TERESA PAULA DOMINGUES DA CUNHA BENTO

Physical activity in adults and elderly adults measured by accelerometry

The influences of age group, gender, time of year, and weather

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Summary

The main purpose of this thesis was to study objectively measured physical activity (PA) in an adult Portuguese population. First, we addressed methodological concerns related to the assessment of PA in this age group and the use of accelerometry by performing a systematic review of studies. We found that the standardisation of the methods used for data collection as well as the methods and units for reporting data are needed for the ability to compare the results between studies. More longitudinal studies, more studies on large sample populations other than U.S. populations, and the collection of data from specific seasons or periods of the year should be encouraged. As part of our study, we summarised valuable information on the methods and the procedures associated with the use of accelerometers, which should promote the accurate use of these devices and the accurate analysis of the collected data.

Because one of the main reasons for assessing and studying PA is to increase the knowledge of the characteristics and behaviours of a population in order to better design adequate strategies that promote PA, we aimed to provide descriptive data on objectively measured PA, to analyse age and gender differences, and to investigate the adherence to PA recommendations. Our findings, in addition to providing valuable information on the total PA level of the studied population, showed that differences in the intensities of performed activities should be considered in the design of interventions for each gender/age group. High correlations were found between the total amount of PA and the moderate to vigorous PA (MVPA) in all gender/age groups, suggesting that this level of intensity has a major impact on the total daily PA in all age groups and that interventions should focus on increasing the amount of MVPA to reverse low levels of PA. Moreover, our data on the levels of compliance with PA recommendations may indicate that interventions that promote an increase in the number of steps taken per day should be encouraged.

Because the season or the period of the year in which a study is carried out has been named as a potential source of variance in daily PA levels, assessing study participants only at one time of the year may result in the erroneous estimation of average PA levels. Thus, we examined if there were changes in PA depending on the time of the year that it was assessed. We found that the period of the year when evaluations took place did influence PA data, especially in the elderly population studied. Women, generally maintained a similar PA level throughout the year, whereas the total PA of men varied during

the first months of the year due to an increase in their MVPA. Regarding the adherence to different PA recommendations, the results from the gender/age groups varied widely among the different periods of the year. Gender differences were only observed from September to December, when 40- to 59-year-old men spent more time being sedentary and less time participating in light activity compared to women of the same age. From January to April, PA significantly fluctuated in the elderly, with a general increase in sedentary activities and a decrease in the steps taken per day.

Finally, according to the literature, weather variables are perceived as a barrier to PA. Therefore, we aimed to explore the effects of the weather on PA. Although our results confirmed that environmental factors do influence an individual's willingness to engage in PA, our data also indicated that these influences are weak. It has been previously suggested that, out of all weather variables, PA is most influenced by precipitation. In our study, we could not confirm that precipitation was the most influential weather factor on PA levels because differences in the levels of influence were found for each gender/age group. Younger women and those who adhered to the 10,000 steps per day PA recommendation did not seem to be affected by weather.

Intervention strategies should focus on increasing the levels of PA participation as well as ensuring the maintenance of a consistent PA level throughout the year by encouraging adherence to daily goals based on the number of steps taken per day, which should be adjusted to the gender/age characteristics of the targeted population. Intervention strategies should also emphasise sustained periods of PA that consist of at least 10 minutes above the MVPA threshold to achieve the at least 30 minutes PA recommendation in the general population and especially in the elderly. Moreover, surveillance data should be used to measure the achievement of the intervention objectives.

The results from this study contribute to the knowledge on the Portuguese population regarding its PA, its compliance with PA guidelines, its PA variance throughout the year, and the factors that may affect its adherence to participation in PA. These data will allow for the improvement of PA promotion strategies and intervention programmes by suggesting recommendations for how interventions can be potentiated and aimed at increasing daily PA levels and inverting sedentary behaviours throughout the year and across age groups.

Key words: accelerometry, elderly, physical activity, recommendations, steps, surveillance, weather

Actividade física em adultos e idosos avaliados por acelerometria – influência do grupo etário, género, período do ano e do clima

Sumário

O principal objectivo desta tese foi estudar a actividade física (AF) de adultos e idosos portugueses quando avaliada por acelerometria.

Inicialmente, realizámos uma revisão sistemática com o intuito de analisar questões relacionadas com a avaliação da AF através de acelerometria nos referidos grupos etários. Verificamos que deverão ser desenvolvidos mais estudos longitudinais que envolvam amostras amplas de populações que não as dos Estados Unidos da América, e que forneçam dados relativos ao período ou estação do ano em que foram avaliadas as amostras. Por outro lado, no sentido de contribuir para a padronização de procedimentos que permita a comparação de resultados entre investigações, assim como da definição da metodologia a aplicar nos restantes estudos, reunimos informação referente aos métodos de recolha e análise dos dados, bem como das formas de reportar os resultados.

Uma das principais razões para a avaliação e estudo da AF prende-se com o aumento do conhecimento das características e comportamentos de uma população para que se possam planear e adequar estratégias de promoção da AF e posteriormente avaliar os seus efeitos. Nesse sentido, tivemos como objectivo fornecer dados descritivos de AF avaliada objectivamente, analisar diferenças entre géneros e níveis etários, e avaliar o cumprimento das recomendações da AF da uma amostra de adultos e idosos portugueses.

Os resultados do nosso estudo indicam que, para além da importante informação relativa ao total de AF realizada diariamente, devem ser considerados nas intervenções os dados relativos aos diferentes níveis de intensidade realizados por cada um dos grupos género/idade e que contribuem para esse total diário de AF. Ao longo da idade, em todos os grupos género/idade observaram-se correlações elevadas da variável total de AF e a intensidade moderada a vigorosa (MVPA), o que nos leva a crer que as intervenções de promoção da AF devem considerar o aumento desta componente para inverter os níveis baixos de AF registada. Mais ainda, os dados sobre o nível de cumprimento das recomendações de AF indiciam que estas intervenções podem recomendar o aumento do número de passos dados por dia para atingir estes objectivos.

Posteriormente, uma vez que a estação ou período do ano em que o estudo se realiza tem sido apontado como uma potencial fonte de variação dos níveis de AF e que a avaliação dos participantes realizada numa determinada altura do ano poderá incorrer em erros na estimação da AF, pretendemos analisar as alterações na AF, quando avaliada em várias alturas do ano.

Verificamos que a estação ou período do ano influencia os resultados da avaliação da AF, especialmente nos idosos. As mulheres, em geral, mantêm os níveis de AF ao longo do ano, e as variações observadas nos homens ocorre nos primeiros meses do ano devido a um aumento da MVPA. Relativamente ao cumprimento das diferentes recomendações de AF, verificou-se uma grande variação entre grupos de género/idade ao longo do ano. As

diferenças entre géneros foram observadas apenas entre Setembro e Dezembro quando os homens de 40-59 anos despendem mais tempo em actividades sedentárias e menos actividades de intensidade leve do que as mulheres da sua faixa etária.

Verificou-se ainda que existe um período do ano em que a AF dos grupos de homens e mulheres idosos decresce de forma inequívoca (Janeiro a Abril), devido ao um aumento significativo de actividades sedentárias associadas ao facto de darem menos passos por dia.

Finalmente, tendo em conta que de acordo com a literatura as variáveis do clima são percepcionadas como uma barreira à participação na AF, tivemos como objectivo explorar os efeitos do clima no envolvimento na AF. Apesar de os resultados confirmarem que estas variáveis têm influência no envolvimento na AF, a influência verificada é fraca. Não foi também possível confirmar que a precipitação é de todas as variáveis do clima a que maior influência tem, tal como sugerido na literatura. Por outro lado, nenhuma das variáveis do clima parece ter influência quer nas mulheres de 20-39 anos, quer nos cumpridores da recomendação dos 10.000 passos diários.

Como indicações para a prática, podemos dizer que considerando os resultados obtidos, as campanhas de promoção da AF devem focar-se no aumento dos níveis de participação na AF, assim como devem garantir a manutenção de um nível constante de AF ao longo do ano no sentido de contrariar a quantidade de tempo despendido em actividades sedentárias. As estratégias de intervenção devem passar por encorajar o cumprimento de objectivos diários baseados no número de passos, de acordo com as características dos vários grupos de género/idade da população em causa. Deve também ser enfatizado o cumprimento de períodos de pelo menos 10 minutos acima do MVPA no cumprimento dos 30 minutos diários acumulados de AF na população em geral, mas em especial nos idosos. Finalmente, deve promover-se a recolha de dados sistemáticos que permitam reportar as alterações verificadas nas características da população no cumprimento destes objectivos.

Os resultados deste estudo contribuem para o conhecimento dos níveis de AF da população portuguesa, do seu desempenho no cumprimento das recomendações de AF, das alterações que verificam ao longo do ano, e dos factores que podem afectar o seu envolvimento na AF. Estes dados são também contributos para a melhor adequação das estratégias de promoção e dos programas de intervenção de AF já que constituem pistas acerca de como potenciar intervenções que tenham como objectivo aumentar os níveis diários de AF e inverter os hábitos sedentários, quer ao longo do ano, quer da idade.

Key words: acelerometria, idosos, actividade física, recomendações, passos, vigilância, clima

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List of Abbreviations

ACSM	American College of Sports Medicine
BMR	Basal metabolic rate
BMI	Body Mass Index
CAD	Coronary artery disease
CVD	Cardiovascular disease
CHD	Coronary heart disease
CDC	Centers for Disease Control and Prevention
COPD	Chronic obstructive pulmonary disease
CI	Confidence interval
DLW	Doubly labeled water
EE	Energy expenditure
HR	Heart rate
LTPA	Leisure-time physical activity
MET	Metabolic Equivalent
MVPA	Moderate-to-vigorous physical activity
PA	Physical activity
PAL	Physical activity level
PAP	Physical activity patterns
RCT	Randomized Controlled Trial
TEE	Total energy expenditure

List of Definitions

Active daily living – The implementation of physical activity as an integral and meaningful part of daily living (6).

Activities of daily living – the activities one engages in during daily life (6).

Accelerometer – Electronic sensors that measure quantity and intensity of movement in terms of acceleration, and depend on the positioning of the body as well as the mechanical properties of the sensor (3, 8).

All-cause mortality – death from any cause.

Body Mass Index (BMI) – Measure of obesity. Body mass (in kilograms) divided by height (in meters) squared (body mass kg/height $(m)^2$.

Built environment – Environment as modified by the construction of any structure or place including, but not limited to, homes, commercial buildings, schools, churches, roads, sidewalks, parks, and recreation centers in the context of its potential effects on daily physical activity (1).

Cardiovascular disease (CVD) – Dysfunctional conditions of the heart, arteries, and veins that supply oxygen to vital life-sustaining areas of the body like the brain, the heart itself, and other vital organs (1).

Coronary heart disease (CHD) – A narrowing of the coronary arteries that feed the heart (atherosclerosis), resulting in an insufficient blood supply to the heart muscle and causing angina (chest pain) or a myocardial infarction (1).

Chronic obstructive pulmonary disease (COPD) – Progressive airflow obstruction that does not vary over a long period of time. Usually caused by cigarette smoking, results in emphysema, chronic bronchitis and small airways disease (4).

Confidence interval (CI) – A band of uncertainty around an estimate of the relative risk. Typically, 95% confidence intervals are used in epidemiologic studies (1).

Daylight – or day length, corresponds to the amount of time of sun exposure.

Disuse – Sedentary behaviour or physical inactivity.

Doubly labeled water (DLW) – biochemical procedure that estimates energy expenditure through biological markers that reflect the rte of metabolism of the body (7).

Effectiveness – Effects of physical activity or exercise programs in real-world conditions, delivered by the real health care system, professionals, or relevant organizations.

Efficacy – effects of controlled evaluation of physical activity or exercise programs under laboratory or carefully controlled conditions (1).

Energy expenditure (EE) – Net transfer of energy required to support skeletal muscle contraction during physical activity. This term is used to quantify the volume or dose of physical activity, computed as the product of frequency, duration and intensity of a specified physical activity and typically expressed as kcal/week or MET hour/week (1).

Epidemiology – The study of the distribution and determinants of heal-related states or events in specified populations, and the application of this study to control of health problems (4).

Exercise – Planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness (2).

Health – a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (1).

Health-related physical fitness – The components of physical fitness that are related to health status, including cardiovascular fitness, musculoskeletal fitness, body composition and metabolism (6).

Heart rate (HR) – the number of times the heart contracts per minute.

Insolation – Amount of solar radiation hitting a surface, measured in energy units such as watts, watts per square meter, watts per square meter per day.

Leisure-time physical activity – Activity undertaken in the individuals discretionary time that substantially increases total daily energy expenditure. The element of personal choice is inherent to the definition (1).

Meta-analysis – Statistical technique that summarises results from studies employing different sample sizes and reliability information, providing a quantitative review of the literature (5).

Metabolic Equivalent (MET) – An estimate of one´s resting metabolic rate while sitting quietly (1 MET = 3.5 mL oxygen per kilogram per minute, or 1 kcal [4,2 kJ] per kilogram per hour) (6).

Morbidity – measures that pertain to disease states and conditions that have not achieved a mortal end point. Common measures of morbidity are disease – or condition-specific incidence rates, hospital admissions, bed-days, treatment costs, loss of physical function and independence, and lost days of work for specific causes (1).

Obesity – A condition of excessive fat accumulation to the extent that health may be impaired (1).

Pedometer – device that provides information on ambulatory activity (7).

Physical activity (PA) – any bodily movement produced by the skeletal muscle that results in energy expenditure (2).

Physical activity level (PAL) – Total daily caloric expenditure divided by total calories from resting metabolism. This term is being increasingly used as an overall indicator of energy expenditure (1).

Physical activity programs, exercise programs, or interventions – Specific purposive efforts to engage with individuals or populations to increase defined and measurable elements of physical activity or exercise and to attribute changes to participation in such programs (1).

Physical fitness – A set of attributes that people have or achieve that relates to the ability to perform physical activity (2).

Precipitation – Rain fall or snow fall

Primary prevention – Prevention of the development of disease in healthy people (4).

Randomized Controlled Trial (RCT) – Trial in which patients are randomly assigned to two groups: one treatment group and one control group. Assigning patients at random reduces the

risk of bias and increases the probability that differences between the groups can be attributed to the treatment (1).

Required activities of daily living – That activity required by a person to survive and lead a productive life (1).

Secondary prevention – Decrease in the risk of mortality and further morbidity in patients with existing disease.

Surveillance data – Regularly collected data that report temporal changes in population characteristics (1).

Structured exercise programs – Planned exercise programs, consisting of continuous aerobic exercise or strength training, conducted under professional supervision, often in facilities or gyms (1).

Tracking of activity levels – Persistence of activity habits (1).

Volume of physical activity – combination of frequency, duration and intensity of physical activity (6).

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Physical activity in adults and elderly adults measured by accelerometry: the influences of age group, gender, time of year, and weather.

Abstract

The main purpose of this thesis was to study objectively measured physical activity (PA) in an adult Portuguese population. Specifically, we aimed to a) address methodological concerns related to the assessment of PA by means of accelerometry; b) provide descriptive data on PA, including the analysis of gender/age differences with regard to PA and investigation of the fulfilment of PA recommendations; c) examine if there are changes in PA when assessed at different times of the year; and d) explore the effects of weather on PA.

Data indicate that intervention strategies should focus on ensuring the maintenance of a consistent PA level throughout the year by encouraging the accomplishment of daily goals based on the number of steps taken per day, which should be adjusted according to the gender/age characteristics of the targeted population. Intervention strategies should also emphasise the importance of compliance with PA recommendations to the general population, but especially to the elderly. Moreover, surveillance data based on accurate criteria should be considered to measure the achievement of the intervention objectives.

The results of this study contribute to the knowledge of the PA of the Portuguese population and will facilitate the improvement of PA promotion strategies and intervention programmes. This study also provides recommendations that could help to potentiate interventions that are aimed at increasing daily PA levels and inverting sedentary behaviours throughout the year and across age groups.

Key words: accelerometry, elderly, physical activity, recommendations, steps, surveillance, weather

Actividade física em adultos e idosos avaliados por acelerometria – influência do grupo etário, género, período do ano e do clima

Abstract

O principal objectivo desta tese foi estudar a actividade física (AF) de adultos e idosos portugueses quando avaliada por aceleromeria.

Mais especificamente pretendemos a) estudar questões metodológicas relacionadas com a avaliação da AF através de acelerometria; b) fornecer dados descritivos da AF avaliada objectivamente, incluindo as análise das diferenças entre géneros e níveis etários, e do cumprimento das recomendações da AF; c) examinar as alterações na AF, quando avaliada em várias alturas do ano; e d) explorar os efeitos do clima no envolvimento na AF.

Os resultados obtidos indicam que as campanhas de promoção da AF devem focar-se no aumento dos níveis de participação na AF, assim como garantir a sua manutenção ao longo do ano. As estratégias de intervenção devem passar pelo cumprimento de objectivos diários baseados no número de passos, e ser enfatizado o cumprimento de períodos de pelo menos 10 minutos de intensidade moderada a vigorosa no cumprimento dos 30 minutos diários acumulados de AF na população em geral, mas em especial nos idosos. Finalmente, deve promover-se a padronização de procedimentos e a recolha de dados sistemáticos que permitam reportar as alterações verificadas nas características da população no cumprimento destes objectivos.

Os resultados deste estudo contribuem para o conhecimento dos níveis de AF da população portuguesa, do seu desempenho no cumprimento das recomendações de AF, das alterações que verificam ao longo do ano, e dos factores que podem afectar o seu envolvimento na AF. Estes dados são também contributos para a melhor adequação das estratégias de promoção e dos programas de intervenção de AF já que constituem pistas acerca de como potenciar intervenções que tenham como objectivo aumentar os níveis diários de AF e inverter os hábitos sedentários, quer ao longo do ano, quer da idade.

Key words: acelerometria, idosos, actividade física, recomendações, passos, vigilância, clima

Chapter 1 – Introduction

Physical activity in adults and elderly adults measured by accelerometry: the influences of age group, gender, time of year, and weather.

1.1. Introduction

It has been well-established by scientific evidence that there are several health benefits associated with regular physical activity (PA). Low to moderate PA significantly reduces the risk of all-cause mortality and cardiovascular diseases (50, 51, 60) and prevents several other diseases, such as obesity, type 2 diabetes, elevated blood lipids, and hypertension (18, 50). Moreover, especially in adults and the elderly, PA is of critical importance for the maintenance of independence, good quality of life, and minimising the burdens of health and social care costs (17).

These well-documented outcomes of PA related to health have also challenged epidemiologists, exercise scientists, clinicians and behavioural researchers to find accurate and reliable methods for the assessment of PA (5, 12, 54, 56). Moreover, the knowledge of the health benefits associated with regular PA and of more precise methods for the assessment of PA has led to the definition of public health guidelines concerning adequate PA levels and the appropriate pattern of PA necessary to maintain health (52).

Despite the evidence supporting the benefits of PA on health and the efforts made to distribute information on PA guidelines, studies and reports of PA prevalence in the U.S. (28, 50), Europe (13, 41), and worldwide (3) have demonstrated that, in general, adults and the elderly do not engage in a sufficient level of PA to confer a positive impact on their health. The majority of people do not perform the minimum recommended amount of PA, and furthermore, a number of studies have shown that PA declines with age (9, 10, 23, 40, 42). Age-related changes in PA take place past adulthood, and a decline in PA occurs after maturity in both males and females in a wide variety of species (21). Furthermore, several epidemiological studies have shown that this general decline in PA with advancing age also occurs in adult humans (9, 10, 23, 40, 42). Researchers state that the age-related decline in PA reflects a complex interaction of biological, psychological, and social factors and that it is unclear whether this trend is due to environmental aspects, biological aspects (42), or both. In addition to age-related changes in PA, gender differences have also been addressed by

research studies. Results from studies based on self-report are somewhat in accordance, concluding that women tend to report less PA than men (9, 37). However, findings diverge among researchers using objective measures, such as motions sensors (4, 7, 25, 49, 58).

Various methods have been used to measure the short-term and long-term PA levels of free-living individuals, and these methods vary greatly in their applicability (12). No single instrument seems to fulfil all of the desired criteria, including validity, reliability, and practicality, without affecting behaviour (22). The methods that are used to measure PA fall into four general categories: subjective reports and observations, indirect calorimetry, double-labelled water (DLW), and portable monitors, such as heart rate monitors, pedometers, and accelerometers (12, 56). The selection of a PA assessment method should take into consideration the experimental goals, sample size, budget, cultural and social/environmental factors, physical burden for the subject, and statistical factors, such as accuracy and precision.

Most epidemiologic data and research on daily PA patterns have relied on self-report (13). However, questionnaires, even when purposely designed and validated, are used to assess PA in sample populations with specific characteristics. Numerous sources of error can be associated with this assessment in the type, intensity, frequency, and duration of PA as well as the environment in which it is performed (13, 14, 52). Thus, researchers must be aware of these sources of error and their impact on the experimental outcomes. The use of DLW to measure PA is regarded as the "gold standard" for the measurement of total energy expenditure (TEE) in free-living conditions (55, 61), is used as the reference measurement for the validation of field methods, and has been extensively used in validation studies (19, 20, 55). However, labelled water is expensive, is not always available (19) and does not provide information about the frequency, intensity, duration or type of physical activities (36). For these reasons, accelerometers have been widely used in research studies because they are considered the most objective and precise technique for the assessment of activity patterns in terms of intensity, frequency, duration, and total PA amount (6, 54, 61).

Despite the growing use of accelerometers to assess PA and the increasing number of studies using this method, there is still a preponderance of studies on U.S. populations involving cross-sectional data. In addition, the majority of published studies involve children or youth populations. Very little information has been published on large samples of young or old adults from countries other than the U.S. (13, 27). Therefore, more information on the populations of

countries that have different characteristics from those of the U.S., especially on adult populations, is crucially important for the identification of how levels of activity are achieved and for the promotion of more adequate intervention strategies according to specific population characteristics and behaviours (13, 15).

As a final point, there have been few systematic review methods developed to analyse data from studies using accelerometers in adult and elderly populations (35, 38). In fact, only one study that involved an elderly adult population has focused on the descriptive and analytic methods used by researchers (35). The literature shows that lower levels of PA and, consequently, health behaviours, are associated with various factors, including social status, marital status, obesity, smoking, lack of time, past exercise behaviour, and environment variables (57).

Regarding the environmental factors that influence health behaviours, some authors have focused their research on the associations between PA and the built environment, whereas others have focused on the natural environment (8). Factors of the natural environment that might influence PA, such as the weather (26), are not possible to control and may have an important role in influencing people to engage in PA on a day-to-day basis, especially because these factors may change daily. For that reason, studies that focus on the effects of the natural environment on PA have a higher relevance to the definition of strategies for the promotion of PA. However, to date, the majority of studies have focused on the variables associated with the built environment and have evaluated PA using subjective measurements in adults (44, 46) and adolescents (29, 30).

Studies that have focused on the effects of weather on PA have used seasons to group various weather indicators or have used objectively measured climate indicators (11). Although a general effect of the weather has been revealed by researchers who used seasonal changes to address the relationship between the weather and PA levels, it has not yet been identified which specific factor is most responsible for the fluctuations in PA levels. In addition, studies that assess weather indicators using objective measures should correspondingly assess PA by objective measures to accurately establish the relationship between these variables; however, very few studies have used objective measurements for both variables simultaneously (11). Finally, only one study has assessed which weather variables may be related to the levels of

engagement in PA and active behaviours, but this study did not involve an adult or elderly population, and it did not use objective methods to measure PA levels (43).

In Portugal, several studies have been developed with the purpose of studying PA patterns and active behaviour using an accelerometer as an objective measure of activity. Numerous studies have been aimed at identifying the types of PA that are performed during leisure time, daily PA patterns, and potential gender differences in children within a school context (24, 32-34, 59). Researchers have also paid a great deal of attention to children with special health conditions, such as overweight/obese children (1), and to adolescents (39, 48). Moreover, some studies have focused on the relationship between PA and cardiovascular risk factors (16), cardiorespiratory fitness and body mass index (2, 31), with a follow-up experimental design in the latter case.

However, in studies involving adult or elderly populations, the examination of PA patterns, active and sedentary behaviours, and obesity has mostly relied on self-report studies (45, 47). To our knowledge, only one study has evaluated PA in large population samples of adults and elderly adults in Portugal using accelerometry (53).

1.2. Research questions

What types and levels of PA are performed by adults and elderly adults of the Portuguese population in terms of age group, gender, time of year, and weather conditions?

1.3. Aims

The main purpose of this thesis was to study the objectively measured PA of adult and elderly adult Portuguese populations. First, we addressed methodological concerns related to the assessment of PA in these age groups by means of accelerometry. Second, we aimed to provide descriptive data on PA that was measured objectively in order to analyse age and gender differences in PA levels as well as the compliance with PA recommendations. Next, we examined if there were changes in PA when they were assessed at different times of the year. Finally, we aimed to explore the effects of weather on PA.

1.4. Structure of the thesis

To fulfil these main objectives, we developed four studies. Accordingly, this thesis comprises the following six chapters.

Chapter 1

This chapter presents the background for this investigation, the main objectives and the structure of the thesis.

Chapter 2

This chapter includes *Study 1*:

Physical activity in adults and elderly adults measured by accelerometry: a systematic review of studies

Based on studies using accelerometers as an objective method to measure PA in adult and elderly populations, this study aimed to a) review the available information on these age groups in terms of time spent performing different intensities of PA, total daily activity, steps taken, and bouts of MVPA and to b) analyse differences between study protocols related to calibration, cut-points, data collection, data reporting, and study design.

Chapter 3

This chapter includes *Study 2*:

Physical activity of Portuguese adults and elderly adults measured by accelerometry: from results to intervention

The purpose of this study was to provide descriptive information on PA that was objectively measured in a considerably large sample of adults and elderly adults and to investigate the levels of adherence to the recommendations for PA in men and women.

Chapter 4

This chapter includes *Study 3*:

Portuguese individuals´ physical activity level as assessed by accelerometry throughout the year

This study aims to describe the daily physical activity (PA) of a considerably large sample of adults and elderly adults throughout the year. We also aim to examine if there are any changes in PA and in achieving PA recommendations when assessed at different periods of the year.

Chapter 5

This chapter includes *Study 4*:

Influences of weather variables on physical activity assessed by accelerometry across age and gender groups

This study aimed to investigate which weather variables influence PA levels and to what extent these factors could explain potential differences found in age groups, genders, compliance to the PA recommendations, at different times of the year.

Chapter 6

In this chapter, we focused on the main findings and conclusions of these studies and summarised the practical implications of this work along with recommendations for future research studies.

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Chapter 2 – Physical activity in adults and elderly adults measured by accelerometry – a systematic review of studies

Physical activity in adults and elderly adults measured by accelerometry: a systematic review of studies

Abstract

Purpose: The purpose of this study was to synthesize the findings from research based on objective measures. A systematic review of accelerometry data from adults and elderly adults was used to describe the methods, results, and data reporting techniques used by researchers.

Methods: Studies using accelerometers as an objective measure to assess PA in adults and the elderly were examined. From an initial 899 studies, only 18 were fully reviewed, and the outcome measures (means, standard deviations and sample sizes) were abstracted and analyzed.

Results: Eleven studies were developed in North America, five were in Europe, and only one reported data from an African country. Very few enrolled elderly adults, and only one reported the season or the time of year when the data collection took place. All data came from cross-sectional designs. Even after meticulously selecting studies that were similar in their methods and analysis, the results were still diverse. Units, data reporting techniques and sample stratification also varied widely across studies, which made comparison between studies or subgroups inappropriate. The most reported and similar variable outcome was the daily average counts per minute.

Conclusions: Standardizing the data collection methods and units for data reporting are needed to compare results across studies. More longitudinal studies and studies with larger samples, samples other than US population, and data regarding the season or time of year when the data were collected should be encouraged.

Keywords: review; adults; accelerometers; elderly; cut-off points.

2.1. Introduction

Physical activity (PA) is extremely important for the maintenance of good health throughout life (4, 20, 23). Age has also been shown to be inversely associated with PA in children and adolescents (3, 40, 43) when evaluated by both self-reported and objective measures of PA (6, 35, 38, 41). However, in adults and the elderly, studies showing this relationship have mainly used self-reported methods, with which several sources of error and limitations are associated (26, 42, 48). In fact, there are few available studies developed for adults, especially the elderly, that use objective measures such as motion sensors (10, 13, 33).

Motion sensors, particularly accelerometers, are reliable and affordable and have been widely used as an alternative to self-reported methods. They provide an estimation of total volume, different levels of intensity and duration of activities, and allow the collection of minute-by-minute data for several consecutive days (18, 36).

The majority of studies that aim to validate PA questionnaires (7, 49) have been cross-sectional and conducted in US populations. Few studies provide information about a large sample of healthy elderly adults (10, 25).

Furthermore, researchers using accelerometers in the elderly have addressed some concerns about their results in this population. Because there are no age-specific cut-offs for accelerometer counts that represent activities of different intensities in elderly adults, all research has been based on the assumption that any given value of counts per minute ($ct \cdot min^{-1}$) represents the same PA intensity whether it is recorded in younger or older adults (6, 18).

In fact, differences in gait (32), functional capacity (34), the metabolic cost of walking, and the type and level of activity in the elderly (10) should be taken into account when comparing to a younger population and must be considered when interpreting the results.

Therefore, there is a need to gather and analyze results from research using objective measures in adults and the elderly to better understand the available data regarding these age groups. To our knowledge, there are no available systematic reviews on accelerometry data in adults and elderly adults that describe the results and analysis methods used by the researchers.

Therefore, the purpose of this paper is to use studies where accelerometers are used to objectively assess PA in adults and the elderly to: a) synthesize the available information regarding these age groups in terms of the time spent at different intensities (sedentary activity or inactivity, light and moderate-to-vigorous physical activity [MVPA], and bouts of

MVPA); b) analyze the differences across study protocols concerning the calibration, cut-off points, data collection, data reporting techniques, and study design.

2.2. Methods

Data sources and search strategy

Potentially relevant studies were retrieved via electronic searches of PubMed Central, Web of Knowledge (ISI), EBSCO and Medline from March 29 to April 15, 2010.

The keywords “accelerometry”, “accelerometer”, “physical activity”, “PA”, “patterns”, “levels”, “adults”, “older adults” and “elderly” were searched in isolation or in combination using “AND” or “OR”. The reference lists of all the retrieved studies were examined to capture any other potentially relevant articles that had not been identified by the database searches.

Study selection

Studies were subjected to analysis if they met the following inclusion criteria: a) publication prior to April 15, 2010; b) inclusion of adults aged 18 years or older; c) inclusion of apparently healthy individuals; d) data collection using uniaxial accelerometers; e) English language; f) data reporting (mean and standard deviation of the accelerometer daily $ct.min^{-1}$, mean and standard deviation of the minutes spent at different levels of PA, mean and standard deviation of the total activity in counts per day, the bouts of sedentary activity or inactivity, and the bouts of moderate-to-vigorous activity); g) data collection for at least 4 days.

Studies were excluded if they: a) included exclusively children or adolescents (under 18 years of age); b) only included patients or individuals with pathologies or abnormalities (e.g., diabetes, cardiovascular disease, chronic obstructive pulmonary disease, osteoarthritis, Parkinson’s disease, and overweight); c) contain no relevant data; d) were not conducted in humans; e) used accelerometers to measure drug effects on an individual’s ability to perform a task.

Studies in foreign languages were not included because of concerns about translation and interpretation. Validity studies, randomized control trails (RCTs), clinical studies, systematic reviews, meta-analyses or other studies involving intervention programs were included if baseline data or relevant data were available.

Studies using biaxial or triaxial accelerometers were excluded because of concerns regarding the validation and comparability of study results.

Quality assessment

The Downs and Black checklist (12) was used to assess the risk of bias. Items that were not relevant to the aims of this study were removed from the Downs' and Black´s original checklist (27 items). The modified version of the checklist consisted of 12 items and included items 1-3, 5-7, 10-12, 18, 20 and 27 from the original list (maximum possible score: 12) and other 8 additional items. Items were included in the list to guarantee the quality of the description of the accelerometry data collection methods. These items were scored if the investigators reported the following (maximum possible score = 8):

1. A minimum of 4 days of data collection
2. Specific hours of data collection (waking hours, sleep, etc.)
3. A minimum number of monitoring hours per day to be considered a valid day of data collection
4. The epoch used in data collection
5. The use of an activity log along with the accelerometer
6. The calibration method of the devices
7. The software used to analyze raw data
8. How the authors accounted for rest, time when the accelerometer was not worn, and artifacts.

Two raters evaluated all of the included studies, and any discrepancies were resolved by consensus.

Extraction of data

Two assessors independently abstracted the data from each study. Study characteristics (e.g., year of publication, country of origin, and study design), subject characteristics (e.g., mean age, age range, and sex), accelerometer and assessment characteristics (make and model, days of data collection, cut-off points and analysis software) were described.

The outcomes of interest included the time spent at activities of different intensities, the bouts of inactivity, the bouts of MVPA, the total daily activity, and meeting the Center for Diseases Control and the American College of Sports Medicine (CDC/ACSM) recommendations for minimum daily PA (2).

Sample sizes, means and standard deviations for each outcome were extracted from each study.

For studies involving both patients and nonpatients, only nonpatient data were used (e.g., obese vs. non-obese). In cases where the authors published multiple articles based on the same data, redundant data were excluded.

Data synthesis

The variables that were studied were the times spent in sedentary activity or inactivity, light activity and MVPA, the bouts of MVPA, the daily mean counts and the total counts per day. These variables were chosen because they represent the choices of a majority of researchers in their analyses and data reporting. Other levels of intensity, such as moderate and vigorous PA, were reported by some but could not be analyzed because only one or two authors presented the data in the same way.

A majority of the selected outcomes from the studies were presented as means and standard deviations. However, a number of studies did not report the results this way. In these cases, the data were not incorporated into the analyses. The same procedure was adopted if the results were not presented at all or presented in a non-comparable manner (e.g., median).

For the variables representing the time spent in activities of different intensities, studies that collected data from 24-h days could not be pooled for analysis, because they derived from a sum of daily counts and, therefore, were non-comparable.

Whenever possible, age group- or gender-specific data were considered. However, very few authors separately reported data from men and women. In the studies where data from different ethnicities or races were reported with the overall results, the overall results were used.

Given the incoherence of the age group data that was reported in studies, ages were divided in 2 groups: mean ages below 60 years and mean ages above 60 years. These limits were defined based on the data stratification chosen by the majority of the authors. However, it was not possible to examine the effect of age for the majority of variables, again because of the inconsistency of the data reporting.

2.3. Results

Study identification

Our initial search identified 899 potentially relevant articles (Figure 2.1). A review of the titles and abstracts resulted in twenty nine citations that could potentially be analyzed. After completing full-text reviews of the 29 articles, eleven did not meet our inclusion criteria. Reasons for study exclusion were no relevant or comparable data (7 studies), no use of a uniaxial accelerometer (3 studies), and redundant data (1 study). Screening the reference lists did not produce additional articles. Thus, eighteen studies were selected (1, 5, 6, 8-11, 15-19, 22, 24, 25, 30, 44, 47).

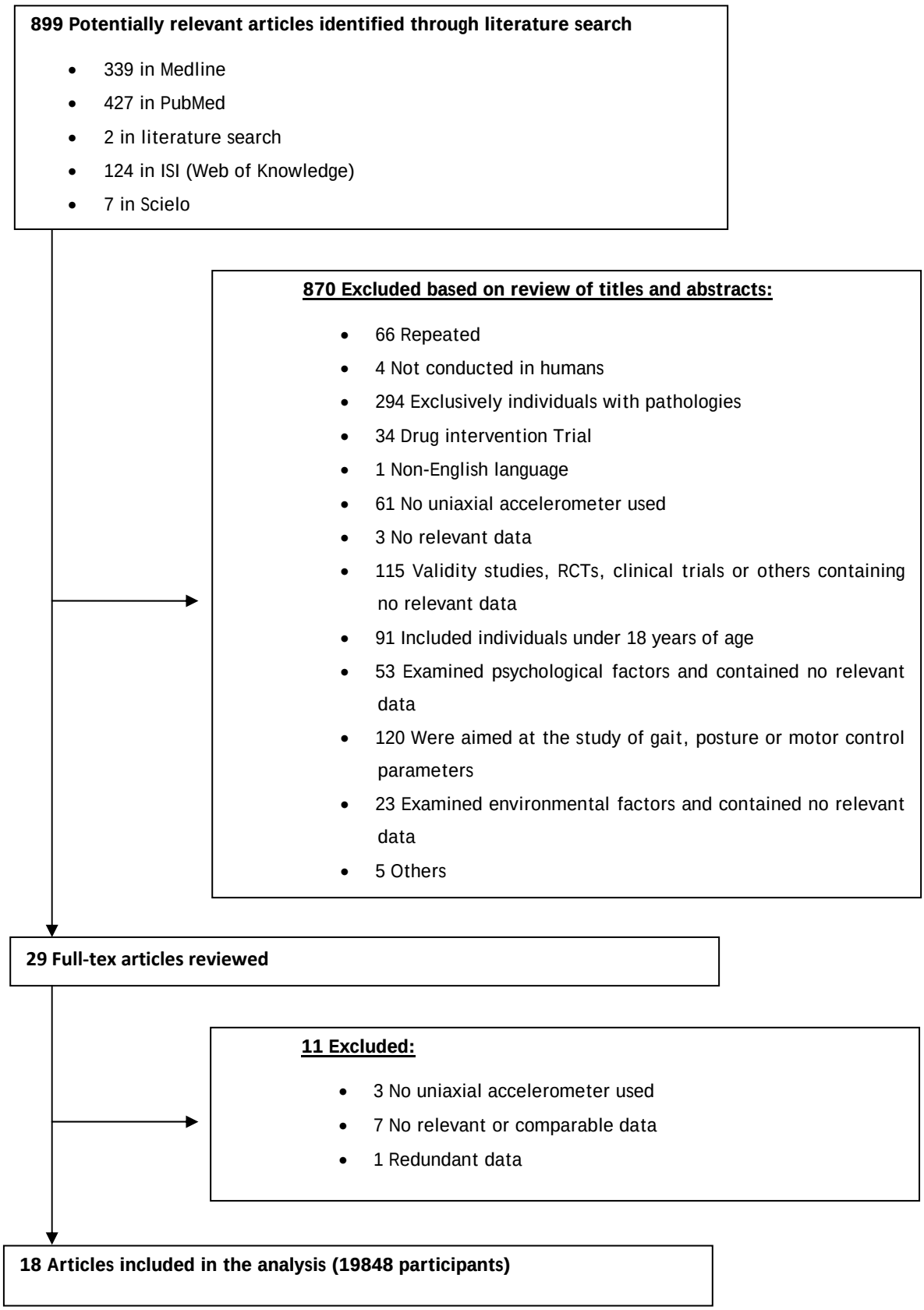

Figure 2.1 - Study Flow Diagram

- Characteristics of selected studies

The study characteristics are described in Table 2.1. Eleven of the eighteen studies were performed in the United States, five in European countries, one in Australia and one in Cameroon. All were published between 2000 and 2009, and most were cross-sectional.

Table 2.1 – Study characteristics

Author, year	Country	N	Mean age or range (years)	Days of data collection	Minimum days of valid monitoring	Hours of data collection	Minimum hours of valid monitoring	Epochs	Activity log	Calibration Method	Software used to analyse data	How to account for rest, not wearing time, and other artifacts?
Davis (2006a)	UK, Italy and France	163 (men and women)	76.1 ± 3.9	7-d	At least 5 days	Waking hours	At least 10 hours per day	1-min	activity log	No reference	Caloric.Bas software (CSA, Inc. 1999), Microsoft Acess 2000 macro	Unusually high and low counts and continuous data base with the same value were excluded
Dinger (2006)	USA	454 (men and women)	19.9 ± 1.6	7-d	At least 5 days	Waking hours	At least 12 hours per day	1-min	No reference	Manufacturer´s calibration of the device	No reference	No reference
Hagströmmer (2007)	Sweden	1114 (men and women)	45 ± 15	7-d	At least 4 days, of which one has to be a weekend day	Waking hours	At least 10 hours per day	1-min	No reference	No reference	Microsoft acess	20 or more minutes of consecutive zeros were eliminated. Accelerometer malfunction was identified as having counts greater than 20000 cpm
Troiano (2007)	USA	4867 (men and women)	6 to >70	7-d	At least 4 days	waking hours	At least 10 hours per day	1-min	7-d activity log	Manufacturer´s calibration of the device	SAS and SUDAAN	No reference

Gerdhem (2008)	Sweden	57 (women only)	80.1 ± 0.1	5-7 d	At least 5 days	Waking hours	At least 08 hours per day	1-min	7-d activity log	Calibration against standardized vertical movement	MATHLAB (MathWorks Inc., Natick, USA)	Sequences of >10 min means "not beeing worn"
Cooper (2000)	UK	108 (men and women)	38.6 ± 9.3	7-d	At least 4 full weekdays and one full weekend day of valid recording	Waking hours	At least 09 hours per day	1-min	No reference	No reference	No reference	No reference
Harris (2009)	UK	N= 1529, n=238 (men and women)	74	7-d	At least 5 days	Waking hours	No reference	5-sec	7-d activity log	No reference	Actigraph Actilife Monitoring System and MAHUFFE.exe available from www.mrc-epid.cam.ac.uk/)	No reference
Strath (2008)	USA	3250 adults (men and women)	47.2 ± 17.0	7-d	At least 4 days	Waking hours	At least 10 hours per day	1-min	No reference	Standardized quality procedures	Blocks of >60 minutes zero counts was considered time not worn	No reference
Mathews (2002)	USA	92 (men and women)	18 - 79	7-d	At least 7 days	Waking hours	At least 12 hours per day	1-m	No reference	Manufacturer´s calibration of the device	No reference	No reference

Johannsen (2008)	USA	206 (men and women)	20 to 101	14-d	At least 7 days	Accelerometer removed only in bathing (24 hours collecting data per day)	At least 22 hours per day	1-m	No reference	No reference	No reference	No reference
Jillcot (2007)	USA	199 (women only)	53.3 ± 6.9	7-d	At least 4 days	Waking hours	At least 06 hours per day. Average wearing time of participants was 11.2 hours	1-min	No reference	No reference	ActiProcess data reduction program used to determine valid wearing time and to generate variables for use in subsequent analyses	20 or more minutes of consecutive zeros were eliminated
Janney (2008)	USA	3809 (men and women)	43 - 47	7-d	At least 4 days	Waking hours	At least 10 hours per day	1-min	No reference	No reference	No reference	60 or more minutes of consecutive zeros were eliminated (considered not worn)
Hawkins (2009)	USA	2688 (men and women)	18 - > 60	7-d	At least 4 days	Waking hours	At least 10 hours per day	1-min	No reference	Manufacturer´s calibration of the device	No reference	60 or more minutes of consecutive zeros were eliminated (considered not worn)
French (2007)	USA	158 (men and women)	47.6 ± 10.2	4-d		Waking hours	No reference	No reference	No reference	No reference	SAS version 8.0	Days in which there were more than 16 hours of consecutive zero readings, were dropped from the analysis.

Davis (2006b)	USA	31 (men and women)	43.6 yr ± 12	7-d	At least 4 days	24h a day	At least 10 hours per day	1-min	writen log	No reference	Microsoft Actisoft to analyse data	60 or more minutes of consecutive zeros were eliminated (considered not worn)
Cust (2008)	Australia	182	57.2	7-d	At least 4 days	Waking hours	At least 10 hours per day	1-min	No reference	No reference	No reference	Activity counts above 18000 were excluded. Consecutive strings of zero-count epoch lasting more than 20 minutes were assumed to be non-wear time
Coleman (2008)	USA	2199 (men and women)	45 ± 11	7-d		Waking hours	At least 10 hours per day	No reference	No reference	No reference	No reference	No reference
Assah (2009)	Cameroon	33 (men and women)	34.2 ± 7.3	7-d	No reference	24h a day	No reference	1-min	No reference	No reference	Excell and MAHUFFE	No reference

- Characteristics of study populations

The articles evaluated 19,848 subjects. The sample sizes of the studies ranged from 33 to 4867 participants.

The ages in the studies ranged from above 18 years to above 70 years. Although the review focused on those aged 18 years or older, one of the studies had participants with ages starting at 6 years. In this case, the data were stratified by age, and the data used in the analysis were only those for the group with ages above 18 years. Twelve studies evaluated midlife groups, and six enrolled elderly adults.

A majority of the studies enrolled both men and women, but two enrolled women exclusively.

Assessment of methodological quality

A majority of studies met 8 or more criteria from Downs' and Black's original list for the assessment of the risk of bias, which suggested good methodological quality. The item that was scored low by a great proportion of studies was the one concerning the "subjects being representative of the entire population from which they were recruited" (12 studies).

Of the eight quality criteria concerning the description of the data collection methods, a mean of 5.38 items were met by all of the studies. One study achieved the maximum score for these items, while another study met only three items. Five of the selected studies (27.7%) did not meet at least half of the quality criteria.

All of the selected studies used the same accelerometer (ActiGraph 7164 or GT1M) and collected the data for at least four days. The majority used data from seven consecutive days. Exceptions were made for one study that collected for fourteen days and another that collected from five to seven-days.

One study reported using only the average from three days of monitoring when one of the days had more than 16 hours of consecutive zero readings, but that study corresponded to only 1.4% of the total sample.

All of the studies asked the participants to remove the equipment during bathing, swimming or skiing, while it continued to collect data. Fourteen studies collected data during waking hours, three collected data throughout the day, and one did not discuss the data collection time. The minimum number of monitoring hours per day that was considered to be a valid day of data collection by the investigators ranged from eight to twelve hours (in the studies collecting data only during waking hours) and twenty two hours (in one study that collected data for 24 hours per day). There was one study that considered six hours per day to be a valid minimum.

However, the average time that the participants wore the device was 11.2 hours per day. Three studies did not discuss the minimum hours of data collection.

Very few studies reported other concerns regarding the methods. These concerns included the calibration of the device (6 studies), using an activity log with the accelerometer (5 studies), which software was analyzed the raw data (10 studies) and how to account for rest, the time when the accelerometer was not worn, and other artifacts (9 studies).

To define the thresholds to differentiate the PA levels in ct·min^{-1}, the cut-offs chosen by the investigators varied. The majority (10 studies) used Freedson cut-off points or adapted these cut-off points to account for inactivity or sedentary activity, according to previous published studies (10, 29) and shown in Table 2.2.

The thresholds for inactive or sedentary activity were variable: <100 ct·min^{-1}: (1, 8, 17); <200 ct·min^{-1}: (10, 18); <251 ct·min^{-1} (15); < 260 ct·min^{-1} (19, 22); <499 ct·min^{-1} (11); <500 ct·min^{-1} (16).

Table 2.2 – Chosen cut-off points by researchers. Intensities in counts per minute (ct·min^{-1}).

Author, year	Sed/Inactiv		MPA	MVPA	VPA
Davis (2006a)	<200	200-1999		> 1999	
Dinger (2006)	<499	500 - 1951	1952 - 5724		≥ 5725
Hagströmmer (2007)	<100			1952 to 5724	≥ 5725
Troiano (2007)			2020		5999
Gerdhem (2008)	<500	500-1952		>1952	
Cooper (2000)		500-1952	1952 - 5724		≥ 5725
Harris (2009)	<200	200-1999	2000-3999		≥ 4000
Strath (2008)				>760	
Mathews (2002)		<500	Moderate 1= 500 to 1951 - non ambulatory activities	Moderate 2= 1952 to 5724 - ambulatory activities	> 5724
Johannsen (2008)		<574		Moderate activity: 575 - 4945	High activity: 4946 to 9317
Jillcot (2007)			574 - 4944		≥ 4945

Janney (2008)	<260	260-1951		≥ 1952	
Hawkins (2009)	<260	260-1951		≥ 1952	
French (2007)	1-251	251-2100		>2100	
Davis (2006b)		500-1952	1952 - 5724		≥ 5725
Cust (2008)	<100	<574	574-4944		>4945
Coleman (2008)				1952	
Assah (2009)	<100	101-1951		1952-5724	>5724

Legend:

Sed/Inactiv – sedentary/inactive intensity; **LPA** – leisure physical activity; **MPA** – moderate physical activity; **MVPA** – moderate-to-vigorous physical activity; **VPA** – vigorous physical activity.

Twelve studies also considered light level of PA, moderate and vigorous PA. Because at least moderate PA is associated with health benefits, all of the studies defined thresholds for moderate PA, either in isolation or in combination with a level of vigorous PA. As seen in light activity data, the limits for this level of PA varied across studies. The most conservative estimate of MVPA was set at 2020 ct·min^{-1} (47). The other studies defined lower limits for this category, but they were not far from this value (1952, 1999 and 2100 ct·min^{-1}). Exceptions were made for the two studies that adopted Swartz cut-off points (45), where the lower limits for moderate PA start at 574 ct·min^{-1}.

Data synthesis

For the selected outcomes data, the results were grouped according to any similarities in their data collection methods, units, and data reporting techniques. Whenever possible, data were also partitioned according to the strata of sex (male, female) and mean age (<60 years and >60 years). The results are summarized in Table 2.3.

Table 2.3 – Summary of results from studies (ct·min^{-1}).

Inactivity				
Author, year	**Subgroup**	**Mean**	**SD**	**N**
Dinger (2006)	fem <60	793.4	72.7	245
	mas < 60	778.6	84.8	209
Hagströmmer (2007)	fem	468	90	614
	mas	451	82	500
	both	459	86	1114
	both <60 a	465	87	92

	both <60 b	459	90	441
	both <60 c	460	84	459
	both >60	451	79	122
Mathews (2002)	fem <60	747,9	66	50
	mas < 60	739,8	66	42
Light activity				
Author, year	**Subgroup**	**Mean**	**SD**	**N**
Dinger (2006)	fem <60	112.2	32.9	245
	mas < 60	118.8	37	209
French (2007)	both <60 a	255.5	13.1	28
	both <60 b	248.8	11.3	36
	both <60 c	220	6.7	94
MVPA				
Author, year	**Subgroup**	**Mean**	**SD**	**N**
Davis (2006a)	fem <60	38.4	18.4	23
	fem >60	16.7	12.1	93
	mas <60	40.4	19.2	22
	mas >60	23.8	20	70
Strath (2008)	fem	78	40.4	1594
	mas	102,7	53.1	1678
Mathews (2002)	fem <60	27.6	23.7	50
	mas < 60	32.6	25.2	42
Coleman (2008)	both <60 a	33	24	1578
	both <60 b	27	21	183
	both <60 c	35	24	429
Bouts od MVPA				
Author, year	**Subgroup**	**Mean**	**SD**	**N**
Davis (2006a)	fem <60	0.5	0.7	23
	fem >60	0.3	0.4	93
	mas <60	0.8	0.5	22
	mas >60	0.5	0.7	70
Troiano (2007)	mas <60 a	10.3	1	212
	mas <60 b	9.9	1.4	217
	mas <60 c	9.3	9.3	259
	mas <60 d	7.1	1.2	204
	mas >60 a	6.5	1.1	269
	mas >60 b	3.5	0.4	355
	fem <60 a	7.4	0.8	219
	fem <60 b	6.5	1.1	240
	fem <60 c	6.6	0.8	258
	fem <60 d	5.7	0.9	219
	fem >60 a	5.8	0.9	287
	fem >60 b	2.2	0.4	349
Daily mean activity				
Author, year	**Subgroup**	**Mean**	**SD**	**N**
Davis (2006a)	fem <60	370	81.1	23
	mas <60	236.1	84.4	93
	fem >60	404.3	134	22
	mas >60	255.1	103.4	70
Dinger (2006)	fem <60	360.3	106.1	245
	mas <60	402.6	113.4	209

Hagströmmer (2007)	fem	385	152	614
	mas	370	131	500
Troiano (2007)	mas <60 a	423.6	12.6	212
	mas <60 b	444.2	13.4	217
	mas <60 c	386.5	11.3	259
	mas <60 d	338.2	11.3	204
	mas >60 a	256.7	8.8	269
	mas >60 b	188.9	5.4	355
	fem <60 a	327.2	6.9	219
	fem <60 b	333.6	8.6	240
	fem <60 c	311.4	8.1	258
	fem <60 d	271.6	7.8	219
	fem >60 a	251.2	6.8	287
	fem >60 b	169.8	3	349
Mathews (2002)	fem <60	300	131.7	50
	mas <60	330	141.7	42
Daily mean activity				
Author, year	**Subgroup**	**Mean**	**SD**	**N**
Dinger (2006)	fem <60	344804.1	110619.5	245
	mas <60	383787.2	112001.3	209
Harris (2009)	fem >60	220031	116764	110
	mas >60	232518	126583	124
Mathews (2002)	fem <60	270188.9	119648.1	50
	mas <60	303359.1	138275	42

We were only able to collect the time spent in inactivity or in sedentary activity from three studies using similar methods as those used for the data collection and the techniques for reporting the results (11, 17, 30). All of the other studies reported no data in this category or reported the data in other ways (1, 16, 22, 25). Only one study provided data for older adults (17).

The minutes per day spent in light activity were reported by four studies (1, 9, 11, 15), but two collected data from a 24 hours period, and no data on adults older than 60 years were presented in the selected studies. Although inconsistency was found across researchers in defining of cut-off points for MVPA, it was possible to assemble the data from four studies (5, 10, 30, 44). Other studies selected a very different cut-off point of 574 ct·min^{-1} (24) or reported data in a non-comparable way (1, 9). A tremendous variation in sample size was observed across studies (from 23 to 1578 participants). Three studies separated the results for men and women, regardless of age (10, 30, 44).

Only three studies reported data regarding the bouts of MVPA (10, 44, 47) using a single method, which consisted of reporting the sum of all minutes spent above the MVPA threshold,

regardless of whether they were performed as single bouts or as sustained bouts of multiple minutes. However, one (44) reported the duration of the bout and not the number of bouts.
The data from five studies reporting the daily mean ct·min^{-1} were retrieved (9, 11, 17, 30, 47). This was the most widely reported variable by the researchers. However, all of the data corresponded to adults but not elderly adults. Finally, three studies separately reported the total counts per day for men and women (11, 18, 30), but only one included older adults (18).

2.4. Discussion

To our knowledge, this article describes the most comprehensive attempt to synthesize published methods from studies that used accelerometry to evaluate and describe PA in adult and elderly adult populations. By establishing very detailed and complete inclusion criteria, this review tried to guarantee that the results came from a group of studies that were very homogeneous in their methods and reporting. New insights have been added to previous reviews that used accelerometry data in adults but could not discern the calibration cut-off points or data collection methods of different study protocols (37). The quality assessment of the studies revealed that just less than one third of the studies had low quality because of a lack of an exhaustive description of the data collection and analysis methods.
However, even after meticulously selecting studies that were similar in their methods and analyses, the results were still diverse. One could speculate that the divergence of participants' mean ages, the chosen cut-off points or even the studies' countries of origin could explain the results or the reporting of the results. For example, in the inactivity or sedentary activity results, the values from two studies (11, 30), appeared to be quite similar and diverged from the other study (17). This may be due to the same cut-off point being chosen by the authors of the two agreeing studies (500 ct·min^{-1}), while a lower cut-off point was chosen by the author of the other study (100 ct·min^{-1}). Otherwise, differences in the sample characteristics may also be taken into account because the two first studies represent American samples, while the latter study used a Swedish sample.
Concerning the sample characteristics of the studies, only six enrolled older adults, and a majority of the research was developed in the North America (eleven studies).
Three were part of the widely known NHANHES 2003-2004 study, where accelerometers were included in a large-scale study for the first time (19, 44, 47). Only five studies reported data from European countries (2971 individuals of the total sample of 19,848). One study reported

data from an African country, and another study reported data from an Asian country. These numbers reveal that, aside from a lack of information available on the elderly, a lack of information also exists on countries with characteristics that are distinct from those of the USA. All of the selected studies were cross-sectional in design. Furthermore, only one study (8) reported the time of year when the data collection took place and had data analysis that accounted for the season. The season has already been identified as potential influence on active behavior (27, 28, 31) and on elderly PA (39, 46), implying the need to repeat the data collection or collect data for longer periods.

Methodological limitations should be considered in this investigation and in the interpretation of its findings. Namely, limitations related to the accelerometer technology should be considered. Accelerometers are unable to accurately capture movements that require minimal vertical displacement of the body, such as weight-lifting or cycling (29). The inclusion criteria of the English-language studies, the selected search databases, and the exclusion of grey literature may also have influences on the number of studies that were selected for analysis.

Unfortunately, incoherent methods and reporting across the studies became major difficulties in analyzing the results from these studies. Although we found consistency in some data collection methods in a number of studies, the chosen cut-off points and units of reporting were inconsistent. In fact, Freedson cut-off points that are derived from a young adult population during treadmill exercise were used the most broadly in the selected studies to define the PA intensity levels (14). In some cases, these did not match the characteristics of the participants enrolled in the studies, and the researchers considered other cut-off values validated for the samples that they found to be more analogous to theirs and used activities similar to those that were likely to be performed by their participants. That was the case for the Swartz cut-off points, which are derived from a broad range of mainly light- to moderate-intensity lifestyle-related activities. Furthermore, because the Freedson cut-off points do not establish a limit for sedentary activity or inactivity, a majority of studies defined the levels for this category using guidance from other previous studies (10, 30).

Moreover, research using more homogenous samples of elderly adults (10, 16, 47) raised the concerns that there were no age-specific cut-off points for accelerometer counts representing intensities for elderly adults. In fact, well-established differences in gait patterns (32) increase the metabolic cost of walking, and one cannot expect that any given count represents the same intensity for both adults and elderly adults. The strategies adopted by the researchers to bypass this limitation were to consider the more conservative estimates of MVPA (10) and to

highlight this limitation and advise care in the interpretation of their findings (16). The study by Troiano *et al.* (47), which enrolled participants ranging from 6 years to more than 70 years old, applied different cut-off points depending on the validated limits for each age group (children and adults). However, the cut-off point for MVPA (2020 ct·min^{-1}) did not differentiate the levels for younger and older adults but was proximal to the one set by Davis (2000 ct·min^{-1}) that we considered to be one of the most conservative.

The definition of a cut-off point is extremely important, because it can affect the number of minutes spent in a specific intensity category. As we discussed above, the choice of the cut-off points affected the divergent results across the studies. This means that an activity of a particular intensity will be assigned to a certain category in some studies but to a different category (higher or lower) in other studies, which affects the results.

The units, data reporting techniques, and sample stratification also varied widely across the studies, which made any comparison between studies or subgroups to further the analysis inappropriate and prevented us from drawing any additional conclusions. The most reported and consensual variable outcome was the daily average ct·min^{-1}, and all other variables could only be assembled for very limited subgroups of no more than 3 studies. A majority of studies did not include elderly adults, and most did not separately report the results of men and women, even when both were included in the samples.

A meta-analysis would allow us to summarize the results from studies with different sample sizes and reliabilities and provide a quantitative review of the literature (21). However, given the nature of our data and the goals of this study, we found that summarizing the effects across all of the subgroups was inadequate. The aforementioned inconsistent data collection and reporting methods and the data stratification presented by the authors made such an analysis methodologically inappropriate.

2.5. Conclusions

In conclusion, the data presented in this paper synthesizes the results of published methods and findings from studies that used accelerometry to evaluate and describe PA in adult and elderly adult populations.

The limited number of studies included in this paper reflects the scarce research done in adults (especially elderly adults) and dictates possible directions for future studies.

An exhaustive criterion was applied during the study selection and quality assessment, but the limitations of the results are consequences of the incoherent methods of data collection and

reporting across researchers. However, we believe that this paper reflects a clear trend in the methodological options and in the units of reporting and should be considered in future studies.

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Chapter 3 – Physical activity of Portuguese adults and elderly adults measured by accelerometry – from results to intervention

Physical activity of Portuguese adults and elderly adults measured by accelerometry: from results to intervention

Abstract

Purpose: This study aims to provide data on objectively measured physical activity (PA) from a large sample of Portuguese adults and elderly adults, to establish comparisons between age and gender groups, and to investigate the accomplishment of recommendations of PA to provide guiding principles for future PA interventions.

Methods: The participants included 257 women (20 to 96 years old, BMI 26.75 ± 4.57 $kg \cdot m^{-2}$) and 178 men (20 to 88 years old, BMI 26.81 ± 3.51 $kg \cdot m^{-2}$) who wore an accelerometer (ActiGraph GT1M, ActiGraph, Pensacola, Fla.) and were monitored for four to seven days. Outcomes measured included the following: time spent in sedentary, light, and moderate-to-vigorous physical activity (MVPA) ($min \cdot day^{-1}$); average daily counts per minute ($ct \cdot min \cdot day^{-1}$); and average daily steps ($steps \cdot day^{-1}$). The results were analysed globally and considered to examine the accomplishment of the PA recommendations.

Results: A high percentage of time is spent in sedentary activity, which is consistent across age groups. Differences between genders in PA were found only in the >60 years old groups, due to significant differences found in the time spent in MVPA. Women revealed no differences in PA until >60 years of age, and no significant differences were found between age groups of men across ages. Strong correlations between daily average $ct \cdot min^{-1}$ and MVPA, between daily average $ct \cdot min^{-1}$ and steps, and between MVPA and steps, were found in all gender/age groups. All gender/age groups revealed a low compliance to PA recommendations.

Conclusions: PA interventions should aim to reverse the amount of sedentary behaviours, focus on increasing the number of steps taken per day and of MVPA, in all gender/age groups but especially in the elderly, and emphasise sustained periods of at least 10 min above MVPA to achieve PA recommendations.

Key words: accelerometry, physical activity, public health, recommendations, aging

3.1 Introduction

Observational and clinical studies suggest that physical activity (PA) plays an important role in reducing the risk of mortality, mainly caused by cardiovascular diseases (33, 34, 43), and in the prevention of other diseases such as obesity, type 2 diabetes, elevated blood lipids, and hypertension (18, 33).

Despite the vast evidence showing the health benefits of PA, studies from the USA (26, 33), Europe (9, 30), and worldwide (1) demonstrate that, in general, adults and elderly adults do not engage in enough PA to have a positive impact on their health, as suggested by the PA recommendations for health (6, 16).

These data become meaningful as a decline in PA is associated with an increase in age. The authors suggest that this process reflects a complex interaction of biological, psychological, and social factors and declare that it is unclear whether the mechanism for the decline in PA is due to environmental or biological aspects (31).

This phenomenon appeared to be common in a great variety of species (20), thus supporting the link between the decline in biological function with age. Moreover, several epidemiological studies showed that the general decline in PA with advanced age (past adulthood) also occurred in humans (7, 8, 21, 29, 31) who, apart from similar biological limitations, have other social constraints preventing participation in PA programmes.

Research on gender differences revealed that women self-report less PA than men (7, 28). However, in studies that used more objective measures, such as motion sensors, the findings diverge. Some authors that used pedometers in their studies have stated that men are more active than women (2, 32, 42), while other studies that use accelerometers have reported no differences between men and women (5, 22).

There is an increase in published reports that use objective measures to assess PA, however, these studies are predominantly performed on cross-sectional U.S.A populations or on children or youth groups. There is little published information on large samples of adults and older adults from other countries (9, 24). Therefore, valuable information on countries with different characteristics from those of the U.S.A, especially of these specific age groups, is of major

importance to identify how levels of activity are achieved and how to promote more adequate intervention strategies according to population characteristics and behaviours.

This study aims to provide data on objectively measured PA from a considerably large sample of Portuguese adults and elderly adults, to establish comparisons between age and gender groups, and to investigate the achievement of recommendations of PA to provide guiding principles for future PA interventions.

3.2. Methods

3.2.1 Participants

Eligible participants were physically healthy adults above 20 years of age, willing to wear a accelerometer everyday, men and women, and residents within the geographic area defined for the study (i.e., Municipality of Vila Real, located in north Portugal). Participants were recruited by word of mouth. To better characterise the population from the defined region, individuals were recruited regardless of whether they were involved in PA or an exercise programme and independently of their marital or socio-economic status.

Of the 627 subjects initially recruited and evaluated, 190 did not wear the accelerometer for at least 4 days, had battery failure, or had equipment malfunction. The participants included 257 women (20 to 96 years old, BMI 26.75 ± 4.57 $kg \cdot m^{-2}$) and 178 men (20 to 88 years old, BMI 26.81 ± 3.51 $kg \cdot m^{-2}$).

To allow for the comparison of data, participants were classified into three categories based on their ages (20-39 years, 40-59 years and ≥60 years) according to stratification data from other studies (17, 36, 37).

3.2.2 Procedures

The study design and experimental procedures were explained to potential participants. After recruitment, participants willing to participate signed an informed consent and completed a socio-demographic questionnaire in addition to being assessed for height and weight.

Subjects were fitted for a belt with an attached accelerometer held closely around their waist (10, 39) and were instructed to wear the accelerometer directly over their iliac crest during all waking hours for four to seven consecutive days, except when showering, bathing, or swimming. Participants were asked to annotate the time on a brief log. Any other activity that was performed while not using the accelerometer had to be annotated in the log (e.g., swimming, showering) to account for non-wear time (rather than malfunction of the device) during data analysis. At the end of the study, individuals delivered the accelerometer and log to the staff.

Data collection began in September, 2008, and ended in April, 2010. August was not included in the evaluation because most participants were on summer vacation.

3.2.3. Accelerometer, data reduction and outcome measures

The ActiGraph models (ActiGraph GT1M, ActiGraph, Pensacola, Fla.) were used to objectively assess PA and were calibrated according to the manufacturer´s instructions. The validity and reliability of accelerometers within and across monitors have been previously tested (25).

Freedson cut-off points (11), adapted by Mathews and colleagues (22), were used to evaluate the time spent in different intensity activities by adults (under 60 years old) . PA intensity categories were defined as follows: inactive (from 0 $ct \cdot min^{-1}$ to 500 $ct \cdot min^{-1}$), light (500 $ct \cdot min^{-1}$ to 1,952 $ct \cdot min^{-1}$); and moderate-to vigorous (above 1,952 $ct \cdot min^{-1}$). These cut-off points were used because they derive from an adult population and were calibrated for walking, the most broadly performed activity.

Considering that cut-off points for the elderly (above 60 years old) are not validated, and the use of a single cut-point for all adults may lead to an underestimate of moderate PA intensity in the elderly, cut-off points by Davis (9) were used. For the elderly group, categories were

defined as the following: sedentary activity (less than 200 ct·min^{-1}), light activity (less than 3 METS, ranging from 200-to 1999 ct·min^{-1}), and MVPA (more than 3 METS, above 1999 ct·min^{-1}). These cut-off points were chosen because they were previously used in other studies with similar samples (9, 12, 14, 15).

Intensity categories defined for adults and elderly adults corresponded to the same metabolic equivalents, but were given different designations by the researchers (e.g., 'inactive' for adults and 'sedentary' for older adults). The categories sedentary activity, light activity, and MVPA were used for both age groups, to standardise the terminology and to facilitate data presentation, interpretation and comparison.

Data used for analysis consisted of at least 4 days of data collection for a minimum of 10 hours per day, in cycles of 1 min 60 min or more of consecutive zero counts were considered missing data or non-wearing time and were eliminated (38). Accelerometer malfunction was identified as having counts greater than 18,000 ct·min^{-1}. Participants´ logs were checked for non-wear time and matched against accelerometer data. The pedometer function was preset to record steps per day (steps·day^{-1}).

Adherence to the recommendations for PA, which suggest a minimum of 30 min of at least moderate PA, on most, preferably every day, was examined whether the participants achieved 30 min of PA throughout the day (6) or in bouts of more than 10 min above the MVPA threshold (16). Because other PA recommendations are relevant, the goal of taking 10,000 steps per day was also analysed.

Our outcome variables were the following:

a) daily time spent in different intensity activities (min·day^{-1}) according to count thresholds (sedentary activity, light activity, or MVPA);

b) average intensity or total PA (ct·min^{-1}) per day; and

c) steps per day (steps·day^{-1}).

Data were reduced using MAHUffe software, available from www.mrc-epid.cam.ac.uk/.

3.3. Statistical analysis

Statistical analysis was conducted using PASW Statistics version 18 (SPSS Inc, USA) and Excel 2007 (Microsoft Corporation). Descriptive statistics were expressed as absolute and relative frequencies, means and standard deviations. Comparisons between genders were made using independent samples test (t-test), and comparisons between age groups were made using One Way ANOVA analysis and Scheffe post hoc test. Pearson´s coefficient was used to check correlations between variables (statistical significance level was set at $p \leq 0.05$).

3.4. Results

The population studied consisted of 435 subjects (59% women) and sample characteristics are summarised in Table 3.1. The final sample included 69.6% of the eligible sample of 627 participants.

Table 3.1 – Descriptive characteristics [age (years), weight (kg), height (cm) and BMI ($kg \cdot m^{-2}$)] of the subjects in total sample sorted by gender.

	Total (N=435)	**Women (N=257)**	**Men (N=178)**
	mean ± SD	**mean ± SD**	**mean ± SD**
Age (yr)	54.99 ± 20.10	58.99 ± 18.93	49.22 ± 20.39
Weight (kg)	69.95 ± 13.31	64.42 ± 11.22	77.93 ± 11.99
Height (cm)	161.43 ± 10.33	155.25 ± 6.96	170.33 ± 7.51
BMI ($kg.m^{-2}$)	26.77 ± 4.16	26.75 ± 4.57	26.81 ± 3.51

The average number of valid days the accelerometer was worn for the whole sample was 4.98 days, and the time worn ranged from 10.22 to 18.48 hours per day.

Time spent performing different intensity activities, daily average ($ct.min^{-1}$), and steps taken per day (mean ± SD), categorised by gender and age groups, are presented in Table 3.2.

Gender differences in daily average $ct \cdot min^{-1}$ were only found between groups of ≥60-years-old ($p=0.026$), with men attaining higher amounts of average daily PA.
Men accumulated 62 min (mean values) more in sedentary time, in the 20-39 and in the 40-59 age groups ($p=0.035$ and $p=0.001$, respectively), and spent 14 more min (mean values) in MVPA above 60 years ($p=0.014$), than women. Women spent more time performing light-intensity activity than men ($p=0.000$) between 40 to 59 years.
The number of steps taken per day differed between genders in the youngest ($p=0.022$) and oldest groups ($p=0.020$). Women in the 20-39-year-old group take significantly more steps per day than men in the same age group, but no significant differences were found in the 40-59 age groups. Women in the older age group (≥60 years old) take significantly less steps per day than men.

Table 3.2 – Time spent in different intensity activities (min·day^{-1}), daily average (ct·min^{-1}), and steps taken (steps·day^{-1}) (mean ± SD) sorted by gender and by age groups.

		Women (♀)				Men (♂)			
	Total	Total ♀	20-39	40-59	≥60	Total ♂	20-39	40-59	≥60
	(n=435)	(n=257)	(n= 47)	(n=83)	(n=127)	(n=178)	(n=72)	(n=44)	(n= 62)
Sedentary (min·day-1)	1163.46 ± 103.27	1154.59 ± 110.51	1149.31 ± 90.06	1114.79 ± 102.81	1182.55 ± 114.58	1176,28 ± 90.59	1183.76 ± 83.69	1176.76 ± 76.03	1167.25 ± 106.93
gender differences found			♀≠♂(1)	♀≠♂(3)			♀≠♂(1)	♀≠♂(3)	
age differences found				≠Y♀>60 (1)	≠Y♀40-59 (2)				
Light (min·day-1)	155.60 ± 76.97	163.76 ± 83.30	164.67 ± 61.81	191.35 ± 65.00	145.39 ± 95.46	143.81 ± 65.23	145.12 ± 51.67	136.84 ± 45.01	147.25 ± 88.09
gender differences found				♀≠♂(4)				♀≠♂(4)	
age differences found				≠Y♀>60 (1)	≠Y♀40-59 (2)				
MVPA (min·day-1)	40.28 ± 32.29	37.26 ± 31.73	54.51 ± 30.29	49.31 ± 29.98	23.01 ± 26.72	44.64 ± 32.68	48.69 ± 27.40	48.99 ± 29.40	36.84 ± 39.00
gender differences found					♀≠♂(5)				♀≠♂(5)
age differences found			≠Y♀ >60 (1)	≠Y♀ >60 (1)	≠Y♀ 20-39 (2); ≠Y♀40-59 (2)				
Daily average (ct·min·day-1)	323.94 ± 187.78	314.07 ± 192.98	411.28 ± 178.46	390.14 ± 170.13	228.38 ± 174.52	338.18 ± 179.59	364.06 ± 143.47	346.53 ± 152.18	302.22 ± 226.17
gender differences found					♀≠♂(6)				♀≠♂(6)
age differences found			≠Y♀>60 (1)	≠Y♀ >60 (1)	≠Y♀ 20-39 (2); ≠Y♀40-59 (2)				
Steps (steps·day-1)	7772.64 ± 4299.71	7645.45 ± 4483.43	9683.49 ± 3459.20	9756.61 ± 3708.12	5511.48 ± 4295.13	7957.31 ± 4023.37	8251.02 ± 3176.24	8598.75 ± 3535.46	7165.75 ± 5028.20
gender differences found			♀≠♂(2)		♀≠♂(7)		♀≠♂(2)		♀≠♂(7)
age differences found			≠Y♀>60 (1)	≠Y♀ >60 (1)	≠Y♀20-39 (2); ≠Y♀40-59 (2)				
Legend:									
♀≠♂-significant gender difference		≠Y♀ -women significant age difference							
♀≠♂(1), p=0.035		≠Y♀ (1), p=0.000							
♀≠♂(2), p=0.022									
♀≠♂(3), p=0.001									
♀≠♂(4), p=0.000									
♀≠♂(5), p=0.014									
♀≠♂(6), p=0.026									
♀≠♂(7), p=0.020									

When considering differences between age groups, significantly higher values of daily average ct·min^{-1}, MVPA, and steps were observed in the younger females compared to the older ones (≥60 years) (all p=0.000). The mean values observed in younger women for these variables are almost two times higher than the mean values observed in older women. Between the 40 to 59-year-old and ≥60-year-old age categories of females, there was a decrease in daily average ct·min^{-1}, MVPA, light activity, and steps taken (all p=0.000) but also an increase in time spent in sedentary activity (p=0.000).

No significant differences were found between age groups of men.

Significant correlations found are presented in Table 3.3. Strong correlations between daily average ct·min^{-1} and MVPA, between daily average ct·min^{-1} and steps, and between MVPA and steps, were found in all age/gender groups.

Table 3.3 – Significant correlations found between variables.

	Women (♀)														
	20-39					40-59					≥60				
	Sedentary	**Light**	**MVPA**	**Daily average**	**Steps**	**Sedentary**	**Light**	**MVPA**	**Daily average**	**Steps**	**Sedentary**	**Light**	**MVPA**	**Daily average**	**Steps**
Sedentary															
r		- 0.808	-0.493	- 0.600	- 0.508		- 0.883	- 0.564	- 0.705	- 0.716		- 0.927	- 0.676	- 0.880	- 0.785
p		0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000
Light															
r	- 0.808			0.358	0.269	- 0.883		0.381	0.575	0.602	- 0.927		- 0.584	0.872	0.764
p	0.000			0.013	0.000			0.000	0.000	0.002	0.000		0.000	0.000	0.002
MVPA															
r	- 0.493			0.938	0.920	- 0.564	0.381		0.935	0.851	- 0.676	- 0.584		0.881	0.885
p	0.000			0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000		0.000	0.000
Daily average															
r	- 0.600	0.358	0.938		0.886	- 0.705	0.575	0.935		0.876	- 0.880	0.872	0.881		0.923
p	0.000	0.013	0.000		0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000		0.000
Steps															
r	- 0.508	0.269	0.920	0.886		- 0.716	0.602	0.851	0.876		- 0.785	0.764	0.885	0.923	
p	0.000	0.000	0.000	0.000		0.000	0.002	0.000	0.000		0.000	0.002	0.000	0.000	
	Men (♂)														
	20-39					40-59					≥60				
	Sedentary	**Light**	**MVPA**	**Daily average**	**Steps**	**Sedentary**	**Light**	**MVPA**	**Daily average**	**Steps**	**Sedentary**	**Light**	**MVPA**	**Daily average**	**Steps**
Sedentary															
r		- 0.751	- 0.457	- 0.630	- 0.585		- 0.554	- 0.485	- 0.578	- 495		- 0.803	- 0.567	- 0.693	- 0.626
p		0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000
Light															
r	- 0.751			0.424	0.357	- 0.554		0.261	0.466	0.444	- 0.803		0.384	0.605	0.565
p	0.000			0.000	0.002	0.000		0.000	0.000	0.002	0.000		0.002	0.000	0.000
MVPA															
r	- 0.457			0.905	0.882	- 0.485	0.261		0.949	0.930	- 0.567	0.384		0.935	0.914
p	0.000			0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.002		0.000	0.000
Daily average															
r	- 0.630	0.424	0.905		0.880	- 0.578	0.466	0.949		0.941	- 0.693	0.605	0.935		0.918
p	0.000	0.000	0.000		0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000		0.000
Steps															
r	- 0.585	0.357	0.882	0.880		- 495	0.444	0.930	0.941		- 0.626	0.565	0.914	0.918	
p	0.000	0.002	0.000	0.000		0.000	0.002	0.000	0.000		0.000	0.000	0.000	0.000	

MVPA - moderate-to-vigorous physical activity

When analysing MVPA in detail, 72.3% and 66.3% of women between 20-39 years of age and 40-59 years of age, respectively, achieved the recommended minimum of 30 min a day (6). Approximately 30% of women in the older age category were compliant. The results were quite similar for men as 75% of 20-39 year-old men, 72.7% of 40-59-year-old men, and 38.7% of above 60-year-old men completed the recommendation, as presented in Figure 3.1.

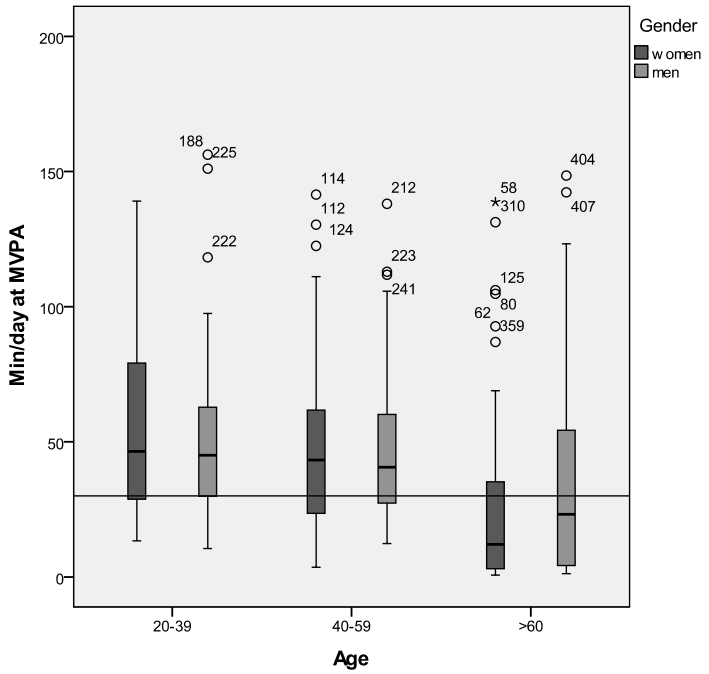

Figure 3.1 - Minutes spent in moderate-to-vigorous (MVPA) PA across age groups of men and women. Minimum recommended level of 30 min is indicated as one horizontal line.

If periods of 10 or more consecutive min of MVPA were considered to equal the current recommendations of PA (16), the percentage of compliers drops to 12.5% and 38.2% in the 20-39 years old group (men and women, respectively), to 20.45% and 37.3% in the 40-59 years old group (men and women, respectively), and to 14.51% and 24.40% in the ≥60 years old group (men and women, respectively).

Finally, our analysis of the number of steps in relation to the minimum 10,000 steps·day^{-1} to be considered "active" (41) is presented in Figure 3.2, with the horizontal line representing the 10,000 steps·day^{-1}. None of the gender and age groups achieved this recommendation in terms

of mean values, and the highest percentage of compliers was observed in the 20-39 and in the 40-59 years-old women (40.42% and 43.37%, respectively).

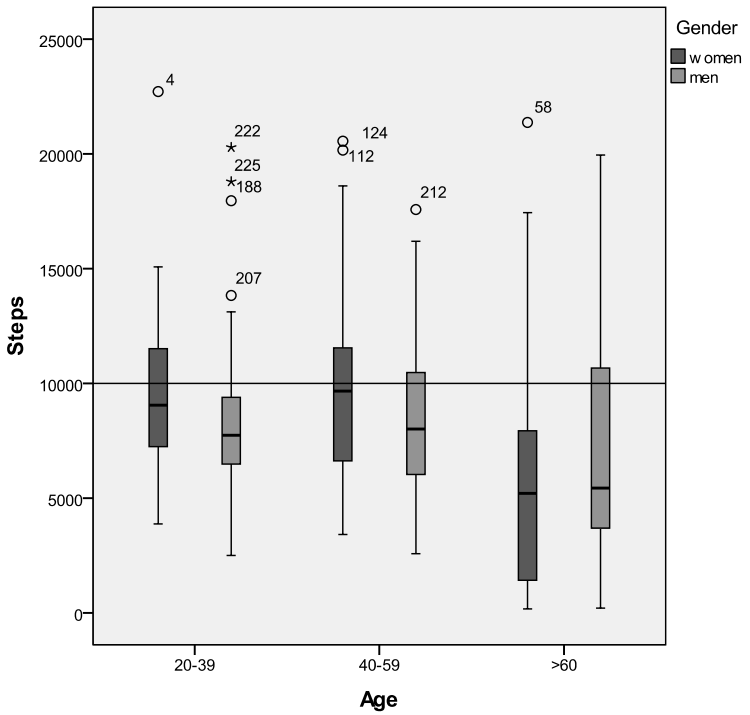

Figure 3.2 - Number of steps taken per day in relation to the recommended minimum of 10,000 steps·day^{-1} (presented as a horizontal line).

3.5. Discussion

To our knowledge, this is the first study to analyse age and gender differences in a large sample of Portuguese adults and elderly adults, to establish comparisons between age and gender groups, and to investigate the achievement of the recommended levels of PA using accelerometry and age-specific cut-off points for adults and elderly adults.

Because very few studies have used accelerometry in European populations of adults and older adults, and considering that the existing studies differ in aims, methods and measured outcomes, some of our data will be matched to the results from other investigations performed outside of Europe. Cut-off values used by researchers to define intensity of activities may influence results involving time spent in different intensity activities; therefore,

caution must be taken when comparing results to reduce possible errors during data interpretation.

According to our data, a big proportion of the time was spent in sedentary activity. This means that a big part of the day was spent in very low intensity behaviours during waking hours, which include sitting, reclining, or lying down at home, at work, in transit, or during leisure time. Similar results using accelerometry on an Australian sample of adults (mean age 53.3 years) found that 57% of waking hours were spent in sedentary behaviour (19). However, these authors used a cut-off value for sedentary activity (<100 ct·min^{-1}) that was lower than our study (<260 ct·min^{-1}), suggesting that the results from our study were based on a more conservative limit and would account for more time in this level than the previous study. This suggests that our sample may be less sedentary compared to others.
Regarding the elderly adults, our results are in agreement with previous studies of U.S.A. populations that show that approximately 60% of their time, which equals more than 8 hours a day, is spent in sedentary behaviours (23).

The results concerning the total amount of PA between genders, as represented by daily average ct·min^{-1}, revealed differences only in the older age group. These data confirm previous findings from other authors using European samples of adults that reported no differences in daily average ct·min^{-1} in both young (9, 13), thus contradicting earlier reports that state that adult men were more physically active than women in North America (10, 40). Our results are different from the those found by Davis (9) who did not find any differences between genders in the older age groups. In Davis´s study participants were involved in a PA programme which could imply similar levels of PA between men and women, and explain the differences in results. Differences from the results found in U.S.A. samples may be related to the mean age of the sample that is lower than ours [20 years old in Dinger´s study (10), versus 29 years-old in our sample] or related to differences in geographic, cultural, socio-demographic or others. The relevance of these findings rely on the fact that previous research based has contributed to the common belief that men were more physically active than women, which has been shown here and in other studies based on accelerometry (9, 13) no to be true for all age categories.

Differences found between men and women in the ≥60 years old group are due to the fact that men accumulate more MVPA, associated to more steps taken per day, as previously reported in European samples (9, 15).
Men and women above 60 years old accumulated approximately 37 min·day^{-1} and 23 min·day^{-1} of MVPA, respectively. Other studies developed with similar samples from European countries using the same cut-off points reported lower results. Eighty-year-old Swedish women attained 13 min per day of MVPA (12), and Davis and colleagues (9) report that older men attained approximately 24 min·day^{-1} and women 17 min·day^{-1}.

Our examination of how similar levels of PA were achieved by men and women in the 20-39 and in the 40 to 59 years of age groups, revealed differences in the combination of intensities of activities. In the younger age group, men accumulate more sedentary time and accumulate few steps per day than women, and in the 40-59 years-old age group, men also spend more min in sedentary activities than women, while women spend more time in light activity than men.

No differences were found in MVPA between men and women, until above 60 years old, when males attained higher values. However, these results are contrary to those in Hagströmmer´s study that observed higher amounts of MVPA in Swedish men (mean age 45±15 years) compared to women. Additionally, a study that involved Portuguese adults identified differences between men and women, with men of 20-39 and 40-59 years of age accumulating more daily min of MVPA than women, but found no differences in males and females above 60 years old (35). Potential differences between the results from these studies might be due to the cut-off points for adults and elderly adults used or may also be explained by variables such as marital status, socio-economic status, geographic and cultural characteristics of the region of origin of the sample.
Analysis by intensities provided another insight because the time spent in each level was able to be estimated, which otherwise would not be possible just by analysing daily average ct·min^{-1}.

Men´s data did not reveal any differences across ages in daily average ct·min^{-1} or in any other variable. However, one must bear in mind that variance of data, especially in the older age

group, is very large which could explain why there were no significant differences found between age groups.

In women, no differences were found in PA until ≥60 years-old. Daily average ct·min^{-1}, MVPA and steps taken remained stable until 60 years old, and only time spent in sedentary increased and time spent in light activities decreased from 40-59 years old and ≥60 years old. These results have been stated earlier by other European researchers (9, 13).

Previous findings state that sedentary activity increases with age (31, 38), especially in older adults (38). In our study, except from 40-59 to ≥60-year-old women, where an increase in time spent in sedentary activity was observed, these behaviours tend to stabilise in both men and women, which could be considered a positive finding because at least this behaviour did not increase over time. However, European researchers found that sessions of 60 min of sedentary activity were significantly higher in older males and females than in their younger counterparts (9). Because time spent in sedentary and light activities in the elderly has been stated to be inversely related to PA level (24), data from these two variables should be taken into account and analysed carefully when a determined sample is being studied.

Other studies have also shown a decline in PA with age (7, 29, 31). Younger adults were more physically active than the elderly (9), and the research indicates that low levels of PA in youth may persist into adulthood (3, 9, 10). According to the literature, the differences between the type and levels of PA in the elderly and young populations are mainly due to a decrease in participation in formal sports and exercise and an increase in activities of daily living, such as walking, and leisurely pursuits, such as gardening (9). In our study, only younger women (20 to 39 years old and 40-59 years old) attained significantly higher amounts of PA and achieved greater intensity activities than older females (above 60 years), however, as stated before, results from the older age group of men may be masked by the high variance of data.

In addition, our study revealed high correlations between daily average ct·min^{-1} and MVPA in all age/gender groups which may imply that this level of intensity has major impact on the total daily PA, across ages, meaning that interventions should focus on increasing the amount of MVPA to reverse the low levels of PA.

The PA recommendations suggest that adults and elderly adults should perform a minimum of 30 minutes of moderate to vigorous PA intensity on most days of the week (6, 16, 27, 44). A high proportion (≥72%) of adults follow these suggestions, however, only approximately 30% of women and 38% of men in the older age category follow these recommendations. Previous studies have reported similar results using the same method in European populations of adults and older adults (9, 12, 13).

The rate of adults that complied with the recommendations decreased dramatically when we only considered periods of 10 or more consecutive minutes above MVPA threshold; these results are also in accordance with previous results from a study on European adult populations (13). These results indicate that this recommendation for PA consisting of 10 consecutive minutes or more is much more demanding than the simple accumulation of 30 min above the MVPA threshold, is more difficult to accomplish within the activities of daily living, and, therefore, may need to be given more attention by PA professionals. However, considering the health benefits associated with these guidelines, they should be a priority for PA intervention programmes.

Results for the number of steps taken per day differ between the youngest and oldest groups and between sexes. These data are in line with the significant correlations found in all age groups of men and women between daily average $ct \cdot min^{-1}$ and steps, meaning that a lower daily average $ct \cdot min^{-1}$ is associated with fewer steps taken.

Except for the important difference between men and women in the older age category, our results across the age groups are in perfect agreement with the data from a descriptive meta-analysis on the number of steps taken per day by adults (4). However, some caution and attention must be paid to the differences in methods used: the meta-analysis used data only from pedometers and not from the pedometer function on accelerometers. It has been stated that valuable information can be extracted from the step-counter of the accelerometer because step counts and activity counts are highly correlated (14). Additionally, in the cited meta-analysis, the majority of studies involved American or Japanese samples, which can introduce cultural differences into the equation.

Above 60 years of age for both men and women, but especially for women, is the time in life where fewer steps are taken per day, as reported by earlier studies (14) and the meta-analysis (4). These results may provide valuable information on sample characteristics because lower accelerometer step counts of the elderly are predicted by factors such as increasing age, poor general health, low exercise self-efficacy, and low perceived exercise control (14).
In addition, none of our gender/age groups accomplished the 10,000 steps per day recommended for adults (41) in terms of mean values. Also, the percentage of non-compliers with the recommendation is more than 50% in all age gender groups. These data, together with the high correlations found between MVPA and steps may indicate that interventions to promote the increase of the number of steps taken per day should be encouraged and may also contribute to the increase in MVPA.

Limitations to our study should also be considered. The study was performed in a convenient sample of adults and older adults that lived in the defined study region, thus these results may be specific to this geographic area and, therefore, other studies should be replicated in another region to account for these differences.

A strength of this study is that the results presented here correspond to compliant participants who followed measurement procedures, although many people did not comply to wearing the device for the minimum number of days during data collection and thus were excluded from the final sample. In fact, all subjects analysed wore the accelerometer for four or more days, for at least 10 h per day, as advised in the literature.

Although lacking validated cut-off values for older people, we recognised that data from the elderly should be analysed differently from adults as the same cut-off value may not be appropriate for differences and characteristics for the elderly population. For this reason, we used cut-off values from previous studies with similar samples (9, 12) that were found to be more suitable than the ones validated for young adults, which is a strength of our study. Additionally, the use of different PA recommendations to examine levels of commitment to PA provided us with more accurate results.

3.6. Conclusions

Our findings indicate that developing PA strategies should consider the analysis of the conjugation of intensity of activities performed daily, provided by the accelerometer, to define objective goals for each gender/age groups. Results indicate a stabilization of the time spent in sedentary activity and of PA across ages, in both men and women until ≥60 years-old. PA interventions should aim to reverse the amount of sedentary behaviours, focus on increasing the number of steps taken per day and of MVPA, especially in the elderly, and emphasise sustained periods of at least 10 min above MVPA to achieve PA recommendations.

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Chapter 4 – Portuguese individuals´ physical activity as assessed by accelerometry troughout the year

Portuguese individuals´ physical activity level as assessed by accelerometry throughout the year

Abstract

Purpose: This study aims to describe the daily physical activity (PA) of a considerably large sample of adults and elderly adults throughout the year. We also aim to examine if there are any changes in PA and in achieving PA recommendations when assessed at different periods of the year.

Methods: Participants, 257 women (ages from 20 years to 96 years, BMI 26.75 $kg \cdot m^{-2}$ ± 4.57 $kg \cdot m^{-2}$) and 178 men (ages from 20 years to 88 years, BMI 26.81 $kg \cdot m^{-2}$ ± 3.51 $kg \cdot m^{-2}$), wore an accelerometer (ActiGraph GT1M, ActiGraph, Pensacola, Fla.) and were monitored for four to seven days. Periods of data collection were defined as T1 (September to December), T2 (January to April), and T3 (May to July). Time spent in different intensity activities ($min \cdot day^{-1}$), average daily counts per min ($ct \cdot min \cdot day^{-1}$), and average daily steps ($steps \cdot day^{-1}$) were analysed for each period of data collection, specifically examining whether PA recommendations were accomplished.

Results: PA does not fluctuate widely throughout the year. Women generally maintain a constant level of PA ($ct \cdot min \cdot day^{-1}$) throughout the year, whereas men show more variations. Results reveal a considerable amount of sedentary time spent by all gender/age groups throughout the year. Data on the compliance with the different PA recommendations vary widely among periods of the year. Less than 50% of the older men and women are compliers with any of the PA recommendations. Gender differences were only observed in T1, when 40-59-year-old men spend more time in sedentary PA and less time in light activity than women of the same age. T2 is when PA significantly decreases, especially in older age groups.

Conclusions: Our results show that the time of year when evaluations take place may influence data on PA and compliance with PA recommendations.

Key words: accelerometry, physical activity, weather, season, elderly, year-long, determinants

4.1. Introduction

Physical inactivity (PA) is the leading risk factor of chronic diseases of lifestyle at the global and regional level (6, 21), and data from numerous studies using objective or self-reported methods of assessment reflect concerns about inactivity levels across countries, ages and conditions (9, 15, 29). Several factors, including personal, social and environment factors (6), are known to influence adults´ engagement in PA.

Various studies using questionnaires have reported monthly variation in leisure time PA (LTPA) in USA and Canadian men and women (22, 24, 26, 27) and in postmenopausal women (26) throughout the year. This monthly variation is affected by season, likely due to the weather, and reflects higher quantities of LTPA in summer compared to winter and other seasons (22, 24, 26, 27, 30). These differences may also be caused by the fewer and shorter sessions of LTPA observed during winter (27). According to reviews of studies in developed societies considering total PA, the winter season is correlated with reduced PA (3), and temperature and rainfall have a dominant influence on PA (30).

One year-long study in the USA that utilised self-reported methods observed seasonal fluctuations in PA throughout the year, but the magnitude of these changes were generally very small. Changes were greater in middle-aged men (18), compared to other age and gender groups. The only year-long study that used accelerometers as an objective measure to assess PA analysed an older Japanese population and reported peaks in low-to-moderate PA in spring and in autumn compared to winter months (37).

Differences in studies may be due to more than climate differences; differences in the methods used may make it difficult to make comparisons between studies' outcomes. In fact, some authors defined four seasons in the year to assess PA (26, 27, 37), whereas others used only two seasons (winter and summer) (10, 23). Moreover, the months included in each period/season varied among researchers, and this difference may have also influenced the results. Criteria for defining the seasons were diverse: weather patterns resembling months (26), periods of data collection (27), designated arbitrarily (37), or no explanation (23). Thus, one season may not match characteristics from the same season in other studies unless weather variables are reported. Nevertheless, relatively consistent results show the influence of the time of year on PA: PA decreases in the winter season and increases in the spring and/or

summer seasons. Additionally, USA sample studies, based on self-report (22, 36), reported a peak of total and moderate intensity activity in July (summer month), whereas the lowest-intensity activity peaks were observed in January (winter month). The authors suggest that factors such as daylight and weather conditions may influence PA participation; thus, the reduced levels of PA observed during winter months may correlate with the period when the environmental conditions worsen and the day length diminishes (22, 27, 28).

Because so few studies address these questions, there is a necessity for studies that are set in geographical areas with distinct seasons and different cultural settings and that measure effects not only during leisure time PA but also total PA using objective measures (26, 35).

Consistent participation in PA during most months of the year is associated to reduced risk of cardiovascular events (19). Moreover, the fluctuations in PA across the year (26) and seasonality in activity behaviours (17, 22) that were observed in previous studies suggest that PA should be assessed several times per year to obtain the most precise data on the typical PA to identify target populations and better plan PA interventions. The season or the time of year during which a study has been carried out has been identified as a potential source of variance in daily PA levels (16, 20), and sampling study participants only once during the year may result in errors in estimating PA (27).

Thus, this study aims to provide information on objectively measured PA using accelerometers in a considerably large sample of Portuguese adults and to examine if there are changes in PA and achieving the recommended levels of PA when assessed during different periods of the year.

4.2. Methods

4.2.1. Participants

Eligible participants were adults over 20 years of age, both males and females, who were residents within the geographic area defined for the study (Municipality of Vila Real, located in

north Portugal), were willing to participate, and did not suffer from any motor incapacity that could limit participation.

Participants were recruited by word of mouth. To better characterise the population within the defined region, individuals were recruited regardless of whether they were involved in PA or an exercise programme and independently of their marital or socio-economic status.

Of the 627 subjects initially recruited and evaluated, 190 did not wear the accelerometer for at least four days or had battery failure or equipment malfunction. Therefore, the final sample includes 435 participants.

Participants were 257 women (aged from 20 years to 96 years, BMI 26.75 $kg \cdot m^{-2} \pm 4.57$ $kg \cdot m^{-2}$) and 178 men (aged from 20 years to 88 years, BMI 26.81 $kg \cdot m^{-2} \pm 3.51$ $kg \cdot m^{-2}$).

Age was classified into three categories (20-39 years, 40-59 years and ≥60 years) according to stratification data from other studies (14, 31, 32) to allow the data to be compared.

4.2.2. Procedures

All study design and experimental procedures were explained to potential participants. After the recruitment, participants willing to participate signed an informed consent, completed a socio-demographic questionnaire, and were assessed for height and weight.

Each individual was monitored for four to seven days (including weekdays and weekend days), according to studies reporting that at least three to five days of monitoring should be considered in adults (34).

Subjects were fitted with a belt to attach the accelerometer closely around their waist (5, 34). Participants were instructed to wear the accelerometer directly over their iliac crest during all waking hours for four to seven consecutive days, except when showering, bathing, and swimming. Participants were asked to put on the accelerometer first thing in the morning, remove it immediately before going to bed at night, and mark the time on a brief log. Any other activity that was performed while not using the accelerometer had to be marked in the log (e.g., swimming, showering) in order to account for the activity in the data analysis as non-

wear time (as opposed to a device malfunction). At the end of the collection days, individuals delivered the accelerometer and the log to the staff.

Data collection began in September, 2008, and ended in April, 2010, and it was performed in three periods of data collection each year to account for differences between periods of the year. The three time periods were as follows: Time 1 (T1: from September to December), Time 2 (T2: from January to April), and Time 3 (T3: from May to July). August was not included in the evaluation because it is summer vacation period for most participants.

These periods were defined considering two factors: personal and daily life organisation according to periods of the year and weather conditions in each period.

Data on weather variables were provided by the Institute of Meteorology of Portugal (I.M., I.P.). However, because the purpose of the study was to identify differences in PA throughout the year, these weather variables were collected and reported only to identify potential differences between periods of the year, and no seasons were defined.

At the time of entry in the study, participants were asked if they were willing to participate in other assessments at a different time of year. Few participants agreed to repeat the evaluations. Although equal sample sizes for each period of the year was an aim, this aim was not possible to accomplish because people´s willingness to participate varied throughout the course of the study.

4.2.3. Accelerometer, data reduction and outcome measures

The Actigraph model (ActiGraph GT1M, ActiGraph, Pensacola, Fla.) was used to objectively assess PA. Devices were calibrated according to the manufacturer´s instructions. The validity and reliability of accelerometers within and across monitors have been tested (25).

To evaluate time spent in different intensity activities in adults (for ages under 60 years), Freedson cut-off points (7), adapted by Mathews and colleagues, were used (20). PA intensity categories were defined as follows: inactive (from 0 ct·min^{-1} to 500 ct·min^{-1}), light (500 ct·min^{-1} to 1,952 ct·min^{-1}); and moderate-to vigorous (above 1,952 ct·min^{-1}). These cut-off points were

used because they derive from an adult population and were calibrated for walking, the most broadly performed activity.

Because there are no validated cut-off points for elderly individuals, and the use of a single cut-off point for all adults may underestimate moderate PA intensity in the elderly, the cut-off points of Davis (4) were used for data on subjects above 60 years. For this population, the defined categories were as follows: sedentary activity (less than 200 ct·min^{-1}), light activity (equivalent to less than 3 METS, ranging from 200-to 1,999 ct·min^{-1}), and moderate-to-vigorous physical activity (equivalent to more than 3 METS, above 1,999 ct·min^{-1}). These cut-off points were chosen because they have already been used in other studies with similar samples (4, 8, 11, 12).

Intensity categories corresponding to the same metabolic equivalents, defined for adults and the elderly, were given different designations by researchers (e.g., 'inactive' for adults and 'sedentary' for the elderly). To standardise the terminology and facilitate data presentation, interpretation and comparisons, the categories sedentary activity, light activity, and moderate-to-vigorous PA (MVPA), were used.

A minimum of 10 hours of data collection per day, on at least 4 days, were considered valid days and were used in analysis. We used 1-min cycles, and 60 min or more of consecutive zero counts were considered as missing data or non-wearing time and were eliminated (33). Accelerometer malfunction was identified as having counts greater than 18,000 ct·min^{-1}. Participants´ logs were checked for non-wear time and matched against the accelerometer data. The pedometer function was pre-set to record steps per day (steps·day^{-1}).

The adherence to PA recommendations for health that suggests that the accumulation of at least 30 min of at least moderate PA on most and, preferably, on all days of the week was examined by considering 30 min accumulated in single min (2) and in bouts of more than 10 min above the MVPA threshold (13). To address other PA recommendations, compliance for the goal of 10,000 steps taken per day was also analysed.

We were able to estimate our outcome variables:

a) Daily time spent in different intensity activities (min·day^{-1}), according to count thresholds (sedentary activity, light activity, or MVPA)

b) Average intensity or total PA ($ct \cdot min^{-1}$) per day

c) Steps per day ($steps \cdot day^{-1}$)

Data were reduced using MAHUffe software (available at www.mrc-epid.cam.ac.uk/).

4.3. Statistical analysis

Statistical analysis was conducted using PASW Statistics version 18 (SPSS Inc., USA) and Excel 2007 (Microsoft Corporation). Descriptive statistics were expressed as absolute and relative frequencies, means and standard deviations. Non-parametric statistics were preferred due to the skewed distribution of most variables. Comparisons between genders were made using Mann Whitney‘s U test. Comparisons between age levels were made using the Kruskal-Wallis test. Whenever significant differences existed, they were isolated using Mann Whitney’s U test (the significance level was set at $p \leq 0.016$ for this test). The statistical significance level was set at $p \leq 0.05$.

4.4. Results

The studied population consisted of 435 subjects (59% women). Sample characteristics are summarised in Table 4.1. The final sample included 69.6% of the eligible sample of 627 participants. Each participant is represented once in the summary table, corresponding to his/her data at the time of entry in the study.

Table 4.1 – Descriptive characteristics of the subjects in the total sample and by gender.

	Total (N=435)	**Women (N=257)**	**Men (N=178)**
	median (1^{st}-3^{rd} quartile)	**median (1^{st}-3^{rd} quartile)**	**median (1^{st}-3^{rd} quartile)**
Age (yr)	56.00 (37.00-71.00)	59.00 (48.00-73.00)	44.50 (31.75-68.00)
Weight (kg)	69.00 (60.60-78.00)	63.10 (57.00-71.70)	77.00 (69.90-84.62)
Height (cm)	160.00 (154.00-170.00)	156.00 (151.00-159.10)	170.55 (165.00-175.00)
BMI (kg/m^2)	26.40 (23.96-29.26)	26.35 (23.52-29.65)	26.54 (24.36-28.76)

Each individual in the entire sample population wore the accelerometer for an average of five days, and the device was worn from 10.22 to 18.48 hours per day.

The data were analysed by periods of the year to examine variations in average daily PA throughout the year. For comparison, weather characteristics for each period of the year, including mean values for temperature, precipitation, relative humidity and daylight hours, are presented in Table 2.

Table 2 - Mean values for temperature (ºC), relative humidity (%), precipitation (mm) and daylight (h), for each period of the year (T).

	Temperature (°C)	**Relative humidity (%)**	**Precipitation (mm)**	**Daylight (h)**
T1 September to December	11.17	77.06	4.51	4.37
T2 January to April	9.11	43.89	3.02	6.26
T3 May to July	19.62	51.69	0.66	10.09

Regarding the daily average ct·min^{-1}, which represents volume of PA, the majority of differences observed during the different time periods were found in men. As seen in Figure 4.1, from T1 to T2, men between 20 years and 39 years significantly increased values of daily average ct·min^{-1} (U=506, p=0.012), whereas men above 60 years decreased their values (U=191, p=0.002). Then, from T2 to T3, men above 60 years observed an increase in PA volume (U=47, p=0.001). Among women, only elderly women demonstrated significant variations from T1 to T2 in daily average ct·min^{-1}, registering higher values (U= 1341, p=0.05) in T1 than in T2.

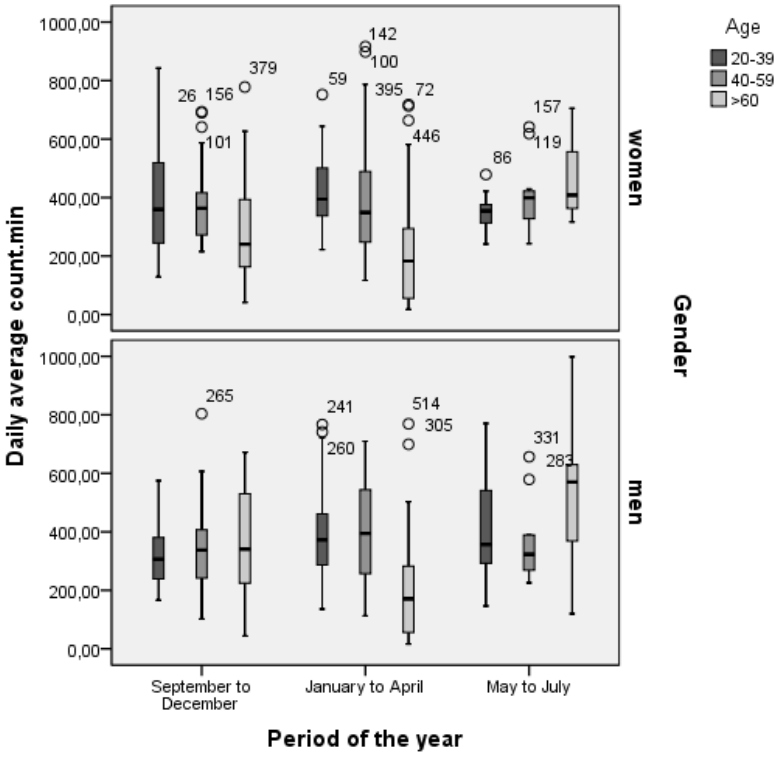

Figure 4.1 – Mean daily counts per min per day, based on gender and age.

As seen in Figures 4.2 and 4.3, our results showed that both men and women above 60 years spent more time in T2 performing sedentary activities (U=223, p=0.009, U=1106, p=0.000, respectively) than they did in T1, whereas both men and women decreased the time spent in light-intensity activities in T2 as compared to T1 (U=182, p=0.001 in men, and U=1103, p=0.000 in women). For this reason, T2 is the period where more sedentary activity took place in older age groups, which accounts for the lowest values of daily ct·min^{-1}.

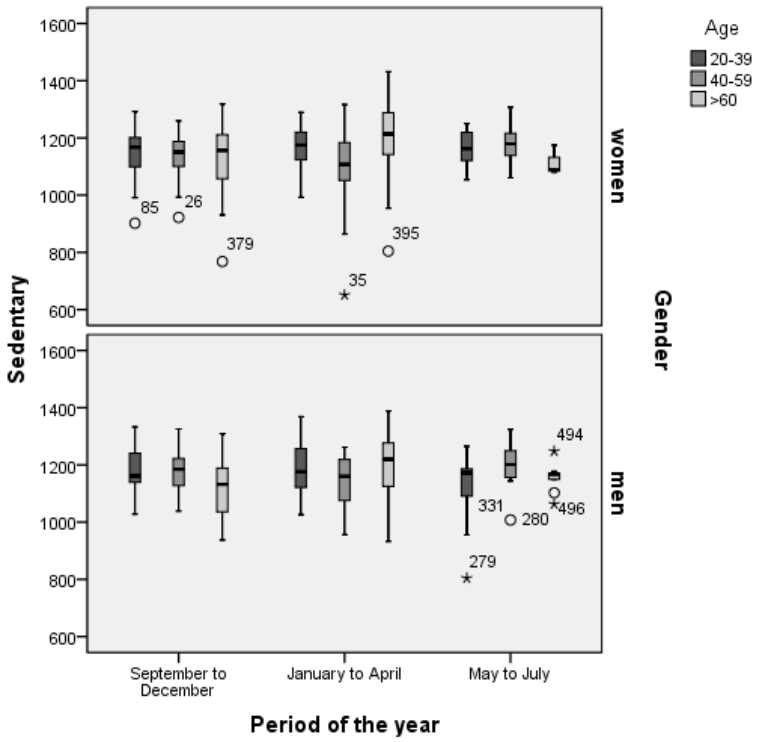

Figure 4.2 – Time spent in inactivity or performing sedentary activities based on gender and age.

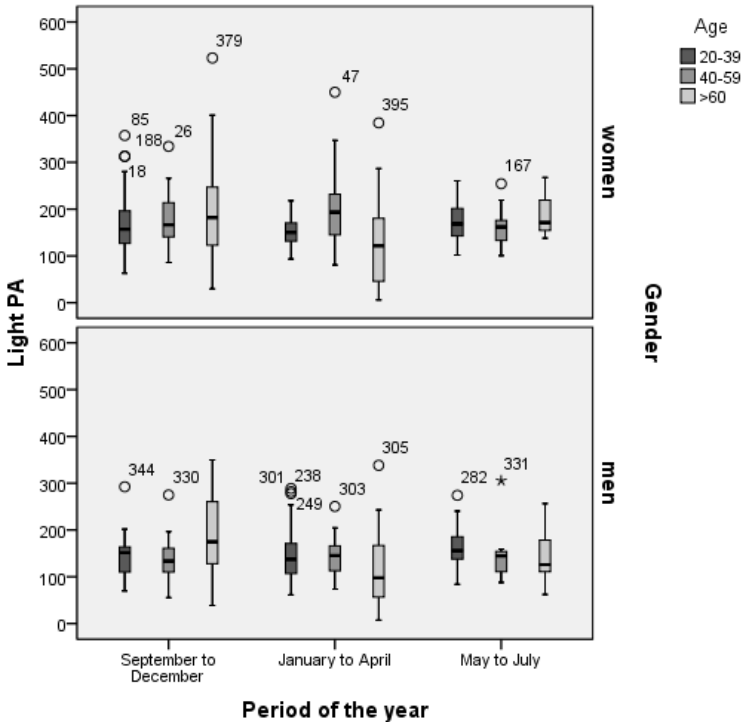

Figure 4.3 – Time spent in light intensity activities based on gender and age

As seen in Figure 4.4, 20-39-year-old men significantly increase MVPA by 15.96 min from T1 to T2 (U=455, p=0.003) and constant values across the other periods of the year. Men aged 40-59 years showed no differences in MVPA levels between periods of the year. Finally, older men (≥60 years) decreased their participation in MVPA by 19.32 min from T1 to T2 (U=192, p=0.002) and increased their participation by 59.62 min from T2 to T3 (U=47, p=0.001).

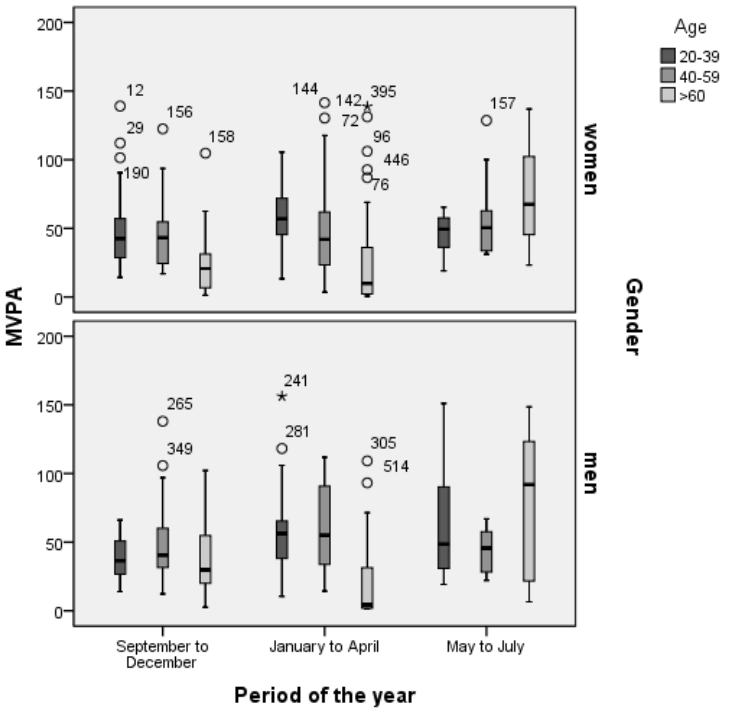

Figure 4.4 – Time spent in moderate-to-vigorous physical activity (MVPA) based on gender and age.

Like the tendency of the daily average ct·min^{-1}, the number of steps taken by older men decreased (U= 177, p=0.001) from T1 to T2 and increased from T2 to T3 (U=33, p=0.001), as seen in Figure 4.5.

Also, males and females in the 20-39-year-old group walked more than twice as far as their over 60-year-old counterparts (women aged 20-39 years 10,079 steps·day^{-1}*versus* women older than 60 years 5,117 steps·day^{-1}; men aged 20-39 years 8,606 steps·day^{-1} *versus* men older than 60 years 4,637 steps·day^{-1}).

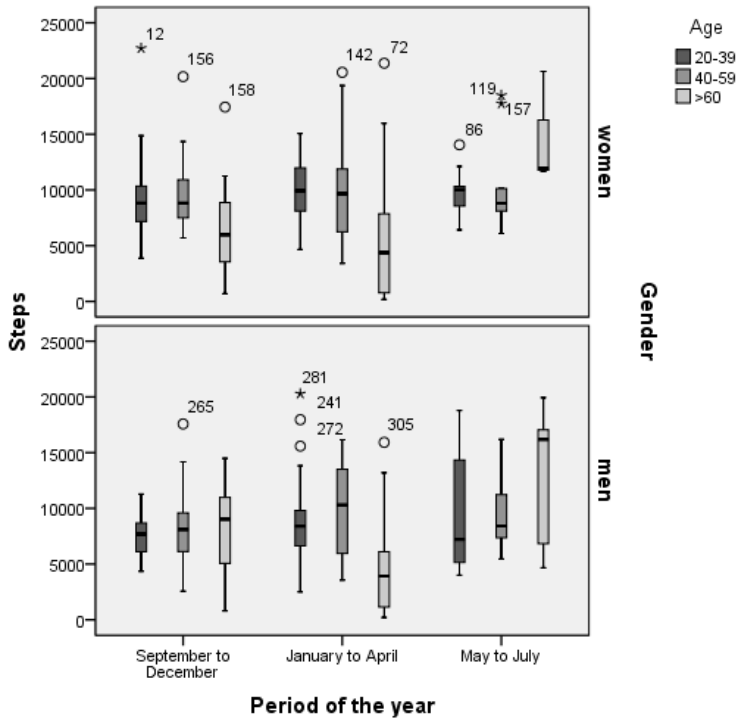

Figure 5 – Steps taken per day based on gender and age.

Gender differences are observed only in T1. During T1, men aged 40-59 years spend more time in sedentary activity (p=0.038) and less time in light activity (p=0.000) than women. Regarding steps taken per day, men aged 20-39 years take fewer steps than women of the same age (p=0.004), whereas men older than 60 years take more steps than older women (1822 steps·day^{-1}, U=0.04).

Regarding the compliance with the guidelines, percentages of compliers to the different PA recommendations are presented in Table 4.3.

More than 50% of men and women of 20-39 and of 40-59 years old comply with the accumulation of 30 min above MVPA threshold, throughout the year. Percentage of compliers drops in all gender/age groups when the accumulation of 30 min requires periods of 10 or more min above the MVPA threshold, especially in men.

Older men and women accumulate less than 30 min of daily MVPA during T1 and T2 (less than 50% of compliers). Unfortunately, due to the reduced sample size of older women in T3 (n=3),

it would not be advisable use their data to draw meaningful conclusions, so we cannot confirm whether the minimum recommendation is met over the period T3.

Very few age groups achieved 50% of compliers with the PA recommendation of achieving 10,000 steps per day across the year (only 20-39 years old women in T3, and 40-59 years old men and women in T2).

Table 4.3 – Percentage of compliers to the different PA recommendations, sorted by gender, by age groups and periods of the year.

	Women (♀)								
	20-39			**40-59**			**≥60**		
	T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
	n=37	n=23	n=14	n=27	n=52	n=11	n=42	n=92	n=3
Accumulating at least 30 min per day above MVPA treshold	67.56%	91.30%	85.71%	74.07%	73.07%	100%	28.57%	30.43%	NC
Accumulating at least 30 min per day above MVPA treshold, of which all are from bouts of 10 min or more	35%	39.1%	28.57%	51.85%	36.53%	54.54%	2.38%	8.69%	NC
Accumulating 10,000 steps per day	29.72%	43.47%	57.14%	37.03%	51.92%	36.36%	11.90%	9.78%	NC
	Men (♂)								
	20-39			**40-59**			**≥60**		
	T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
	n=30	n=44	n=12	n=34	n=10	n=10	n=23	n=33	n=9
Accumulating at least 30 min per day above MVPA treshold	70%	88.63%	83.33%	79.41%	80%	60%	47.82%	27.27%	66.66%
Accumulating at least 30 min per day above MVPA treshold, of which all are from bouts of 10 min or more	16.66%	13.63%	16.66%	20.58%	30%	30%	2.35%	3.03%	55.55%
Accumulating 10,000 steps per day	13.33%	20.45%	33.33%	20.58%	50%	40%	43.47%	12.12%	66.66%
Legend:									
MVPA - moderate-to-vigorous physical activity									
NC - Not calculated due to reduced sample size									

4.5. Discussion

To our knowledge, this is the first study to describe daily life PA throughout the year using accelerometers in a considerably large sample of adults and elderly. We also examined whether there were any changes in PA and in achieving the PA recommendations during different periods of the year.

The season during which a study is carried out has been described as a potential source of variance in daily PA (16, 20). For this reason, we defined various monitoring periods to analyse differences that derive from the time of year when the PA assessment took place.

PA does not fluctuate widely throughout the year. In men and women in the ≥60 years old group, a decrease in daily average $ct \cdot min^{-1}$ was observed, from T1 to T2, due to an increase in the time spent in sedentary activity and due to a reduction in the light intensity activities. Men ≥60 years old also showed a decrease in MVPA and in the number of steps taken per day, which may also justify the decrease in daily average $ct \cdot min^{-1}$.

In men, increase in daily average $ct \cdot min^{-1}$ were due to an increase observed in MVPA from T1 (September to December) to T2 (January to April) in the 20- to 39-year-old group.

Worrying data is associated to the results on the amount of sedentary time spent by all gender/age groups throughout the year. Data from previous studies also state that inactivity was prevalent across all months of the year when assessed by means of self-report (27).

T2 (January to April) corresponded to the period where a great amount of sedentary activity took place in older age groups, associated to a decrease in light intensity activities, and who reached their lowest values of daily average $ct \cdot min^{-1}$. Looking at these variations observed in daily average $ct \cdot min^{-1}$ in the older age group of women, one could address several concerns about the implications on health, because variations were not due to variations of MVPA, as seen previously in other gender/age groups, but due to an increase in sedentary time and to a reduction in the light intensity activities.

Other authors found that the amount of LTPA reached the lowest value in January, which is a probable cause for an overall decrease in the amount of PA. The authors speculated that PA was affected by season and that PA levels would follow the same pattern as the average daily

temperature and hours of daylight (27). In fact, in Portugal, and especially in the region where this study took place, temperatures decreased between January and April, which may explain why PA tended to decrease during this period, particularly in elderly people. We believe that the higher susceptibility of this group to becoming sick may favour sedentary activities performed in a warm environment like a home.

No gender differences were found in daily average $ct \cdot min^{-1}$ throughout the year but differences were observed in sedentary time, light activity and steps taken, in T1. Males aged 40-59 years spend more time performing sedentary activities and less time in light activity than women. Other European studies revealed that men tend to attain higher values of different PA intensities and engage less in household duties than women (23). These household activities may fall into the light-intensity category, where differences were found.

The levels of adherence to the various PA recommendations in the different gender/age groups varied widely between the periods of the year. Our data showed that greater than 50% of men and women who were 20-39 or 40-59 years old complied with the recommendation that one should accumulate 30 minutes of PA per day above the MVPA threshold throughout the course of a year. However, the percentage of those who complied with this recommendation dropped in all gender/age groups when the accumulation of 30 minutes required periods of 10 or more minutes above the MVPA threshold, especially in men. Moreover, very few age groups achieved a level of 50% of compliers with the PA recommendation of 10,000 steps per every day across the year (only 20- to 39-year-old women in T3 and 40- to 59-year-old men and women in T2).

Thus, it appears that the PA recommendation that advises the accumulation of 30 minutes of PA per day with bouts consisting of 10 or more minutes above the MVPA threshold is extremely difficult to adhere to in all gender/age groups, with the exception of the group of 40- to 59-year old women.

Less than 50% of the elderly men and women complied with any of the PA recommendations. In accordance with our results, the literature shows that people of retirement age (older than 65 years) are less likely to meet the PA target (1).

Our results showed a positive (>50% of compliers) and relative stabilisation of the compliance with the PA recommendation for the accumulation of 30 minutes of PA above the MVPA threshold throughout the year. These findings agree with the results from a previous European study (subjects were 45 to 69 years old) based on self-report that observed constant levels of the minimum daily recommended PA across seasons in women (23).

In contrast, when we considered the other two PA recommendations, the percentage of those who complied with these recommendations was dramatically reduced.

Because the recommendation of accumulating 30 minutes per day with bouts of 10 or more minutes above the MVPA threshold may be difficult to implement and measured by the common individual, it may be advisable for PA promotion strategies to encourage the accomplishment of the 10,000 steps per day goal, which could be easily measured by a pedometer.

The limitations of our study should also be considered. Although accelerometers are light, small and inconspicuous (4), some participants refuse to wear or do not wear the devices on all days of data collection, which may explain the loss of so much data and the few samples collected during T3. This time period was one of the hardest periods of the year to collect data because many participants refused to participate due to their involvement in family gatherings such as marriages and baptisms or because they would be going to the beach more often; thus, they thought that using the devices would be an inconvenience.

Moreover, data may be specific to the characteristics of this geographic area. Other studies may be replicated elsewhere to account for differences associated with this factor.

4.6. Conclusions

Results from this study showed that the time of year when evaluations take place may influence the PA data and compliance with PA recommendations.

PA does not fluctuate widely throughout the year, except in the youngest and in the older age groups, between T1 (September-December) and T2 (January to April).

T2 (January to April) corresponded to the period where a great amount of sedentary activity took place in older age groups and a considerable amount of sedentary time was spent by all gender/age groups throughout the year.

No gender differences were found in daily average $ct \cdot min^{-1}$ throughout the year but in T1 (September-December).

Less than 50% of the elderly men and women complied with any of the PA recommendations, PA recommendation that advises the accumulation of 30 minutes of PA per day with bouts consisting of 10 or more minutes above the MVPA threshold is extremely difficult to adhere to in all gender/age groups, with the exception of the group of 40- to 59-year old women.

Intervention strategies should focus on increasing the levels of PA participation to ensure the maintenance of a consistent PA level throughout the year by encouraging the accomplishment of daily goals based on the number of steps.

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Chapter 5 – Influence of the weather variables on physical activity assessed by accelerometry across age and gender groups

Influences of weather variables on physical activity assessed by accelerometry across age and gender groups

Abstract

Purpose: The purpose of this research was to study the effects of weather on physical activity (PA) and on compliance to minimum PA recommendations.

Methods: The participants included 257 women and 178 men who were divided into three age groups (20–39 years, 40–59 years and >60 years old). They wore an accelerometer and were monitored for four to seven days. Time spent in moderate-to-vigorous PA (MVPA), average daily counts per minute, average daily steps, and weather variables [mean air temperature (T), relative humidity (RH), precipitation (PREC), and daylight hours (DL)] were measured on the monitoring days and analysed to explore the influence of weather on PA and on compliance to the PA recommendations.

Results: The number of steps taken by women 40–59 years old was negatively influenced by daylight. The total amount of PA and MVPA of women above 60 years was influenced by PREC. TEMP was the cause of 9% of the variation in the total volume of PA, 11% of MVPA, and 12% of the number of steps taken per day for men above 60 years. For all other gender/age groups, weather indicators did not explain the variation in PA. Neither of the age and gender groups of the compliers to the 10,000 steps per day recommendation was influenced by weather variables.

Conclusions: Our results confirm that environmental factors influence an individual's will to engage in PA, especially elderly individuals, and should be taken into consideration when defining more adequate interventions and health promotion efforts designed to increase PA in the general population.

Key words: accelerometry, physical activity, weather, elderly adults

5.1. Introduction

Sedentary behaviour is related to several chronic diseases and is among the top three modifiable risk factors for premature mortality (44), cardiovascular disease and several other chronic diseases, including diabetes, cancer, obesity, hypertension, bone and joint diseases and depression (2, 4, 19, 26, 27, 37, 43). Despite these risks, a high percentage of people are inactive. To define more adequate strategies to promote physical activity (PA), several studies on the barriers that prevent an active lifestyle have been performed (5, 17, 24, 41).

Lower levels of PA, and consequently poor health behaviours, are associated with the following factors: marital status, obesity, smoking, time constraints, past exercise habits, and environmental variables (41). According to a meta-analysis by Humpel et al. (2002a), environmental factors, such as accessibility to facilities, opportunities for activity, weather, safety, and aesthetic attributes, affect health behaviours. Research on environmental factors affecting PA has focused on the association between PA and either the built environment (5, 16, 23) or the natural environment (24).

Studies that focus on the attributes of the built environment that might influence PA (16, 23, 34) have shown that neighbourhood characteristics influence the active living behaviours of a population. Availability, accessibility, general functionality, and the aesthetics of the neighbourhood are positively associated with the level of PA. The relevance of this research relies on findings that suggest that active transportation or recreational pursuits are associated with perceived access to facilities (16, 34). For that matter, modifying and enhancing these attributes and perceptions about them may have a positive impact on one's PA. These strategies are among the most promising for increasing PA and have permanent effects on a large number of people (29).

However, when considering natural environmental factors (including the terrain, vegetation and weather) that influence active behaviours, other questions have been raised (7, 23, 24). In contrast to built environmental factors, factors associated with the natural environment, such as the weather, besides not being possible to control, may also play an important role in influencing people's engagement in PA on a day-to-day basis, especially because these factors it may change daily.

According to Humpel et al. (17), weather variables are a barrier to PA. Studies based on self-reporting and objective measures show that people who are committed to exercise or engage in PA for pleasure are less likely to alter their PA behaviours due to adverse weather conditions (7, 12, 18).

A review by Chan et al. (6) focused on the effects of weather conditions on PA and categorised studies into two groups: studies that used season as a weather indicator and studies that objectively measured climatological conditions. Of the 24 studies reviewed, 16 used season as a climate indicator, and the other 8 examined the effects of weather (isolated weather indicators) on PA.

Studies that evaluated the influence of weather on PA as measured objectively with seasons have shown decreased moderate-to-vigorous PA (MVPA) during the winter season, which confirms results from self-reports (6). Other methods to measure PA include using accelerometers (which are affordable, relatively inconspicuous and have been widely used in research), that permit larger sample sizes and allow a broad range of daily activities to be measured.

Although there appears to be a general effect of the weather when associating season with PA, the most important factor that causes fluctuations in PA level has not been objectively identified. An important fact should be taken into consideration when defining strategies that are more adequate to promote PA: if people are reluctant to engage in PA or prefer active transportation because of constraints related to weather conditions, knowing which adverse conditions influence behaviour will help define alternatives to reverse these inactive habits.

In analysing the methods used in the eight studies in Chan's meta-analysis that examined the effects of weather (isolated weather indicators) on PA, we found that only one study measured PA by means of accelerometry involving adult samples in the United States (22).

The purpose of this research was to study the effects of weather on PA. More specifically, we aimed to analyse which weather variables most influence total PA, MVPA, and steps taken per day (measured by an accelerometer). Moreover, we aimed to analyse these influences on compliance to the minimum PA recommendations.

5.2. Methods

5.2.1. Participants

Eligible participants were male and female adults over 20 years of age who resided within the geographic area defined for the study (Municipality of Vila Real, located in north Portugal), were willing to participate, and who did not suffer from any motor incapacity that could limit their participation.

Participants were recruited by word of mouth. To better characterise the population within the defined region, individuals were recruited regardless of whether they were involved in PA or an exercise programme and independently of their marital or socio-economic status.

Of the 627 subjects initially recruited and evaluated, 190 did not wear the accelerometer for at least four days or had battery failure or equipment malfunction. Therefore, the final sample included 435 participants.

The participants included 257 women (aged from 20 years to 96 years, BMI 26.75 $kg \cdot m^{-2} \pm 4.57$ $kg \cdot m^{-2}$) and 178 men (aged from 20 years to 88 years, BMI 26.81 $kg \cdot m^{-2} \pm 3.51$ $kg \cdot m^{-2}$).

To compare data, the participants were classified into three age categories (20–39 years, 40–59 years and ≥ 60 years), according to the stratification data from other studies (15, 32, 33).

5.2.2. Procedures

The study design and experimental procedures were explained to potential participants. After recruitment, participants willing to participate signed an informed consent and completed a socio-demographic questionnaire in addition to being assessed for height and weight.

Each individual was monitored for four to seven days (including weekdays and weekend days), according to studies reporting that at least three to five days of monitoring should be considered in adults (40).

Subjects were fitted with a belt with an attached accelerometer held closely around their waist (9, 40) and were instructed to wear the accelerometer directly over their iliac crest during all

waking hours for four to seven consecutive days, except when showering, bathing, or swimming. Participants were asked to put on the accelerometer first thing in the morning, remove it immediately before going to bed at night, and record the times in a brief log. Any other activity that was performed while not using the accelerometer (e.g., swimming or showering) had to be marked in the log to account for the activity in the data analysis as non-wear time (as opposed to a malfunction in the device). At the end of the collection days, individuals delivered the accelerometer and log to the staff.

Data collection began in September 2008 and ended in April 2010. August was not included in the evaluation because most participants were on summer holiday.

5.2.3. Accelerometer, data reduction and outcome measures

The ActiGraph model (ActiGraph GT1M, ActiGraph, Pensacola, Fla.) was used to assess PA objectively. Devices were calibrated according to the manufacturer's instructions. The validity and reliability of accelerometers within and across monitors have been previously tested (25).

Freedson cut-off points (10), adapted by Mathews and colleagues, were used to evaluate the time spent in different-intensity activities those under 60 years old (21). PA intensity categories were defined as the following: inactive (from 0 $ct \cdot min^{-1}$ to 500 $ct \cdot min^{-1}$), light (500 $ct \cdot min^{-1}$ to 1,952 $ct \cdot min^{-1}$), and moderate to vigorous (above 1,952 $ct \cdot min^{-1}$). These cut-off points were derived from an adult population and were calibrated for walking, the most frequently performed activity.

Because there are no validated cut-off points for elderly individuals and the use of a single cut-off point for all adults may underestimate moderate PA intensity in the elderly, the cut-off points from Davis (8) were used to analyse data from subjects above 60 years old. For this population, the defined categories included sedentary activity (less than 200 $ct \cdot min^{-1}$), light activity (less than 3 METS, ranging from 200 to 1,999 $ct \cdot min^{-1}$), and moderate-to-vigorous physical activity (more than 3 METS, above 1,999 $ct \cdot min^{-1}$). These cut-off points were chosen because they have been used in other studies with similar samples (8, 11, 13, 14).

Intensity categories that corresponded to the same metabolic equivalents as defined for adults and the elderly were given different designations by the researchers (e.g., 'inactive' for adults and 'sedentary' for the elderly). To standardise the terminology and facilitate data presentation, interpretation and comparisons, the categories sedentary activity, light activity, and moderate-to-vigorous PA (MVPA) were used.

Valid data used for analysis consisted of days when a minimum of 10 h of data was collected per day for at least four days. We used 1-min cycles, and 60 min or more of consecutive zero counts were considered missing data or non-wear time and were eliminated from the study (39). Accelerometer malfunction was identified as having counts greater than 18,000 $ct \cdot min^{-1}$. Participants' logs were checked for non-wear time and matched against the accelerometer data. The pedometer function was pre-set to record steps per day ($steps \cdot day^{-1}$).

Recent public recommendations have noted the importance of environmental factors as potential barriers to regular participation in healthy levels of PA (4). Adherence to recommendations for PA, which suggest accumulating a minimum of 30 min of MVPA on most days or, preferably, every day for health benefits (28, 31). These PA recommendations were examined by accumulation in single minutes or in bouts of more than 10 minutes above the MVPA threshold. Because other PA recommendations are relevant, compliance to the goal of 10,000 steps per day was also analysed.

We estimated our outcome variables according to the following:

a) Daily time spent in MVPA ($min \cdot day^{-1}$);

b) Daily average intensity of total PA ($ct \cdot min^{-1}$); and

c) Steps per day ($steps \cdot day^{-1}$).

Data were reduced using MAHUffe software, available online (www.mrc-epid.cam.ac.uk/).

Objective measures of PA were combined with objective measures of weather indicators to accurately correlate the two. Results from daily weather variables (temperature, precipitation, percentage of relative humidity, and daylight hours) were considered for each participant on the days that accelerometer data were collected. Data from weather variables were provided by the Institute of Meteorology of Portugal (I.M., I.P.).

5.3. Statistical analysis

Statistical analysis was conducted using PASW Statistics version 18 (SPSS Inc, USA) and Excel 2007 (Microsoft Corporation). Descriptive statistics are expressed as absolute and relative frequencies, means and standard deviations.

Linear regression was used to estimate MVPA (ct·min-^{1}), daily mean ct·min^{-1} (ct·min-^{1}), and steps per day from weather variables using a stepwise method. Weather variables comprised the following: mean daily air temperature (°C), mean relative humidity (%), total precipitation (mm) and total daylight (h).

Statistical significance level was set at $p \leq 0.05$.

5.4. Results

The studied population consisted of 435 subjects (59% women). Their characteristics are summarised in Table 5.1. The final sample included 69.6% of the eligible sample of 627 participants.

Table 5.1 – Descriptive characteristics of the subjects in total sorted by gender

	All (N=435)	**Women (N=257)**	**Men (N=178)**
	Mean ± SD	Mean ± SD	Mean ± SD
Age (yr)	54.99 ± 20.10	58.99 ± 18.93	49.22 ± 20.39
Weight (kg)	69.95 ± 13.31	64.42 ± 11.22	77.93 ± 11.99
Height (cm)	161.43 ± 10.33	155.25 ± 6.96	170.33 ± 7.51
BMI (kg/m^2)	26.77 ± 4.16	26.75 ± 4.57	26.81 ± 3.51

The average number of valid days the accelerometer was worn ranged from 4 to 7 days for the whole sample, and the time the device was worn ranged from 10.22 to 18.48 hours per day.

Descriptive characteristics of the weather variables corresponding to the days of PA data collection are summarised in Table 5.2.

Table 5.2 – Descriptive characteristics of weather variables during the days of PA data collection.

	Temperature (ºC)	**Relative Humidity (%)**	**Precipitation (mm)**	**Daylight (h)**
Mean	12.7	64.5	2.48	6.92
SD	4.82	13.38	3.97	3.27
minimum	2.02	30.66	00.00	0.27
maximum	24.12	92.50	16.61	13.40

Four percent of the variation in the total volume of PA in women aged 40–59 years was caused by relative humidity (r=0.23, p=0.03).

The length of daylight showed a correlation coefficient of r=0.24 (p=0.02) with the number of steps taken daily by women of 40–59 years. The proportion of the PA variation in steps taken explained by the number of hours of daylight was approximately 4%, and for each increase of one hour of daylight, there was a mean decrease in 245 steps taken per day.

The total amount of PA and MVPA in women above 60 years old were influenced negatively by precipitation (r=0.18, p=0.03 and r=0.192, p=0.03, respectively), with effect magnitudes of approximately 2% and 3%, respectively.

In men 20–39 years old, MVPA was influenced by relative humidity (r=0.22, p=0.0). Nineteen percent of the variation in MVPA was explained by relative humidity.

For men above 60 years old, temperature explained 9% of the variation in total volume of PA (r=0.32, p=0.01), 11% of the fluctuation in MVPA (r=0.36, p=0.00), and 12% of the number of steps taken per day (r=0.36, p=0.00). As the temperature increased by 1°C, older men increased the total volume of PA by 12 ct·min^{-1}, spent 2 min·day^{-1} more in MVPA, and took 307 more steps per day.

For all other gender/age groups, weather indicators did not explain the variations in PA.

Analysis of compliance with the recommendation of at least 30 min above MVPA showed that variation in MVPA in women aged 20 to 39 years was influenced by precipitation (r=0.34, p=0.04), explaining 8% of this variation. An increase in precipitation induced a mean increase in MVPA of 3 min·day^{-1}.

Fluctuations in PA in complying women 40–59 years old were explained by 8%, but in an inverse way by temperature (r=0.31, p=0.01). Increases in temperature of 1°C reflected a mean decrease in MVPA of approximately 2 min·day^{-1}.

Among men aged 20–39 years who complied with the referred target PA, fluctuations in MVPA were due to daylight and to relative humidity (r=0.49, p=0.00). Increases in daylight of 1 h and in relative humidity of 1% induced mean increases in MVPA of 9.8 and 1.9 min·day^{-1}, respectively.

Precipitation explained approximately 13% of the variation in MVPA in complying men 40 to 59 years old (r=0.40, p=0.02). As precipitation increased by 1 mm, MVPA decreased approximately 4 min·day^{-1}. Finally, complying men above 60 years of age were affected by temperature (r=0.43, p=0.03), which explained approximately 15% of the variation in MVPA.

Neither of the gender or age groups of the compliers to the recommendation of 10,000 steps per day none of the gender/age groups showed to was influenced by weather variables.

5.5. Discussion

This study aimed to examine the effects of weather variables on total PA, MVPA, and steps taken per day in adults and elderly individuals. Moreover, we analysed these influences on compliers to the recommended PA.

To our knowledge, only one study in the U.S. has measured PA by means of accelerometry and has isolated weather variables to simultaneously analyse the effects of weather in PA in adults and elderly individuals (22).

Our results show that variations in PA level and in the number of steps taken per day in a Portuguese population were influenced by different weather factors, but the magnitude of these effects varied. Previous studies involving elderly adults based on pedometers found similar correlations between weather variables and PA (38).

Surprisingly, daylight had a small (4%) but negative influence on the number of steps taken daily by women 40–59 years old. These results indicate that an increase in daylight led to a decrease in the number of steps taken per day. Research based on self-reporting methods suggests that day length positively influences PA in normal people (22), and studies using accelerometry have found similar results in functionally impaired elderly people (36). However, researches using pedometers suggested that day length has little influence on PA, meaning that results are not clear. Finally, studies using objective measures similar to the ones used in this study have not yet been reported for normal adults and elderly individuals or adults stratified by age and gender groups.

The total amount of PA and MVPA in elderly women were negatively influenced by precipitation. These findings are in line with previous research on the relationship between older women's participation in an exercise class and environmental variables, which found that any amount of precipitation induced a 25–40% decrease in class attendance (42). Furthermore, a study consisting of 41 older Japanese people (above 70 years) revealed that the number of steps taken per day decreased with increasing precipitation (38), as well as for other studies involving only women (7, 38). We could not confirm that precipitation was the most influential on PA of all the weather variables, as suggested previously (6), because different influences were found for each age and gender group.

In older men, temperature was the weather variable that best explained the variation in total PA, MVPA and the number of steps taken per day. As temperature increased by 1°C, older men increased their total PA by 12 $ct \cdot min^{-1}$, spent 2 min more in MVPA, and took 307 more steps per day. The results for older men confirm data from previous studies that used self-reporting (22) and objective measures (3, 7, 38, 45) and that found a curvilinear relationship between the number of steps taken and temperature in older adults. One of those studies (3) showed that PA during the summer peaked at temperatures of 20°C and declined as temperatures

continue to rise beyond this value, until it reached 30°C. At that point, they observed a significant drop in PA. These results referred to PA and weather variables measured for a period of 7 hours, which corresponded to daytime (0700 to 1900 hours). However, the activities performed by elderly individuals may have been taking place during the early hours of the morning or late hours of the afternoon to avoid extreme temperatures and were thus not accounted for in their results (3). Studies have also suggested that since thermoregulatory capacity decreases with age (1, 30), younger adults less were less affected by temperature than elderly adults. This assumption may explain the differences in results found in this variable, for these age groups.

Self-reporting studies show that individuals committed to exercise or that engage in PA for pleasure are less likely to refer to weather as a barrier or to alter their behaviours towards PA due to adverse weather conditions (12, 17). Our analysis of compliers to the recommendation of attaining at least 30 min of MVPA showed that variations in MVPA in women 20 to 39 years old were positively influenced by precipitation. These results may seem surprising; however, previous studies based on self-reporting have also found that days of uninterrupted precipitation have positive effects on PA among men (22), probably due to a peak in household activities. In another perspective, women of this age may also be involved in organized activities performed in a more controlled environment, as suggested previously for younger groups of age (20). The fluctuations in MVPA in complying women 40–59 years old were weakly explained by temperature and in men of the same age by precipitation. Complying men above 60 years old were affected by temperature. These results may indicate that compliers to PA are influenced by weather variables, which contradicts previous results. However this recommendation has weaknesses because it considers the accumulation of 30 individual min above the MVPA threshold and not only those performed in bouts of 10 or more min above this threshold, as advised in the newest recommendations of PA.

Regarding the individuals who complied with the PA recommendation for 10,000 steps per day, none of these individuals, regardless of their age or gender groups, was observed to be influenced by weather variables. These results agree with previous findings that suggest that individuals highly engaged in PA are less likely to refer to weather as a barrier or to alter their behaviours towards PA in adverse weather conditions (12, 17). Previous studies have also revealed that despite the rain patterns, a small amount of walking still takes place (7). This

argument could explain our results if we consider that individuals attaining the target PA are, in some way, committed to an active lifestyle. If this were true, then regardless of the weather conditions, they would continue to engage in PA. In addition, observational studies on the direct effects of weather in real-time reveal that regular joggers and walkers are not influenced by any of the weather variables (35).

In our study, when an objective assessment of PA was made, objective measures of weather indicators were also taken. Thus, a more accurate correlation between PA and weather elements was established. However, it was impossible to analyse hour-to-hour data because data from I.M., Portugal, referred only to daily measures (over 24 h) and hourly data were not available. The data presented in this study corresponded to daily isolated weather variables associated with day-to-day measured PA and not to a season, which would include several weather variables, associated with PA.

Our participants were recruited bearing in mind the need to have individuals both involved and not involved in PA and/or exercise programs to avoid the bias that has occurred in other studies whose sample was recruited from intervention programs and therefore may not be representative of the whole population.

Because the availability of accelerometers was limited, only approximately 10 participants were able to use the devices at the same time, during the same weather conditions. However, individuals wore the accelerometer for an average of 4 days, which represented the individual's PA during a wide range of weather variables and combinations thereof.

From another perspective, the data of weather variables are restricted to the weather characteristics in the specific region where the data collection took place, which may have limited the amplitude of each variable and may not have accounted for all weather ranges and combinations from other specific locations. For these reasons, the results from this investigation may not be generalised to other populations.

5.6. Conclusions

Our results confirm that environmental factors may influence an individual's will to engage in PA, especially in elderly individuals. The variation in MVPA in younger men was explained by relative humidity. Daylight negatively influenced the number of steps taken per day in middle-aged women, and older women were more influenced by precipitation, whereas older men were more influenced by temperature.

This relevant information should be taken into consideration when defining adequate interventions and health promotion efforts designed to increase PA levels in the general population. If people are reluctant to engage in PA or prefer active transportation because of constraints related to weather conditions, only knowing which adverse conditions influence that their behaviour will permit the definition of alternatives to reverse their inactive habits. In contrast to other environmental factors (such as those of the built environment), factors associated to the natural environment, such as the weather, in addition to not being controllable, may influence people's engagement in PA on a day-to-day basis, especially because it may change daily.

Future investigations should use accelerometers, which would provide data from different intensities of PA and could be matched to hourly data of weather variables. In addition, analysis of the influences of weather variables on individuals involved or not in exercise or PA interventions would help clarify whether individuals who are firmly committed to PA are less influenced by weather factors. Finally, more studies that provide data from gender and age groups in large samples, explore comparisons between rural and urban settings, or study differences in demographic characteristics of the sample should be encouraged.

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Chapter 6 – Conclusions

6.1. Introduction

The starting point of this investigation was to further our knowledge on the daily PA of adults and elderly individuals using objective methods. Specifically, we aimed to a) address methodological concerns related to the assessment of PA by means of accelerometry in these age groups; b) provide descriptive data on objectively measured PA to analyse age and gender differences and to investigate the accomplishment of PA recommendations; c) to examine if there are differences in PA levels when they are assessed at different times of the year; and d) to explore the effects of weather conditions on PA.

6.2. Main findings

Observational and clinical studies suggest that PA plays an important role in reducing the risk of all-cause mortality (Lee & Paffenbarger, 2000; Wei, Kampert, Nichaman, Paffenbarger, & Blair, 1999), particularly in reducing the risk of cardiovascular diseases (Services, 1996; Sesso, Paffenbarger, & Lee, 2000; Wei, et al., 1999) and in the prevention of several other diseases such as obesity, type 2 diabetes, elevated blood lipids, and hypertension (Health, 2004; Services, 1996). However, despite evidence supporting the health benefits of PA, studies and reports on PA prevalence in U.S. (Metzger, et al., 2008; Services, 1996), Europe (Davis & Fox, 2006; Rutten, et al., 2003), and worldwide (Assembly, 2004) have demonstrated that, in general, adults and elderly adults do not engage in sufficient amounts of PA to positively impact their health.

Accurate data are needed to address questions related to an individual's level of engagement in PA and to address the overall characteristics of populations with regards to PA; therefore, accurate methods of assessment are needed for use in these types of investigations. Several methods have been used to measure PA in free-living individuals in both short-term and long-term studies. These methods can vary greatly in their applicability (Chen & Bassett, 2005), and they can be classified into four general categories: subjective reports and observations, indirect calorimetry, DLW, and portable monitors, such as heart rate monitors, pedometers, and accelerometers (Chen & Bassett, 2005; Troiano, 2005).

The selection of a PA assessment method should take into consideration the experimental goals, sample size, budget, cultural and social/environmental factors, physical burden for the subject, and statistical factors, such as accuracy and precision.

There are few available studies that have used objective measures, such as motion sensors, to measure PA in adults, especially in elderly populations (Davis & Fox, 2006; Fox, Stathi, McKenna, & Davis, 2007; Meijer, Goris, Wouters, & Westerterp, 2001). The majority of these studies have relied on self-report methods, which are associated with several sources of error and limitations (Jorstad-Stein, Hauer, & Becker, 2005; Schutz, Weinsier, & Hunter, 2001; C. E. Tudor-Locke & Myers, 2001). For these reasons, we decided to study these particular populations using accelerometry.

There are some concerns associated with the use of this technology, which are important to consider in order to produce accurate results and to better define the study methodology. Thus, we first aimed to review the available data from studies that used accelerometers in adults and elderly adults in Chapter 2. Data were collected on the time spent performing different intensities of PA, daily total PA, and the number of steps taken per day, and then we analysed the differences between study protocols (calibration, cut-points, collection of data and study design) by systematic review.

The results from this study provided us with an overview of the research that has been previously performed in adult and elderly populations, and this review represents an important contribution of this body of work. We found that more than two thirds of the studies involved participants from the U.S., whereas those involving European participants represented only 15% of the sample populations.

We believe that information on countries that have different population characteristics from those of the U.S., especially from these specific adult age groups, is of major importance for the identification of how PA levels are achieved and for the promotion of more adequate intervention strategies according to population characteristics and behaviours.

Previous studies have been mostly cross-sectional and have diverged widely in the ways that they reported data. Only one study identified the time of year at which assessments took place, which suggested a direction that should be taken in our research. Moreover, the

consistency of some data collection methods and the limitations presented by the researchers provided valuable information for the definition of methodology and procedures to be used in the present study.

In our study, there was a great concern about the selection of the cut-off points that were used to define the intensity limits of PA. From the review of studies involving adults, we observed that there was no consensus on or validation of specific cut-off points for PA intensity levels for elderly adults. Thus, our choice of cut-off points was based on the characteristics of the participants in this study and on calibration method activities that have been previously used to define cut-off points.

We originally planned to use a longitudinal design for this study. However, adhering to this design became impossible due to constraints that were associated with wearing the device, the availability of repeat assessments, and the loss of recorded data or equipment malfunction. Thus, it was only possible to gather longitudinal data from a few participants.

The results presented in Chapter 3 revealed that the total PA of the study population, represented by the daily average $ct.min^{-1}$, was similar to findings from previous studies (Davis & Fox, 2006; Hagströmer, Oja, & Sjöström, 2007). The measurement of the total PA levels showed differences only in the elderly adult age group, similar to other studies of European adults (Davis & Fox, 2006; Hagströmer, et al., 2007). However, our results contradicted earlier reports that showed that adult men were more physically active than adult women in North America (Dinger & Behrens, 2006; Trost, Owen, Bauman, Sallis, & Brown, 2002).

Although similar total amounts of PA were attained, there were differences in the PA intensity levels between men and women of some age groups. Although the measurement of the total PA of a population is important information, analysis of PA by intensity levels provides better insight into the data because it allows for the estimation of the amount of minutes spent at each intensity level and indicates the corresponding contribution to the total PA.

Although previous studies have reported that PA declines with age, there may be differences in the ways that total PA is achieved with increasing age. In fact, the literature has indicated that there are differences in the types and levels of PA characteristics in elderly people. Elderly

individuals participate less in formal sports and exercise, but more in daily activities, such as walking (Davis & Fox, 2006), compared to younger adults.

The high correlations that were found between daily average ct.min^{-1} and MVPA in all gender/age groups may imply that this level of intensity has a major impact on the total daily PA across all age groups. This finding suggests that interventions should focus on increasing the amount of MVPA to reverse low levels of PA. In fact, there are currently no defined thresholds for the optimal or minimum amounts of PA needed to provide health benefits or for the effects of PA intensity on health status. However, evidence shows that the intensity of PA is inversely and linearly associated with mortality (Lee & Paffenbarger, 2000).

In this study, our MVPA results were slightly higher than those reported by other studies on European populations (Davis & Fox, 2006; Hagströmer, et al., 2007). Our results also showed that there were no differences in MVPA between men and women until we examined ages above 60 years; at these ages, males attained higher MVPA values, similar to previous reports on European populations (Davis & Fox, 2006; Harris, Owen, Victor, et al., 2009).

It has been previously observed that sedentary activity increases with age (Sallis, 2000; Troiano, et al., 2008), especially in older adults (Troiano, et al., 2008). Except in the groups of women who were 40-59 and >60 years old and who spent a greater amount of time being sedentary, we observed that these behaviours tended to be stabilised, which could be considered a positive finding because at least this behaviour did not increase over time. However, considering the large amount of time that our study population spent being sedentary, it is important to acknowledge the adverse effects of a sedentary and inactive lifestyle on health. Sedentary or inactive behaviours and general physical inactivity are modifiable risk factors for cardiovascular disease and several other chronic diseases, including diabetes, cancer, obesity, hypertension, bone and joint diseases and depression (Blair, Cheng, & Holder, 2001; C.D.C., 1996; Kesäniemi, Riddoch, Reeder, Blair, & Sorensen, 2010; Nelson, et al., 2007; Paffenbarger, Hyde, & Hsieh, 1986; Taylor, Brown, & Ebrahim, 2004; Warburton, Nicol, & Bredin, 2006).

According to our data, a big proportion of the time was spent in sedentary activity. This means that a big part of the day was spent in very low intensity behaviours during waking hours, which include sitting, reclining, or lying down at home, at work, in transit, or during leisure time. Similar results were obtained by a study that used accelerometry in an Australian sample

population of adults (mean age, 53.3 years) and found that 57% of waking hours were spent being sedentary (Healy, Dunstan, & Salmon, 2007). Our results are in agreement with those of previous studies on U.S. populations showing that elderly adults spend approximately 60% of their time, which adds up to more than 8 hours a day, being sedentary (Matthews, et al., 2008).

The PA recommendations suggest that adults and elderly adults should perform a minimum of 30 minutes of moderate to vigorous PA intensity on most days of the week (C.D.C., 1996; Nelson, et al., 2007; WHO, 2005) to obtain optimal health benefits. Data including single minutes or sustained bouts of more than 10 minutes above MVPA threshold, were analysed in our study. This analysis revealed that a high proportion (≥72%) of adults follow these suggestions; however, only approximately 30% of women and 38% of men in the elderly age group followed these recommendations. Previous studies have reported similar results using the same method as our study in European adult and elderly adult populations (Davis & Fox, 2006; Gerdhem, Dencker, Ringsberg, & Akesson, 2008; Hagströmer, et al., 2007).

The rate of adults that complied with the recommendations decreased dramatically when we only considered periods of 10 or more consecutive minutes above MVPA threshold; these results are also in accordance with previous results from a study on European adult populations (Hagströmer, et al., 2007). These results indicate that this recommendation for PA consisting of 10 consecutive minutes or more is much more demanding than the simple accumulation of 30 min above the MVPA threshold, is more difficult to accomplish within the activities of daily living, and, therefore, may need to be given more attention by PA professionals. However, considering the health benefits associated with these guidelines, they should be a priority for PA intervention programmes.

Importantly, longitudinal studies suggest that reported walking and stair climbing independently predicts longevity (Lee & Paffenbarger, 2000). In our study, the number of steps taken per day differed between the youngest and oldest groups and between the sexes. These data are in agreement with the significant correlations found in all age groups of men and women between the daily average $ct.min^{-1}$ and the number of steps taken per day; in other words, these data suggest that a lower daily average $ct.min^{-1}$ is associated with fewer steps taken per day.

When we analysed our data in terms of the recommended daily goal of 10,000 steps for adults (C. Tudor-Locke & Bassett, 2004), we found that none of our gender or age groups accomplished this recommendation in terms of mean values. For both elderly men and women, but especially for women above 60 years of age, this is the period of life in which markedly fewer steps were taken per day, as has been reported by earlier studies (Harris, Owen, & Victor, 2009) and by meta-analysis (Bohannon, 2007). In addition, the percentage of those who did not comply with this recommendation was more than 50% among all gender/age groups. These data, together with the high correlations found between MVPA and the number of daily steps, may indicate that interventions that act to promote an increase in the number of steps taken per day should be encouraged and may also contribute to an increase in MVPA.

The results presented in Chapter 3 represent the overall characteristics of the sample population at a specific time frame when evaluations took place. Knowledge about the current PA levels of a population is a valuable reference for the determination of which interventions and how interventions for the promotion of PA should be developed (Martin, Morrow, Jackson, & Dunn, 2000). However, the main goal for researchers and practitioners should be to promote strategies that encourage people to have a less sedentary lifestyle and to engage in regular PA over a lifetime, not only during a specific time of the year or during a specific time of one's life.

In fact, consistent participation in PA during most months of the year has been related to a reduced risk for cardiovascular events (Magnus, Matroos, & Strackee, 1979). Moreover, the previously observed fluctuations in PA throughout the year (Newman, et al., 2009) and seasonality of activity behaviours (Levin, Jacobs, Ainsworth, Richardson, & Leon, 1999; Matthews, Freedson, & Stanek, 2001) suggest that there is a need to assess PA levels several times per year to obtain the most precise data on typical PA to identify target populations and to plan PA interventions. Furthermore, the season or the time of the year in which a study is carried out has been identified as a potential source of variance in the reporting of daily PA levels (King, Stokols, Talen, Brassington, & Killingsworth, 2002; Matthews, Ainsworth, Thompson, & Basset, 2002), and therefore, studies that consider PA assessment at only one time of the year may be biased (Pivarnik, Reeves, & Rafferty, 2003).

For these reasons, in Chapter 4, we analysed and discussed fluctuations in all types and intensities of PA throughout the year.

Several studies have reported that there are monthly variations in leisure time PA (LTPA) observed throughout the year in men and women (Matthews, et al., 2001; Merchant, Dehghan, & Akhtar-Danesh, 2007; Newman, et al., 2009; Pivarnik, et al., 2003) and in postmenopausal women (Newman, et al., 2009) using questionnaires. However, only one study in a Japanese population that used accelerometry has reported fluctuations in PA (Yasunaga, et al., 2008) throughout the year. Our data demonstrated that PA does not fluctuate widely throughout the year; however, in men, a fluctuation was found due to an increase observed in MVPA from T1 (September to December) to T2 (January to April) in the 20- to 39-year-old group.

Gender differences were only observed in T1 (September to December), when 40- to 59-year-old men spent more time being sedentary and less time performing light activity than women of the same age.

Our research showed that there was a period of the year when PA significantly decreased in the elderly. This decrease consisted of an increase in sedentary activities and a decrease in the number of steps taken per day. These changes occurred in T2 (January to April), the period when more sedentary activity took place in older age groups. Other researchers found that the quantity of LTPA was lowest in January, which could be a probable cause for the overall decrease in the amount of PA during T2. Moreover, these authors speculated about the cyclical nature of PA, which follows the same pattern as the average daily temperature and the hours of daylight (Pivarnik, et al., 2003).

The levels of adherence to the various PA recommendations in the different gender/age groups varied widely between the periods of the year. Our data showed that greater than 50% of men and women who were 20-39 or 40-59 years old complied with the recommendation that one should accumulate 30 minutes of PA per day above the MVPA threshold throughout the course of a year. However, the percentage of those who complied with this recommendation dropped in all gender/age groups when the accumulation of 30 minutes required periods of 10 or more minutes above the MVPA threshold, especially in men. Moreover, very few age groups achieved a level of 50% of compliers with the PA

recommendation of 10,000 steps per every day across the year (only 20- to 39-year-old women in T3 and 40- to 59-year-old men and women in T2).

Thus, it appears that the PA recommendation that advises the accumulation of 30 minutes of PA per day with bouts consisting of 10 or more minutes above the MVPA threshold is extremely difficult to adhere to in all gender/age groups, with the exception of the group of 40- to 59-year old women.

Less than 50% of the elderly men and women complied with any of the PA recommendations. In accordance with our results, the literature shows that people of retirement age (older than 65 years) are less likely to meet the PA target (Allender, Hutchinson, & Foster, 2008).

Our results showed a positive (>50% of compliers) and relative stabilisation of the compliance with the PA recommendation for the accumulation of 30 minutes of PA above the MVPA threshold throughout the year. These findings agree with the results from a previous European study (subjects were 45 to 69 years old) based on self-report that observed constant levels of the minimum daily recommended PA across seasons in women (Mein, Shipley, Hillsdon, Ellison, & Marmot, 2005).

In contrast, when we considered the other two PA recommendations, the percentage of those who complied with these recommendations was dramatically reduced.

Because the recommendation of accumulating 30 minutes per day with bouts of 10 or more minutes above the MVPA threshold may be difficult to implement and measured by the common individual, it may be advisable for PA promotion strategies to encourage the accomplishment of the 10,000 steps per day goal, which could be easily measured by a pedometer.

This study resulted in the identification of the specific time of year and in the detection of the predominant intensity activities in which people are usually involved. We believe that this information is of high relevance to researchers and practitioners because it will allow them to define more structured and improved goal-oriented strategies for the promotion of PA.

Multiple studies have reported monthly variations in total PA and in LTPA in both men and women (Matthews, et al., 2001; Merchant, et al., 2007; Newman, et al., 2009; Pivarnik, et al.,

2003; Yasunaga, et al., 2008) throughout the year. These monthly variations were affected by season, likely due to weather conditions, and reflected higher quantities of LTPA in the winter compared to the summer and other seasons (Matthews, et al., 2001; Merchant, et al., 2007; Newman, et al., 2009; Pivarnik, et al., 2003; Shepard & Aoyagi, 2009). These differences may also be caused by fewer and shorter LTPA sessions observed in the winter (Pivarnik, et al., 2003). In addition, according to a reviews of studies considering total PA in developed societies, the winter season has been correlated with a reduction in PA (Chan & Ryan, 2009), and temperature and rainfall have been shown to have a dominant influence on PA (Shepard & Aoyagi, 2009). Because of such reports in the literature and because differences in PA had been observed between the periods of the year, we aimed to explore the influences of weather variables on PA in Chapter 5.

Although our results confirmed that environmental factors do influence an individual's willingness to engage in PA, similarly to previously published studies (Chan, Ryan, & Tudor-Locke, 2006; Matthews, et al., 2001), our data indicated that these influences are extremely weak. We could not confirm that precipitation, out of all weather variables, is the most influential on PA as suggested previously (Chan & Ryan, 2009) because different influences were observed based on age and gender groups.

Younger women did not appear to be influenced by weather variables in any case, whereas the MVPA of similarly aged men was explained by the relative humidity.

Surprisingly, daylight had a small (4%), but negative, influence on the number of steps taken daily by women who were 40–59 years old. These results indicate that an increase in daylight led to a decrease in the number of steps taken per day. Research based on self-reporting methods suggests that day length positively influences PA in normal people (Matthews, et al., 2001), and studies using accelerometry have found similar results in functionally impaired elderly people (Sumukadas, Witham, Struthers, & McMurdo, 2009). However, studies using objective measures similar to the ones used in this study have not yet been reported for normal adults, elderly individuals or adults stratified by age and gender groups. The total PA and MVPA of elderly women were negatively influenced by precipitation in women and by temperature in men.

Studies based on self-report methods showed that people who are committed to exercise or who engage in PA for pleasure are less likely to view the weather as a barrier to PA or to alter their behaviours towards PA in adverse weather conditions (Godin, 1994; Humpel, Owen, & Leslie, 2002). Our analysis of the individuals who complied with the recommendation that one should participate in at least 30 minutes of MVPA showed that the variation of MVPA in women who are 20-39 years old is positively influenced by precipitation. At first, these results may seem counterintuitive; however, previous studies based on self-report have also found that days of solid precipitation had positive effects on PA in men (Matthews, et al., 2001), likely due to a peak in household activities. Fluctuations in MVPA in women who are 40-59 years old and who complied with the same recommendation were weakly explained by temperature (8%).

Regarding the individuals who complied with the PA recommendation for 10,000 steps per day, none of these individuals, regardless of their age or gender groups, was observed to be influenced by weather variables. These results are in agreement with previous findings that have suggested that individuals who are highly engaged in PA are less likely to view the weather as a barrier or to alter their PA behaviours in adverse weather conditions (Godin, 1994; Humpel, et al., 2002). Studies have also revealed that, despite rain patterns, a small amount of walking still takes place (Chan, et al., 2006). This argument could help to explain our results if we assume that the individuals who were attaining their target PA were, in some way, committed to an active lifestyle. If this were true, regardless of weather conditions, they would continue to engage in PA.

6.3. Implications for practice

Despite a loss of approximately 30% of the initial sample population in the present study due to factors such as not wearing the accelerometer equipment for at least four days and loss of collected data associated with battery failure or equipment malfunction, uniaxial accelerometers are adequate and reliable instruments for the assessment of PA in large sample populations. Although there may be some individuals who refuse to wear an accelerometer for an entire week, a required minimum of four days of wearing an

accelerometer for data collection is feasible for the majority of individuals and provides reliable data on daily PA.

Data on the time spent at different intensity activities during the daily life of an individual, which are provided by the accelerometer, can be used as a baseline PA level and as the starting point for an intervention programme designed to enhance an individual's active lifestyle or to promote their engagement in PA. Moreover, the detection of the predominant intensity levels of the activities in which people are accustomed to will allow for more structured and goal-oriented strategies for the promotion of PA.

The information that would be possible to pass on to each individual regarding their day-to-day or weekly performance in terms of the PA target recommendations and the explanations of the health benefits associated with attaining those targets could be of high value and could help to guarantee an effective and individualised intervention over long periods of time.

Our results showed differences in PA data that were collected at different times of the year. Therefore, it would be advisable to repeat assessments at different times of the year to provide more accurate data on sedentary behaviours and responsiveness and/or commitment to an active lifestyle or exercise programme throughout the year.

Moreover, because certain times of the year are associated with decreased amounts of engagement in PA in specific age groups, especially in the elderly, PA promotion programmes should unite efforts to plan well-built interventions during these times of the year to minimise this observed reduction in PA. These programmes should also encourage stable involvement in an active lifestyle or exercise programme throughout the year rather than participation during a restricted period of time to ensure increased health benefits in the long-term.

Our study revealed high correlations between average daily average $ct.min^{-1}$ and MVPA in all gender/age groups, which may imply that this level of intensity has a major impact on the total amount of daily PA across age groups and suggests that interventions should focus on increasing the amount of MVPA to reverse the observed low levels of PA.

Our results indicate a relative stabilisation of the adherence to PA recommendations throughout the year if we rated our observations according to the PA recommendation for accumulating 30 minutes above the MVPA threshold. The rate of adults that complied with the

PA recommendations decreased dramatically when we rated our observations according to the recommendation for PA that included periods of 10 or more consecutive minutes above the MVPA, indicating that this recommendation is much more demanding than the simple accumulation of 30 minutes above the MVPA threshold and is more difficult to accomplish within the activities of daily living; therefore, these recommendations may need more attention from PA professionals.

Intervention strategies should focus on increasing the levels of participation in PA to ensure the maintenance of a consistent PA level throughout the year by encouraging the accomplishment of daily goals based on the number of steps taken per day; this type of goal could be easily measured by affordable equipment, such as a pedometer, and also emphasises the performance of sustained periods of PA (at least 10 minutes) in order to achieve PA recommendations.

Less than 50% of the elderly men and women in the present study complied with any of the PA recommendations, which makes this population a top priority for intervention programmes.

Overall, environmental factors may have a weak influence on an individual's will to engage in PA. However, as an example, our data indicate that elderly individuals are more affected by temperature; therefore, intervention strategies should account for age group when defining adequate interventions and health promotion efforts designed to increase PA levels in this specific population as well as in the general population.

If people are reluctant to engage in PA or prefer active transportation due to constraints related to weather conditions, then understanding which adverse conditions influence their behaviour will permit the establishment of alternatives to reverse inactive habits (e.g., utilisation of indoor facilities, advice on the selection of adequate equipment or on the activities to do in the home environment). Factors associated with the natural environment, such as the weather, in addition to not being controllable, may influence an individual's engagement in PA on a day-to-day basis, especially because these factors may change daily.

Summary

Intervention strategies should focus on increasing the levels of participation in PA and on ensuring the maintenance of a consistent PA level throughout the year by encouraging the accomplishment of daily goals based on the number of steps, which should be adjusted to gender/age characteristics of the population. Intervention strategies should also emphasise sustained periods of at least 10 minutes above the MVPA threshold in order to achieve PA recommendations for the general population, but especially for the elderly. Moreover, surveillance data should be considered as a method to assess the levels of achievement of the intervention objectives.

The results from this study contribute to the knowledge of the Portuguese population with respect to its PA levels, its compliance with PA guidelines, its variance throughout the year, and the factors that may affect its adherence to participation in PA, such as weather conditions. These data will contribute to the improvement of PA promotion strategies and intervention programmes through the resulting recommendations for ways to potentiate interventions aimed at increasing daily PA levels and reversing sedentary behaviours throughout the year and across age groups.

6.4. Future research

- Longitudinal studies would be of high value to account for follow-up and updated data as well as to provide more accurate estimations of PA levels and for the collection of surveillance data throughout the year on factors that influence PA.
- Investment in the defining of cut-off points for the elderly or in the development of procedures for the reduction of raw data from accelerometers should be encouraged to account for individualisation of the assessments and results.
- To analyse differences in PA between weekdays and weekend days and between periods of the day would allow for better structuring and planning of the promotion of PA interventions.

- To study the influence of other determinants of PA and how they affect the level of engagement in PA.
- To examine health benefits associated with predominant levels of PA.
- To programme PA interventions based on daily goals and on the number of steps taken per day along with the corresponding analysis of such a programme's long-term impacts on health and lifestyle.
- To use accelerometers to provide data on different intensities of PA and to match the collected data with hourly data on weather variables.
- Analysis of the influences of weather variables in individuals who are and who are not involved in exercise or PA interventions would help to clarify if the individuals committed to PA are less influenced by weather factors than those who are not committed to PA.
- Studies are needed to provide data on gender and age groups and to explore comparisons between rural and urban settings, different locations, and/or differences in sample demographic characteristics.

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Physical activity in adults and elderly adults measured by accelerometry – The influences of age group, gender, time of year, and weather.

Submitted manuscripts

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TERESA PAULA DOMINGUES DA CUNHA BENTO

Physical activity in adults and elderly adults measured by accelerometry

The influences of age group, gender, time of year, and weather

DISSERTAÇÃO DE DOUTORAMENTO

EM CIÊNCIAS DO DESPORTO

Universidade de Trás-os-Montes e Alto Douro
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UNIVERSIDADE DE TRÁS-OS-MONTES E ALTO DOURO

Teresa Paula Domingues da Cunha Bento

Physical activity in adults and elderly adults measured by accelerometry

The influences of age group, gender, time of year, and weather

Este trabalho foi expressamente elaborado com vista à obtenção do grau de Doutor em Ciências do Desporto, de acordo com o disposto no Decreto-lei nº216/92, de 13 de Outubro.

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