago, Illinois, USA) was used for all the analyses. The level of significance was set at 5%.

RESULTS

The prevalence of male adolescents regularly engaged in organized sports was 53% for the total sample (58% and 46% for the younger older age-groups, respectively). The popularity of sports was as follows: soccer (n=43), basketball (n=9), volleyball (n=5), track and fields (n=5), handball (n=5), rugby (n=4), judo (n=3), karate (n=3), swimming (n=3), tennis (n=3), rowing (n=2), sailing (n=1), gymnastics (n=1), martial arts (n=1). Descriptive statistics for chronological age, body size, sedentary behavior, PA intensity levels, TDEE, and the portion of MVEE are presented for the younger and older age groups in Tables 8.1. and 8.2., respectively.

Anthropometric variables did not differ between sport participants and non-participants in both age groups (Table 8.1.). Boys 13-14 years who participated in organized sport were significantly more active (counts/min/day) than those who did not participate on week days, at the weekend, and across total days. Among male adolescents aged 15-16 years, participants in organized sports were also significantly more active than non-participants on week days and across 5 days; these groups did not significantly differ on habitual PA at the weekend.

Male sport participants in the two age-groups spent less time in sedentary activities than non-participants on week-days and across total days, but not at the weekend. Male sport participants and non-participants did not differ in time devoted to light physical activities independent of age group and day.

Male participants in organized sports spent significantly more time in MVPA than non-participants, although the p value for the older group was marginal ($p=0.08$) at the weekend.

Absolute estimated DEE increased from 13-14 to 15-16 years of age in sport participants and non-participants, but DEE per unit body mass slightly decreased with age among sport participants, 45.7 $kcal \cdot Kg \cdot min^{-1}$ at 13-14 years to 44.7 $kcal \cdot Kg \cdot min^{-1}$ at 15-16 years. The corresponding trend was similar in non-participants, 42.1 $kcal \cdot Kg \cdot min^{-1}$ at 13-14 years to 41.4 $kcal \cdot Kg \cdot min^{-1}$ at 15-16 years. Comparisons between male sport participants and non-participants were only significant for estimated DEE per unit of body mass in the two age groups. As expected, both absolute and relative estimates of MVEE were higher in sport participants than in non-participants.

Based on the 3-day diary record, organized sports accounted for 13.3% and 10.5% of TDEE among younger and older male adolescent participants, respectively. When limited to activities of moderate-to-vigorous intensity, participation in sport accounted for 42% and 35% of EE in moderate-to-vigorous intensities in the two age groups, respectively.

Table 8.1. Results of the independent sample *t*-tests for differences between adolescents who participate in organized youth sports and who do not, for males aged 13-14 years.

		Participants (n=58)	Non-participants (n=42)	t	p
Anthropometry	Chronological age, years	13.5±0.6	13.4±0.6	-.796	0.43
	Height, cm	160.4±9.5	161.1±8.3	.398	0.69
	Weight, Kg	50.1±9.7	51.3±12.3	.531	0.60
	BMI, Kg/m^2	19.38±2.90	19.52±3.18	.240	0.81
Accelerometry	PA [b] (week days), counts/min/day	598±193	498±115	-2.896	0.01
	PA (weekend), counts/min/day	449±215	358±143	-2.398	0.02
	PA [b] (total of 5 days), counts/min/day	539±161	442±111	-3.365	0.01
	SED (week days), min/day	696.7±65.5	729.9±60.3	2.584	0.01
	SED (weekend), min/day	656.6±78.3	681.4±96.9	1.415	0.16
	SED (total of 5 days), min/day	680.6±53.9	710.3±61.4	2.573	0.01
	Light PA (week days), min/day	61.8±17.6	65.8±18.7	1.089	0.28
	Light PA (weekend), min/day	62.0±27.1	60.8±30.1	-.203	0.84
	Light PA (total of 5 days), min/day	61.7±18.3	63.7±20.3	.507	0.61
	MVPA [b] (week days), min/day	113.7±41.2	96.1±29.0	-2.170	0.03
	MVPA (weekend), min/day	72.1±40.8	51.6±33.8	-2.749	0.01
	MVPA (total of 5 days), min/day	96.9±33.7	78.2±26.8	-2.974	0.01
3-day diary	TDEE, Kcal/day	2281±485	2144±543	-1.326	0.19
	TDEE, Kcal/Kg/day	45.7±5.6	42.1±6.3	-2.968	0.01
	MVEE [b], Kcal/day	778±390	534±339	-3.474	0.01
	MVEE, Kcal/Kg/day	15.6±7.1	10.9±6.9	-3.362	0.01

PA (Physical Activity); SED (minutes spent sedentary); MVPA (Moderate to Vigorous Physical Activity); TDEE (Daily Energy Expenditure); MVEE (Moderate to Vigorous Energy Expenditure). [b] Log-transformed values were used in the analysis.

Table 8.2. Results of the independent sample *t*-tests for differences between adolescents who participate in organized youth sports and who do not, for males aged 15-16 years.

		Participants (n=30)	Non-participants (n=35)	t	p
Anthropometry	Chronological age, years	15.1±0.5	15.4±0.6	1.981	0.05
	Height, cm	169.8±6.2	171.3±8.3	.829	0.41
	Weight, Kg	61.0±9.4	64.1±10.5	1.221	0.23
	BMI, Kg/m^2	21.19±3.43	21.79±3.17	.738	0.46
Accelerometry	PA [b] (week days), counts/min/day	560±210	435±141	-2.904	0.01
	PA (weekend), counts/min/day	454±147	388±177	-1.607	0.11
	PA [b] (total of 5 days), counts/min/day	518±156	416±130	-2.997	0.01
	SED (week days), min/day	709.2±70.9	743.9±46.3	2.298	0.03
	SED (weekend), min/day	648.6±87.5	669.3±71.4	1.051	0.30
	SED (total of 5 days), min/day	684.9±67.8	714.0±44.6	2.008	0.05
	Light PA (week days), min/day	79.6±22.9	73.5±21.3	-1.108	0.27
	Light PA (weekend), min/day	74.0±27.8	71.7±31.8	-.318	0.75
	Light PA (total of 5 days), min/day	77.3±20.5	72.7±22.4	-.866	0.39
	MVPA [b] (week days), min/day	85.1±33.9	63.9±25.1	-2.858	0.01
	MVPA (weekend), min/day	56.9±30.0	43.0±32.1	-1.799	0.08
	MVPA (total of 5 days), min/day	73.8±24.1	55.4±24.2	-3.050	0.01
3-day diary	TDEE, Kcal/day	2739±599	2662±574	-.528	0.60
	TDEE, Kcal/Kg/day	44.7±5.1	41.4±4.6	-2.783	0.01
	MVEE [b], Kcal/day	894±465	570±420	-3.832	0.00
	MVEE, Kcal/Kg/day	14.4±6.3	8.7±5.7	-3.811	0.00

PA (Physical Activity); SED (minutes spent sedentary); MVPA (Moderate to Vigorous Physical Activity); TDEE (Daily Energy Expenditure); MVEE (Moderate to Vigorous Energy Expenditure). [b] Log-transformed values were used in the analysis.

DISCUSSION

Sports participation contributes to a substantial portion of daily PA and DEE in Portuguese male adolescents. Results were consistent with the available literature (Aarnio et al. 2002b; Katzmarzyk and Malina 1998; Pfeiffer et al. 2006; Trost et al. 1997; Wickel and Eisenmann 2007); youth involved in sport have higher levels of daily PA and MVPA than non-participants. Portuguese youth participants in sport also spent less time to sedentary behaviors estimated from accelerometry. This is consistent with less time spent in television viewing noted in American adolescent sport participants relative to non-participants (Katzmarzyk and Malina 1998).

Youth generally identify PA with sport (Malina 2008), although attention to sport as an important domain to promote PA among children and adolescents is relatively recent development (Arruza et al. 2009). Nevertheless, professionals and institutions concerned with the promotion of adolescent health and health-related behaviors should consider provision of opportunities for participation in sport and policies to promote continued participation in sports across adolescence. This is important from two perspectives. First, youth involved in sport have higher levels of MVPA, and regular participation in MVPA has health, fitness and behavioural benefits - weight control, less adiposity, increased bone mineral content, improved aerobic capacity and muscular strength and endurance, self-concept, among others (Cumming and Riddoch 2008; Strong et al. 2005). Second, participation in sports during adolescence tends to track at higher levels than other indicators of physical activity so that youth who are active in sport during adolescence are more likely to be physically active in young adulthood (Malina 2001; Malina 2009a). Thus, sport participation has the potential for health, fitness and behavioral benefits during youth and also for transfer to adult physical activity.

Although the number of Portuguese adolescents officially engaged in sports has increased in the past decades (Adelino et al. 2005b), it should be noted that organized sports accounted for only a modest portion of DEE in the current study (10.5%-13.3%). This may be somewhat misleading since the percentage of adolescent males who attained a minimum of 60 minutes$\cdot$day^{-1} of MVPA in all five days was 88% and 81% for sport participants and non-participants, respectively, at 13-14 years, and 73% and 37% for sport participants and non-participants, respectively, at 15-16 years. The difference among older adolescents highlights the important of keeping youth involved in sport as adolescence progresses. Available studies of sport participants and non-participants have not systematically considered age-related variation in the contribution of organized sport to physical activity and EE (Katzmarzyk and Malina 1998; Wickel and Eisenmann 2007).

Among US youth, organized sports contributed to 23% of time spent in MVPA in boys 6-12 years (Wickel and Eisenmann 2007) and to about 65% of the daily EE in MVPA in boys 12-14 years (Katzmarzyk and Malina 1998). In the present study, organized sport contributed to 42% and 35% of daily EE in MVPA in Portuguese male adolescents 13-14 years and 15-16 years, respectively. Results of the three studies of boys suggest an age trend, specifically an increase in the contribution of sports to daily MVPA from childhood to about 14 years and then a decline in older boys. There is a need to look at EE in other forms of PA during childhood and adolescence. For example, recess accounted for 16% of total time spent in MPVA in boys 6-12 years (Wickel and Eisenmann 2007). In the present study, the percentage of boys who accumulated a minimum of 60 minutes of MVPA on all five measured days (accelerometry) decreased differentially with age in sport participants and non-participants: from 88% to 73% among sport participants compared to 81% to 34% among non-participants. The results suggested that the age-related decline in PA may be more marked among non-participants in sports compared to those who continue to participate. The results also highlighted the need to pay closer attention to the activity habits of those who drop out of sport either voluntarily or involuntarily.

A variety of factors is associated with participation in sport. Studies suggest that preteen youth were most likely to participate in organized physical activities; subsequently, participation in sport declines during adolescence as does the amount of time devoted to MVPA (Malina 2009b). In general, older adolescents tend to be involved in different types of activities, particularly related to social behaviors. Among Portuguese adolescents, changing interests (including interest in risk taking behaviours associated with alcohol and smoking) and social demands (homework, employment, parental pressures) were important factors for cessation of sport participation (Coelho e Silva et al. 2003). Among American adolescents, older males reduced the number of physical and sport activities both in and out of school and indicated a preference sedentary pursuits in their free time, including being with friends, watching television, or going to the cinema (Crespo et al. 2001).

Costs associated with sport participation may be an additional factor that influences participation in organized sports. Higher socioeconomic status and parental educational level were associated with more sport practice (Fernandes et al. 2010).

Sport-related costs and time commitments were among factor that influenced the decision of parents about their child's participation in organized sport among Australian youth (Hardy et al., 2010). Portuguese adolescents were more likely to participate in sports when their family also participated; a related factor was socioeconomic status (Seabra et al. 2008).

Variation in physiological demands of specific sports available to youth in different countries also contributes to variation in studies of PA conducted in different settings and with different methods. Among US boys 6-12 years, basketball was the sport with the least time spent at or below a light intensity, whereas soccer was the sport with highest accumulation of vigorous activity (Wickel and Eisenmann 2007). Soccer (48%) and basketball (13%) were to primary sports in which the Portuguese male adolescents participated. A related factor that may contribute to variation among studies is season of the year (Belanger et al. 2009; Tucker and Gilliland 2007). The study of US youth 12-14 years was conducted in January and February in mid-Michigan which characteristically has relatively severe winters (Katzmarzyk and Malina 1998). Except for downhill skiing, sport activities of this sample were conducted indoors. Estimated time in PA was higher among youth involved in skiing (Katzmarzyk and Malina 1998). The Compendium of Physical Activity (Ainsworth et al. 2000), on the other hand, tends to treat sport generically and not in terms of the specific activities that comprise a sport. The use of accelerometry permitted estimates of time and EE and in turn the contribution of sport participation to total daily energy expenditure. This is of relevance to estimates of EE in specific youth sports for overweight and obese children who probably have different effort patterns in training sessions and games.

Additional sources of variation in PA and EE in youth are week days vs. weekend days. Studies have consistently shown a decrease of PA from week days to the weekend, primarily in PA of high intensity levels (Rowlands et al. 2008). The present study showed the same trend across the two age groups, which may be attributable to daily routines of Portuguese students that require compulsory physical education classes, involve many school sport programs, and allow free recess time on week days during which PA may be performed. On the other hand, adolescents of both age-groups are largely parent-dependent for sport and other physical activities at the weekend.

In addition to MVPA, the present study also showed a high amount of time devoted on sedentary activities. Observations may have been related to an increase in academic work needed to prepare for university entrance examinations, especially among the 15-16 years age-group. It is also possible that time spent sedentary occurred to compensate for time spent in sport and physical education participation. Previous research in Portugal has demonstrated that more active groups also spent more time in screen activities (TV viewing, electronic devices, internet), indicating that PA and sedentary behaviour are not the two sides of the same coin (Machado-Rodrigues et al. 2009). Therefore, increasing organized sport programs, especially at the weekend, may play an important role in reducing or preventing sedentary lifestyles. Furthermore, promoting family-based programs at the weekend might be an important strategy to augment active behaviours among youth.

It is difficult to compare results of the present study to sport participation/non-participation contrasts in other countries as the data are not strictly comparable. However, this study is one of the first studies to demonstrate the contribution of organized sport to estimated daily PA and EE in Portuguese male adolescents. The results suggest a need to target older adolescents who show reduced participation in sports and to enhance opportunities active behaviours, and reduce sedentary behaviours over the weekend, perhaps by educating parents and providing environments for family-based programs.

Physical activity is often indicated as important in the prevention of overweight and obesity among youth. Of relevance to Portugal, southern European populations have a higher prevalence of overweight and obesity compared to Central and Northern European populations (Lobstein 2010; Padez et al. 2004). Although sport is a major context of PA and EE among youth, one can inquire whether the PA associated with youth sports of sufficient duration and intensity to prevent overweight and obesity and to bring about a reduction in adiposity in those who are at risk. Experimental activity programs in overweight and obese youth result in reductions in overall adiposity and abdominal adiposity. However, the beneficial effects are lost when the interventions are stopped and competitive sports are a well known selective arena. On the other hand, many competitive sport programs are not conducive to successful participation by overweight and obese youth. Obese youth are often less proficient in motor skills and components of physical fitness which may reduce the likelihood of experiencing success in a sport (Malina et al. 2004). American football, wrestling and weight events in track and field athletics are exceptions and may have a place for adolescents who may be overweight or obese.

Limitation of the study should be noted. First, the study was cross-sectional and inferences on casual relationships are not warranted. Second, although the data were collected during the spring, the interval of data collection was spread over several months given the number of accelerometers available. Third, the results are limited to Portuguese male youth 13 to 16 years of age living in Midlands region of the country. Nevertheless, further investigations are needed to better understand the role of sport participation in healthy lifestyles among youth of both genders.

CONCLUSION

Organized sport appears to be an important component of daily activity energy expenditure among male adolescents. The amount of PA declined from week days to weekend days in both sport participants and non-participants. Evidence suggest that participation in organized sports affords many health benefits to most adolescents (Taliaferro et al. 2010). Therefore, promoting sport participation may serve in the prevention of multiple health risk behaviors among adolescents and represents a potentially important contribution to health policy and practice.

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CHAPTER IX

Correlates of aerobic fitness in urban and rural Portuguese adolescents[6]

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CORRELATES OF AEROBIC FITNESS IN URBAN AND RURAL PORTUGUESE ADOLESCENTS

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ABSTRACT

Background: Improving physical fitness is often an objective of programs aimed at preventing obesity among youth.

Aim: To evaluate the association between cardiorespiratory fitness (CRF) and area of residence controlling for several correlates in adolescents.

Subjects and methods: CRF was assessed with the progressive aerobic cardiovascular endurance run (PACER) in a cross-sectional sample of 362 Portuguese adolescents (165 males, 197 females) 13 to 16 years of age. Youth were classified by area of residence as urban or rural. Gender, age, weight status, parental education, screen time (inactivity) and moderate-to-vigorous physical activity (MVPA) were statistically controlled. Logistic regression analysis was used.

Results: Adolescents of both sexes from rural settings were 76% more likely to be classified as aerobically fit compared to those from urban areas. The odds ratio for CRF in the final model was similar in boys (OR=0.24, 95% CI 0.06 - 0.99, $p<0.05$) and girls (OR= 0.24, 95% CI 0.07 - 0.76, $p<0.05$). MVPA and weight status were important predictors of CRF in Portuguese adolescents 13-16 years of age. Maternal education was an additional predictor in girls.

Conclusion: CRF and rural/urban settings were significantly related in this sample of Portuguese adolescents of both sexes.

Keywords*: Health promotion, geographic contexts, adolescence, accelerometry, aerobic fitness*

INTRODUCTION

Physical fitness is generally viewed as having morphological, muscular, motor, cardiovascular and metabolic components (Shephard and Bouchard 1994). Cardiorespiratory fitness (CRF), the capacity of the cardiovascular and respiratory systems to carry out prolonged strenuous exercise, is often considered as the most important relative to health status (Ortega et al. 2008). CRF as reflected in absolute maximal oxygen uptake (peak VO2) improves, on average, with age during childhood and adolescence in males and during childhood females, and tends to reach a plateau or decline slightly during adolescence in females. Per unit mass, however, CRF is stable from childhood through adolescence in males, and declines with age in females (Malina et al. 2004).

Evidence based primarily on distance runs suggests that the CRF of youth has declined by 0.36% to 0.43% per year over the past 40 years (Olds et al. 2006; Tomkinson et al. 2007). Data from a recent survey (Sandercock et al. 2010) indicates a larger decline in CRF in British males (7%) and females (9%) over a 10 years period. The secular decline in CRF is attributed, in part, to a reduction in habitual physical activity and the increased prevalence of overweight and obesity among youth (Malina and Katzmarzyk 2006; Pate et al. 2006). In contrast to field measures of CRF, peak VO2 shows little change since the 1960s in American children of both sexes and adolescent boys, but a decline in adolescent girls since the 1980s (Eisenmann and Malina 2002). Sampling is an issue in studies of peak VO2 since it is unlikely that overweight or obese youth would volunteer for laboratory studies. On the other hand, school-based estimates of peak VO2 of Danish adolescents has not changed between 1983 and 2003, although the BMI has increased by 10% at the upper deciles of the distribution (Andersen et al. 2010).

Allowing for limitations of secular comparisons of CRF, weight status, especially excess weight-for-height, is an important factor affecting CRF in youth. Physical activity and physical inactivity are also correlates of CRF among youth. Correlations between CRF and habitual physical activity (based largely on questionnaires) are moderate at best (Katzmarzyk et al. 1998a; Katzmarzyk et al. 1999; Gutin et al. 2005), while the relationship of CRF and physical inactivity has received less attention (Katzmarzyk et al. 1998b; Hussey et al. 2007). Socio-economic factors related to parental education and occupation and living conditions may also play an important role in the understanding CRF and health-related behaviours of adolescents, although the literature in this area is equivocal (Riddoch et al. 2007).

Area of residence is a factor that influences lifestyle, especially opportunities for physical activity, and in turn CRF and public health policy (Allender et al. 2008). Although data are limited, more youth from rural areas were more likely to be classified as aerobically fit than their urban peers in Oman (Albarwami et al. 2009) and Australia (Dollman et al. 2002). The proportion of the world's population living in urban areas has grown from 14% to >50% since the last decade or two of the twentieth century and the present (Ezzati et al. 2005). The trend has been noted in Portugal where more than 45% of the national population lives in two metropolitan areas, Lisbon and Oporto (Barreto 2000).

Research dealing with the potential influence of area of residence, parental education, physical activity and weight status on CRF of Portuguese youth is rather limited, especially for the population in the Portuguese Midlands (Coelho e Silva et al. 2003; Mota et al. 2007a). Given recent economic conditions, inequalities between urban and rural communities have apparently increased (INE 2001). The purpose of this study was to examine the association between CRF and area of residence in adolescents controlling for several potential correlates, including gender, age, weight status, type of housing, parental education, sedentary behaviour and physical activity in Portuguese adolescents.

METHODS

Study design and sampling

This school-based study was part of the *Midlands Adolescent Lifestyle Study* (MALS), a cross-sectional research project conducted in Midlands of Portugal. The sample comprised 362 adolescents aged 13 to 16 years (14.2±1.0 years), 165 males and 197 females, from seven secondary schools. The research was approved by the *Scientific Committee* of the *University of Coimbra* and prior to collection of data, consent was provided by the *Regional Education Office*. The project was also registered in the *Portuguese Commission for Data Protection* [Process #3132006]. The nature and scope of the study were explained to the adolescents and their parents or guardians. Both youth and their parents/guardians provided informed written consent.

Anthropometry

Chronological age was calculated as the difference between date of birth and date of height and weight measurements. Participants were divided into two age-groups: 13-14 and 15-16 years. Height and weight were measured at school in the morning using a portable stadiometer (Harpenden model 98.603, Holtain Ltd, Crosswell, UK) and a portable scale (Seca model 770, Hanover, MD, USA) to the nearest 0.1 cm and 0.1 kg, respectively, with participants in t-shirt and shorts, and without shoes. The body mass index (BMI, kg/m^2) was calculated, and youth were classified as normal weight or overweight/obese based on age- and sex-specific BMI criteria of the *International Obesity Task Force* (Cole et al. 2000).

Cardiorespiratory fitness (CRF)

CRF was assessed by the *Progressive Aerobic Cardiovascular Endurance Run* test (PACER). PACER is a multistage 20-m endurance shuttle run test (Leger et al. 1988) which is scored as the number of “laps” completed at volitional exhaustion. The protocol was as follows. Participants ran between 2 lines 20-m apart using the cadence dictated by a CD emitting audible signals at prescribed intervals. Initial speed was set at 8.5 km/h for the first minute and then was increased 0.5 km/h each subsequent minute. When participants could no longer keep up with the pace by reaching the line at the time of the tone, participation was finished at the second fault and the number of laps completed was recorded. The test provides a valid and reliable field measure of VO_{2max} in children and adolescents (Leger et al. 1988; van Mechelen et al. 1986), and is part of the Physical Education (PE) curriculum in Portugal. The test protocol was explained in full before the start and all testing was done in PE classes under dry weather conditions.

Replicate measurements of the PACER were taken on 23 students, one week apart. Technical errors of measurement (σ_e) and reliability (R) were calculated (Mueller and Martorell 1988). The technical error and reliability coefficient were 2.6 “laps” (51.6 m) and 0.97, respectively. Participants were divided into fit and unfit according to the age and sex-specific cut-off points defined by the *Prudential Fitnessgram Battery* (Cooper Institute 1999).

Area of residence

Participants were classified by residence as urban or rural according criteria of the Portuguese Statistical System (Monteiro 2000). Urban areas were defined as a city with more than 500 inhabitants/Km^2 or more than 50,000 inhabitants. Rural areas were defined as villages with no more than100 inhabitants/Km^2 or with total population under 2000 people. Accordingly, of the 165 males, 116 were rural and 49 were urban; of the 197 females, 141 were rural and 56 were urban. Participants were also classified according to the type of housing: flat (apartment) or house.

Parental education

Educational background of parents was used as a proxy for socio-economic status. It was based on the Portuguese Educational System [(1) 9 years or less – sub-secondary; (2) 10–12 years – secondary, and (3) higher education)]. The three educational levels defined, respectively, socio-economic categories: 1 = Low Education; 2 = Middle Education and 3 = High Education. Similar procedures have used in the Portuguese context (Mota et al. 2007b; Santos et al. 2003).

Physical activity

ActiGraph GT1M accelerometers (ActiGraph™, LLC, Fort Walton Beach, FL, USA) were used to estimate physical activities in the moderate-to-vigorous range. Moderate-to-vigorous physical activity (MVPA) levels were estimated from accelerometer counts for five consecutive days (three week days and both weekend days). Participants wore the accelerometer over the hip; it was held firmly in place with an elastic belt. Participants were instructed to remove the monitor while showering or participating in water activities. The accelerometer was not worn during sleeping hours and was applied while dressing in the morning.

The accelerometer data were electronically downloaded using the *ActiLife software*. The *MAHUffe program* was used to reduce the data in a file containing minute-by-minute counts. Participants who did not have 10 hours of valid measured data for each of the five days were excluded. The threshold of MVPA was determined using age-specific regression equations (Freedson et al. 1997) published in Trost and colleagues (Trost et al. 2002). These criteria have been previously used in epidemiological studies of youth (Riddoch et al. 2004; Nader et al. 2008).

Sedentary behaviour

Screen time (TV viewing, computer time, video games) is a common measure of sedentary behaviours (Tremblay 2010). The amount of time spent on screen activities was estimated from an activity diary (Bouchard et al. 1983; Machado Rodrigues et al. 2010) and was expressed as minutes per day. Respondents were grouped as watching TV and using a computer (including video games) $\leq$2 h/day and >2 h/day following the protocol suggested by the *American Academy of Pediatrics* (American Academy of Pediatrics 2001).

Statistical analysis

Gender, weight status, MVPA, time in sedentary activities, and parental education are indicated as factors affecting CRF (Freitas et al. 2002; Jimenez-Pavon et al. 2010; Malina et al. 2004). Corresponding data for variation in CRF by area of residence are less extensive (Reyes et al. 2003; Malina et al. 2004). Associations between CRF and area of residence, controlling for potentially confounding effects of age, MVPA, screen time, weight status and parental education were assessed using logistic regression. Since there was a significant interaction between CRF and gender ($p<0.01$), all analyses were done separately for males and females. A series of logistic regression models were used to explore and control for the potential confounders. In the minimally adjusted model (Model 1), area of residence was the sole predictor of CRF. Parental education and type of residence (flat vs. house) were subsequently added as potential confounders (Model 2). Finally, age group, weight status, MVPA and screen time were added as potential confounders (Model 3). Significance was set at $p\leq0.05$. SPSS 15.0 (SPSS Inc., Chicago, Illinois, USA) was used.

RESULTS

Characteristics of the sample are summarized in Table 9.1. About 15% of the adolescents were classified as unfit by the PACER test. Participants classified as unfit were more likely to be female (64%) and non-active (64%). Male adolescents classified as fit devoted 18 more minutes on MVPA per day than their unfit counterparts. The corresponding value for females was 15 more minutes per day on MVPA. For total sample, fit adolescents devoted, on average, 72 minutes/day of MVPA, while the corresponding value for the unfit was 54 minutes/day.

Table 9.1. Demographic characteristics of unfit and fit adolescents 13-16 years of age.

	Unfit (n=56)	Fit (n=306)
Gender (percentages)		
Males	35.7	47.4
Females	64.3	52.6
Age-group (percentages)		
13-14 yrs	53.6	60.5
15-16 yrs	46.4	39.5
Overweight (percentages)		
Normal weight	55.4	82.4
Overweight/Obesity	44.6	17.6
Area of Residence (percentages)		
Rural	58.9	73.2
Urban	41.1	26.8
Type of housing (percentages)		
House	69.6	70.9
Flat	30.4	29.1
Paternal Education (percentages)		
Low	21.4	20.3
Medium	51.8	55.9
High	26.8	23.9
Maternal Education (percentages)		
Low	26.8	17.6
Medium	48.2	53.9
High	25.0	28.4
Screen time (percentages)		
$\leq$ 2 hours	30.4	32.0
> 2 hours	69.6	68.0
Physical Activity (percentages)		
Active, $\geq$ 60 min MVPA/day	35.7	61.4
Inactive, < 60 min MVPA/day	64.3	38.6
Minutes in MVPA (daily mean)	54	72

MVPA (Moderate-to-Vigorous Physical Activity).

The association between CRF and area of residence in the three models is shown in Table 9.2. CRF was associated with area of residence in both sexes, and the association was not altered with adjustment for the potential confounding factors indicated above (i.e., age, MVPA, time spent in two physically inactive behaviours, weight status and parental education). The final regression model showed that male and female adolescents from rural settings were 76% more likely to be classified as aerobically fit than adolescents in urban areas. The odds ratio for CRF in boys was 0.37 [95% CI 0.14 - 0.95, p<0.05] in model 1 and 0.24 (95% CI 0.06 - 0.99, p<0.05) in model 3. The odds ratio for CRF in girls was 0.65 (95% CI 0.30 - 1.39, ns) in model 1 and 0.24 (95% CI 0.07 - 0.76, p<0.05). Inspection of the final regression model also indicated that males resident in rural areas were 85% more likely to have normal weight compared to males resident in urban areas (odds ratio: 0.15, 95% CI 0.05 - 0.42, p<0.001). As expected, active (≥60min/day of MVPA) male adolescents were 73% more likely to be classified as fit than their less active peers (odds ratio: 0.27, 95% CI 0.09 - 0.84, p<0.05).

Table 9.2. The association between CRF and area of residence in adolescents.

			Cardiorespiratory Fitness				
Group	n	Model [a]	*B*	S.E.	e^B	95% C.I.	p
Males	165	1	-1,00	0.49	0.37	0.14 to 0.95	0.04
		2	-1.07	0.61	0.35	0.10 to 1.15	0.08
		3	-1.44	0.73	0.24	0.06 to 0.99	0.04
Females	197	1	-.44	0.39	0.65	0.30 to 1.39	0.26
		2	-1.32	0.56	0.27	0.09 to 0.80	0.02
		3	-1.45	0.60	0.24	0.07 to 0.76	0.02

[a] Model 1 = rural vs. urban; Model 2 = model 1 + maternal education, paternal education, and type of residence; Model 3 = model 2 + age group, weight status, MVPA, physical inactivity.

Among females, the final regression model revealed that a higher level of maternal education (college graduate or professional degree) was significantly associated with increased likelihood of having a high level of CRF (odds ratio: 2.64, 95% CI 1.25 – 5.60, p<0.01). Female adolescents with normal weight were 71% more likely to be classified as unfit compared to overweight peers (odds ratio: 0.29, 95% CI 0.12 - 0.69, p<0.01). Finally, less active female adolescents were 64% more likely to be unfit more active peers (odds ratio: 0.36, 95% CI 0.15 - 0.86, p<0.05).

DISCUSSION

Information considering relationships between CRF and residence characteristics, parental education, physical activity and inactivity among Portuguese youth is rather limited, especially for the population of the Midland region of Portugal. This region between the major urban centres of Lisbon and Porto contains a mixture of mid-size urban centres and rural communities. Social inequalities between urban and rural communities are evident in the form of health and educational resources (Barreto 2000). According to the *National Statistics* (INE 2001), the population of the most important urban centre of Portuguese Midlands (city of Coimbra) increased 6.75% between 1991 and 2001, which was more than the proportional increase of the total population of Portugal over the same period (4.08%).

The association between CRF and area of residence persisted when several potentially confounding factors were included in the logistic regression models. The result contrasts previous research in the Portuguese Midlands which showed few differences among urban, semi-urban and rural adolescents in several physical fitness tests (Coelho e Silva et al. 2003). This study, however, did not use a corresponding measure of CRF. In the present study, adolescent males and females from rural settings were 76% more likely to be classified as aerobically fit than adolescents from urban areas, consistent with observations from Oman (Albarwani et al. 2009) and Australia (Albarwani et al. 2009; Dollman et al. 2002).

The interaction of several environmental factors may explain why rural Portuguese youth were more likely to be classified as physically fit on the PACER test of CRF. Variation in school physical education programs may be a factor, but the quality of the Portuguese curriculum, based largely on sport education and practice, does not differ among rural and urban schools. Time spent outdoors is positively related to physical activity in youth (Sallis et al. 2000), so that perceived safety of the environment may be a factor. Portuguese female adolescents living in high-crime neighbourhoods, which were more frequent in urban communities, were less active outdoors (Mota et al. 2007b). It possible that rural adolescents resided in safer neighbourhoods and were more likely to be physically active, which increased the likelihood of being classified as aerobically fit. An additional factor that may moderate the relationship between CRF and area of residence may be parental attitudes towards physical activity and physical fitness; both were relevant determinants of physically active behaviors among Portuguese adolescents (Seabra 2004). Transport to school may also influence physical activity. In the earlier study of adolescents from Portuguese Midlands, a greater percentage of urban than rural youth walked to school, while a greater percentage of rural than urban youth used public transport (Coelho e Silva et al. 2003). It is not clear, however, whether mode of transport significantly affects the CRF of youth.

CRF and MVPA were positively associated in Portuguese males (odds ratio: 0.27, 95% CI 0.09 - 0.84, $p<0.05$) and females (odds ratio: 0.36, 95% CI 0.15 - 0.86, $p<0.05$). The PACER test was used in the present study; it generally elicits a maximal effort in most youth (Voss and Sandercock 2009). Although different indicators of both physical activity and CRF are used in studies of youth, results are consistent by showing a moderate relationship between activity and CRF (Katzmarzyk et al. 1998a; Gutin et al. 2005; Hussey et al. 2007). Using an objective measure of PA, the relationship between daily physical activity and VO_{2PEAK} was positive and low, but the relationships between the vigorous portion of PA and peak VO2 was stronger ($r=0.32$ for males, $r=0.30$ for females, $p<0.05$) (Dencker et al. 2006). Most variance in aerobic fitness was also explained by vigorous than moderate PA in a sample of American adolescents (Gutin et al. 2005).

Weight status was negatively associated with CRF in Portuguese adolescents; overweight and obese males and females had lower CRF than normal weight peers. Previous studies in Portuguese youth (Mota et al. 2002; Mota et al. 2006) suggested that CRF (one-mile run) was inversely and significantly associated with BMI. In a short-term longitudinal study of Portuguese youth, a reduction in CRF over time was positively associated with weight gain (Mota et al. 2009). Excess body mass and indicators of adiposity are negatively associated with CRF and other components of physical fitness in youth (Huang and Malina 2010; Malina et al. 2004).

Level of education in mothers was associated with higher level of CRF in female, but not in male adolescents (Table 9.2.). Girls with mothers who had graduated or had a professional degree were significantly more likely to have a higher level of CRF (odds ratio: 2.64, 95% CI 1.25 – 5.60, $p<0.01$). It has also been suggested that mothers with higher levels of education are more likely to engage in health promoting behaviours and thus present an influential role model for children (Desai and Alva 1998; Sherar et al. 2009). It is also possible that mothers with higher education have normal weight status and in turn encourage their daughters to maintain a healthy weight, which in turn may impact CRF. Maternal weight status was not available in the present study.

Studies considering the influence of socioeconomic status (SES) on CRF are relatively few and observations are somewhat inconsistent. SES (based on parental occupation, education, income and housing) and CRF (12 min walk-run) were not related in females but were negatively related in males resident on the island of Madeira (Freitas et al. 2002). On the other hand, SES and CRF (20 m shuttle run test) were not related among Spanish male adolescents, but Spanish girls with higher paternal educational or parental professional level had higher levels of muscular strength, speed-agility and CRF (Jimenez-Pavon et al. 2010). Social and cultural settings per se and variation in indicators of SES in different countries as well as different assessments of CRF may contribute to the variable results. Nevertheless, parents serve as role models for physical activity from early childhood through adolescence (Sherar et al. 2009). Their role as models for physical fitness remains to be established.

Several limitations of the study should be recognized. The results are limited to youth aged 13 to 16 years living in Midlands region of Portugal. The relationship between CRF and area of residence may be influenced by other factors not considered in the study, e.g., distance from home to school, availability of physical activity facilities, perception of the area of residence, attitudes towards physical activity and CRF, social inequalities not reflected in parental education, and perhaps subtle cultural differences among youth. Although accelerometers provide an objective and reasonably accurate measure of PA, the instrument does not capture several specific activities, e.g., manual and water activities. The 60-second epoch underestimated time spent in vigorous and very vigorous portions of physical activity in children (Nilsson et al. 2002), and also overestimated time in moderate activity and vigorous activity but underestimated time in very hard activity relative to a 1-second epoch in children 7-11 years (Rowlands et al. 2006). On the other hand, time spent in vigorous PA and very hard PA represented only 2.4% of the total PA time in a sample of children 8-10 yrs (Baquet et al. 2007). Length of epoch is thus important in studies of children. The current study was done with adolescents where corresponding comparisons of epoch length are not available.

CONCLUSION

Rural residence, MVPA and weight status were important predictors of CRF in Portuguese adolescents 13-16 years of age. Maternal education was an additional predictor in girls.

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CHAPTER X

Relationships between obesity, cardiorespiratory fitness, sedentary behaviour and objective intensity levels of physical activity in rural and urban Portuguese adolescents [7]

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RELATIONSHIPS BETWEEN OBESITY, CARDIORESPIRATORY FITNESS, SEDENTARY BEHAVIOUR AND OBJECTIVE INTENSITY LEVELS OF PHYSICAL ACTIVITY IN RURAL AND URBAN PORTUGUESE ADOLESCENTS

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ABSTRACT

Background: Cardiorespiratory fitness (CRF) is considered one of the most important health markers, with an important role in the prevention of youth obesity. ***Purpose:*** This study was designed to examine the associations between body mass index (BMI) and CRF, sedentary behaviour and physical activity (PA) intensity levels in a sample of adolescents from different areas of residence. ***Methods:*** The sample comprised 362 adolescents (165 males, 197 females, aged 13-16 years). CRF was assessed by the *Progressive Aerobic Cardiovascular Endurance Run test*. A GT1M accelerometer was used to obtain five consecutive days of PA data. Pearson´s correlations were conducted to analyze associations among aforementioned variables. Subsequently, Fisher's r to z transformation between all variables was used to test the effect of area of residence on magnitude of correlation coefficients. A logistic regression analysis, with age and gender as covariates, was performed by area of residence using categorical levels of CRF and PA. ***Results:*** Results demonstrated that BMI was inversely correlated with CRF among both rural ($r=-0.29$, $p<0.01$) and urban ($r=-0.42$, $p<0.01$) adolescents. Rural adolescents were less active at the weekend than urban peers. Both rural and urban youth with higher levels of CRF had a lower relative risk of being overweight/obese [rural: (OR=0.95, 95% CI 0.93-0.97, $p<0.01$); urban: (OR=0.92, 95% CI 0.88-0.96, $p<0.01$] than peers with normal weight. ***Conclusion:*** Observations in Portuguese youth indicate an important association between BMI and CRF in both rural and urban settings. Place of residence also has an important impact on weight status of Portuguese adolescents.

Keywords: *adolescence, adiposity, cardiorespiratory fitness, accelerometry, area of residence*

INTRODUCTION

The aetiology of obesity is complex and believed to be linked with environment factors that contribute to the increasing adoption of sedentary behaviours. The prevalence of overweight and obesity among adolescents has substantially increased in many countries during the past two decades. Recent studies estimated that more than 30% of children and adolescents in North America, 21%-25% in Australia and, approximately 20% in Europe were overweight or obese (Lobstein, 2010; Padez et al., 2004). Further research indicated that about 18% of European school children (25 EU member states) were overweight, with an annual rise in prevalence between 0.55% and 1.65%, i.e. more than 400,000 new cases every year. Effectiveness of interventions or prevention strategies strongly depends upon an understanding of the causes and correlates of obesity. Further, predictive models for adolescents living in metropolitan areas are not necessarily applicable to small and isolated rural areas.

The need to promote regular involvement in physical activity (PA) in young people has been recognized by public health authorities throughout the world, in part because children and adolescents with overweight and obesity are at an increased risk of co-morbidities including type 2 diabetes, endocrine and orthopaedic disorders, and low health-related quality of life (Strong et al., 2005). PA has a potentially important role in weight control and is inversely related with adiposity (Ara et al., 2007; Gutin, Yin, Humphries, & Barbeau, 2005; Riddoch et al., 2007). Evidence dealing with the influence of regular PA on the health of youth is dependent, in part, on methodological assessment protocols. Current emphasis is on objective assessments of PA which provide information on intensity levels which are important in the association between PA and health outcomes (Gutin et al., 2005).

Cardiorespiratory fitness (CRF) is considered an most important health markers with an important role in the prevention of youth obesity (Ortega et al., 2008). Recent epidemiologic studies suggest high levels of CRF may offset much of the excess mortality risk and are negatively associated with body fatness (Hussey et al., 2007; McGavock et al., 2009). The effect of overweight on indicators of health-related physical fitness, however, varies with the component of fitness being analyzed. In spite of having poorer muscular strength and CRF, overweight adolescents tend to have similar flexibility and even better isometric strength compared with normal-weight adolescents (Mak et al., 2010). On the other hand, it is not clear whether obese adolescents are less physically active or less physically fit than non-obese peers (Deforche et al., 2003). The literature does not systematically consider the concomitant influences of PA and CRF on body fatness relative to sociogeographic contexts or areas of residence.

During and beyond the twentieth century, the proportion of the world's population living in urban areas has grown from 14% to over 50% (Ezzati et al., 2005). The same trend has been verified in Portugal for the past four decades where over 45% of people presently live in the two largest metropolitan areas, Lisbon and Oporto (Barreto, 2000). The process of urbanization experienced in the developing world has been associated with increased mortality from lifestyle-related diseases such as cancer and cardiovascular disease (Allender et al., 2008). On the other hand, residents in rural communities with low population density frequently have limited access to health care, and have lower numbers and diversity of specialized health professionals per population compared to urban centres (Allender et al., 2008). Rural areas are also often characterized by socioeconomic, educational and nutritional inequities that have an important impact on the development of children and youth (Barreto, 2000; Reyes et al., 2003).

The prevalence of overweight and obesity has increased among rural compared to urban school youth in the United States (Lutfiyya et al., 2007), Canada (Bruner et al., 2008) and in Spain (Moreno et al., 2001), although the trend was not apparent in Turkey (Ozdirenc, Ozcan, Akin, & Gelecek, 2005) and Oman (Albarwani et al., 2009). Results of studies comparing PA in rural and urban youth, however, are equivocal (Albarwani et al., 2009; Lutfiyya et al., 2007). The same is true for studies of physical fitness (Albarwani et al., 2009; Dollman et al., 2002). Nevertheless, sociogeographic variation of PA and associated health outcomes cannot be generalized across countries.

Given that the effects of urbanization on obesity, PA, sedentary behaviour and physical fitness are seemingly variable among and within specific countries and regions, more research is needed to improve our understanding of how CRF and active lifestyles relate to weight status in specific sociogeographic contexts in order to define educational and perhaps clinical interventions. Therefore, the purpose of this study was to examine relationships among BMI and CRF, intensity of PA, and sedentary behaviour in a sample of rural and urban Portuguese adolescents. It was hypothesized that weight status would be inversely related to CRF and PA, and positively related to sedentary behaviour in the different geographic communities.

METHODS

Study design and sampling

The study was part of a cross-sectional school-based survey of the prevalence of overweight/obesity in Portugal (Sardinha et al., 2010). All administrative regions of mainland Portugal (Alentejo, Allgarve, Midlands, Lisbon and North) were surveyed. The population was selected by proportionate stratified random sampling taking into account the location (region) and the number of students by age (10-18 years) and gender in each school. Schools were randomly selected within each region until the established number of subjects by region was attained. Details described elsewhere (Sardinha et al., 2010). The present study was the specific part of the *Midlands Adolescent Lifestyle Study* that included 362 adolescents resident in the Portuguese Midlands (165 males, 197 females; aged 13-16 years), in grades 7 through 9, from seven secondary schools that had valid accelerometer-based data according to later mentioned criteria.

The project was registered at the *Portuguese Commission for Data Protection* [Process #3132006] and approved by the *Scientific Committee* of the *University of Coimbra*. Informed written assent was obtained from participants and informed consent was obtained from parents or guardians.

Anthropometry

Height and weight were measured at the schools in the morning using a portable stadiometer (Harpenden model 98.603, Holtain Ltd, Crosswell, UK) and a portable scale (Seca model 770, Hanover, MD, USA) to the nearest 0.1 cm and 0.1 kg, respectively, with participants in t-shirt and shorts. The body mass index (BMI, Kg/m^2) was calculated and categorized using age and sex-adjusted cut-off points described by Cole and colleagues (Cole et al., 2000). The sample was divided into two weight-status groups, normal weight (BMI < 25 kg/m^2) and overweight/obese (BMI ≥ 25 kg/m^2).

Daily physical activity by intensity level

The *ActiGraph GT1M* accelerometer (ActiGraph™, LLC, Fort Walton Beach, FL, USA) was used for direct assessment physical activity (PA) and sedentary behaviour. The device has been widely validated in laboratory and free-living conditions with children and adolescents (Freedson et al., 2005). Participants wore the accelerometer over the hip for five consecutive days (from Thursday until Monday). It was held firmly in place with an elastic belt. Each student was instructed to remove the monitor every time he/she performed swimming activities or while showering.

On completion of accelerometer data collection, the data were electronically downloaded using the *ActiLife software*. The *MAHUffe program* was used to reduce the data in a file containing minute-by-minute movement counts for each adolescent. Files with an incomplete data for at least 5 days were excluded from subsequent analyses (i.e., if they failed to provide a minimum of 600 minutes of valid accelerometer data per day). The sedentary behaviour was estimated with a specific cut-point established against continuous measurement of energy expenditure (EE) by respiration calorimetry (Puyau et al., 2002). Intensity-levels of physical activity were determined using age-specific regression equation (Trost et al., 2002). These cut-points and inclusion criteria have been used in previous youth epidemiological studies (Riddoch et al., 2004; Nader et al., 2008), and the output was expressed as average of minutes spent in different physical activity intensities, and as counts per minute, consistent with those investigations.

Data for 362 youth (74% of the initial sample) met the criteria for inclusion and were used for subsequent analyses. The records of 130 students of the total sample (n=492) failed to achieve 10 hours of registered time on each of the 5 measured days. There were no significant differences in the distributions of included and excluded participants by sex [$\chi_{(1)}^2$=1.22; p=0.27], age [$\chi_{(1)}^2$=2.88 p=0.09], and weight status [$\chi_{(1)}^2$=0.48 p=0.49].

Cardiorespiratory fitness (CRF)

CRF was assessed by the *Progressive Aerobic Cardiovascular Endurance Run* test (PACER). The is a 20-m endurance shuttle run test (Leger et al., 1988) that was scored as the number of "laps". Participants were required to run between 2 lines 20 m apart using the cadence dictated by a CD emitting sonorous signals at prescribed intervals. The initial speed was set at 8.5 km/h for the first minute and was increased 0.5 km/h each subsequent minute. The test provides a valid and reliable field measure of VO_{2max} in children and adolescents (Leger et al., 1988; van Mechelen et al., 1986) and is frequently used in Physical Education (PE) curriculum. The PACER was carried out in each school's gymnasium, under standardized conditions. The results were recorded and total running distance to complete the shuttle run test was used in the present analysis. Physical fitness test was administered in a PE lesson after the anthropometry was completed.

Replicate measurements of the PACER were taken on twenty three students who performed the aerobic endurance protocol twice, one week apart, and technical errors of measurement (σ_e) and reliability (R) were calculated (Mueller and Martorell, 1988). Technical error and reliability coefficient were 2.6 "laps" (51.6 m) and 0.97, respectively. Participants were divided into fit and unfit groups based on 20m endurance shuttle run times according to the age and sex-specific cut-off points defined by the *Prudential Fitnessgram Battery* (Cooper Institute, 1999).

Area of residence

Participants were classified by area of residence as urban or rural according to the criteria of the Portuguese Statistical System (Monteiro, 2000). Urban areas were defined as a city with more than 500 inhabitants/Km^2 or more than 50,000 inhabitants. Rural areas were defined as villages with no more than100 inhabitants/Km^2 or with total population under 2000 people. Participants were also classified by residence in a flat (apartment) or house.

Statistical analysis

Descriptive statistics included mean and standard deviation, and analysis of variance was used to investigate relevant geographic characteristics of the sample. Prior to analysis, tests for normality were conducted on measures of habitual PA (counts per minute) and in its intensity portions (light PA, and moderate-to-vigorous PA). Results indicated that PA measures were not normality distributed; therefore, log transformation (Log10) of the variables was used in the analysis.

Pearson´s correlations were performed to examine associations among BMI and CRF, time spent sedentary, physical activity in its different portions of intensity variables on week and weekend days, and anthropometric variables. Subsequently, Fisher's r to z transformation (Fisher, 1925) was used to test for differences in correlation coefficients across area of residence. In addition, logistic regression analysis with age and gender as covariates examined the relative contributions of the predictors (CRF, sedentary behaviour, PA intensity) to weight status by area of residence. Regression models were performed using categorical levels for CRF and MVPA. Active participants were classified as those who met and did not meet established international PA recommendations (e.g., 60 min/day) (Strong et al., 2005). The analyses were carried out using the SPSS 15.0 program (SPSS Inc., Chicago, Illinois, USA). The level of significance was set at 5%.

RESULTS

By adopting the *International Obesity Task Force* cut-offs for weight status classification (Cole et al., 2000), 18.0% of the sample was classified as overweight (16.4% for boys, 19.3% for girls) and 3.9% as obese (boys: 4.2%; girls: 3.6%). The corresponding percentages of overweight and obese were, respectively, 17% and 5.1% in rural youth, and 20% and 1% in urban youth. Descriptive statistics for anthropometric, CRF, PA intensity and sedentary behaviour variables between geographic context groups are presented in Table 10.1.

Table 10.1. Descriptive characteristics of adolescents by area of residence.

	Rural (n=257)	Urban (n=105)
	Mean ± SD	Mean ± SD
Chronological age, years	14.3±1.0	14.0±1.0 *
Height, cm	161.1±8.5	161.4±8.5
Weight, Kg	54.6±11.0	52.8±10.0
BMI, Kg/m^2	20.96±3.42	20.19±3.08 *
PA [b] (week days), counts/min/day	468.4±149.1	488.5±189.3
PA [b] (weekend), counts/min/day	366.8±149.8	407.3±222.4
PA [b] (total of 5 days), counts/min/day	427.7±131.5	456.0±166.9
SED (week days), min/day	734.9±61.4	727.4±68.2
SED (weekend), min/day	673.7±81.9	653.7±77.8 *
SED (total of 5 days), min/day	710.3±57.0	697.8±57.5
Light PA [b] (week days), min/day	71.2±21.2	60.1±21.7 *
Light PA [b] (weekend), min/day	65.1±29.0	59.7±26.5
Light PA [b] (total of 5 days), min/day	68.7±22.0	59.8±20.2 *
MVPA [b] (week days), min/day	83.1±33.7	81.8±39.2
MVPA [b] (weekend), min/day	47.8±32.2	55.0±37.9
MVPA [b] (total of 5 days), min/day	68.8±29.3	71.0±33.7
CRF	54.3±24.0	44.3±20.7 **

* *P*<0.05; ** *P*<0.01; BMI (Body Mass Index); PA (Physical Activity); SED (minutes spent sedentary); MVPA (Moderate-to-Vigorous Physical Activity); [b] Log-transformed values were used in the analysis.

Adolescents from rural areas had higher BMI (p<0.05) than their urban peers. Rural adolescents also tended to be less active (total PA, counts/min/day) on week days, at the weekend and across 5 days but the differences did not reach a significant level. A significant main effect was observed between geographic groups and sedentary activities at the weekend; rural participants spent more time in sedentary activities than urban peers (p<0.05). Adolescents from rural communities, on the other hand, had higher CRF levels than urban youth (p<0.01).

Table 10.2. Bivariate correlations between CRF, BMI, and physical activity in its different intensity portions by geographic contexts.

	BMI		
	Rural adolescents (n=257)	Urban adolescents (n=105)	Δr (p)
Chronological age	0.19**	0.09	(0.19)
Gender [a]	0.12	0.18	(0.30)
PA [b] (week days), counts/min/day	-0.06	-0.19	(0.13)
PA [b] (weekend), counts/min/day	0.05	-0.14	(0.05)
PA [b] (total of 5 days), counts/min/day	-0.02	-0.19*	(0.07)
SED (week days), min/day	-0.03	0.08	(0.17)
SED (weekend), min/day	-0.08	0.06	(0.12)
SED (total of 5 days), min/day	-0.06	0.09	(0.10)
Light PA [b] (week days), min/day	0.10	0.02	(0.25)
Light PA [b] (weekend), min/day	0.11	0.01	(0.20)
Light PA [b] (total of 5 days), min/day	0.11	0.01	(0.20)
MVPA [b] (week days), min/day	-0.08	-0.19*	(0.17)
MVPA [b] (weekend), min/day	-0.02	-0.08	(0.30)
MVPA [b] (total of 5 days), min/day	-0.07	-0.18	(0.17)
BMI	1	1	-
CRF	-0.29**	-0.42**	(0.10)

** *P*<0.01; [a] [(1) Males; (2) Females]; BMI (Body Mass Index); PA (Physical Activity); SED (minutes spent sedentary); MVPA (Moderate to Vigorous Physical Activity); (CRF) Cardiorespiratory Fitness.
[b] Log-transformed values were used in the analysis.

Table 10.3. Logistic regression analysis for variables predicting overweight/obesity adjusted for chronological age and gender.

	Rural					Urban				
Predictor	*B*	*SE B*	e^B	95% C.I. for e^B	*p*	*B*	*SE B*	e^B	95% C.I. for e^B	*p*
CRF	-0.06	0.01	0.95	0.93 to 0.97	0.01	-0.09	0.24	0.92	0.88 to 0.96	0.00
PA, counts/min	0.00	0.00	1.00	0.99 to 1.01	0.30	0.00	0.00	1.00	1.00 to 1.01	0.62
SED PA	0.00	0.00	1.00	0.99 to 1.01	0.92	0.00	0.01	1.00	0.99 to 1.02	0.61
Light PA	-0.00	0.01	1.00	0.98 to 1.02	0.82	-0.01	0.02	0.98	0.95 to 1.02	0.31
MVPA	-0.00	0.01	0.99	0.98 to 1.02	0.84	0.01	0.01	1.01	0.99 to 1.03	0.37
Constant	0.52					2.98				
χ^2	35.44					18.47				
df	5					5				

(CRF) Cardiorespiratory Fitness; PA (Physical Activity); SED (minutes spent sedentary); MVPA (Moderate to Vigorous Physical Activity).

The bivariate correlations among variables under study are presented in Table 10.2. BMI was inversely correlated with CRF among both rural (r=-0.29, p<0.01) and urban (r=-0.42, p<0.01) adolescents. Differences in relationships between rural and urban youth were not consistently significant, except for the relationship between BMI and total PA at the weekend (p<0.05), although that association for total days approached statistical significance (Table 10.2.).

Logistic regression analyses, adjusted for age and gender by geographic context, indicated a significant inverse association between overweight status and CRF (Table 10.3.). Adolescents with higher levels of CRF presented lower relative risk of being overweight/obese [rural: (OR=0.95, 95% CI 0.93-0.97, p<0.01); urban: (OR=0.92, 95% CI 0.88-0.96, p<0.01] than normal weight youth. Neither total amount of PA nor intense level of PA had a significant association with BMI.

DISCUSSION

This study examined the associations between BMI, PA intensity and CRF among rural and urban Portuguese adolescents. Presently available information about the relationship of these constructs in rural communities is relatively limited, especially for overweight/obese adolescents and using objective measures of PA. Moreover, youth from Southern European countries have the highest prevalence of overweight and obesity in Europe (Padez et al., 2004).

Adjusting for age and gender, adolescents from both rural and urban areas with higher levels of CRF presented lower relative risk of being overweight/obese than normal weight. This observation was consistent with the findings of previous studies that have documented low levels of CRF to be strongly and independently associated with high total adiposity as indicated by BMI (Ara et al., 2007), skinfolds thicknesses (Ara et al., 2007) and waist circumference (Hussey et al., 2007). Longitudinal data for Portuguese adolescents (Aires et al., 2010) indicated that youth who have higher BMI and lower CRF were more likely to have greater gain in the BMI over time. Similar findings were noted in Canadian youth 6-15 years whose weight status and fitness were tracked for 2 years (McGavock et al., 2009). An inverse association between BMI and CRF was found for both rural and urban adolescents in the present study. Since the PACER test is part of Portuguese physical education curriculum, schools are a crucial place for identifying high-risk adolescents and for using available resources to provide specific programs for these youth in order to enhance CRF. Collectively, the studies highlight the importance of increasing CRF as a protective effect among adolescents.

Results of the *MALS* suggested a relatively weak relationship between PA intensity and BMI in both urban and rural adolescents. Given the analytical strategy used, it is difficult to compare results of the present study to urban-rural contrasts in other countries. Whereas some studies have observed an equally weak, or no relationship between MVPA and adiposity (Hussey et al., 2007), others provided more convincing evidence of an inverse and significant association between these constructs (Gutin et al., 2005). For example, a recent study (Riddoch et al., 2009) suggests that the association of fat mass at age 14 (outcome) with PA at 12 (exposure) were especially evident for both total PA (accelerometer counts/min) and daily amount of MVPA (min/day).

Differences among studies in the reported associations depend, in part, on the methods of assessment and analysis. Whereas previous studies (Gutin et al., 2005; Hussey et al., 2007) used the BMI, sum of skinfolds or waist circumference to assess adiposity, others have used fat mass measured by dual emission x ray absorptiometry that could have influenced the strength of association between PA and body mass (Riddoch et al., 2009). On the other hand, PA is a complex multidimensional behaviour that is difficult to access in free-living populations of adolescents and for which a gold standard method does not exist. Therefore, even using objective measures of PA, specific issues such as number of days assessed, seasonal variation, selected epoch or cut-points to differentiate intensity levels may contribute to discrepancies among studies.

Criteria used to classify active and inactive youth also vary among studies. There is some debate within the scientific community regarding optimum levels of PA required to prevent clustering of cardiovascular disease risk factors. Some suggest that PA levels should be higher than current international guidelines of at least one hour per day of moderate intensity PA (Andersen et al., 2006). However, little is known about optimum levels of PA needed by overweight and obese youth.

Social and cultural variation between rural and urban areas and between and within various countries and regions is reasonably well documented (Barreto, 2000; Reyes et al., 2003). Among urban youth, low income neighbourhoods generally have a negative influence on health, academic achievement and behavioural outcomes (Cicognani et al., 2008). Young people living in neighbourhoods with good access to shops tend to have healthier diets and were less likely to be overweight (Veugelers et al., 2008). Economic status of area of residence may also influence access to recreational facilities, playing sports and active leisure. This is relevant as participation in organized sports is related to MVPA. Portuguese adolescents from the present study spent 11%-13% of total daily energy expenditure in organized sports that corresponded to 35%-42% of moderate-to-vigorous portion of daily energy expenditure. Urban youth tend to be more active than their rural counterparts, and it may be suggested, perhaps, that regular sport participation is a more likely feature among urban adolescents.

In Portugal, the high prevalence of overweight youth has been attributed, in part, to the rapid social changes in demography with a strong concentration in the metropolitan areas, a shift from an agriculture-based economy into services (e.g., migration from rural to urban communities), a decrease in walking or bicycle-based mobility, and a greater proportion of people living in apartments with fewer opportunities for access to playgrounds (Barreto, 2000). The city of Coimbra is the primary urban centre in the Midlands and has a higher percentage of general practitioners per 1000 people (19.3‰) and lower infant mortality (5.1‰) compared to other cities in Portugal. These estimates may reflect better general living conditions and, consequently, may be related to healthy behaviours and physically active lifestyles.

Adolescents living in urban communities were more active, particularly at the weekend, and had lower prevalence of obesity. However, the urban adolescents also demonstrated poorer performance in the CRF test compared with rural adolescents. Similar trends have been previously observed in youth from Oman and Australia (Albarwani et al., 2009; Dollman et al., 2002).

The present study suggested that area of residence (living in rural and urban communities) may play an important role in enhancing active lifestyles among this sample of Portuguese adolescents. An advantage of this study compared to previous studies was that it examined differences in the relationships among BMI, CRF and objectively measured PA (on week days and weekend days separately) in urban and rural adolescents. An understanding of relationships among weight status, PA and CRF in communities with socioeconomic, educational and nutritional inequities has the potential to inform programs of physical education, sports activities, and specific programs for overweight youth. Positive experiences in PA even for those with high body fatness are a crucial strategy for promoting active lifestyles and reducing the negative impact of obesity on public health.

Limitations of the current study should be also recognized. First, the results are limited to Portuguese youth 13 to 16 years living in Midlands region. Relations among BMI, CRF, and PA may vary with age, culture or socioeconomic status. The built environments of the communities were not considered. Second, although accelerometry provides an objective and reasonably accurate measure of PA, it does not capture all aspects of PA (e.g., sports/activities that involve water or where wearing the accelerometer presents physical risk). The cut-offs for intensity categories are also somewhat arbitrary because they depend on the type of activities performed when establishing the relation between activity counts and energy expenditure. Third, although the data were collected during the spring, the interval of data collection was spread over several months given the number of accelerometers available. Finally, the BMI is the most widely used indicator of overweight/obesity in epidemiological studies, but it may capture variation in body composition relevant to PA and CRF.

CONCLUSION

Because of the increasing prevalence of obesity and the decreasing physical fitness in adolescents, effective policies to promote PA among adolescents are needed. Results highlight a need to better understand the details of daily life of adolescents in urban and rural settings to define educational and perhaps clinical interventions. The results also emphasize the need to enhance active and reduce sedentary behaviours during adolescence, mainly at the weekend.

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CHAPTER XI

Main findings and recommendations for future research

11. MAIN FINDINGS AND RECOMMENDATIONS FOR FUTURE RESEARCH

11.1. Main findings and conclusions

The purpose of this thesis was to provide a comprehensive analysis of biological and socio-geographical factors that help to explain variance in sedentary and physical activity behaviours in adolescents and address a number of methodological issues regarding the assessment of physical activity in youth. More specifically, the current thesis emphasizes the agreement between objective and self-report measures of physical activity and the rural-urban contrasts in the activity, fitness and sedentary behaviour of a sample of adolescents from Portuguese Midland communities. In addition, it examined the contribution of organized sport to estimated daily energy expenditure, and the correlates of cardiorespiratory fitness among young people.

Leading an active life during adolescence may have a positive influence on chronic diseases such as obesity, diabetes, and cardiovascular diseases (Cumming and Riddoch 2008; Malina 2001). Current public health guidelines recommend that adolescents should engage in moderate to vigorous physical activity for at least 60 minutes every day (O'Donovan et al. 2010; Strong et al. 2005). This amount of physical activity seems to be necessary to achieve beneficial effects on health in adolescence (Strong et al. 2005), but most epidemiological studies have shown that adolescents do not meet the physical activity recommendations (Martinez-Gomez et al. 2010a; Troiano et al. 2008) et al., 2008; Martinez-Gomez et al., 2010). Besides time devoted on physical activity, measurement issues are also important to reach the accurate picture of physical activity among children and adolescents.

Physical activity assessment issues

The findings from study one revealed moderate correlations between physical activity measures provided by the 3-day diary and accelerometry and are consistent with previous research (Gwynn et al. 2010; Hagstromer et al. 2008; Ottevaere et al. 2011a). For example, Martinez-Gomez and co-workers (Martinez-Gomez et al. 2010b) also reported moderate correlations between the activity monitor and the diary administered over the three days among Spanish adolescents. In addition, analogous findings were reported with different self report measurements, such as the *Adolescent Physical Activity Recall Questionnaire*, in Australia (Gwynn et al. 2010).

The Bland–Altman plot of differences between estimated activity energy expenditure (AEE) based on the diary and accelerometry relative to mean estimated AEE based on the two protocols (kcal/min) revealed that, among the total sample, approximately 97% of cases fall within the upper and lower limits of agreement. Although currently considered the method of choice for assessing physical activity, accelerometers remain limited in a number of ways. For example, they are impractical when assessing certain activities, such as contact sports or water based-activities. In addition, failure to wear the accelerometer is another potential source of error in estimates of AEE. When not taking into account the non-wear activity diary and dealing with the non-wearing time of the accelerometer, some adolescents could be misclassified as not being physically active according to the physical activity recommendation (Ottevaere et al. 2011b). Results from Martinez-Gomez and colleagues' study revealed Spanish adolescents with lower levels of agreement on the third day but it was not clear if this is due to design features (week days v. weekend) or to participant compliance with the survey or the activity monitoring protocol (Martinez-Gomez et al. 2010b).

The results of the current study suggested that the 3-day diary was a valid supplement for assessing daily energy expenditure (EE) and its AEE component in Portuguese adolescents. However, considerably more high-quality research is required to examine the validity and reliability of promising physical activity self-report for youth (Chinapaw et al. 2011), particularly examining further factors that might influence the relationship between AEE provide by objective and subjective physical activity instruments. Therefore, the trend of the bias and also whether or not that error is more apparent on specific groups of adolescents should probably be highlighted.

Taking into account the aforementioned concern, study two from the present thesis aimed to evaluate the agreement between self-reported and objective estimates of activity energy expenditure by age, sex and weight-status. Partial correlations between protocols were significantly higher in males than in females and did not vary with age group. The 3-day diary underestimated activity energy expenditure, especially among overweight/obese adolescents (-0.74 $kcal.min^{-1}$) and participants 15-16 years of age (-0.43 $kcal.min^{-1}$). Since self-reported physical activity is prone to misreporting and the correlations between the 3-day diary and accelerometer were no more than moderate, results should be interpreted with caution.

Among youth, self-report protocols may be affected by a number of factors, including the nature of the behavior recalled. Most daily activities are intermittent and may involve substantial rest periods, which may lead to significant overestimation of time spent on daily activities (Slootmaker et al. 2009; Trost et al. 2002). In addition, such intermittent activities are probably more difficult to define or quantify than occupational activities or structured exercises (Armstrong and Welsman 2006; Cumming and Riddoch 2008). Since the accelerometer is not a gold standard for assessment activity energy expenditure, the disagreement between instruments may result from weaknesses inherent to both instruments. Therefore, the bias could result from the inaccuracy in the diary entries or from the accelerometer limitations previously mentioned. Further, it should be clearly emphasised that the accuracy of the 3-day diary depends on the adolescents' willingness to adhere to the instruction as well as their ability to correctly identify the appropriate activity code. Accordingly, those working to improve physical activity levels of youth should be aware of these and other factors in order to better develop future educational and clinical interventions/strategies for health promotion. Therefore, research using a multi-method design to provide quantitative and qualitative data of physical activity is recommended in youth.

Sedentary behaviours and physical activity:
Is biological maturation a confounding factor?

There is growing evidence to suggest that biological processes are involved in regulating habitual daily physical activity and energy expenditure, however, most studies addressing the age- and sex-associated variation in physical activity levels in children and adolescents focus on environmental and psycho-social aspects (Ferreira et al. 2007; Sallis 2000). Biological determinants of physical activity have only sparsely received attention. Consistent with the assumption that physical activity has a biological basis, results from study three revealed that the main effect of sex on sedentary behaviour was attenuated and non-significant when biological maturation was statistically controlled for. In addition, results suggested the sex differences on MVPA were no longer significant for weekend days and the effect size was attenuated for the other days when biological maturation was statistically controlled for. These findings are largely consistent with previous research performed in Canada (Sherar et al. 2007), U.S. (Thompson et al.

2003), and United Kingdom (Cumming et al. 2008) identifying biological maturation as a source of variation in sex differences in physical activity and sedentary behaviour during adolescence.

Sex-related differences in the physical activity associated with advanced maturation may explain why adolescent females are less likely to engage in certain exercise behaviours when compared with males of a similar age. Many of the physical changes associated with advanced maturation in females (i.e., widening of the hips, breast development, increased proportional fat mass) are considered less conducive to successful engagement in moderate and vigorous forms of physical activity (Baxter-Jones et al. 2005; Malina et al. 2004). Indeed, advanced maturation in females is associated with poorer performance in tasks that involve weight bearing or endurance (Malina et al. 2004). In contrast, advanced maturation in males (i.e., greater proportional muscle mass, widening of the shoulders) is generally associated with superior athletic performance in males, particularly in activities that require strength, speed, or power (Malina et al. 2004).

Although differences in the timing and tempo of biological maturation may contribute to sex differences in physically active and sedentary behaviours, it is likely that a combination of the social, psychological, physical and physiological changes associated with biological maturation rather than maturity status per se underlie the observations (Cumming et al. 2008; Malina et al. 2004). However, the results of study three, in line with previous research above mentioned, has potential implications for the promotion of active lifestyles during adolescence. Needless to say, intervention targeting boys and girls of the same chronological ages may have to consider differences in biological maturation.

Urbanization and health-related behaviours

Epidemiological studies suggest that a significant portion of the cardiovascular disease epidemic is attributable to changes in lifestyle risk factors, exemplified by reduction in physical activity and increased consumption of high-energy processed foods. Research examining differences in the physical activity and health outcomes in urban and rural youth has produced equivocal findings. Study four revealed rural youth of both sexes had higher levels of cardiorespiratory fitness than their urban peers. These data are consistent with findings from other studies in which youth from rural locations were more likely to be classified as fit than their urban counterparts, in Spain (Chillon et al. 2011), Oman (Albarwani et al. 2009) and Australia (Dollman et al. 2002). Rural boys, however, were less active than urban boys, particularly at the weekend, whereas urban girls were significantly less active than rural females on week days and across total assessed days. These findings are consistent with previous studies by showing rural male and female adolescents less physically active than their urban peers in U.S. (Liu et al. 2008; Lutfiyya et al. 2007) and Iceland (Kristjansdottir and Vilhjalmsson 2001).

On the other hand, urban boys spent less time on sedentary activities than rural boys and rural adolescents of both sexes tend to spend more time on screen activities than urban youth. These findings contrast with U.S. studies that suggest that urban youth of both sexes are more sedentary than rural youth (Liu et al. 2008; Springer et al. 2006). It should be noted, however, the latter U.S. studies used electronic media as a proxy for sedentary behaviours. Of relevance, TV viewing and computer use are not the only form of sedentary behaviour in adolescents, who also spend substantial amounts of time sitting in school classes, riding in cars, eating, socialising, reading and studying.

It is difficult to compare results of the present study to urban-rural contrasts in other countries as the data are not strictly comparable. However, the nature of physical activity required and social and familial influences among rural adolescents might explain the larger amount of time in MVPA by rural female girls of the present study. Seabra and co-workers (Seabra et al. 2011), in a sample of 3352 Portuguese youth aged 10–18 years, point out that mother's and sibling's physical activity and peer influence are important determinants of adolescents' physical activity level. Furthermore, rural girls were more likely to be involved in domestic activities and at times in light agricultural activities (Coelho e Silva et al. 2003). Our findings (i.e. study four) show that screen time was also greater among rural girls and probably influence opportunities for outdoor social interactions.

Although the results suggest a potential impact of socio-geographic factors on physical activity, cardiorespiratory fitness and sedentary behaviour of Portuguese youth, they also highlight a need to better understand the details of daily life in urban and rural settings. In addition, the current study emphasizes the need to enhance active behaviours and reduce sedentary one at the weekend during adolescence. Therefore, health-related behaviours may not be similarly programmed in different socio-geographic contexts.

Participation in organized sport

Sport participation, which correlates with reduced involvement in multiple health risk behaviours among adolescents, is considered to be a priority among those involved in the public health and the promotion of active lifestyles. In fact, organized sport appears to be a relevant component of daily activity energy expenditure among adolescents (Katzmarzyk and Malina 1998; Wickel and Eisenmann 2007). Study five from the current thesis revealed youth involved in sport have higher levels of daily physical activity and MVPA than non-participants corroborating with previous research performed in U.S. (Katzmarzyk and Malina 1998; Wickel and Eisenmann 2007), Finland (Aarnio et al. 2002a; Aarnio et al. 2002b) and Estonia (Saar and Jurimae 2007). Among US youth, organized sports contributed to 23% of time spent in MVPA in boys aged 6-12 years (Wickel and Eisenmann 2007) and to about 65% of the daily energy expenditure in MVPA in boys aged 12-14 years (Katzmarzyk and Malina 1998). In the present study five, organized sport contributed to 42% and 35% of daily energy expenditure in MVPA in Portuguese male adolescents aged 13-14 years and 15-16 years, respectively. Results of the latter three studies of boys suggest an age trend, specifically an increase in the contribution of sports to daily MVPA from childhood to about 14 years and then a decline in older boys.

Youth sport participants also spend less time engaged in sedentary behaviors. This is consistent with less time spent in television viewing noted in American adolescent sport participants relative to non-participants (Katzmarzyk and Malina 1998). Therefore, increasing organized sport programs, especially at the weekend, may play an important role in reducing or preventing sedentary lifestyles in youth. Furthermore, promoting family-based programs at the weekends might be an important strategy to enhance active behaviours among youth. This is important from two perspectives. First, youth involved in sport have higher levels of MVPA, and regular participation in MVPA has health, fitness and behavioural benefits - weight control, less adiposity, increased bone mineral content, improved aerobic capacity and muscular strength and endurance, enhanced self-concept, among others (Cumming and Riddoch 2008; Strong et al. 2005). Second, participation in sports during adolescence tends to track at higher levels than other indicators of physical activity so that youth who are active in sport during adolescence are more likely to be physically active in young adulthood (Malina 2001; Malina 2009). Thus, sport participation during adolescence has the potential for health, fitness and behavioural benefits.

Cardiorespiratory fitness and socio-geographic factors

Improving physical fitness is also an objective of programs aimed at preventing obesity among youth, and urbanization is periodically highlighted as a factor that influences cardiovascular fitness and several health-related behaviours. The association between cardiorespiratory fitness and area of residence persisted when several potentially confounding factors were included in the logistic regression models (study six). The result contrasts previous research in the Portuguese Midlands which showed few differences among urban, semi-urban and rural adolescents in several physical fitness tests (Coelho e Silva et al. 2003). This study, however, did not use a corresponding measure of cardiorespiratory fitness. In the study six, male and female adolescents from rural settings were 76% more likely to be classified as aerobically fit than adolescents from urban areas, consistent with observations from youth of Spain (Chillon et al. 2011), Oman (Albarwani et al. 2009) and Australia (Dollman et al. 2002).

Maternal education was associated with higher level of cardiorespiratory fitness in female, but not in male adolescents. Girls with mothers who had graduated or had a professional degree were significantly more likely to have a higher level of cardiorespiratory fitness. Results from the *European Youth Heart Study* (Kristensen et al. 2006) revealed the presence of a social gradient in the prevalence of low physical fitness among youth, favouring the children of high socioeconomic status. It has also been suggested that mothers with higher levels of education are more likely to engage in health promoting behaviours and thus present an influential role model for children (Desai and Alva 1998; Sherar et al. 2009). Of relevance, maternal education has been positively associated with activity behaviours among children and adolescents activity (Butcher et al. 2008; Gordon-Larsen et al. 2000; Hesketh et al. 2006; Lasheras et al. 2001). It is also possible that mothers with higher education have normal weight status and in turn encourage their daughters to maintain a healthy weight, which in turn may impact cardiorespiratory fitness.

In addition, results of the study six showed that cardiorespiratory fitness and MVPA were positively associated in Portuguese males and females. Although different indicators of both physical activity and cardiorespiratory fitness are used in studies of youth, results are consistent with the international literature by showing a moderate relationship between activity and cardiorespiratory fitness (Gutin et al. 2005; Hussey et al. 2007; Katzmarzyk et al. 1998). In fact, the available studies often reveal over 80% of the variability in physical fitness is not accounted for by physical activity. For example, in the *Quebéc Family Study* (Katzmarzyk et al. 1998), only 11-21% of variance in fitness items was explained by physical activity variables suggesting a potential interaction between demographic, educational and cultural features of the environment with lifestyle as an additional source of variation.

In summary, study six revealed that area of residence, MVPA and weight status were important predictors of cardiorespiratory fitness in Portuguese adolescents 13-16 years of age. Maternal education was an additional predictor in girls. It should also be noted that school-based physical fitness testing is an important local surveillance resource. Awareness of factors related to cardiorespiratory fitness among adolescents may facilitate the enhancement of cardiorespiratory fitness and in turn serve to reduce the risk of overweight and obesity among adolescents.

Obesity and cardiorespiratory fitness and physical activity

Because of the increasing prevalence of obesity and the decreasing physical fitness in adolescents, effective policies to promote physical activity among adolescents are needed. Understanding the relationships between weight status, cardiorespiratory fitness, and physical activity has the potential to inform programs of physical education, sports activities, and specific programs for overweight youth. In study seven, after adjustment for age and gender, adolescents from both rural and urban contexts with higher levels of cardiorespiratory fitness presented lower relative risk of being overweight/obese than normal weight. This observation is consistent with the findings of previous studies that have documented low levels of cardiorespiratory fitness is strongly and independently associated with high total adiposity, both with BMI (Aires et al. 2010b; Ara et al. 2007; Dumith et al. 2010; He et al. 2011; Mota et al. 2006), skinfolds thicknesses (Ara et al. 2007; Ruiz et al. 2006), and waist circumference (Hussey et al. 2007), which highlight the crucial challenge of increasing cardiorespiratory fitness for a protective effect among adolescents. Longitudinal data from Portuguese children (Mota et al. 2009) and adolescents (Aires et al. 2010a) revealed that youth who have higher BMI and lower cardiorespiratory fitness were more likely to have greater BMI gain over time. Similar findings were noted in 6-15 year-old Canadian youth followed for 2 years (McGavock et al. 2009) and among 8-13 year-old Chinese youth followed for 18 months (He et al. 2011). Since the PACER test is part of Portuguese physical education curriculum, schools are a crucial place for identifying high-risk adolescents and for using available resources to provide specific programs for these youth in order to enhance cardiorespiratory fitness as a protective effect among adolescents.

Results of the study seven also suggested a relatively weak relationship between physical activity intensity and BMI in both urban and rural adolescents, however, in line with results of a recent systematic review (Jimenez-Pavon et al. 2010). Some studies have observed an equally weak, or no relationship between MVPA and adiposity (Hussey et al. 2007), others provided more convincing evidence of an inverse and significant association between these constructs (Duncan et al. 2010; Gutin et al. 2005; Hands et al. 2011). Differences among studies in the reported associations depend, in part, on the methods of assessment and analysis techniques. Even using objective measures of physical activity, specific issues such as number of days assessed, seasonal variation, selected epoch or cut-points to differentiate intensity levels may contribute to discrepancies among studies.

In conclusion, those results highlight a need to better understand the details of daily life of adolescents in urban and rural settings to define educational and perhaps clinical interventions. The results also emphasize the need to enhance active and reduce sedentary behaviours during adolescence.

11.2. Limitations and recommendations for future research

Specific limitations of the seven studies included in this thesis were individually considered in previous chapters 4 to 10. The purpose of this section is to point out more general concerns regarding the collective work in this manuscript and to integrate these for future research.

The cross sectional design of the studies may not accurately reflect individual changes in sedentary behaviour or physical activity over time (e.g., differences between 13-14 years and 15-16 years age groups) as would be found with a longitudinal study design. However, the cross-sectional studies have an additional advantage once it avoids any intervention effect that might occur from repeated questioning about physical activity.

Although accelerometers have become an important activity assessment tool, there are some limitations that need to be considered when reviewing the results of studies included in the present thesis. It is important to bear in mind that the physical activity assessment, data extraction techniques, classification of activity intensity and reporting of physical activity data from accelerometers is inconsistent across studies and therefore choices made in the present research will affect reported results. However, because children and adolescents are often unable to supply with accuracy the details regarding the different dimensions of physical activity, it also becomes hard to state witch instrument is truly the best choice to be used.

It should be noted that the participant in the current study demonstrated significant variations in both physical activity and, to a lesser extent, sedentary behaviour. That is variation in physical activity was marked both between and within participants. Whereas some participants were clearly more or less active than others, the activity of some participants varied greatly across the period of data collection (i.e., some active days and some less active days). It is essential that researchers better understand and control for individual differences in physical activity and sedentary behaviour as they may have important implications for both weight status and health.

Recommendations for future research

According to the important public health priority on promotion of active lifestyles among young people, and taking into account the related potential factors that influence physical activity, sedentary behaviour and cardiorespiratory fitness, future research should consider the following directions:

1) There is still a need to clarify the agreement of AEE between self-report and objective physical activity measures in children and adolescents, especially at high intensity levels of physical activity. In other words, further instrumental validation studies to enhance physical activity instruments should be performed in order to better describe the true behaviours of adolescents.

2) Methods and instruments to assess physical activity are somewhat different among studies, and particularly variable among and within specific countries and regions. Research should adopt similar instruments of physical activity assessment and also analogous criteria of data analysis to make more comparable findings among studies. Therefore, a contextual validation including social and geographic factors that influence time spent sedentary and physical activity would be actually welcome.

3) Further research is needed to establish the complex inter-relationships among adiposity, biological maturation, and energy expenditure during puberty, particularly at early ages of adolescence. In addition, selectively sampling boys and girls at the extremes of the maturity continuum within single chronological age groups may provide insights into potential associations.

4) Studies have shown that physical fitness is related to physical activity in adolescents but correlations are generally low to moderate. Furthermore, within a group of children of the same chronological age there are likely to be children who have advantages in physical fitness tests due largely to variation in maturity status (Malina et al. 2004). Therefore, there is a need for creative research designs, both cross-sectional and longitudinal, to inform our understanding of relationships among biological maturity, physical fitness and physical activity during the transition into adolescence and during adolescence, per se.

5) Further research is needed to clarify contrasting results of the time spent sedentary, physical activity and fitness in rural and urban communities, mainly using nationally representative samples of adolescents.

6) Since the results of the present thesis suggested that the age-related decline in physical activity may be more marked among non-participants in sports compared to those who continue to participate, it should be also highlighted the need to pay closer attention to the activity habits of those who drop out of sport either voluntarily or involuntarily.

7) In addition, organized sport appears to be an important component of daily activity energy expenditure among male adolescents. Therefore, further investigations are needed to better understand the role of sport participation in healthy lifestyles among youth of both sexes.

8) Research using built environment variables is recommended to enhance the understanding of how further factors (e.g., distance from home to school, availability of physical activity facilities, perception of the area of residence, and perhaps attitudes towards physical activity and cardiorepiratory fitness) relate to that urban-rural contrast on health-related behaviours (e.g. physical activity and sedentary behaviour) in order to define educational and clinical interventions.

9) Furthermore, it has been often assumed that individuals with very low birth weight report lower levels of physical activity as adults. Future research should perhaps aspire to examine whether birth weight acts as a biological determinant of physical activity and time spent sedentary.

10) Finally, epidemiological studies suggest that a significant part of the cardiovascular disease epidemic is attributable to changes in lifestyle risk factors, such as high levels of sedentary habits and increased consumption of high-energy processed foods. Therefore, the independent association between sedentary behaviour and the metabolic syndrome might be an important goal for future researches in adolescents from the Portuguese Midlands. Furthermore, the analyses of the interactions between health-related behaviours and psychological and social variables should also be performed.

In conclusion, the science to support future work would be strengthened by integrating longitudinal study designs, considering the generalizability and diversity of the populations and contexts under study, exploring dose response relationships, and encouraging surveillance.

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APPENDIX A

Example of the 3-day diary

APPENDIX B

Questionnaire (familial data)

APPENDIX C

Information letter (parent and adolescents), parental consent form, and child assent form

APPENDIX D

Dissemination of the project to date with the support of *Fundação para a Ciência e a Tecnologia* [SRFH/BD/38988/2007]

DISSEMINATION OF THE PROJECT TO DATE

Fundação para a Ciência e a Tecnologia [SRFH/BD/38988/2007]

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1. PUBLICATIONS / SCIENTIFIC PRESENTATIONS

a) Articles in peer review international journals

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c) Abstracts and Proceedings of International Meetings

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d) Articles in national Journals

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Machado Rodrigues AM, Coelho e Silva MJ (2009). Dispêndio energético e Actividade Física na Adolescência. *I Curso de Mestrado em Actividade Física em Contexto escolar*. *Faculdade de Ciências do Desporto e Educação Física - Universidade de Coimbra*. Setembro/Outubro.

Machado Rodrigues AM, Coelho e Silva MJ (2009). Avaliação da Actividade Física por Acelerometria em Crianças e Adolescentes. I *Curso de Doutoramento em Ciências do Desporto*. *Faculdade de Ciências do Desporto e Educação Física - Universidade de Coimbr*a. 20 e 27 de Março.

Coelho e Silva MJ, Machado Rodrigues AM, Figueiredo AJ, Rêgo I (2009). Contributo do Desporto no Dispêndio energético diário em populações pediátricas. *IX Fórum Internacional de Desporto*. Coimbra (Portugal). 6-7 Março.

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Machado Rodrigues AM, Coelho e Silva MJ (2008). Avaliação da Actividade Física em Idade Pediátrica. [unidade curricular: Actividades Físicas de Lazer e Ciclos de Vida]. *3º Curso de Mestrado em Lazer e Desenvolvimento Local. Faculdade de Ciências do Desporto e Educação Física - Universidade de Coimbra*. 5 de Janeiro de 2008.