



Active living and built environment: Active transport to school in Portuguese adolescents

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ERRATA

Na Introdução, página 5 onde se lê “PAPER I: analyze the associations between the perceptions of the built environment with objective measured overall physical activity and active transport in adolescents;” deverá ler-se “PAPER I: analyze the associations between the perceptions of the built environment with overall physical activity and active transport in adolescents”;

No Capítulo 2 - Experimental work, página 27, a figura 2 “PALMS data flow diagram” não foi impressa a cores pelo que deverá ser substituída pela que se segue:

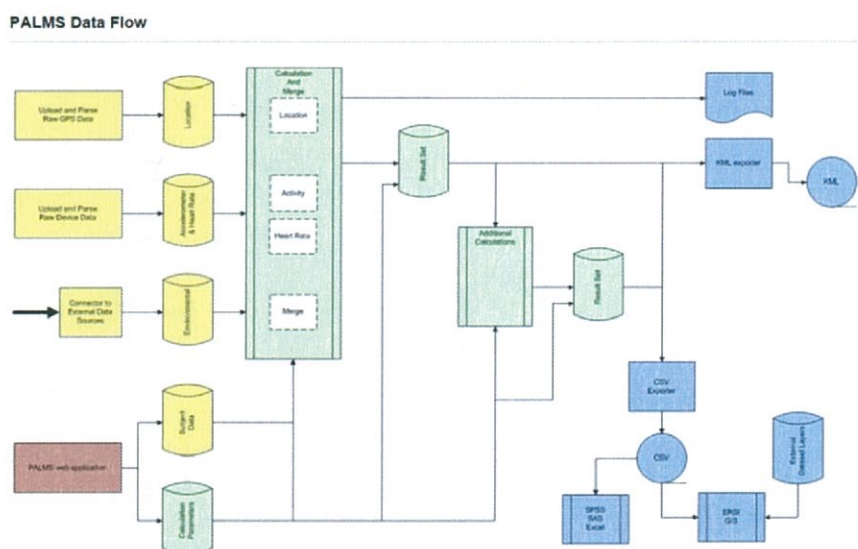
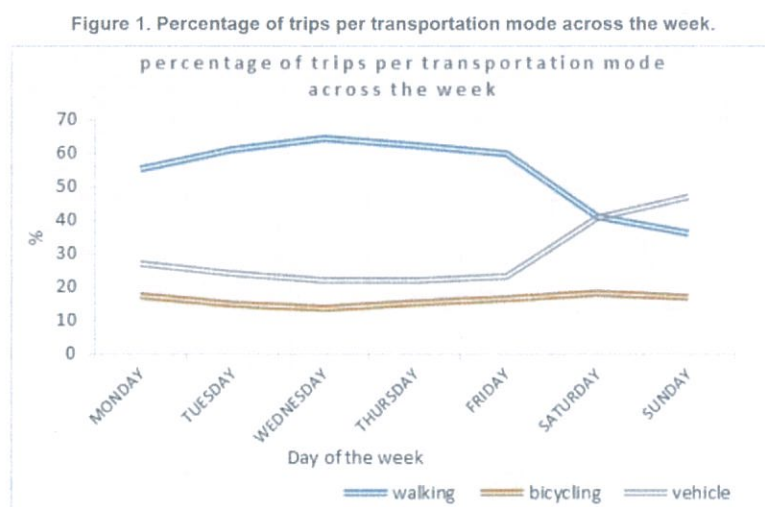


Fig.2 PALMS data flow diagram

Ainda no Capítulo 2 - PAPER IV, página 70, a figura 1 “Percentage of trips per transportation mode across the week” não foi impressa a cores e deverá ser substituída pela que se segue:



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ABSTRACT

The declining levels of participation in general physical activity have led active commuting to school (ACS) to be seen as a key strategy to increase physical activity (PA) levels in school-aged children and built environmental interventions have been recommended by international authorities. However, this is a new area of research and several limitations exist in the conceptualization and methodology of current research. As little is known about the importance of ACS for children's health and no data exists on the patterns and environmental correlates of this behavior in Portuguese adolescents, an essential step for the development of evidence-based and effective interventions, the aims of this thesis were: a) to analyze the associations between the perceptions of the built environment with overall PA and active transport; b) identify the proportion of activity spent at different PA domains; c) examine the relationship between ACS and metabolic risk factors; d) explore ACS behavior using an objective methodology.

Four papers involving 1067 youth (574 girls) between 10 and 18 years old from public schools in Porto area were conducted. Outcome measures involved both self-reported and objective measures of means of transport to school (How do you usually travel to school?" and "How do you usually travel from school?"; GPS and accelerometer GT3x), PA (Telama et al., 1997); accelerometers GT1M; GT3x) and built environment (PEACH project questionnaire (Page et al., 2010); GPS and GIS). Secondary measures included dietary intake through 24h recall, anthropometric measurements according to standard protocols and sociodemographic data accessed through a questionnaire. PALMS and Arc GIS were used to combine data from accelerometer, GPS and built environment.

Cross-sectional results from our thesis suggest that perceptions of environment correlates are gender and behavior specific with higher levels of overall PA being predicted by better perceptions of sports equipment at home and aesthetics within the neighborhood among both boys and girls and among boys, respectively. On the other hand ACS, was associated with safety perceptions in girls. Linear regression analysis showed that the most important predictors of daily MVPA were transport domain in girls and leisure domain for boys, however boys spent a higher proportion of time in MVPA bouts in the school domain.

Walking was found to be the most frequent means of transport to school while cycling was found to be unusual in Portuguese children. Distance emerged as a significant predictor of ACS as increased distances were associated with higher levels of passive transportation to school. Results also indicate that 2.0 km seems to be a reasonable maximum distance for walking between home and school. On average, a walking round trip home-school-home represented 40% of recommended daily MVPA. Moreover, children who walked to school had higher odds of having a better waist circumference and HDL-C profile when compared to children using passive means of transport. Finally, our findings suggest that the combined use of GPS, GIS and accelerometer can help solve the methodological issues traditionally seen in this field of research as they give us an environmental exposure measure, can spatially locate PA and can be used to objectively access active transport.

In conclusions findings from our research suggest ACS may play an important role for increasing PA levels and for health improvement. Efforts to increase ACS should include improved safety and decreased distance between home and school and that can be only achieved in a multi-sectorial intervention that targets specific built environmental features.

RESUMO

Os baixos níveis de participação em atividade física AF levaram a que o transporte ativo para a escola (TAE) fosse visto como uma potencial estratégia-chave para aumentar os níveis de AF em crianças e jovens em idade escolar, de tal modo que várias intervenções ao nível do ambiente construído têm sido propostas pelas autoridades internacionais no sentido de aumentar este comportamento. Contudo, esta é uma área de pesquisa muito recente e várias limitações existem ao nível da conceptualização e metodologias.

Como pouco se sabe acerca da importância do TAE para a saúde infantil e não existem dados acerca do padrão deste comportamento nem das suas relações com o ambiente em adolescentes portugueses, esta tese teve como principais objetivos: a) analisar as associações entre as perceções do ambiente construído, a AF e o TAE; b) identificar a proporção de atividade física realizada em cada um de quatro domínios (lazer, escola, transporte e casa); c) examinar a relação entre o TAE e fatores de risco metabólico; d) explorar padrões de TAE usando uma metodologia objetiva.

Para tal foram elaborados quatro estudos envolvendo 1067 crianças e jovens (574 raparigas) entre os 10 e os 18 anos de escola públicas da área do grande Porto. Para avaliação das variáveis principais do estudo foram utilizadas quer medidas subjetivas quer medidas objetivas: O transporte ativo foi avaliado através da pergunta “Como te costumavas deslocar de e para a escola?” no estudo I e III enquanto no estudo IV foi utilizada uma combinação de dados obtidos pelo GPS e acelerómetro; A atividade física foi medida pelo questionário criado por Telama (1997) no estudo I e por acelerómetros nos restantes; o ambiente construído foi obtido por questionário (Peach project) (Page et al. 2010) e por recurso a GPS e sistemas de informação geográfica. De entre as variáveis confundidoras a ingestão calórica foi obtida com recurso à recordação de 24h, os dados antropométricos pela utilização dos protocolos padrão e os dados sociodemográficos foram obtidos por questionário. Para combinação e tratamento dos dados obtidos pelo acelerómetro, GPS e ambiente construído foram usados os softwares PALMS e Arc GIS.

Os resultados da nossa tese sugerem que as relações entre as perceções do ambiente e a atividade física são específicas em termos de género e de tipo de comportamento avaliado. No geral, melhores níveis de AF total estão associadas a uma melhor perceção de equipamento desportivo em casa entre rapazes e raparigas e a questões estéticas na vizinhança nos rapazes. Por outro lado, o TAE mostrou-se associado a perceções de maior segurança em raparigas.

A análise de regressão linear mostrou que os preditores mais importantes do MVPA diário foram o domínio do transporte nas raparigas e o domínio do lazer nos rapazes. No entanto, entre os rapazes uma maior proporção do tempo total em bouts de MVPA foi passada no domínio escola.

Ir a pé para a escola foi o modo de transporte mais frequentemente utilizado e a bicicleta o menos comum. Os resultados mostraram que a distância de casa à escola é um preditor significativo do TAE e maiores distâncias associam-se a maiores níveis de transporte passivo nas deslocações casa-escola. Distâncias até 2 km são aparentemente razoáveis para deslocações a pé no percurso casa-escola. Em média uma viagem casa-escola-casa representou cerca de 40% dos 60 minutos de MVPA recomendados em crianças e jovens. Além disso, utilizadores de TAE apresentaram uma maior probabilidade de terem melhor perfil lipídico de HDL-C e um menor perímetro da cintura do que utilizadores de meios passivos nas viagens casa-escola. Os resultados desta tese sugerem ainda que a utilização combinada de GPS, acelerómetro e sistemas de informação geográfica podem ajudar a

ultrapassar algumas falhas metodológicas tradicionais desta área de estudo, uma vez que nos permitem localizar espacialmente a atividade física, dão uma medida de exposição ambiental, e sobretudo porque podem constituir uma medição objetiva dos meios de transporte utilizados.

Os resultados da nossa pesquisa sugerem que o TAE poderá desempenhar um importante papel no aumento dos níveis de AF e na melhoria da saúde. Assim, as intervenções para aumentar os níveis de TAE devem incluir diminuição das distâncias entre casa e a escola e melhorias a nível da segurança; alterações essas que serão conseguidas apenas com uma intervenção multisectorial centrada em características específicas do ambiente.

LIST OF ABBREVIATIONS

ACS: Active commuting to and from school

AG: Active group

ANOVA: Analysis of variance

BMI: Body mass index

CDC: Center of Disease Control

CI: Confidence interval

CM: centimeter

CVD: cardiovascular disease

GIS: Geographical Information System

GLU: Glucose

GPS: Global Position System

HDL: High-density lipoprotein cholesterol

ICC: Intra-class correlation

IDF: International diabetes federation

INE: National Statistics Institute

Kcal: Kilocalories

Kg: Kilograms

Km: Kilometers

Km/h: Kilometers per hour

LAG: Low active group

Md/dl: Milligrams per deciliter

Min/day: Minutes per day

MM hg: Millimeter of mercury

MVPA: Moderate to vigorous physical activity

N: Number

OR: Odds ratio

PA: Physical activity

PALMS: Personal Activity Location Measurement System

PE: Physical education

SD: Standard deviation

SLOTH: Sleep, leisure, occupation, transport and home

SES: Socioeconomic status

TG: Triglycerides

UK: United Kingdom

US: United States

WC: Waist circumference

WHO: World Health Organization

INTRODUCTION

Regular physical activity, of at least moderate intensity, is widely recognized for its health benefits in children and adolescents and may play an important role in both primary and secondary prevention of cardiovascular disease (CVD). Evidence accumulated over the years shows that being physically active can help reduce the prevalence of obesity in children and is associated with a decrease in cardiovascular risk factors such as lipid disorders, high blood pressure, insulin resistance, among others non-traditional cardiovascular risk factors (inflammatory markers, endothelial function and heart rate variability) (Expert panel on integrated guidelines for cardiovascular health risk reduction in children adolescents, 2011). Additionally, physical activity can lead to improved bone health (Gunter et al., 2012), enhanced academic performance (Howie & Pate, 2012), better physical fitness and reduced symptoms of anxiety and depression (Mota-Pereira et al., 2011; Twisk, 2001). The worldwide recognition of such evidence are expressed in the current recommendations for Physical Activity for children and adolescents widespread by international public health authorities (Centers for Disease Control and Prevention; United Kingdom Department of Health; World Health Organization, 2010). These guidelines advocate that children and adolescents should engage in at least 60 minutes per day of moderate to vigorous physical activity (MVPA) and in muscle- and bone-strengthening activities on at least 3 days of the week to achieve and maintain physical and mental health benefits and prevent non communicable diseases (World Health Organization, 2010). Unfortunately, worldwide and national representative data show that most children are far from accomplishing these recommendations (Hallal et al., 2012) In addition physical activity levels decline substantially with age, particularly throughout adolescence (Dumith et al., 2011). Data from the Health Behavior in School-aged Children study involving 35 countries in Europe and North America, reveals only 34% of youth meeting physical activity guidelines and places Portugal in the bottom quartile satisfying this criteria (World Health Organization, 2004). According to this report only 33.6% and 16.6% of Portuguese 11-15 year-olds boys and girls, respectively, are sufficiently active. Similarly, another study involving Portuguese youth found that 36% of 10-11 year-olds children and 4% of 16-17 year-olds adolescents meet physical activity guidelines after using an accelerometer for four consecutive days (Baptista et al., 2012). Moreover, physical activity patterns of European youth

were consistently found to be sporadic and with few sustained periods of MVPA (Armstrong & Welsman, 2006) that may be insufficient for achieving and maintaining health benefits.

The declining levels of participation in general physical activity together with the low rates of active transportation have led active commuting to school (ACS) to be seen as a key strategy to increase physical activity levels in school-aged children (National Safe Routes to School Taskforce, 2008). However, little is known about the importance of ACS for children's health as the long-term health benefits of regular ACS are unknown (Sirard & Slater, 2008). Furthermore, only a couple of studies have addressed ACS in Portugal and no data exists on the patterns and correlates of this behavior, an essential step for the development of evidence-based and effective interventions. In order to fulfill this knowledge gap, the current dissertation will explore associations between active commuting and metabolic health and describe ACS patterns in Portuguese children.

For effective promotion of physical activity behaviors among youth built environmental interventions have been recommended by international authorities (World Health Organization, 2007). However, despite several environmental correlates for physical activity have been suggested in adults (McCormack & Shiell, 2011) evidence for youth is not consistent, as indicated by a large number of null associations (de Vet et al., 2011; Ferreira et al., 2007). One possible explanation is since the area of built environment and physical activity is still in its infancy, limitations exist in the conceptualization and methodology of current research. This includes the definitions of environmental features, neighborhoods, no standard measurement, and statistical analyses. In fact a recent review identified several gaps in the literature such a) as reliance on North American studies (70% of the papers), b) a small number of studies used objective methods to access both built environment and physical activity variables; c) few used physical activity behavior specific measures for the built environment; c) few used population specific analyses and d) there were almost no longitudinal studies (Ding et al., 2011).

This dissertation will try to help clarifying some of these gaps. To begin with, we'll be one of the first teams conducting the research in Portugal that has a very different built environment from the United States. Given the large variation in

built environment, evidence suggest that findings should be viewed within their national context as relationships between the built environment and physical activity are context specific (Giles-Corti et al., 2009); Second, as ecological models suggest correlates are specific to domains (Sallis et al., 2006), we will look at behavior specific environmental correlates for active commuting to school and leisure time physical activity; Third, we will use behavior specific methods to access transport related physical activity with self-reported and a new objective methodology (global position system). Fourth, environmental variables will be measured subjectively through questionnaires and objectively with geographical information systems (GIS) as there is more consistent support for variables when environments were objectively measured (Ding et al., 2011). Finally, we will use a brand-new web-based application that may be the key to uniform measures and methods in the study of the built environment and physical activity and allow comparability of results across countries.

This thesis includes four papers using three separate datasets, united by the overarching theme of understanding the built environmental influences on active living and particularly the active commuting behavior in youth:

Paper I: analyze the associations between the perceptions of the built environment with objective measured overall physical activity and active transport in adolescents;

Paper II: identify the proportion of activity and MVPA time spent at different PA domains;

Paper III: examine the relationship between active commuting to/from school and metabolic risk factors;

Paper IV: explore active commuting to school behavior using an objective methodology.

CHAPTER 1 - Theoretical background

ECOLOGICAL MODEL FOR PHYSICAL ACTIVITY

Identifying the factors that can be changed to influence physical activity behavior is crucial to address potential barriers and create opportunities to engage in sustainable active lifestyles. Intrapersonal and interpersonal variables are widely studied, however approaches to understand behavior change proposed throughout the years mostly focused on individual and social factors showed only limited success (Bauman et al., 2012). Small to moderate effect sizes, modest recruitment rates and poor physical activity maintenance discloses that changing individual behaviors in isolation may be difficult, particularly in an environment that constrains the behavior (Sallis et al., 2006). On the other hand, usual physical activity takes place during daily activities within the built environment in specific places (United Kingdom Faculty of Public Health, 2013). So, focusing on the environmental characteristics of those places may reveal potential targets and leverages for change. Moreover, environmental interventions are promising to the extent that are expected to have widespread long-term impact on the population as changes in the built environment can benefit a large number of people at a time and are easily integrated into daily life (Ding, 2012).

Several theories and models are guiding the selection of variables for study. Resulting from the integration of ideas from a broad range of disciplines including public health, urban design, transportation plan and economy, current theoretical framework based on ecological models, recognizes that decisions to be physically active are likely to be influenced by different factors, operating at multiple levels in a complex relationship (Sallis et al., 2006). Individual (age, gender, attitudes), social (support networks, social norms) and physical environmental (built environment, economic, policy) variables are thought to affect active behaviors concurrently (Sallis et al., 2006). Additionally, as interactions at different levels can happen, each levels' separate effect on behavior could be enhanced or decreased. A conceptual ecological model for physical activity showing different levels of influence and associated variables is illustrated in figure 1. A key precept of ecological models is the inclusion of environmental and policy variables that may influence behavior.

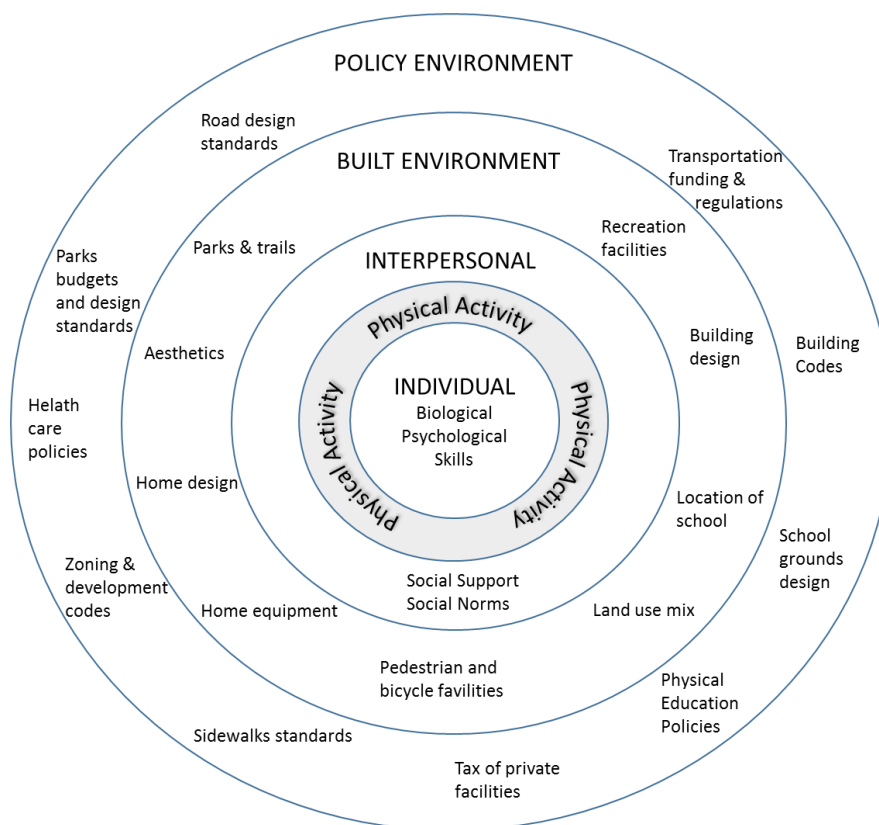


Figure 1. An ecological model of physical activity adapted from Sallis et al. 2006

Individuals are not the focus, rather is the dynamic and reciprocal interaction between people and the environment where they live, learn, work and play (Sallis et al., 2006). According to ecological models multilevel interventions to increase physical activity will be most effective when operated at different levels (Heath et al., 2012) targeting individuals, social environments, physical environments and policies (Sallis et al., 2006). Given this, relationships between variables are likely to be specific to the social, political and economic context, highlighting the need for studies on the role of the built environment on active living in the Portuguese context.

ACTIVE COMMUTING TO SCHOOL

Until recently, strategies to promote physical activity were essentially built on structured exercise programs, sports and physical education classes (van Sluijs et al., 2007). Yet, children can engage in and accumulate physical activity in

several domains (Pratt et al., 2004). In fact, as physical activity has expanded to a broader range of activities “Active living” has emerged as a broader concept that incorporates exercise, recreational activities, household and occupational activities, and active transportation (Sallis et al.).

Despite being a behavior neglected for several years in physical activity research, active commuting to and from school have seen a rapidly grow in the body of literature in last years. Active commuting may be described as any form of human-powered transportation including walking, cycling and other non-motorized vehicles like small wheeled transport (National Public Health Partnership and the Strategic Inter-Government Forum on Physical Activity and Health, 2001). In fact, active commuting to and from school can be a potentially important contributor to daily physical activity for school-aged children due to its regularity. Research findings suggest that active commuters, mostly walkers, are more physically active than those children who use motorized transport to school and differences can be as high as twenty more minutes of MVPA (Faulkner et al., 2009). Active commuting to and from school has also been significantly associated with a healthier body composition in youth and improved cardiorespiratory fitness (Lubans et al., 2011). One longitudinal study extended these findings showing, after 6 years of follow-up, that students who did not cycle to school at baseline, but who had changed to cycling at follow-up, were significantly fitter than those who did not cycle to school at either time point (Cooper et al., 2008). Using the same Danish sample, another study identified an enhanced pattern of CVD risk factor profile: better cholesterol/HDL ratio, better glucose metabolism, and a lower composite CVD risk factor score in children that cycled to school compared to the ones using other means of transport (Andersen et al., 2011). In addition active commuting has been suggested to enhance social interaction (Kearns et al., 2003) and promote independent mobility (Marques et al., 2012), while minimizing the impact of traffic congestion and the associated environmental costs (Kearns et al., 2003).

Data for active commuting in children is scarce in Portugal, however similarly to countries like the United States (McDonald, 2007) or United Kingdom (Black et al., 2001), transportation statistics demonstrates an increasing prevalence of motorized transportation in the general population. From 2001 to 2011 car trips

increased from 45.7% to 61.6%; on the other hand, there was a 34.7% reduction in the number of active trips over the same period as walking trips decreased from 25.1% to 16.4%. In the Northern region these significant changes in the travel patterns are explicit by the alarming declining in walking trips from 37% in 1991 to 27.9% in 2001 and to only 16.9% in 2011. These numbers represent a 54% drop in active commuting (Instituto Nacional de Estatística, 2003, 2012) and a decreased potential to achieve physical activity recommendations.

Active commuting to school has been self-reported by 56% of 15 years old European adolescents (including Portuguese) in the European Youth Heart Study back in 1998-9. Cross country data show similar results in children's rates of active commuting to and from school. A study conducted in 2004 in the city of Aveiro, with an area of 199,9 km and 60,000 inhabitants revealed that 52.6% of the 14.7 years old participant girls usually went to school by active means (Mota et al., 2007). In 2006 another study, in Barcelos (area:378.7 km²; population:122,096 inhabitants) 66% of the students, aged 14.5 years old, walked or biked to school (Santos et al., 2009). More recently, two different investigations conducted by our group in Porto suggest a potential decreasing tendency in active commuting. In 2007/8 44% of adolescents reported active commuting to school (Pizarro, 2009) while in 2010/2011 only 26% reported to walk or bike to school (Marques et al., 2012).

Regardless the importance of active commuting to school for children's health isn't completely known, understanding the patterns and correlates of this behavior is an essential step for the development of evidence-based interventions.

BUILT ENVIRONMENT

The built environment is a multidimensional concept defined broadly as all of the buildings, spaces, and products created or modified by people (Health Canada, 2002). It encompasses land use patterns, the transportation system, urban design and features that provide opportunities for travel and physical activity (Committee on Physical Activity Health Transportation and Land Use, 2005). Land use refers to the spatial distribution of activities. The transportation system includes the physical infrastructures and services that provide the connectivity

between places. Urban design refers to the design of the city and the physical elements within it, and encompasses the aesthetical, and functional qualities of the built environment and relates both land use and the transportation system. The built environment varies from large-scale urban areas to rural development and personal space and it includes both indoor and outdoor places. Environment is changing constantly in countless ways, some are fast (e.g. pedestrians on a downtown center during day vs night) and some are slow (e.g. deterioration of buildings exteriors) (Handy et al., 2002). This continuous modifications of the built environment provide opportunities, over time, to create more activity-friendly environments and may have public health relevance because of the relationship between physical activity and health (Committee on Physical Activity Health Transportation and Land Use, 2005).

Evidence suggests that built environment can act as a barrier or a positive influence on health behaviors and it has been related to CVD and risk factors (Diez Roux, 2003) such as hypertension, diabetes, obesity and physical activity. Most of these associations have been established through measures of area socioeconomic status (Diez Roux, 2003) and only fewer studies have looked at other neighborhood features. For example, Nazmi et al. (Nazmi et al., 2010) examined associations between neighborhood deprivation, problems, safety, and cohesion with circulating levels of inflammatory markers. After adjustment for race and socioeconomic status (SES), results showed that higher levels of neighborhood deprivation and problems were associated with higher levels of fibrinogen whereas higher levels of safety were associated with lower levels of fibrinogen and interleukin-6. In another paper, Baldock et al. (Baldock et al., 2012) reported a negative association between metabolic syndrome with land-use mix, aesthetics, and infrastructure for walking, and a positive association with perceived crime and barriers to walking, despite these associations were weakly mediated by walking. Another study, looking at associations of specific features of the neighborhood environment with hypertension found that better walkability, availability of healthy foods, safety and social cohesion reduced the probability of being hypertensive in a way equivalent to the effect of a 4 to 14 years reduction in age (Mujahid et al., 2008). Also, a growing body of evidence demonstrates positive associations between characteristics of the built environment, including

land use mix, proximity/ number of recreational facilities / food stores, urban sprawl and obesity in all age groups (Papavas et al., 2007).

BUILT ENVIRONMENT AND ACTIVE COMMUTING TO SCHOOL (ACS)

There is a body of research showing that built environment may play an important role influencing travel behavior (Committee on Physical Activity Health Transportation and Land Use, 2005), even after taking neighborhood preferences and attitudes into account (Handy et al., 2006). Besides some mixed results, built environment factors including destinations, neighborhood walkability¹ and safety have been argued to affect opportunities and promote active commuting in youth (Giles-Corti et al., 2009). Distance is the most consistent correlate of active commuting to school. Most findings provide evidence that increasing distances travelled are inversely associated with rates of children's ACS (Pont et al., 2009). Despite no universal definition exists for a feasible distance to school, European studies estimate that 2 kilometers (Km) to 2.4 Km are a reasonable distance for walking and 4 Km to 8 Km for cycling (Nelson et al., 2008; Van Dyck et al., 2010) in adolescents. However, even within this distance research estimate that only 31% of United States children walked to school (Centers for Disease Control and Prevention, 2002), while in Ireland only more than 40% of the adolescents living within 4 Km from school commuted passively (Nelson et al., 2008). Proximity of destinations is somewhat determined by neighborhood walkability¹ features. Kerr et al. observed a positive association between a Geographical Information System (GIS)² derived walkability index and ACS (Kerr et al., 2006). Neighborhoods with better street connectivity (Mota et al., 2007), mixed land use and higher population densities are shown to have a possible positive association with higher rates of children's ACS (Panter et al., 2008; Pont et al., 2009). Thus, there appear to be inconsistencies in the evidence as for example the lack of association found by Braza et al. for objectively measured connectivity and ACS

1) Walkable neighborhoods are characterized by (a) street networks that provide street connectivity and a variety of direct routes to destinations; (b) moderate to high urban density; (c) mixed land uses incorporating residential dwellings, shops, utilities, services and parks.

2) GIS has been defined as the "integration of software, hardware, and data for capturing, storing, analyzing and displaying all forms of geographically referenced information" - ESRI

(Braza et al., 2004) or the interesting association between perceived lower degree of land use mix and ACS in Belgian adolescents (De Meester et al., 2013).

There is some evidence that safety (crime and traffic) is a key factor in whether youth walk or cycle to school (Panter et al., 2008; Sirard & Slater, 2008), particularly through parents' concerns and willingness to allow their children to use active means to commute to school (Giles-Corti et al., 2009). Worries about abduction/molestation, traffic danger, several roads to cross, and lack of traffic lights have all been negatively associated with active transport and independent mobility (Bringolf-Isler et al., 2008; Nelson & Woods, 2010; Salmon et al., 2007; Santos et al., 2013; Trapp et al., 2012). Some neighborhood design environmental factors namely, presence of facilities which assist walking and cycling, having parks, play areas, sporting venues or recreation facilities in neighborhoods have also been found to enhance rates of ACS among children and adolescents (Panter et al., 2008; Pont et al., 2009).

Recently Wong et al. conducted a systematic review of GIS measured environmental correlates of ACS. Except for distance to school, in general study results on the association between built environment features with ACS found no consistent evidence. Consistent findings of positive or negative associations were not found for land use mix, residential density, and intersection density. For some variables such as having a busy road crossing or a busy road located along the route to school, greenery or neighborhood walkability there were either positive, negative or null relationships reported across studies (Wong et al., 2011). Therefore, findings with regard to the relationship between built environment features and school travel choices are still inconclusive.

BUILT ENVIRONMENT AND PHYSICAL ACTIVITY IN YOUTH

It has been hypothesized that adapting the built environment may encourage physical activity to levels that are beneficial to health. To date several built environment features and combinations of attributes that may be related to physical activity were identified. However, relations between physical activity and built environment among youth are not well understood yet as findings are

complex and inconsistent across studies (Davison & Lawson, 2006; de Vet et al., 2011).

In one of the first review papers on the influence of physical environment on physical activity (self-reported and objectively measured), 33 studies including both objective and perceived measures of environment were categorized according to three dimensions: recreational infrastructure, transport infrastructure and local conditions. Results showed consistent associations between physical activity and transport infrastructure dimension. Number of roads and traffic density were negatively associated with children's participation in physical activity while positive associations were found for presence of sidewalks, access to destinations, available public transportation and controlled intersections. Although less consistent, recreational infrastructure features namely, access to recreational facilities and schools were also associated with more physical activity. Inversely, local conditions such as crime and area deprivation were associated with lower levels of activity (Davison & Lawson, 2006).

Vet et al. (de Vet et al., 2011) provided a comprehensive synthesis of environmental factors related to physical activity in youth and identified factors that are unrelated to physical activity in order to narrow the scope of future studies and interventions. In this systematic review of reviews physical activity was consistently more related to school and neighborhood characteristics than to personal and societal environments. Based only on strong reviews, the authors found that variables such as teacher socioeconomic status, specific school types (public and high schools), facilities for physical activity in the school and in the neighborhood, and traffic safety were positive influences for physical activity.

A different approach grouped correlates of physical activity in four environmental types (physical, socio-cultural, economic and policies) for each environmental settings: home, educational institution, neighborhood, city/municipality and region (Ferreira et al., 2007). Results did not identify any feature of the built environment to be associated with children or adolescents' physical activity. Availability and/or accessibility of exercise equipment both at home and in the neighborhood and presence of facilities for physical activity in the neighborhood were consistently unrelated to physical activity. The most interesting result was that objectively measured crime incidence was negatively associated with adolescent's physical

activity level, whereas no association was found between perceived neighborhood safety and physical activity. This calls our attention to the different methods used in the assessment of environmental variables. In fact, that may be a weakness of most of the review papers as different methods may mean different aspects observed. Similarly, different instruments may measure different aspects of physical activity behavior.

As heterogeneity across studies poses a major challenge for summarizing findings, a recent review stratified results by measurement modes of physical activity and environmental features (Ding et al., 2011). Results showed that the mode of measurement influenced observed associations between physical activity and environment. Findings from this study revealed land use mix and residential density as most supported built environment correlates for children and adolescent's physical activity levels. Evidence were also present for access to recreation facilities, walkability, traffic speed/volume, pedestrian safety, incivilities and vegetation in children's reported physical activity level. However, no environmental attribute was consistently associated with objectively measured overall physical activity in youth; and associations were weaker when environmental attributes were measured by participant's perceptions. Apparently, associations were more stable when environmental attributes were objectively measured and physical activity reported. In the end, as no environmental variable was supported as a consistent correlate of physical activity across all four combinations of measurement modes, no clear conclusion can be made (Ding et al., 2011).

MEASURING THE BUILT ENVIRONMENT AND ACTIVE COMMUTING

As the relationship between the built environment features and active behaviors (physical activity and active commuting) remains unclear, it is possible that the different definitions and methods used to measure physical activity and built environment features have been responsible for the inconsistencies found. Despite a rapid growth in this research area and several methods of measuring both the built environment and physical activity outcomes have been applied, few studies used similar methods turning comparison between investigations a hard task.

Used methods for assessing the built environment features relevant to the study of physical activity include three categories of data: (1) perceived measures obtained by telephone interview or self-administered questionnaires; (2) observational measures obtained using systematic observational methods (audits); and (3) archival data sets that are often layered and analyzed with GIS (Brownson et al., 2009).

Evidence on the association between the built environment and physical activity behavior is derived mostly from self-report data on individuals' perceptions of their environments. Constrains of this approach is that they can be very time consuming, have high declining response rates and bias from social desirability as some respondents may not feel comfortable disclosing that they live in an impoverished area (Dunstan et al., 2005) and same-source bias if both outcome and predictor variables are collected from the same data source (Duncan & Raudenbush, 1999). Nevertheless, this method allows researchers to explore how residents experience their neighborhoods as places to live.

GIS-based measures has allowed for an increasing ability to objectively assess attributes of the physical environment hypothesized to be related to behavioral and health outcomes, but these measures are limited by availability of data. Not only the lack of data in many locations, but also the low or unknown quality and completeness of data, the difficulty or cost of access, and the lack of standardization make this approach very complex (Brownson et al., 2009).

Research examining the degree of correspondence between perceived and objective measures of the physical activity environment show considerable low agreement in several features (Kirtland et al., 2003) as for example access to physical activity facilities (Ball et al., 2008), parks (Lackey & Kaczynski, 2009) or even crime (McGinn et al., 2008). Using telephone surveys and GIS measures of the built environment, McGinn et al. (McGinn et al., 2007) studied the association of perceptions and objective measures with leisure, walking, and transportation activity. Results showed that objective and perceived measures of the built environment were in poor agreement as calculated by kappa coefficients (McGinn et al., 2007). Despite relationships varied among study sites, few associations were found between any of the physical activity outcomes and perceptions, while some were found for objective measures. Moreover, when

both objective and perceived measures of the built environment were combined into the same model, independent associations with physical activity were observed, therefore authors conclude that evaluating both objective and perceived measures of the built environment may be necessary when examining the relationship with physical activity. Exploring different methods for assessing physical activity and built environment, Ding et al. (Ding et al., 2011) found no environmental variable, measured either objectively or subjectively, to be a consistent correlate of physical activity. Actually, objective and perceptions of environmental features have been shown to have different associations with different physical activity types in several studies included in Dings research. Numerous explanations have been suggested for the low levels of agreement between perceived and observed neighborhood conditions. First, people perceive the objective environment according to their personal beliefs, cultural values, desires and expectations (Nasar, 2008). Thus, two individuals in the same environment may perceive it differently. Second, definitions of neighborhood or community are likely to vary between individuals and different GIS-based buffer sizes are used in different studies. Therefore, the respondents' varying ability to estimate distances accurately is likely to influence concordance with observed measures (Brownson et al., 2009). For example Census tracts are commonly used to define the neighborhood despite residents are not frequently aware of that boundaries or have a different subjective definition of neighborhood (Coulton et al., 2001). Third, despite GIS allow spatial analysis, linking physical activity with some environmental features (Brownson et al., 2009), they cannot record the actual use of these features.

Thus, recent studies have begun using global position system (GPS) receivers a means to objectively assess spatial position and combined with other instruments like accelerometers, to provide location information for physical activity (Krenn et al., 2011). Thereby, giving context specific knowledge of physical activity patterns and revealing the truth neighborhood to which participant is exposed. Together with GIS this approach will allow objective assessment of which built environmental features most influence physical activity and provide important information of how people interact with their environment that can be used to design activity friendly neighborhoods. However, there are no guidelines or

standardization for handling GPS data and that may be holding the advance of this field (Kerr et al., 2011).

GPS is a satellite based global navigation system made up of a network of 24 satellites that orbit Earth. These satellites transmit radio signals to GPS receivers providing a precise location at any point on Earth's surface. Position of a GPS receiver is calculated by comparing the time a signal was transmitted with the time it was received. When a GPS is turned on it undergo an initialization process that synchronize the receiver clock with the atomic clocks placed in the satellites. To determine location a GPS receiver must be locked on to the signal of at least three satellites. Once receiver's position has been determined, the GPS unit can calculate other information, such as speed, direction, bearing, track, trip distance, and more. One shortcoming of GPS receivers is that they require a direct line of sight with the satellites. The more satellites a GPS receiver can "see," the better the accuracy. Buildings, terrain, electronic interference, atmospheric conditions or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground (<http://www8.garmin.com/aboutGPS/>).

GPS-enhanced research should have less respondent burden, provide a more accurate and detailed information of the spatial and temporal aspects of personal travel than self-report surveys and allow for automated activity type, location, timing, and travel mode identification (Program, 2014). Despite the problems with data loss reported in a review (Krenn et al., 2011) previous research show a high accuracy under various environmental conditions, good signal acquisition time (Duncan et al., 2009), and acceptable dynamic accuracy during different modes of transportation, in different environments (Schipperijn et al., 2014).

Besides measurement issues, inconsistencies in correlate studies may be partly explained by some researchers fail to consider and measure behavior specific environmental correlates (Giles-Corti et al., 2005) that are likely to differ between physical activity domains, i.e. areas of life in which activity is done. There are several settings and domains where children can engage in and accumulate physical activity. According to the SLOTH model each day can be categorized in five domains: Sleep, Leisure, Occupation, Transportation, and Home where people allocate their time and where individuals may choose be either physically active or inactive in the four non-sleep domains (Pratt et al., 2004). As

demonstrated by Giles-Corti et al. (Giles-Corti et al., 2005), the more closely environmental measures match the specific behavior of interest and the setting in which the behavior takes place the better is the predictive capacity of behavioral model. One of the first papers addressing this specificity is the work of Susan Handy comparing residents of highly and not highly walkable neighborhoods. Results shown significant differences in transport-related or utilitarian trips, but no difference in walking for exercise (Handy, 1992). Therefore, the most relevant geographic scale is likely to differ by built environment variable, behavior of interest, and population (Brownson et al., 2009).

Research on specific physical activity behaviors is still a recent area of investigation and particularly studies in active commuting are somewhat limited due to the lack of standardization in what defines an active commuter (Sirard & Slater, 2008). For example a review on walking and biking to school (Sirard & Slater, 2008) showed that some surveys ask about the usual mode of transportation during a usual week or a specific day, others asked about the number of days using a certain mode of travel or ask detailed number of minutes spent in different forms of active transport; some studies reported only dichotomized variables, while others differentiated between number of days and trips in active transport. Some studies looked at overall active transport and others differentiate walking and cycling, so caution should be used when comparing frequencies. Moreover, these methodologies do not account for the use of multiple modes of transport (Lee et al., 2008). Almost all studies rely exclusively on self or proxy reports and no routine exist for objective assessment of this behavior. Recently the use of GPS technology is offering a solution to this problem as it allows researchers to objectively assess walking, bicycling and vehicle trips. Only a few studies have employed GPS and accelerometer data and different complex approaches have been used to associate a travel mode with a sequence of GPS points (Program, 2014) requiring support from computer scientists or mathematicians (Kerr et al., 2011). Findings suggest high accuracy rates (>90%) for identifying transportation modes using a combination of variables collected with GPS and accelerometer, usually speed and activity or steps both in controlled environments (Troped et al., 2008) and in real world conditions (Ellis et al., 2014).

CHAPTER 2 – Experimental work

Experimental work

This thesis was conducted in several middle and high schools in Porto district. Studies I,II and IV are part of SALTA project (Environmental Support for Leisure and Active Transport), a longitudinal study in Porto area, Portugal, designed to examine environmental and social influences on PA in children and adolescents. Data for study III was collected as part of The IPEN (International Physical Activity and Environment Network) Adolescent project. The IPEN studies are observational epidemiologic multi-country cross-sectional study.

Participants in the study were recruited from different schools with the aim to maximize variance in environmental attributes and socio-economic status (SES). Adolescents between 10 and 18 years old provided a voluntary written consent from their parents to participate in this study. Data were anonymous and confidential and were collected between November 2008 and May 2014. Ethical approval for this study was obtained from the Faculty of Sports ethics committee, the Foundation for the Science and Technology and by the regional section of the Ministry of Education

The basic information of the participant, variables and instruments used in each paper of this thesis are presented in table 1. Detailed methodological procedures can be found at the materials and methods section of each paper.

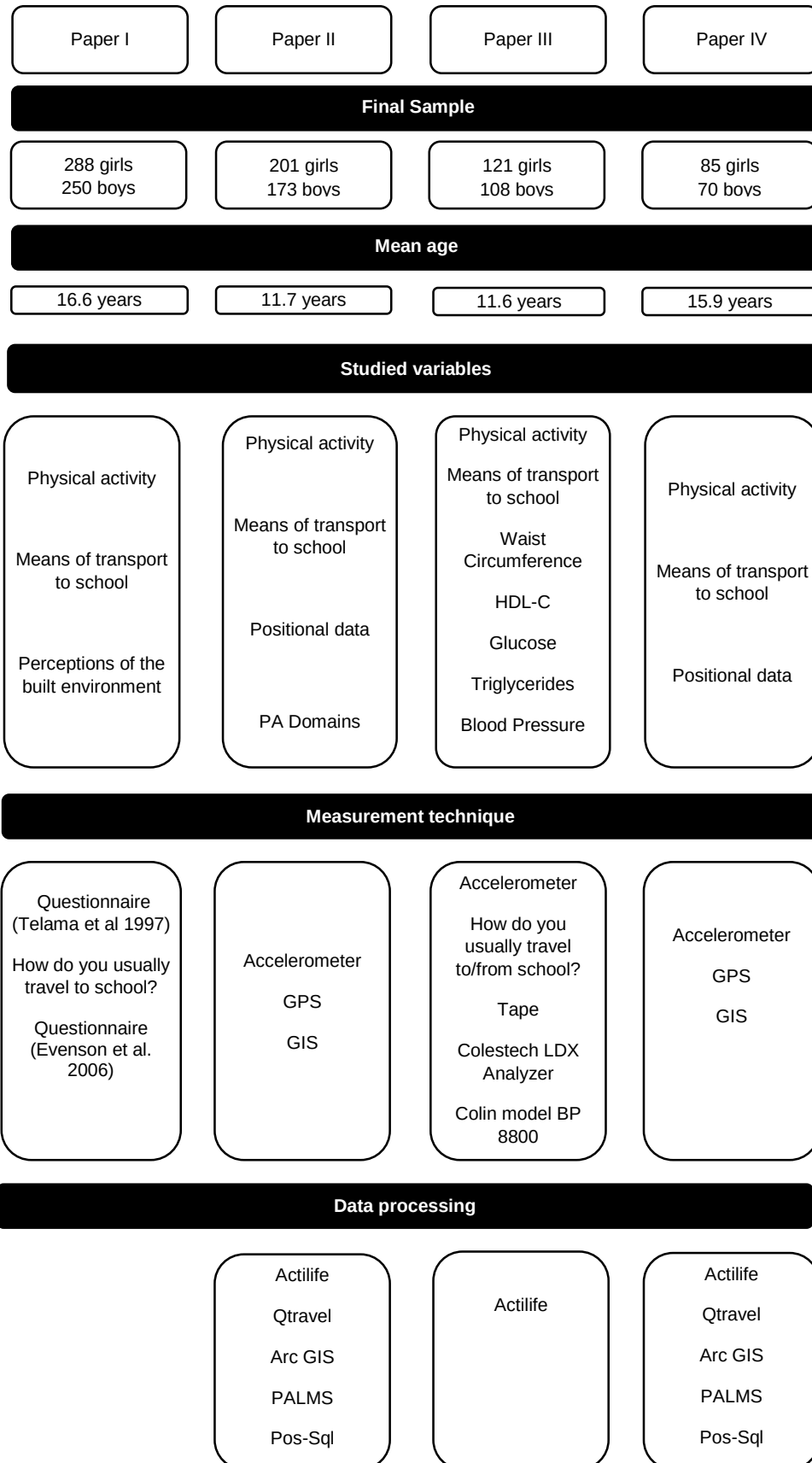


Fig.1 Experimental work diagram

PALMS software

Personal Activity Location Measurement System (PALMS) is a web based computer program and comprises 3 subsystems: data import and storage (yellow); processing and analysis (green); and visualization and export (blue) (figure3). Its main function is to store, process and merge time-stamped data from devices such as accelerometers, heart-rate monitors and GPS instruments.

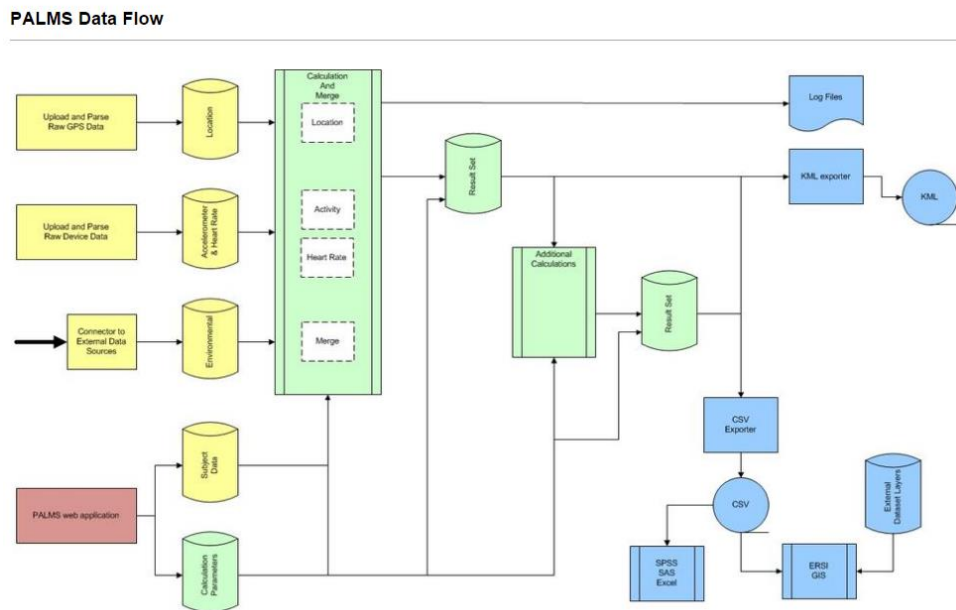


Fig.2 PALMS data flow diagram

The outputs PALMS produces consist of filtered and cleaned GPS points linked with physical activity data for those points.

One of the features of PALMS is its calculation function, which identifies variables of interest, including trips, transportation modes, activity intensity, and GPS data points. These calculations are the functions used to define the parameters for filtering and merging data and for summarizing results sets.

First, the GPS processing algorithms clean the data, removing the errors caused by indoor jitter and outdoor multipath reflections. Once the errors have been removed, the data is analyzed to detect indoors/outdoors positions, trips, locations and modes of transportation. The processing is done in multiple passes; the output of one pass becomes the input of the next. A typical sequence of passes would be: preprocess data (computes derived variables like duration, distance traveled, direction, speed, acceleration, elevation delta from the inputs

supplied by the GPS), clean data, detect trips, detect locations, and classify mode of transportation.

GPS filtering parameters and their meaning are presented in the following table (Table1).

Table 1. GPS filtering parameters and their meaning			
FUNCTIONAL BLOCK	PARAMETER	PROTOCOL	USAGE
LOSS OF SIGNAL	<i>Max duration allowed (in seconds)</i>	600	Maximum amount of time between GPS fixes allowed to occur before loss-of-signal (LOS) is declared.
	<i>Remove lone fixes</i>	check	When checked, "lone" fixes are removed. A lone fix is one that occurs after LOS is declared.
INVALID VALUES FILTER	<i>Filter invalid fixes</i>	check	When checked, filter (remove) invalid points from the calculation.
	<i>Max speed (Km/hr)</i>	130	Consider fix invalid if speed greater than this value
	<i>Max change in elevation (meters)</i>	1000	Consider fix invalid if elevation delta greater than this value over the interval
	<i>Min change in distance required over 3 fixes (meters)</i>	10	Discard fix if change in distance between fix 1 and fix 3 is less than this value. Indicates a forwards and backwards movement that typically is cause by GPS jitter.
INDOORS DETECTION	<i>Detect indoors</i>	check	When checked, mark fixes as indoors or outdoors if additional satellite information has been recorded by the GPS.
	<i>Max satellite ratio when indoors</i>	50	Maximum ratio of satellites-used / satellites-in-view to be considered indoors. Values greater than this are marked as outdoors.
	<i>Max SNR value when indoors</i>	225	Maximum signal-noise value to be considered indoors. Values greater than this are marked as outdoors. Default is for Qstarz GPS
TRIP DETECTION	<i>Min distance traveled over one minute (meters)</i>	25	Minimum distance that must be traveled over one minute to indicate the start of a trip.
	<i>Min trip length (meters)</i>	100	Trips less than this distance in length are not classified as trips.
	<i>Min trip duration (seconds)</i>	120	Trips less than this duration are not classified as trips.
	<i>Min pause time (seconds)</i>	120	When duration at point exceeds this value, point is marked as a pause point.
	<i>Max pause time (seconds)</i>	180	When duration of pause exceeds this value, point is marked as an end point.
	<i>Max % of trip allowed within a single location</i>	100	Max percentage of a trip's fixes that are allowed to occur within a single location.
	<i>Max % of trip allowed indoors</i>	75	Max percentage of a trip's fixes that are allowed to occur indoors.
	<i>Remove indoor points from trip starts and ends</i>	check	When checked, points estimated to be indoors are removed from the starts and ends of trips.
LOCATION DETECTION	<i>Include trip pauses as locations</i>	uncheck	When check, pauses occurring during a trip are included as locations.
	<i>Trap indoor points within location</i>	uncheck	When checked, stationary indoor GPS fixes within a given radius of the location will be set to the center of the location.
	<i>Trap outdoor points within location</i>	uncheck	When checked, stationary outdoor GPS fixes within a given radius of the location will be set to the center of the location.
	<i>Trap points that are part of a trip</i>	uncheck	When checked, also include GPS fixes that are part of a trip.
	<i>Allow locations without trips</i>	uncheck	When checked, locations may be identified that are not associated with a trip.
	<i>Reset location numbers for each participant</i>	uncheck	When checked, location numbers are reset for each participant. When unchecked, location numbers will be the same for all participants in a calculation.
	<i>Cluster radius (meters)</i>	30	Defines radius of location in which fixes are trapped
	<i>Min time at location (seconds)</i>	300	Minimum amount of time that must be spent at a location for it to be considered a location.

MODE OF TRANSPORTATION	Vehicle speed cutoff (km/h)	35	Speeds greater than this are marked as vehicle
	Bicycle speed cutoff (km/h)	10	Speeds greater than this are marked as bicycle
	Walk speed cutoff (km/h)	1	Speeds greater than this are marked as pedestrian
	Percentile of speed samples to consider	90	Above comparisons are made at this percentile.
	Classification segment length (in meters)	30	Minimum length of a trip segment used to classify mode transportation.
COMPUTE AVERAGES	Compute average speed	unchecked	When checked, computes and presents speed as a moving average over N GPS samples.
	Compute average elevation	unchecked	When checked, computes and presents elevation delta as a moving average over N GPS samples
	Number of GPS samples to average	3	Number of samples (N) used to compute the moving average

Second, PALMS accelerometer sensor processing will detect and mark non-wearing conditions, bouts of activity and sedentary periods. After that, activity will be classified as moderate, vigorous and very vigorous based on designated cut points. The following protocol for accelerometer processing was used (Table 2).

Table 2. PALMS accelerometer protocol

FUNCTIONAL BLOCK	PARAMETER	PROTOCOL	USAGE
ACCELEROMETER CALCULATIONS	Include accelerometer	check	When checked, accelerometer data will be processed.
	Use vector magnitude (if available)	unchecked	When checked, vector magnitude values will be used in place of axis 1 count data.
NOT WEARING TIME	Mark not wearing	check	When checked, non-wearing time will be marked with a value of -2
	Minutes of zeros in a row	60	Number of consecutive minutes of zeros that must be present for period to be marked as not wearing.
ACTIVITY BOUTS DETECTION	Detect activity bouts	check	When checked, detect bouts of activity
	Activity bout length (minutes)	5	Minimum duration of bout
	Activity bout upper limit (counts)	9999	Maximum limit of activity to be considered part of a bout
	Activity bout lower limit (counts)	2295	Minimum level of activity to be considered part of a bout
	Activity bout tolerance (minutes)	2	Number of consecutive minutes allowed outside of the activity limits that will still be considered part of a bout
SEDENTARY BOUTS DETECTION	Detect sedentary bouts	check	When checked, detect bouts of sedentary periods (non-activity)
	Sedentary bout length (minutes)	30	Minimum duration on sedentary bout
	Sedentary bout upper limit (counts)	180	Maximum level of activity to be considered sedentary
	Sedentary bout tolerance (minutes)	1	Number of consecutive minutes of activity allowed during sedentary bout
CUTOFF VALUES	Very hard (counts)	99999	Counts greater than this value will be classified as very hard (very vigorous)
	Hard (counts)	4011	Counts greater than this value and less than the above value will be classified as hard (vigorous)
	Moderate (counts)	2295	Counts greater than this value and less than the above value will be classified as moderate
	Light (counts)	100	Counts greater than this value and less than the above value will be classified as light. Counts less than this value will be classified as sedentary.

Finally, to merge the GPS and activity time-stamped data streams, PALMS creates a new timeline based on the start and end times of either GPS or activity data streams according to user-desired interval. PALMS will then re-classify modes of transportation based on accelerometer data. The data processing finished with detection and mark of gaps in data and allows user to collapse or expand these gaps. In order to process the merging of GPS and activity data the parameters exposed on table 3 have been set.

Table 3. PALMS GPS and accelerometer data merging protocol

FUNCTIONAL BLOCK	PARAMETER	PROTOCOL	USAGE
MERGE OPTIONS	<i>Merge data to GPS</i>	unchecked	When checked, activity data is aligned to the GPS timeline. Data without GPS fixes are discarded.
	<i>Start first day at midnight</i>	unchecked	When checked, the timeline for the first day of data starts at midnight. Otherwise, it starts at the timestamp of the first data sample.
MISSING GPS FIXES	<i>Insert missing fixes</i>	check	When checked, gaps in GPS fixes are replaced by the last valid fix.
	<i>Insert until a max duration</i>	unchecked	When checked, continue inserting missing fixes until the max duration (specified below) is reached.
	<i>Max number of seconds to insert</i>	600	Max number of seconds to replace missing fixes with last valid fix. After this duration is reached, the location is marked as unknown.
MARK EVENTS			Events are marked and the event number incremented when a change in the participant's activity occurs. The options below allow you to determine which changes are to be marked as events.
	<i>Mark trips</i>	check	When checked, trip starts and trip ends are marked as events.
	<i>Mark pause points</i>	check	When checked, the start and stop of pauses that occur within a trip are marked as events.
	<i>Mark location changes</i>	unchecked	When checked, a change in the location number is marked as an event.
	<i>Mark activity bouts</i>	check	When checked, the start and end of an activity bout is marked as an event.
	<i>Mark sedentary bouts</i>	check	When checked, the start and end of a sedentary bout is marked as an event.

Paper I

Physical activity and active transport are predicted by adolescents' different built environment perceptions

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Abstract

Aim Recent studies suggest that increasing rates of obesity and other chronic health conditions may be linked to characteristics of the built environment that reduce opportunities for daily activity. The aim of this study is to analyze the associations between the perceptions of the built environment with physical activity (PA) and active transport in adolescents. **Subject and methods** Participants were 538 adolescents (288 girls) aged 16.56 ± 1.27 years old, from Porto, Portugal. Physical activity (PA) and perceptions of environmental characteristics were assessed by self-report questionnaires in 2009.

Results Logistic regression analyses showed a significant association between boys (OR 4.85, 95% CI: 1.149–10.94) and girl's (OR 2.63, 1.55–4.40) PA and the presence of sports equipment at home. "Interesting things to look at while walking" was also associated with higher levels of PA, but only in boys (OR 3.54, 1.149–10.94). In girls, active transport was predicted by the perception of safety to walk or jog (OR 3.88, 1.36–11.07) and streets well lit at night (OR 2.93, 1.44–5.96).

Conclusion Our study identified several associations of active behaviors with the physical environment that may contribute to the development of environmental interventions and policies regarding the community design and health promotion.

Keywords Built environment · Physical activity · Active commuting · Safety · Sports equipment

Introduction

Promotion of physical activity (PA) in children and adolescents is particularly important for the direct improvement of health and quality of life in childhood and adolescence (Hallal et al. 2006) and, indirectly, as PA tracks from adolescence into adulthood. The increasing rates of obesity and other chronic health conditions in these ages is a highly relevant issue for health policies and quality of life. To promote PA and healthy lifestyles among youth more effectively, it is important to understand factors that might influence adolescents' participation in PA that could be target for change (Deforche et al. 2010).

Opportunities to be active such as provided by a built environment that encourages physical activity (e.g. playgrounds) or by social support for physical activity and direct parental help for physical activity have also been previously identified as related to youth physical activity (Sallis et al. 2000).

Despite the recent surge of research in environmental attributes and their association with physical activity behavior, research in this area is still in its infancy. Consistent associations between the built environment and PA among children and adolescents, either perceived or objectively measured, have been previously pointed out (Davison and Lawson 2006), but it is not clear if those associations might be replicated in European countries (Wendel-Vos et al. 2007).

As physical activity takes place in a number of different contexts, including sports clubs, supervised activities during and after school, active transport and informal play, determinants of physical activity are likely to be different for each context (Giles-Corti et al. 2005a). For children of younger ages, active transport should be considered as a major key factor to increase PA levels (Tudor-Locke et al.

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2001) and to reduce important negative health outcomes such as obesity (Rosenberg et al. 2006).

Although some studies have identified critical physical environmental factors related to PA among European adolescents (Deforche et al. 2010; Santos et al. 2009), differences regarding built environmental influences in specific physical activity behaviors have not yet been well described. Such knowledge might provide an important contribution to design and implement relevant policies and effective programs to increase opportunities for PA within the European context. Therefore the aim of this study was to investigate associations between perceptions of the built environment with PA and with active transport regarding adolescents.

Methods

Sample

All public schools within the Porto area (Portugal) were invited by mail and email to participate in the study. Eighteen schools from three counties agreed to participate. The potential sample comprised 630 students, representing 10% of population between 15 to 24 years old, registered in public schools in that county.

To be eligible, students needed to participate in physical education classes (mandatory within the Portuguese Educational System), and report an absence of physical and mental health problems. Both participants and their parents received a complete explanation of the purpose of the investigation and in the case of a positive participation, signed a written consent to participate in the study. Data were anonymous and confidential and were collected during physical education (PE) classes, between November 2008 and July 2009.

Measures

PA

PA was assessed by a questionnaire previously used in the Portuguese context with good reliability (ICC: 0.92–0.96; Mota and Esculcas 2002). A significant and negative correlation was found between the index of PA and the heart rate at rest, serum insulin and skin fold measurements and was assumed to be an indication of validation of the activity measure (Raitakari et al. 1994). The questionnaire had five questions with four choices: (1) Do you take part in organized sports outside school?; (2) Do you take part in non-organized sports outside school?; (3) How many times a week do you take part in sports or some physical activity outside school for at least 20 minutes at a time? (4) How

many hours a week do you usually take part in some physical activity outside school to the extent that you get out of breath or sweat?; (5) Do you take part in competitive sports? A maximum of 20 points could be reached overall. According to the total sum of the points, a PA index was obtained which divided the sample into four different activity categories: the sedentary group (0–5); low active group (6–10); moderately active group (11–15); and vigorously active group (16–20). According to procedures adopted previously (Santos et al. 2009), for statistical analysis, the subjects were grouped into two categories: the low-active group (LAG, $n=184$), which comprised the sedentary and low active participants; and the active group (AG, $n=354$), which comprised the moderately and vigorously active participants.

Perceptions of the environment

Adolescent's perceptions of neighborhood characteristics were accessed by a questionnaire from Evenson et al. (2006) developed with the main objective of examining the test–retest reliability of a survey designed for youth to assess perceptions of physical environmental factors and transportation. This questionnaire consisted of 21 statements concerning physical factors of the environment and transport grouped into 4 dimensions (Safety, Aesthetics, Facilities near home, and Transport). The test–retest correlation presented by the questionnaire authors' showed moderate reliability. The Cronbach test was applied to our data and the score obtained was acceptable ($\alpha=.63$), which in our opinion may be due to the complexity involved in the evaluation of perceptions.

The 21-item survey included the following 8 statements regarding perceived safety of the environment: (1) It is safe to walk or jog in my neighborhood; (2) It is safe to ride a bike in my neighborhood; (3) In my neighborhood, walkers and bikers on the streets can easily be seen by people in their homes; (4) There is so much traffic that it makes it hard to walk in my neighborhood; (5) There is a lot of crime in my neighborhood; (6) I often see other girls or boys playing outdoors in my neighborhood; (7) There are lots of loose or scary dogs in my neighborhood; (8) My neighborhood streets are well lit at night.

For aesthetics domains, four statements were also included: (9) There are trees along the streets in my neighborhood; (10) There are many interesting things to look at while walking in my neighborhood; (11) When walking in my neighborhood, there are a lot of exhaust fumes or other bad smells; (12) There usually is not garbage or litter in my neighborhood.

The following statements were given regarding physical activity facilities close to home: (13) There is enough sports equipment at home to use for physical

activity; (14) here are sidewalks on most of the streets in my neighborhood; (15) There are bicycle or walking trails in my neighborhood.

The final six statements given were regarding transportation: (16) There are many places I like to go within easy walking distance of my home; (17) My parents (or guardians) worry about something happening to me if I go somewhere on my own; (18) My parents (or guardians) allow me to walk in our neighborhood on my own; (19) My parents (or guardians) allow me to bike on my own; (20) My parents (or guardians) allow me to take public transportation on my own; (21) It is easy to walk or bike to a transit stop (bus, trolley) from my home.

The questions had a five-point Likert response scale including strongly disagree, somewhat disagree, somewhat agree, and strongly agree; additionally there was also a neither agree nor disagree response option. For statistical analysis, however, responses to items were collapsed into three categories: (1) agree, including the responses options of somewhat agree and strongly agree; (2) disagree, including strongly disagree and somewhat disagree and (3) neither agree nor disagree. The original questionnaire (English version) was translated into Portuguese according to procedures previously described (Sperber et al. 1994).

Active transport

Active transport to and from school was accessed by questionnaire. Participants were asked if they walked, bicycled, went by car, or went by bus to and from school. Based on their answers, the respondents were categorized as using active (walking, bicycling) or passive (bus, riding in a private vehicle) commuting (Tudor-Locke et al. 2001).

Demographics

Data on socio economic status (SES), age and county of residence was also collected. SES was accessed based on the mother's level of education and was collapsed into three categories: ≤ 9 years (low SES), 10–12 years (medium SES)

and >12 years of education (high SES) according to Portuguese educational system.

Data analysis

Data was analyzed using SPSS (version 17; SPSS, Inc., Chicago, IL). Significance level was set at 5% ($p < 0.05$). Descriptive statistics were used to characterize the sample. Between-group comparisons of continuous variables were performed using Mann-Whitney test as some variables did not meet normality. Chi-square tests and the Fisher exact test were used for between-group comparisons of categorical variables or for differences in proportions. As gender differences in physical activity are frequently reported (Hovell et al. 1999; Sallis et al. 1996) bivariate logistic regression models were conducted separately by gender to estimate the effect of each perceived environmental feature (21 items) on the probability of being “active” and of using active transport. Only variables that were significant ($p < 0.05$) in the individual models were considered in the final model (adjusted to age, county of residence, PA level, means of transport and environment perceptions) of the logistic regression to find out their relation to PA and active transport. SES was also adjusted for, since several correlations of PA and perceptions with this variable were previously reported (Mota et al. 2010).

Results

From the 630 questionnaires collected, 92 were excluded because they were incomplete; therefore, the final sample was composed of 538 individuals (288 girls and 250 boys). Descriptive characteristics of the participants are listed in Table 1. A total of 538 adolescences (mean age 16.6 ± 1.3 years) were enrolled in this study. The prevalence of the AG was 65.8%; however, the prevalence of boys was significantly higher than girls in this category ($p < 0.001$). It seems also important to note that participants used passive transport (such as bus, car or motor vehicle) to school more

Table 1 Sample characteristics

Variable	Total sample ($n=538$)	Boys ($n=250$)	Girls ($n=288$)	p -value ^a
Age, M $\pm$ SD	16.6 $\pm$ 1.3	16.8 $\pm$ 1.3	16.3 $\pm$ 1.2	0.00
Weight, M $\pm$ SD	62.4 $\pm$ 11.9	68.3 $\pm$ 12.2	57.4 $\pm$ 9.0	0.00
BMI, M $\pm$ SD	21.7 $\pm$ 3.6	22.1 $\pm$ 4.1	21.3 $\pm$ 3.2	0.003
Active group, n (%)	354 (65.8)	213 (85.2)	141 (49.0)	<0.001
Active transport, n (%)	241 (44.8)	121 (48.4)	120 (41.7)	0.119
Mother's level of education				
≤ 9 years	290 (53.9)	124 (49.6)	166 (57.6)	0.107
10–12 years	142 (26.4)	76 (30.4)	66 (22.9)	
>12 years	106 (19.7)	50 (20.0)	56 (19.4)	

^a Mann-Whitney test for continuous variables; Chi-square test or Fisher's Exact test (two-tailed) for categorical variables

Table 2 Multiple logistic regressions examining associations between perceived neighborhood environment and odds of being active (AG)

Items	Likert scale	Boys			Girls		
		OR ^a	95% CI	<i>p</i>	OR ^a	95% CI	<i>p</i>
Sports equipment at home	Disagree			<0.001			<0.001
	Neither A/D	1.76	0.70–4.47	0.23	2.06	0.94–4.52	0.07
	Agree	4.85	2.05–11.45	<0.001	2.63	1.55–4.40	<0.001
Interesting things to look at	Disagree			0.06			
	Neither A/D	1.87	0.762–4.60	0.17			
	Agree	3.54	1.149–10.94	0.03			

AG active group; A/D agree nor disagree

^a Adjusted for age, SES, BMI, means of transport and environment perceptions

frequently (55.2%). Age, weight and BMI were significantly different between boys and girls. In contrast, the mother's level of education did not differ significantly between genders.

Logistic regression analyses (Table 2) showed a statistically significant association between boys (OR 4.85, 95% CI: 1.149–10.94) and girls PA (OR 2.63, 1.55–4.40) and the presence of sports equipment at home (item No. 13). A question related to aesthetic within the neighborhood "Interesting things to look at while walking" (item No. 10) was also associated with higher levels of PA, but only in boys (OR 3.54, 1.149–10.94).

Streets well lit at night were found to predict active transport in girls (OR 2.93, 1.44–5.96; item No. 8; Table 3). Interestingly, the absence of opinion about the safety to walk or jog in the neighborhood in girls was also a predictor (OR 3.88, 1.36–11.07) of active transport to school.

Discussion

To create effective interventions to increase children and adolescents PA we need to understand what environmental factors stimulate individuals to become more physically active. This study examines the associations between built environment perceptions with PA and active transport in

adolescents. Consistent with our expectations some environmental characteristics of the neighborhood were found to predict active behaviours.

Although in Portugal most studies showed significant associations between PA and aesthetics only in girls (Mota et al. 2007; Santos et al. 2008), data from our study showed a significant predictive value of the aesthetic dimension—"interesting things to look at while walking"—only in boys' PA. Interestingly, previous studies have already found predictive values of this dimension in adolescents (Mota et al. 2005; Evenson et al. 2006). Thus, building places with interesting things to see such as, e.g. beautiful landscapes, enjoyable sceneries, can be an important motivator for PA. Studies carried out in adult populations showed that men, but not women, increased PA as their perceptions of the aesthetic qualities of the environment improved (Humpel et al. 2004a), although no causal relations were presented. In addition, a study from Humpel et al. (2004b) also found out that the perception of a high aesthetic value of the neighborhood increased, by about four times, the probability of men walking more as exercise. Thus, it seems that being more active gives a better understanding of the environment, either by an improved relation to and awareness of the surroundings or by familiarity.

The presence of sports equipment at home was also a predictor of PA both in boys (OR=4.85, 95% CI: 2.05–11.45)

Table 3 Multiple logistic regressions examining associations between perceived neighborhood environment and odds of using active transport to school in girls

Items	Likert scale	Girls		
		OR ^a	95% CI	<i>p</i>
Streets well lit at night	Disagree			0.02
	Neither A/D	3.88	1.36–11.07	0.01
	Agree	1.18	0.57–2.46	0.66
Safety to walk or jog	Disagree			0.01
	Neither A/D	1.82	0.72–4.57	0.20
	Agree	2.93	1.44–5.96	0.003

A/D agree nor disagree

^a Adjusted for age, SES, BMI, PA and environment perceptions

and girls (OR=2.63, 95% CI: 1.55–4.40). Similar results were found by Evenson et al. (2006) and Fein et al. (2004). Conversely, a review on the influence of the attributes of physical environment on PA did not identify any associations between sports equipment at home and PA (Davison and Lawson 2006). Although there are some differences in measuring the access to facilities and PA, other studies support our results showing that increased availability of PA facilities and equipment in the neighborhood and at school are associated with higher levels of PA (Davison and Lawson 2006; Granner et al. 2007) and that the perceptions of less parks or playgrounds are associated with a lower likelihood of walking and bicycling in the neighborhood (Timperio et al. 2004). Davison and Lawson (2006) call our attention to an important detail, despite the relations found, no study measured directly if the facilities were actually used for PA by the sample. Apparently, existing facilities raise awareness to the importance of PA as it makes the choice of being active much easier, while their absence may act as a barrier. Although this could not be a direct relation, it is at least indirect and it should be taken into account in interventions to promote PA.

The logistic regression, adjusted for independent variables, showed that the perception of good street lighting at night was a significant predictive of active transport in girls. These associations are in line with results from the CLAN study (Carver et al. 2008a). In fact, better lighting has been associated with less crime and increased activity of people after dark, thus increasing surveillance (Foster and Giles-Corti 2008) and a sense of security.

Interestingly, the lack of opinion on the safety for walking in the neighborhood was also predictive of active transport in girls. A possible explanation for these results may be because girls do not have any other choice but to go walking to school and therefore this is irrelevant for some of them and they do not even pay attention to what is happening around them.

Contradictory results are recurrently reported in the literature. For example, Carver et al. (2005) found that adolescent girls' perceptions of safety in the streets were positively associated with walking for transport. In another study, Carver et al. (2008b) observed that the girls who reported more safety on the paths they use were less likely to walk regularly. Also, Granner et al. (2007) found that people who met the PA recommendations and are frequent users of active transport reported lack of safety more frequently. In line with our research these results show that perceptions of safety are possibly influenced by a greater use or a greater attention placed on safety.

Our data increases the understanding of correlates of adolescent's PA and active transport among European adolescents since the majority of the studies on built environment are being developed in Australia, United

States and Canadá (Davison and Lawson 2006) and the physical environmental attributes in Europe are likely to differ from those countries; therefore, the relationships found there may not be applicable in Europe.

In order to contribute to the development of environmental interventions that are tailored to this age group's needs and preferences, our study identified several cross-sectional associations of active behaviors (PA and active transport) with the physical environment. It highlighted that different behaviors (PA and active transport) are associated with different characteristics of the environment thus supporting the hypothesis that the environment has behavior specific associations with PA (Giles-Corti et al. 2005b).

However, these results call for studies with more objective measures to determine the place where children are being physically active to determine their specific characteristics. The cross-sectional design of our study did not allow us to establish the direction of the relations found; thus, longitudinal studies are needed for a better understanding. In addition, the autonomy of the children in choosing their active behaviors was not addressed. However, the role of children's independence in choosing their physical activity behaviours and time spent outdoors is not yet well understood as children are subject to their parents' restrictions (Brustad 1996). Parents and children perceptions should be considered in the strategies to promote active behaviors in these age groups.

In conclusion, our data lend support to our preliminary hypothesis that perceptions of environment correlates are gender and behavior specific. Our findings may have an influence on the interventions and policy regarding the community design and the promotion of PA and health as they validate the role of the environment in PA and active transport.

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Conflict of interest statement The authors declare that there are no conflicts of interest.

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Paper II

TITLE: How children allocate their active time?

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ABSTRACT

PURPOSE: To better inform health promotion strategies our study aimed to identify how children allocate their non-sedentary and MVPA time in the different domains.

METHODS: 201 girls and 173 boys aged 11.7 years old wore an accelerometer and a GPS on opposite sides of the waist for 7 consecutive days. PALMS software was used to combine GPS and accelerometer data. PALMS also categorized non-sedentary (>100 count per minute, cpm) time and bouts of 5 minutes of moderate to vigorous physical activity (MVPA) (>2295cpm). Geographical information system allocated activity time into 4 domains: school, leisure, transport and home.

RESULTS: Overall, a higher proportion of time in MVPA bouts of at least 5 minutes was found in the transport domain (45.5%), school (30.5%), leisure (21.3%) and home (2.7%). Differences between genders were found for the proportion of time spent in both non-sedentary and MVPA time across domains ($p < 0.005$). Girls (54.5%) had significantly more MVPA than boys (35.2%) in the transport domain, whereas boys spent more of their MVPA bout time in school (37.0%) and leisure (24.9%) when compared to girls (24.7% and 18.1, respectively). There were no significant differences in the home domain.

CONCLUSIONS: Overall, the transport domain emerged as the most important contributor to MVPA so interventions and policies aiming to increase this regular behavior may be of particular relevance for children. For boys, the school domain was the most relevant for MVPA. Strategies should consider gender differences when targeting each domain.

KEYWORDS: Physical activity domains; GPS; built environment; transport; school; leisure

1. INTRODUCTION

For effective promotion of physical activity (PA) behaviors among youth, built environmental interventions have been recommended by international authorities (World Health Organization, 2007). However, despite several environmental correlates for PA being suggested in adults (McCormack and Shiell, 2011) evidence for youth is not consistent, as indicated by a large number of null associations (de Vet et al., 2011, Ferreira et al., 2007). One possible explanation is that since the area of built environment and PA research is still young, limitations exist in the conceptualization and methodology of current research (Ding et al., 2011). This includes the definitions of environmental features, neighborhoods, lack of standard measurement, and statistical analyses. So far, the body of research objectively examining associations between built environment and PA primarily considers PA to take place within an area defined through a GIS buffer and in close proximity to home or school locations (e.g. Frank et al., 2005). However, data from adults' population suggest most of MVPA occurs in locations more than 1km far from home (Troped et al., 2010). Taking this into consideration, one may ponder if this research approach is catching all real life PA and if inconsistencies in literature may reflect the lack of knowledge of real individual exposure to environments.

Ecological models of PA postulate that correlates are specific to domains and the SLOTH model delineates 4 domains of PA (Leisure, Occupation, Transportation and Home) important to identify the variety of environments and policies that may influence PA (Pratt, 2004). Identifying the locations where children spend their activity time, as well as their exposure to PA domains may help define relevant domains for effective PA promotion and better understand the relation between PA and environment.

As it remains unclear which domains are more important targets for PA interventions the aim of this study was to spatially identify the proportion of MVPA spent at different domains.

2. METHODS

Sample

This study uses the baseline data from the SALTA Project (Environmental Support for Leisure and Active Transport), a longitudinal study in the Porto area, Portugal, designed to examine environmental and social influences on PA in children and adolescents (Pizarro et al., 2013).

All public middle-schools in the Porto area (n = 65) were invited to take part in the study by letter, email and telephone. Fifty schools were excluded, 37 declined to participate and 13 did not reply to our invitation. From the 15 middle-schools that agreed to participate, 6 schools were not included due to logistical difficulties and this may have introduced a selection bias. The final sample included 9 middle-schools, resulting in a total of 652 participants. All participants were informed about the objectives of the study and parents or guardians of each participant provided a written informed consent. Participants' characteristics are listed in Table [1](#). This study was conducted according to the guidelines laid down in the Declaration of Helsinki. Ethical approval for this study was obtained from the Faculty of Sports, University of Porto, Scientific committee,

the Portuguese Foundation for the Science and Technology and by the Regional section of the Ministry of Education.

Measures

Physical Activity: Physical activity was measured using Actigraph accelerometers, model GT3X+ (Actigraph, Pensacola, FL). Accelerometers were initialized to collect data at 30 Hz and Actilife software (version 6.11) was used to initialize and download devices, and compile the data into 30 second epochs.

Positional data: were recorded every 15 seconds using a Qstarz BT-Q1000XT GPS Travel Recorder. Besides a high accuracy under various environmental conditions and good signal acquisition time (Duncan et al., 2009), this device also showed an acceptable dynamic accuracy during different modes of transportation, in different environments (Schipperijn et al., 2014).

GPS and Accelerometer Protocols: Participants were requested to wear the accelerometer and the GPS device attached to an elastic belt and placed on opposite sides of their waist for 7 consecutive days. Children were trained to switch on and off and to charge the GPS monitors overnight. Instructions were given to wear the monitors all times except when sleeping, bathing, swimming or other water activities.

Data Processing

As a first step the Personal Activity Location Measurement System (PALMS) was used to aggregate and process accelerometer and GPS data into 30 second epochs. MVPA was classified based on Evenson's et al. (2008) cut points and non-wear time was defined as 60 minutes of continuous zeros. Moreover, bouts of at least 5 minutes of consecutive MVPA were calculated. PALMS was also used to identify trips based on distance and speed between GPS points. Groups of sequential fixes (≥ 2 minutes) were considered trips if they spanned ≥ 100 meters with an average speed of ≥ 1.5 km/hour, allowing for pauses of up to 3 minutes accounting for circumstances such as stop lights

Next, the file produced in PALMS was inspected and invalid accelerometer points (due to non-wear or malfunctioning) were excluded. Finally, each valid epoch was assigned to the different domains using ArcGIS. Domains were categorized according to the SLOTH model (Pratt et al., 2004) and included the active living domains of leisure, school, transport and home.

The classification of activity domains was hierarchical to make sure that each epoch were assigned to only one domain. Epochs in the school domain were categorized first followed by epochs belonging to home domain. We've started with the identification and definition of the school polygons using Google Maps. Afterwards, participants' home addresses were geocoded and a 25m Euclidean buffer was created around each participant's home to define the home domain. Each epoch was then allocated to school and home domain through a "point-in-polygon" overlay operation. All remaining points that were classified as a trip in PALMS were assigned to transport domain and finally, all other valid epochs were classified as leisure domain.

Anthropometric measurements were taken with adolescents in bare feet and lightly dressed. Height (cm) was measured with SECA 206 stadiometer Measuring Tape (SECA, Hamburg

Germany) and weight (Kg) was assessed using digital scales (TANITA BF-522 W, Tokyo, Japan). Participants body mass index (BMI) was calculated as weight (kg)/height (m)².

Data analysis

All analyses were performed using SPSS v. 21. Descriptive statistics (means and standard deviations) were used to describe the sample. One way ANOVA and Mann-Whitney-U tests were used to examine the differences between genders in the proportions of time spent in the different domains. Linear regression analyses were conducted to predict mean daily MVPA from the proportion of the total time that were spent in 5 min bouts of MVPA.

3. RESULTS:

From the eligible sample, 414 students (63%) agreed to use the accelerometers and GPS devices. After a first screening, data was unavailable for 40 students (9.7%) due to device-malfunctioning, downloading errors, and lost devices.

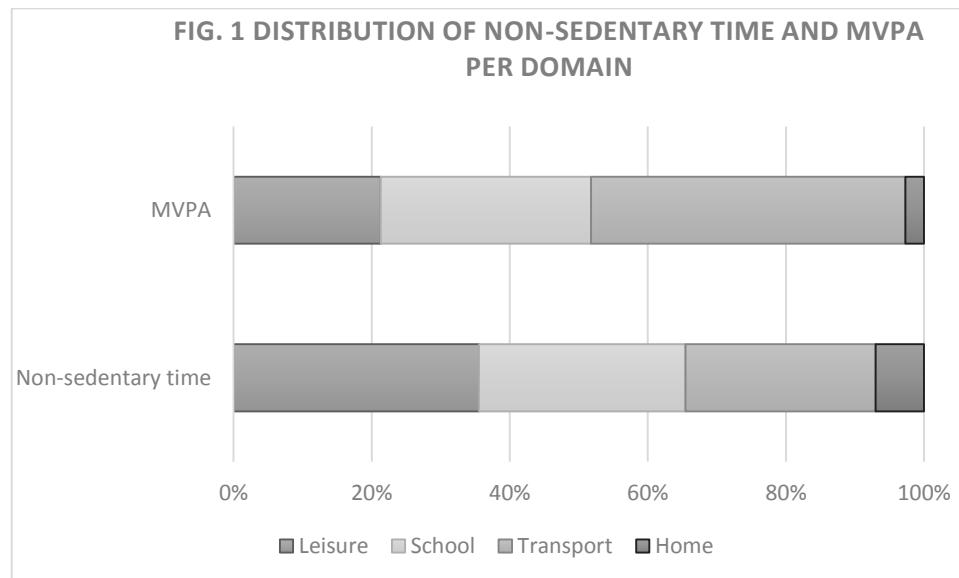
Table 1 shows the characteristics of the children remaining in the analysis (n=374).

Table 1. Sample characteristics of 374 Portuguese children (SALTA study -2011)

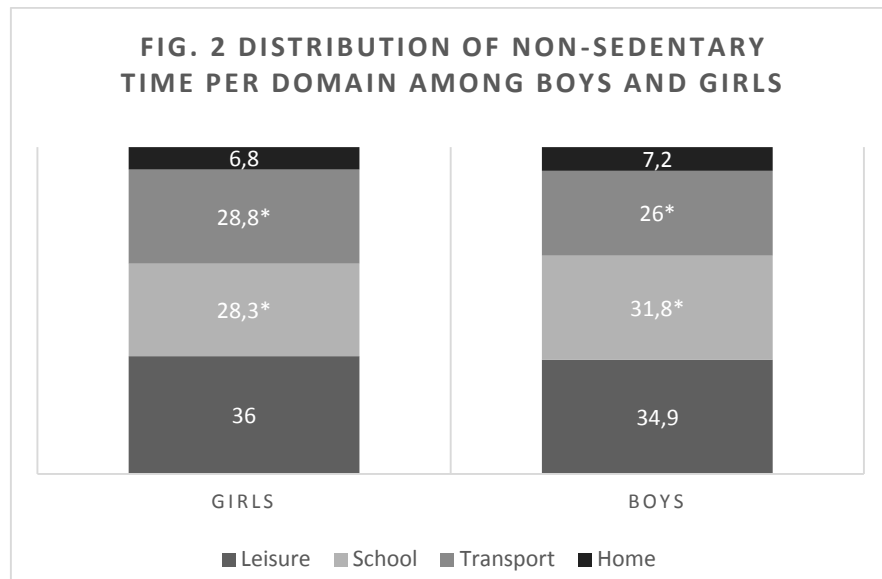
Variable	All	Girls	Boys
Gender n (%)	374 (100)	201 (53.74)	173 (46.26)
Age mean (SD)	11.69 (0.88)	11.73 (0.90)	11.64 (0.85)
BMI mean (SD)	20.91 (3.92)	21.12 (3.99)	20.66 (3.83)
MVPA mean (SD)	38.15 (20.88)	31.04 (17.00)	47.12 (22.00)

Legend: n: number; %: percentage; SD: standard deviation

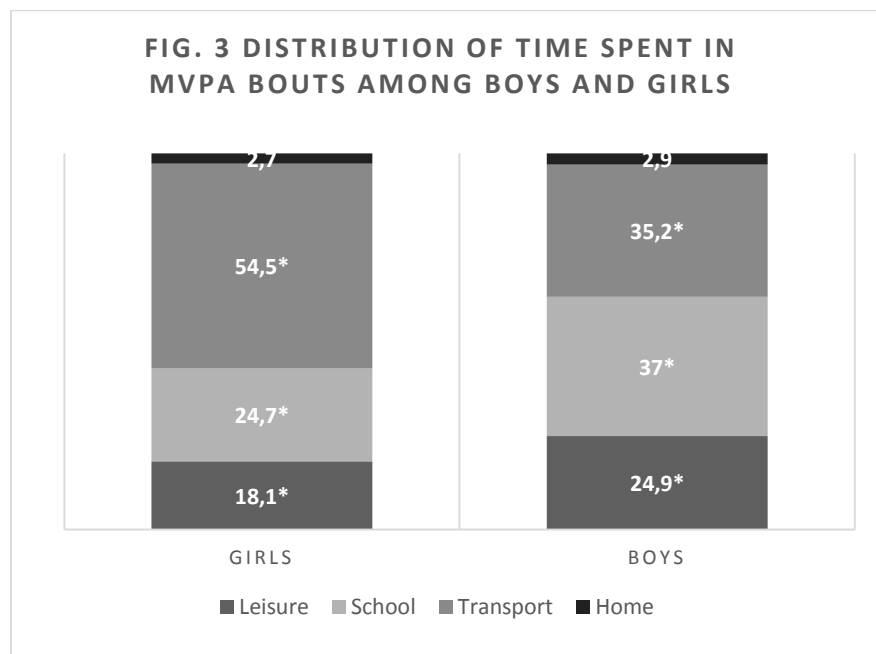
Children spent most of their non-sedentary time (>100cpm) in the leisure domain (35.5%) followed by school (29.9%), transport (27.5%) and home (7%) domains. However, a higher proportion of time in MVPA bouts of at least 5 minutes was found in the transport domain (45.5%), school (30.5%), leisure (21.3%) and home (2.7%) (Figure 1).



Differences between genders were found for the proportion of time spent in both non-sedentary and MVPA time across domains. Girls spent significantly more time in transport (29%) than boys (26%); and boys gathered more non-sedentary time in the school domain (32%) when compared to girls (28%) (Figure 2).



Looking at the proportion of time spent in MVPA bouts (Figure 3), significant differences ($p < 0.005$) were observed in all domains except home. Girls (54.5%) had significantly more MVPA than boys (35.2%) in the transport domain, whereas boys spent more of their MVPA bout time in school (37.0%) and leisure (24.9%), when compared to girls (24.7% and 18.1, respectively).



Linear regression analyses were conducted separately for boys and girls to predict mean daily MVPA from the proportion of time spent in 5 minute bouts of MVPA in the different domains $F(4,164) = 65.85$, $p < 0.001$ for girls and $F(4,143) = 68.28$, $p < 0.001$ for boys.

Results suggest that the proportion of the total time that were spent in 5 minute bouts of MVPA in each domain accounted for around 60% (59% for girls and 65% for boys) of the explained

variability in daily MVPA. The most important contributors were the transport domain in girls and the leisure domain for boys. Regression coefficients and standard errors can be found in table 2.

Table 2. Linear regression analyses: Time spent in 5 minute bouts of MVPA in Activity domains predicting daily MVPA.

	Variable	B	Std. Error	Beta	Sig
GIRLS	Intercept	13.47	1.37		
	SCHOOL	1.64	0.37	0.22	.00
	HOME	3.12	1.28	0.12	.02
	LEISURE	3.12	0.32	0.49	.00
	TRANSPORT	1.40	0.13	0.53	.00
BOYS	Intercept	10.03	2.28		
	SCHOOL	0.94	0.26	0.19	.00
	HOME	4.01	0.92	0.22	.00
	LEISURE	2.44	0.19	0.65	.00
	TRANSPORT	1.72	0.23	0.39	.00

4. DISCUSSION:

This study contributes to PA and built environment research by providing a clear idea of children's exposure to the different PA domains as well as quantifying the most important domains for MVPA, using objective measures of both environment and PA.

Overall, the largest proportion of MVPA was found in the transport domain while home domain had the smallest proportion of time in MVPA.

Previous research supports that the transport domain is the largest contributor to MVPA with reported proportions of daily MVPA between 30 and 35% (Rainham et al., 2012, Klinker et al., 2014) advocating the potential influence interventions in this domain may have for increasing PA levels. The importance of transport in this age group has also been emphasized in other studies reporting that each active trip to school may account for approximately 20% of daily recommended MVPA (Southward et al., 2012). Moreover, previous studies suggest that active transport to school is particularly relevant as might impact positively on children's health, particularly waist circumference and HDL-C levels (Pizarro et al., 2013).

Differences found between genders in MVPA domains supports the importance of school grounds for boys and may reflect preferences for involvement in different activities during school hours. Traditionally boys use their recess time to play competitive games, like football, while girls view recess as an opportunity to socialize with friends (Ridgers et al., 2012). These findings are supported in the literature as girls usually accumulate less MVPA and more sedentary time than

boys throughout the school day, including lunch time (Nettlefold et al., 2011) and recess (Ridgers et al., 2012, Dessing et al., 2013). According to a recent study, these differences in activity levels are mostly found in contexts for self-organized play, such as during school breaks and after-school day care (Nielsen et al., 2011). The authors go further and state that settings for self-organized PA may privilege boys as they are prepared with equipment of their interest (pitches, goals) and that the settings do not support girls interests (gymnastics and dance) (Nielsen et al., 2011). This could also be true for results found in the leisure domain. Taking this into consideration, it seems imperative to provide schools with spaces and equipment offering a suitable environment to stimulate girls' PA interests.

An interesting finding from our research is the low percentage of both non-sedentary (7%) and MVPA (3%) time spent at home. We can think of a number of reasons that may help explain these findings; It could be that children usually are involved in sedentary activities when at home; Children may have turned off the equipment at this location for recharging or other purposes; the GPS device may not work properly inside some buildings or it could be that the data collection procedure was not suited to capture this information for other unknown reasons. In contrast to our findings, a couple of studies have revealed home as an important location for MVPA (Maddison et al., 2010, Oreskovic et al., 2012). For example, Oreskovic et al. found that 11-12 years old children spent 30.4% of their non-sedentary time and 33.5% of their MVPA at their Home location. One possible reason argued by the authors is the cool temperatures in the northeastern part of the USA where the study was conducted, however these comparably high percentages were also found for activity time during the summer. On the other hand, similarly to our results, Klinker et al. (2014) also observed a small proportion of time spent in MVPA at the home domain, which might be indicative of the importance of outdoor play to PA levels (Cooper et al., 2010, Sallis et al., 2000).

The leisure domain accounted for 18% and 25% of total MVPA in girls and boys respectively. Previous studies showed that children accumulated high amounts of PA in playgrounds, sports facilities and urban green space (Klinker. et al., 2014). In fact, access to recreational facilities and green space are frequently associated to youth's PA levels in literature (Ding et al., 2011, Davison et al., 2008) and they are often related to leisure domain. Unexpectedly, the leisure domain was the domain where children spent most of their non-sedentary time (>100cpm), and the percentage of MVPA use found in this domain may partially explain the low levels of overall MVPA found in our sample (38.15min/day).

The relatively low percentages of time spent in MVPA in the leisure and home domains may result from leisure time activities becoming increasingly sedentary. According to the Center of Disease Control children spend on average 7.5 h/day using various entertainment media. Laptops, video game consoles, tablets, cell phones with built in games, live social networks to chat, multiplayer networks, etc. may encourage sedentary activities in settings traditionally used for PA (Must and Tybor, 2005). For example, a recent study reported that almost every child in the sample took a smartphone or tablet to school on a daily basis and these electronic devices were found to be a

barrier to PA during recess for both children who played with devices and for their classmates who preferred to play group games (Pawlowski et al., 2014).

Findings from our study need to be further explored in other populations and contexts. Additionally, more detailed information on subdomains and in the specific features of the built environment in each location may help explain differences in PA behaviors. Since distance to locations can act as a moderator in these young age groups it seems relevant to address this aspect in future research. Given the results in the Home domain, it could be interesting to further study the home location and sedentary behavior there. The use of GPS and accelerometers isn't without limitations and some locations are likely to be misclassified as well as some underestimation of physical activity intensity may have occurred for activities such as bicycling or swimming. On the other hand, other studies have often used different approaches to define MVPA, either by using different PA intensity cut-points and by including inclusion of all MVPA counts irrespectively of bouts.

As a novel objective methodology, the combined use of GPS and accelerometers data is a strength of our study and every investigation helps advance the field of built environment and physical activity research. Others strengths include the relatively large sample from different environmental contexts.

The results from our study show significant gender differences in the use of the four SLOTH approach domains for PA. It highlights the importance of the school and transport domain for boys and girls respectively, and adds new information that will help to advance interventions for PA promotion. It highlights the need for a careful consideration to spatial context to be addressed in PA research.

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Paper III

RESEARCH

Open Access

Is walking to school associated with improved metabolic health?

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Abstract

Background: Active commuting to/from school is an important source of physical activity that has been declining over the past years. Although it is an affordable and simple way of increasing physical activity levels it is still unclear whether it has enough potential to improve health. Therefore, the aim of this cross sectional study was to examine the relationship between active commuting to/from school and metabolic risk factors in 10 to 12 year old children.

Methods: Participants were 229 adolescents, selected through consecutive sampling, (121 girls) with mean age of 11.65 (± 0.73) years old from Porto, Portugal. Means of transport to/from school was accessed by asking: "How do you usually travel to school?" and "How do you usually travel from school?". Active commuting was considered if children reported at least one of the trips (to or from school) by active means. Total physical activity was obtained with Actigraph accelerometer for 7 consecutive days. Lipid profile measurements were conducted with Cholestech LDX[®] analyser. Waist circumference and blood pressure were measured by standard methods. The criteria for metabolic syndrome defined by International Diabetes Federation for children and adolescents were used.

Results: Adjusted binary logistic regression analysis suggested that walkers have higher odds to have a better waist circumference (OR = 2.64, 95% CI = 1.63-6.01) and better high density lipoprotein cholesterol (OR = 2.14, 95% CI = 1.01-4.52) profiles than non-active commuters, independent of moderate-to-vigorous physical activity. No associations were found for other metabolic risk factors.

Conclusions: Exertions to increase and maintain walking to school may be particularly relevant as it is likely to have a positive impact on children's health and eventually decrease metabolic and cardiovascular diseases.

Keywords: HDL-C, Waist circumference, Active commuting, Cardiovascular disease risk factors

Introduction

Being physically active can help reduce the prevalence of obesity in children and is associated with a decrease in cardiovascular risk factors such as lipid disorders, high blood pressure, insulin resistance among others [1]. Recent studies suggest that low levels of high-density lipoprotein cholesterol (HDL-C) are an important and independent risk factor for cardiovascular disease (CVD) [2] and are linked to worse CVD outcomes [3]. This should be a major cause of concern because cardiovascular risk factors tend to track into adulthood [4] and the process of atherosclerosis, the pathologic basis for clinical CVD starts early in childhood [1].

Active commuting to/from school (ACS) should be considered a key factor to reduce important negative health outcomes as it has been identified as an important source of physical activity (PA) for young people [5,6]. However in Portugal, similarly to most developed countries, data on transport suggests a decline in active commuting over the past years. For example, in Porto, walking trips to work/school decreased from 27% in 1991 to only 19% in 2001. Inversely, car was the most used transport to work/school in 2001 (49%), increasing over than 100% when compared to 1991 when only 23% of the journeys were made by car, showing dramatically changes in transport patterns (INE, 2003). These shifts are replicated, all over the world, in children's decreasing number of walking trips to/from school [7,8].

Although some evidence supports that ACS is associated with a healthier body composition and higher

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levels of cardiorespiratory fitness among youth [9], it remains unclear whether ACS has the potential to improve health through a better metabolic profile as research on this topic is scarce. To our knowledge, only two studies have addressed the relationship between ACS and metabolic risk factors in children [10,11]. A research in Danish children and adolescents found no differences in CVD risk factors between passive travelers and walkers, but 15-year-olds that cycled to school showed consistently better CVD risk profile compared with noncyclists [10]. Moreover children who did not cycle at baseline and had changed to cycling at follow up had better cholesterol/HDL ratio, better glucose metabolism, and a lower composite CVD risk factor score than those who did not cycle at either time point. On the other hand, Chillón and colleagues [11] found no significant associations between means of transport to school and cardio metabolic risk factors in a longitudinal study in Swedish children. Although both studies were developed in north European countries, with strong traditions of cycling to school, findings show conflicting results. In addition, PA in these studies could be underestimated as bicycling is not accurately measured by the accelerometer, therefore influencing the results. Moreover, any of the studies considered diet intake although it has a well-recognized role affecting cardiovascular health and risk factors for CVD [12]. The study from Andersen and coworkers [10] found no differences between walking and non-active means of transport in relation to CVD risk profile, however previous research show that walking has the potential to play a key role in the primary and secondary prevention of CVD in younger, middle, and older men and women, in both healthy and patient populations [13].

The aim of this study was to examine the relationship between ACS and metabolic risk factors having known potential confounders in consideration. It is our intention to improve the understanding of this issue since ACS is likely to be easily incorporated into daily living activities, positively impacting health outcomes.

Methods

Participants

Data for this study is a part of SALTA PROJECT STUDY (Environmental Support for Leisure and Active Transport), a longitudinal study being developed in Porto area, Portugal, designed to examine environmental and social influences on PA. Ethical approval for this study was obtained from the Faculty of Sports ethics committee, the Foundation for the Science and Technology and by the regional section of the ministry of Education.

All public middle-schools in Porto area were invited to take part in the SALTA PROJECT by letter, email and

telephone. From a total of 65 schools, 37 declined to participate, 13 did not reply to our invitation and 15 schools agreed to take part in this study. Due to lack of resources and failure in bilateral talks, data were only collected in 9 middle-schools with a total population of 1555 students in the 6th grade. Respondents included 652 children who agreed to participate and had parental written consent to take part in the study. After eliminating subjects due to collecting errors, SALTA PROJECT final sample comprised 641 children (41.2%; 342 boys and 299 girls) with a mean age of 11.60 years old. From those, 121 girls and 108 boys with mean age of 11.65 (± 0.73) years old had parental authorization to collect capillary blood samples and took part in this particular study.

Testing protocol

Data collection was performed in the school gymnasium between 08:20 and 11:00 a.m. As children were overnight fasting, lipid profile was firstly accessed. After blood samples were taken children were given light breakfast. Subsequently, participants fulfilled a demographic questionnaire and determined their maturational stage. Following a 5 minute rest in a separate room, blood pressure was measured. Afterwards anthropometric data was collected and nutritional information was gathered; lastly accelerometer devices were placed right before the testing protocol was over.

Measurements

Means of transport to and from school

Means of transport to and from school was accessed by questionnaire. Participants were asked "How do you usually travel to school?" and "How do you usually travel from school?". Possible answers included walking, cycling, by car or by public transport. Based on their answers the respondents were categorized as active commuters (walking and cycling) or non-active commuters (car or public transport) to/from school. If subjects reported at least one of the trips as active they were included in the active commuting group [14]. Previous studies have demonstrated evidence for reliability and validity for similar questions [15].

Metabolic risk factors

Waist circumference (WC) was measured with a non-metallic tape midway between the lower rib margin to the anterior superior iliac crest [16] at the end of normal expiration.

Capillary fasting blood samples were taken from the middle finger by trained professionals according to Center of Disease Control capillary blood sample protocol. Blood samples were drawn in capillary tubes (35 μ l,

Selzer) coated with lithium heparin and immediately assayed using Colestest LDX Analyser in order to obtain values of plasmatic total cholesterol (TC), HDL-C, triglycerides (TG), and fasting glucose (GLU). A daily optic check was conducted on the analyzer used for the study.

Systolic and diastolic blood pressure measurements were performed with Colin model BP 8800 (Critikron, Inc., Tampa, FL) on the right arm after a 5 minute rest. Participants were in a comfortably seated position with their back supported and legs not crossed. The arm was bared without constrictive clothes, supported at the heart level and resting in a table. At least two readings were performed at 1-minute intervals; if there was a > 5 mmHg difference between the first and second readings additional readings were done. The average of two readings with < 5 mmHg difference were used for analysis [17].

Clustered metabolic risk score

The cluster for metabolic syndrome for children and adolescents defined by International Diabetes Federation (IDF) was used to access the metabolic risk factors [18] and included WC $\geq 90^{\text{th}}$ percentile, HDL-C < 40 mg/dL, TG ≥ 150 mg/dL, GLU ≥ 100 mg/dL, and systolic blood pressure ≥ 130 or diastolic blood pressure ≥ 85 mmHg. In regards to blood pressure if the participant had at least one of the systolic or diastolic blood pressure values above the reference they were included in the risk group.

Confounders

Total physical activity was measured with Actigraph accelerometers, model GT1M (Actigraph, Pensacola, FL). Participants were instructed to use the accelerometer attached to an elastic belt and placed above the right iliac crest for 7 consecutive days. Instructions were given to wear the monitor all times except when sleeping, bathing, swimming or other water activities. Data was collected in 30 seconds epochs and a minimum recording of 8 hours on at least 4 days (1 weekend day) were considered valid data. 60 minutes of consecutive zeros were considered invalid data. PA data was processed using Actilife software (Actigraph LLC Pensacola, FL) and summarized as time spent in moderate and vigorous PA (MVPA), defined as ≥ 2296 counts/min. This cut points for PA intensities developed by Evenson and colleagues [19] seem to exhibit significantly better accuracy than others in children and adolescents [20].

Anthropometric measurements were taken with children in bare feet and lightly dressed. Height (cm) was measured with SECA 206 Bodymeter Measuring Tape (SECA, Hamburg Germany). Weight (Kg) and body fat percentage were accessed using digital scales (TANITA BF-522 W, Tokyo, Japan). Body mass index (BMI) was

calculated as weight (kg) / height (m)². Overweight and obesity were defined according to sex- and age-specific BMI cut points established by Cole et al. [21].

Socioeconomic status (SES) was obtained based on parents report of their educational level and was collapsed into three categories according to Portuguese Educational System: ≤ 6 years (low), 7–12 years (medium) and > 12 (high) similarly to procedures applied in the Portuguese context before [22].

Participants were asked to self-determine their *pubertal stage* using the pattern of development diagrams for pubic hair and breasts or genital development established by Tanner [23]. If the responses differed between pubic hair and breasts/genital development, then the pubic hair stage was used.

Food intake was assessed by a trained nutritionist using the 24-hour recall and supported by a food quantification manual to allow more accurate portion size estimation. Data were then analyzed using Food Processor Plus (ESHA Research, Salem, OR). The 24-h recall is the most commonly used dietary assessment method because it is easy to administer, can be performed in large-scale studies [24,25] and can be used to assess adequacy of energy and macronutrient intakes.

Statistical analyses

Data was analysed using IBM SPSS Statistics (version 20; SPSS, Inc., Chicago, IL). Significance level was set at 5% ($p < 0.05$). Descriptive statistics were used to characterize the sample. Point biserial correlation determined the associations between walking and MVPA. Regression analysis models were conducted to establish associations between metabolic risk factors and walking. Known potential confounders for the CVD risk factors, namely body fat percentage, calories from fat, age, gender, SES, pubertal stage and minutes in MVPA were included in the analysis to find the model that best fits the observed data. Variables were retained in the models if backward elimination resulted in a greater than 10% change in the estimated effect measures. Interactions between walking and each confounder were studied when accessing the associations of walking and each metabolic risk factor.

Results

Demographic characteristics of the initial sample did not differ significantly from the final sample included in this particular study.

Sample characteristics are presented in Table 1. About 53% of the students were girls and most prevalent tanner stages were 3 and 4. Sample SES was predominantly (87%) medium and low. Among 229 students 75% made at least one trip (to or from school) by active means. Interestingly, walking was the only active means of transport reported. Noteworthy 85.5% of the children

Table 1 Descriptive statistics for participants in the study

Variable	Frequency (n)	Frequency (%)
Girls	121	52.8
Means of Transport		
Walking	171	75
Cycling	0	0
Public transport	10	4.4
Car	43	18.8
Socio Economic Status		
Low	54	34
Medium	85	53
High	20	13
Tanner Stage		
2	32	15
3	87	39
4	78	35
5	25	11
	Mean (SD)	
Age (years)	11.65 (0.73)	
% Body Fat	22.92 (7.84)	
Calories (Kcal)	2133.95 (495.3)	
Calories from Fat (Kcal)	680.85 (374.06)	
Waist Circumference (cm)	70.71 (9.97)	
Total Cholesterol (mg/dL)	148.29 (26.39)	
HDL-C (mg/dL)	48.23 (13.31)	
Triglycerides (mg/dL)	69.69 (33.62)	
Glucose (mg/dL)	90.24 (7.83)	
Average Systolic Blood Pressure (mm hg)	116.35 (13.12)	
Average Diastolic Blood Pressure (mm hg)	61.19 (8.28)	
Physical activity (min/day MVPA)	39.53 (20.26)	

Legend: *SD* standard deviation, *HDL-C* high density lipoprotein-cholesterol, *kcal* kilocalories; *cm* centimeters, *mg/dL* milligrams per deciliter, *mm hg* millimeter of mercury, *min/day in MVPA* minutes per day in moderate to vigorous physical activity.

did not achieve daily PA recommendations of 60 minutes of MVPA and MVPA mean time was about 40 minutes. Association between walking and MVPA was also assessed but no significant relation was found ($p = 0.102$). Mean sample metabolic components were within normal values [18]. Table 2 provides the number of subjects exhibiting each component of the metabolic syndrome. Metabolic syndrome defined by abdominal obesity ($WC \geq 90^{\text{th}}$ percentile) and the presence of two or more other clinical features ($HDL < 40$ mg/dL, $TG \geq 150$ mg/dL, $GLU \geq 100$ mg/dL and systolic blood pressure ≥ 130 or diastolic blood pressure ≥ 85 mmHg) was observed in only 3% of the sample. Most prevalent lipid disorder was low levels

Table 2 Distribution of the metabolic syndrome and related components

Metabolic Risk Factors	At risk definition	Frequency (%)
Waist Circumference	$\geq 90^{\text{th}}$ percentile	16.4
HDL-C	< 40 mg/dL	25.5
Triglycerides	≥ 150 mg/dL	2.5
Glucose	≥ 100 mg/dL	8.8
Blood Pressure	$\geq 130/\geq 85$ mm hg	15.1
Metabolic Syndrome	$WC \geq 90^{\text{th}} + 2$ other	3
Physical Activity	< 60 min/day in MVPA	85.6

Legend: *HDL-C* high density lipoprotein- cholesterol, *mg/dL* milligrams per deciliter, *mm hg* millimeter of mercury, *WC* waist circumference, *min/day in MVPA* minutes per day in moderate to vigorous physical activity.

of HDL-C (25.5%) and just a small number of children ($n = 5$) had high TG levels.

Results from crude and adjusted binary logistic regressions between metabolic risk factors and walking are presented in Table 3.

Crude binary logistic regressions showed significant associations between walking and $WC < 90^{\text{th}}$ percentile ($OR = 2.28$, $95\%CI = 1.06 - 4.95$) and $HDL-C \geq 40$ mg/dL ($OR = 2.17$, $95\%CI = 1.10-4.25$). Adjusted analysis still suggests higher odds, in walkers, to have a better WC ($OR = 2.64$, $95\%CI = 1.63-6.01$) and HDL-C ($OR = 2.14$, $95\%CI = 1.01-4.52$) profiles than non-active commuters. No significant interactions were found by walking on any metabolic risk outcome (results not presented).

Discussion

The aim of this cross-sectional study was to analyze the relationship between ACS and the metabolic risk factors for children defined by IDF. Findings suggest a significant association of walking with both WC and HDL-C providing implications for children health promotion. Unlike other studies we controlled for confounding by dietary fat intake and MVPA, which would better estimate the impact of walking on the metabolic risk factors.

Our results suggest a beneficial association between walking to/from school and WC, after controlling for MVPA. In line with our findings Rowe and colleagues [26] compared active and passive school commuters and found that children who actively commute to school have healthier waist adiposity, body weight, cholesterol sub-fractions, blood lipids and possibly inflammation. Also a longitudinal research focusing on cycling to school and weight found lower odds of being overweight in children who cycled to school [27]. Despite the heterogeneity of ACS definitions, a recent review on ACS health-related fitness in children and adolescents found an association between this active behaviour with a healthier body composition [9]. These findings could be

Table 3 Association between walking and metabolic risk factors

Dependent variable	Crude OR	95% CI	Adjusted OR	95% CI
Waist Circumference ^a	2.28	1.06 - 4.95*	2.64 ^b	1.63-6.01*
HDL-C ^a	2.33	1.15 - 4.71*	2.14 ^c	1.01-4.52*
Triglycerides ^a	2.04	0.33 - 12.50	-	-
Glucose ^a	1.17	0.40 - 3.43	-	-
Blood Pressure ^a	1.79	0.82 - 3.91	-	-

Legend: HDL-C high density lipoprotein-cholesterol, OR odds ratio, 95% CI 95 percent confidence interval.

a) Reference Category: At risk.

b) Adjusted for gender, % body fat, minutes in moderate-to-vigorous physical activity.

c) Adjusted for age and tanner stage.

especially significant for obese children that usually have less PA opportunities implying that walking to school may be a simple and effective strategy, that can be implemented almost everywhere, to help control and reduce overweight.

While the association between walking and fatness has been well investigated, limited evidence exists regarding other metabolic health parameters of children who walk to school. Despite data in adults provide strong evidence that people who are more physically active have higher HDL-C levels, results vary considerably depending on the characteristics of the exercise programs and the assessing methods. In children, thus evidence suggest a favorable lipoprotein profile related to higher habitual physical activity, and that increases in HDL-C and reductions in low density lipoprotein cholesterol may be possible with regular exercise, the dose-response relationship remains elusive [28]. Findings from our study, add information to current knowledge suggesting that walking to school may be of relevance for a better HDL-C profile. In line with our findings, in a meta-analysis from Kodama and collaborators [29] including 25 articles, regular aerobic exercise was modestly associated with clinically important elevation in HDL-C levels. In addition the exercise duration has been previously highlighted as the most important element of an exercise prescription [30]. In fact, it is assumed that a minimum exercise volume is needed to significantly increase HDL-C [30]. Although, a dose-response relationship between the amount of exercise performed and HDL-C has been suggested [30,31] research shows conflicting results. The exercise volumes suggested by previous studies varies between 20 minutes of exercise 3 to 4 times a week and 60 minutes of combined exercises at a maximum heart rate of 75%. Interestingly, in our study 86% of the students took less than 15 minutes to get to school, and only 13% took more than 15 minutes (data not shown), still our results suggest that walking to/from school predicts higher HDL-C levels. This can indicate that even small amounts of walking may play an important role in health. Despite the fact that 75% of our sample were active commuters, a large percentage (85%) were not

sufficiently active to reach the recommended daily MVPA. As point biserial correlation didn't show any association between means of transport to/from school and minutes in MVPA this may imply that walking could be of light intensities and therefore not enough to be considered in PA recommendations. In fact is likely that exercise-induced changes in HDL-C are the result of the interaction amongst each exercise component (intensity, frequency, duration of each exercise session and length of the exercise training period) however the relative contribution of each exercise component has not been established yet [32], particularly in children. Apparently, evidence point toward favourable changes to occur incrementally and reach statistical significance at approximately 7–10 miles per week or 1200 to 1600 kcal, what seems to fit in our sample [32]. We could also speculate that walking is just about the only MVPA children engage most days of the week and children who walk to/from school may spend less time in other forms of MVPA.

In contrast to our results, a longitudinal research in children showed no difference in CVD risk factors between passive travelers and walkers suggesting that self-selected intensities of walking were not enough to improve cardiovascular health when compared to cycling [8]. Nonetheless, in our data the inclusion of several confounders such as body fat percentage, minutes of MVPA and fat intake did not significantly altered our regression model, one may suggest that walking was an important factor for the main differences in HDL-C levels. We may also speculate that intensities achieved when walking to and from school may be relevant enough for good HDL-C levels.

The present study focus on walking in 10 to 12 year old children by contrast with the most prevalent research that commonly focuses on the effects of total PA or different types of training in metabolic risk factors. To our knowledge data from the present study are novel information regarding the association between walking and metabolic risk factors in Portuguese youths. The use of objective measures of PA and anthropometry are also important strengths of this study. Differently from other

research we adjusted analysis for potential confounders such as diet, SES, and demographics as the risk of metabolic syndrome is strongly associated with sociodemographic and lifestyle patterns including adequate diet, healthy weight and regular PA [33].

This study has some limitations notable of comment. Our independent variable, means of transport to and from school, relies on self-reported information. The cross sectional design of our study did not allow us to determine the direction of the observed associations. Nonetheless our data suggests that any active commuting is associated with better health. Finally the lack of results in other metabolic factors may be due to the lack of statistical power to show differences as was the case for triglycerides and glucose. Further research to clarify the threshold needed in each exercise component to obtain metabolic benefits should be conducted in children who walk to school in order to study the effect of this behaviour in health.

Future investigation should include Global Position System (GPS) technology during walking and combine it with accelerometer data. Therefore, more reliable information on time travelled, distance, intensities and patterns of this specific behaviour could be obtained and it would decrease the bias of self-reporting methods.

Even though walking has decreased in recent years, it still is an affordable and easy way of getting high daily PA levels, without the costs associated with regular exercise programs. Walking should be consider a major key factor to increase PA levels [14] and reduce important health outcomes such as obesity [34]. Countries such as Denmark and Holland show that it is possible to maintain and improve high levels of active commuting and our data reinforces that even small amounts of this behavior has potential to be of clinical relevance for health.

Conclusion

In summary, the findings from this study showed that walkers have higher odds of having a better WC and HDL-C profile than children who use passive means of transport to/from school, after adjusting for MVPA and diet. For that reason exertions to increase and maintain walking in children may be particularly relevant as it is likely to positively impact health and decrease metabolic and CVD.

Abbreviations

HDL-C: High density lipoprotein cholesterol; CVD: Cardiovascular disease; ACS: Active commuting to/from School; PA: Physical activity; WC: Waist circumference; TC: Total cholesterol; TG: Triglyceride; GLU: Fasting glucose; IDF: International Diabetes Federation; mg/dL: Milligrams per deciliter; mm hg: Millimeter of mercury; MVPA: Moderate to vigorous physical activity; cm: Centimeters; BMI: Body mass index; SES: Socio economic status; SD: Standard deviation; kcal: Kilocalories; OR: Odds ratio; 95% CI: 95 percent confidence interval; GPS: Global Position System.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

ANP and MPS conceived and coordinated the study. ANP conceptualized and drafted the paper after contribution to data acquisition, analysis and interpretation. JCR, EM, JM, MPS contribute to further development and critical revision of the manuscript. JCR made substantial contributions data acquisition. EM assisted in the statistical analysis. MPS and JM contributed with grant funding for the project. All authors approved the final version of the manuscript.

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Paper IV

TITLE: ACTIVE COMMUTING TO SCHOOL IN PORTUGUESE ADOLESCENTS: USING PALMS TO DETECT TRIPS.

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Abstract

The declining levels of physical activity (PA) have led to active commuting to school (ACS) being seen as a key strategy to increase PA levels in school-aged children. In Portugal, no data exists on the patterns of this behavior, an essential step for developing evidence-based and effective interventions.

The purpose of this study is to explore the travel to school behavior using a new objective methodology.

Methods: 155 adolescents (mean age 15.9 ± 1.1 years) wore an accelerometer and a GPS on opposite sides of their waist for 7 consecutive days. Home and school addresses were geocoded to identify home-school trips. The web-based tool PALMS was used to combine GPS and accelerometer data, categorize Moderate to Vigorous Physical Activity (MVPA) and classify trip mode of home-school trips into: walking, bicycling or vehicle.

Results: 609 trips were identified as home-school trips. Walking was the most frequent trip mode (60.8%) whereas bicycling was less common (14.4%). Median home-school walking trip length was 0.94km and 96.7% of the trips were under 2km. Each walking trip (to or from school) contributed with an average of 12 (± 5.6) minutes to daily MVPA. Differences were found whether the trip started at home or at school, particularly for minutes in MVPA and duration of the walking trips. Logistic regression analysis showed increasing distance to be associated with lower odds of ACS (OR: 0.20; 95% CI: 0.14-0.28).

Conclusion: PALMS is a friendly web-based tool to objectively classify trip modes. Walking to school and back home can contribute with up to 40% of recommended daily MVPA, so increasing this behavior may be of particular relevance to increase PA levels. On the other hand, cycling is underused in home-school trips and strategies to promote the use of bicycle could also be of interest, especially in trips longer than 2km.

KEY-WORDS: Active travel; GPS; means of transport; distance; adolescents; physical activity

INTRODUCTION

Active commuting to school (ACS) has been proposed as a potentially source of physical activity (PA) in children and adolescents (Chillon et al., 2010; Davison et al., 2008) and can represent 20 to 30% of daily moderate to vigorous physical activity (MVPA) (Klinker et al., 2014; Southward et al.). With decreasing levels of physical activity in children and adolescents, ACS due to its regular nature, is likely to be a key element for children's health (Pizarro et al., 2013; Tudor-Locke et al., 2001) and interventions to encourage ACS are becoming a priority in some countries (Active Healthy Kids Canada, 2013; National Safe Routes to School Taskforce, 2008). However, most research on transport-related physical activity (PA) relies on self-reported data and geographic information systems (GIS) based estimates of routes taken, which are not always representative of actual routes (Duncan and Mummery, 2007). Thus, comparing results across studies should be done with caution as discrepant methods are commonly used to access and classify ACS (Sirard and Slater, 2008).

Global position system (GPS) tracking used in combination with accelerometer data, is arising as an objective approach to assess means of transport and reduce self-reporting bias (Feng and Timmermans, 2013; Kerr et al., 2011). Moreover, as several built environment features that may be related to ACS were identified (Pont et al., 2009), the joint use of GPS data and GIS can inform researchers about the real exposure to these different environments. Despite the advantages advocated by this new approach, data processing emerges as a challenge due to the large size and complexity of this type of data. Novel and robust methods are requested to improve the investigation on the relationship between PA and environment (McCrorie et al., 2014). The Personal Activity Location Measurement System (PALMS) is a web-based application capable of integrating and processing activity and location data in a relatively simple way and may be the key to unify methods and allow for comparison of results helping in clarification of findings in this field.

Similar to countries like the United States (McDonald, 2007) or United Kingdom (Black et al., 2001), Portuguese transportation statistics reveal an alarming drop of 54% in active commuting in the general population in the last 10 years. Despite being scarce, data for ACS in Portugal shows that only around half of the students use active transportation (Cooper et al., 2005; Mota et al., 2007) and reveals a huge potential for interventions to increase physical activity. While evidence suggest that ACS is influenced by country specific environmental and cultural factors (Faulkner et al., 2009), little is known about Portuguese adolescent's mode of travel to school, distance and time travelled. Therefore, the aim of this study was to explore travel behavior in Portuguese adolescents using a new objective methodology to provide a more complete description of the daily transport patterns to better inform policies for physical activity promotion.

METHODS

Three public schools from Porto County were selected to participate in this study, with the aim to maximize variance in environmental attributes potentially related to physical activity and socio-economic status (SES). One hundred and fifty five adolescents (55% females) between 14 and

18 years (mean age 15.9 ± 1.1) provided a voluntary written consent from their parents to participate in this study. Data were confidential and were collected between February 2013 and May 2014. Ethical approval for this study was obtained from the Faculty of Sports ethics committee, the Portuguese Foundation for Science and Technology and from the regional section of the Ministry of Education.

MEASUREMENTS

Physical Activity: Physical activity was measured using Actigraph accelerometers, model GT3X+ (Actigraph, Pensacola, FL). Accelerometers were initialized to collect 30 Hz and Actilife software was used to initialize and download devices, and compile the RAW data to 30 second epochs. Evenson cut-points were used to categorize MVPA (2296 counts/min) (Evenson et al., 2008) as they seem to exhibit significantly better accuracy than others in children and adolescents (Trost et al., 2011).

Positional data: were recorded every 15 seconds using a Qstarz BT-Q1000XT Travel Recorder. Besides a high accuracy under various environmental conditions and good signal acquisition time (Duncan et al., 2009), this device also showed an acceptable dynamic accuracy during different modes of transportation, in different environments. The median error during walking trips was 3.9 m, 2.0m for bicycle trips, 1.5m for bus and 0.5m for car (Schipperijn et al., 2014).

GPS and Accelerometer Protocols: Participants were requested to wear the accelerometer and the GPS device attached to an elastic belt and placed on opposite sides of their waist for 7 consecutive days. Children were trained to switch on and off and to charge the GPS monitors overnight. Instructions were given to wear the monitors all times except when sleeping, bathing, swimming or other water activities.

The Personal Activity Location Measurement System (PALMS) was used for *Data processing and analyses*. First, PALMS used distance and speed between GPS points to classify whether each epoch was part of a trip and the trip mode based on the following protocol:

- groups of sequential fixes (≥ 2 minutes) were considered trips if they spanned ≥ 100 meters with an average speed of ≥ 1.5 km/hour
- pauses of up to 3 minutes were allowed during a trip to account for circumstances such as stop lights
- Trips were classified into Walking trips if they had a 90th percentile speed of < 10 km/hour; trips with a 90th percentile speed between 10 and 35 km/hour were classified as bicycling trips and trips were considered vehicle trips if they had a 90th percentile speed of ≥ 35 km/h (Carlson et al., 2014).
- points estimated to be indoors are removed from the starts and ends of trips.

Second, PALMS processed accelerometer data based on Evenson's cut points and a non-wear time definition of 60 minutes of consecutive zeros (Evenson et al., 2008). Finally, data was processed to produce a 30 second aggregated dataset with the information from both monitors. School and participant's home addresses were then geocoded. A school was defined as the parcel on which the geocode point fell, while a 25m Euclidean buffer was applied to participants'

home address point to account for signal errors. Afterwards, a PostgreSQL database was built to combine the PALMS dataset with GIS data to identify trips that started at school and ended at home and vice-versa.

Anthropometric measurements were taken with adolescents in bare feet and lightly dressed. Height (cm) was measured with SECA 206 Bodymeter Measuring Tape (SECA, Hamburg Germany) and weight (Kg) was assessed using digital scales (TANITA BF-522 W, Tokyo, Japan). Participants body mass index (BMI) was calculated as weight (kg)/height (m)². Adolescents were then categorized into 'normal weight' or 'overweight' (including obese) according to age- and sex-specific cut-off points for children by Cole et al. [34].

Demographic data was obtained through a questionnaire including information on birth date, home address and gender.

STATISTICAL PROCEDURES

Data was analysed using IBM SPSS Statistics (version 21; SPSS, Inc., Chicago, IL). Significance level was set at 5% ($p < 0.05$). Descriptive statistics were used to characterize the sample. Binomial logistic regression models were conducted to ascertain the effects of distance, age, body mass index (BMI), gender and school and their interaction with the participant on the likelihood to active commute to school. To find the model that best fits the observed data variables were only retained in the models if backward elimination resulted in a greater than 10% change in the estimated effect measures.

RESULTS

Sample characteristics

Table 1. Sample characteristics and overall trips

Gender (%)	Male	45
	Female	55
Age (mean/SD)		15.9±1.1
BMI (Mean/SD)		22.4±3.5
Weight status (%)	Normal weight	73.5
	Overweight/obese	26.5
Daily MVPA (mean/SD)		55.2±23.5 min
Trips (%)	Walking	57.6
	Bicycle	16
	Vehicle	26.4
Trip duration (median)	Walking	6.5 min
	Bicycle	5 min
	Vehicle	7.5 min
Trip length (median/mean)	Walking	0.34 km / 0.53 km
	Bicycling/bus	0.72 km / 1.13 km
	Vehicle	2.82 km / 5.84 km
Active commuting (%)	School/home	9.6
	Other destinations	90.5

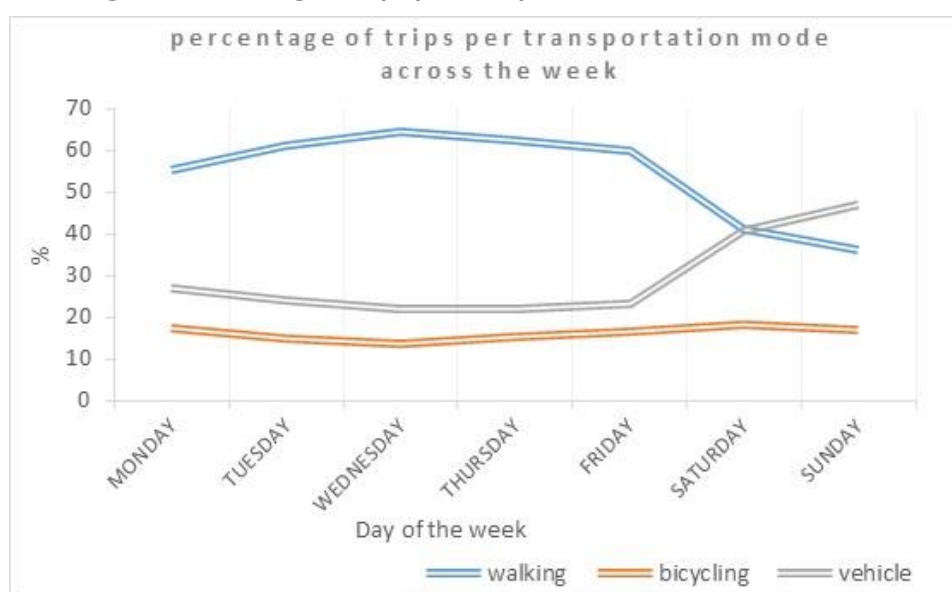
Legend: %-percentage; SD-Standard deviation; BMI-Body mass index; min-minutes; km-Kilometers

Descriptive data for the demographic characteristics and trips can be found in Table 1.

A total of 7220 trips were identified with a median length of 678.16 meters and a median duration of 6.5 minutes. From these trips, 73.6% (5312) were active trips (walking and bicycle) while 26.4% (1908) were passive. The longest active trip detected was 4439.3 meters.

Walking was the preferred mode of travel in our sample (57.6%) while only 16% of all trips detected were done by bicycle. As expected, walking trips were used for shorter distances (mean 0.53km) while motorized vehicle trips were considerably longer (mean 5.84km). During weekend days a 20% drop in walking trips was observed while the number of vehicle trips increased (Figure 1). Home-school-home trips constituted 9.5% of the total number of active trips. Looking at participants instead of trips we found that 64% of the adolescents used active transport to school during most school days.

Figure 1. Percentage of trips per transportation mode across the week.



Journey between home and school

60.7% of the adolescents had valid GPS information for at least one of their home-school-home journeys. A higher proportion of females had valid data on home-school trips (61 vs 39% $p=0.000$) when compared to males. No differences were found between adolescents with valid vs invalid data on home-school-home trips in age or BMI.

On average participants recorded 7 trips between home and school. The most frequently used travel mode was walking (68.8%), followed by vehicle (16.7%) and bicycle (14.4%). Median walking trip length between home and school was 0.94 km, with the longest walking trip being 3.38 km. For walking home-school trips the mean time spent in MVPA was 12 ± 5.6 minutes, i.e. 20% of recommended guidelines of 60 minutes of MVPA. Further characteristics of the school journey are provided in Table 2.

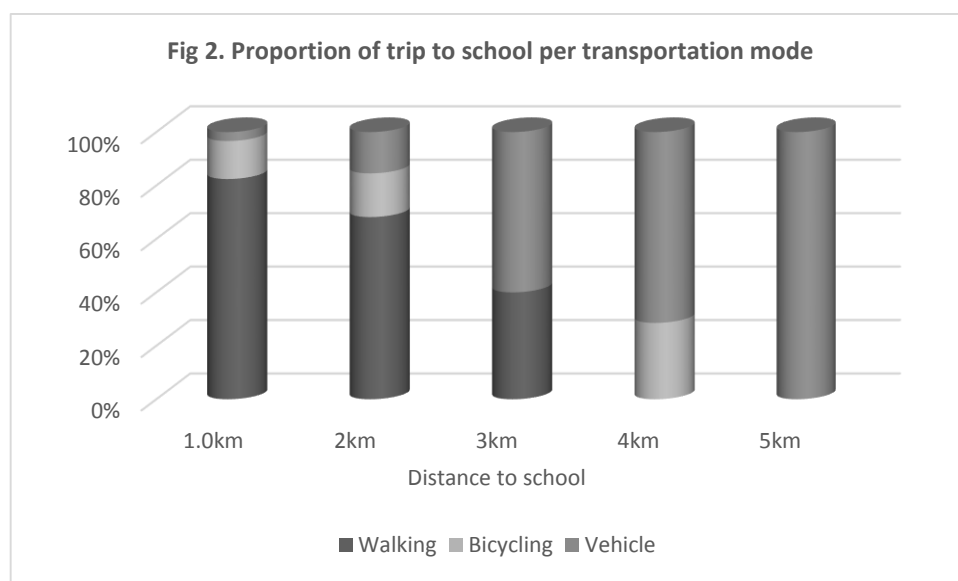
As illustrated in figure 2, after the first km as distance increases, the number of walking trips decreases and are replaced by an increasing number of vehicle trips, as expected. Journeys longer than 4.5km are exclusively made by vehicle while in trips under 0.5km no vehicle trips were

observed and at 1 km only a small percentage of vehicle trips were observed (3.3%). Bicycle trips were observed within a 4.5km range.

Table 2. Trips to school characteristics

	Walking	Bicyling	Vehicle
Trips (%)	60.8	14.4	16.7
Trip duration (median)	14.5min	7.0min	8.0min
(mean/SD)	15.4±1.1min	7.7±4.0min	9.2±5.0min
Trip length (median)	0.94km	1.08km	2.81km
(mean/SD)	1.1±0.5km	1.2±0.8km	3.5±2.7km
Minutes in MVPA (mean/SD)	12.0±5.6 min	2.2±2.6min	1.3±1.6min
Speed (mean/SD)	4.1±0.7 km/h	9.7±3.0km/h	21.3±7.3km/h

Legend: min-minutes; SD-Standard deviation; km-Kilometers; MVPA-moderate to vigorous physical activity



Distance travelled by transportation mode

Almost all of the walking trips to/from school (96.7%) were within 2km. Similarly, bicycle trips occurred mostly (92%) within 2km. Of the vehicle trips 80.7% were within 3.5 km and 96.4% within 5km (Table 3).

Direction of the trip

As home to school and school to home trips usually don't take place at the same times of the day, meaning diverse environmental context (social, traffic, day-light), differences between trip

direction were tested. Significant differences in minutes in MVPA and duration were found whether the trip started at home or at school (Table 4).

Table 3. Distance covered by trip mode

Distance (km)	Walking		Bicycling		Vehicle	
	%	Cum %	%	Cum %	%	Cum %
less than 0.5	9.8	9.8	10.2	10.2	0	0
0.5 to 1.0	47	56.8	38.6	48.9	9.6	9.6
1.0 to 1.5	22	78.8	22.7	71.6	20.5	30.1
1.5 to 2.0	17.9	96.7	20.5	92	20.5	50.6
2.0 to 2.5	2.4	99	1.1	93.2	8.4	59
2.5 to 3.0	1	100	0	93.2	7.2	66.3
3.0 to 3.5			1.1	94.3	14.5	80.7
3.5 to 4.0			2.3	96.6	6	86.7
4.0 to 4.5			3.4	100	6	92.8
4.5 to 5.0					3.6	96.4
more than 5.0					3.6	100

Legend: km-Kilometers; Cum %-cumulative percentage

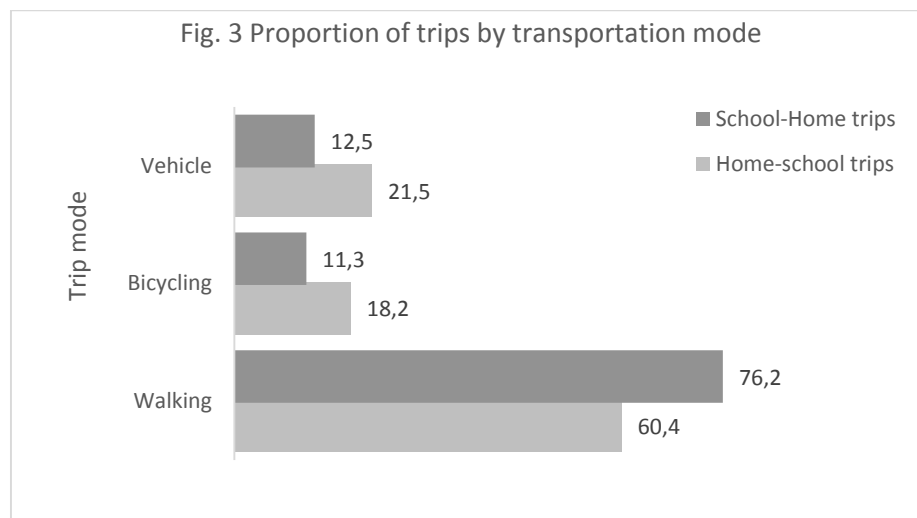
Table 4. Differences in home to school vs school to home trips by transportation mode

Home to school		School to Home	Sig. (2-tailed)	95% CI	
Walking					
length (km)	1	1.1	0.059	-190.7	3.6
minMVPA (min)	11.4	12.5	.035*	-2.3	-0.1
duration (min)	14	16.5	.000*	-3.8	-1.2
Bicycling					
length (km)	1.3	1.2	0.69	-292.3	439.7
minMVPA (min)	2.8	1.3	.004*	0.5	2.5
duration (min)	8.2	6.9	0.145	-0.5	3
Vehicle					
length (km)	3.5	3.6	0.805	-1269.6	987.8
minMVPA (min)	1.3	0.1	.000*	0.7	1.7
duration (min)	9.3	9.1	0.832	-1.9	2.3

Legend: km-Kilometers; minMVPA- minutes in moderate to vigorous physical activity; min-minutes; CI- Confidence Interval

When walking was the mode of transportation, home to school trips took longer and had more minutes in MVPA than the school to home trips. Minutes spent in MVPA during the trips were also different for bicycling and vehicle however in those cases the home to school trip contributed with more time in MVPA.

Despite walking was the dominant mode of transportation in both directions, a significant 16% increase in walking trips was found for school-home trips when compared to home-school trips (Figure 3).



Correlates of transportation mode

The final logistic regression model was statistically significant [$\chi^2 (2) = 205.7, p = .000$], explained 48.2% (Nagelkerke R^2) of the variance in means of transport to school and correctly classified 90.5% of cases. For each additional km in trip distance there was an 80% decrease in the odds of active commuting (OR: 0.20; 95% CI: 0.14-0.28).

DISCUSSION

Our study was one of the first using objective methods to classify trip modes in home-school journeys and measuring the actual route distance. To date most studies have relied on less accurate methods.

Our results showed that walking was the most frequent (68.8%) means of travel in home-school trips. Although a higher percentage was found, this result is in line with another European study that reported walking as main mode used in 44.8% of home-school trips followed by cycling (34.6%) (Dessing et al., 2014). On the other hand, a Belgian investigation, centered on participants instead of trips, observed that only 6.6% of the adolescents walked to school while 51.8% cycled there (Van Dyck et al., 2010). Despite the different walking percentages, active transportation was the main mode to get to school in these studies supporting previous research (Chillon et al., 2010; Santos et al., 2009). In contrast, motorized transport in home-school journeys was the most used method of transport in the US (Centers for Disease Control and Prevention, 2002), Australia (Harten and Olds, 2004) and even in UK (Transport, 2014) where distances to school are usually longer than in most European countries (2008). For example, in Portugal schools are built so the optimum distance one should live from school is 1.5km or 30 minutes walking, and the maximum distance is set at 2.2km or 45 minutes walking (Departamento de Avaliação Prospectiva e Planeamento, 2000). In our sample 50% of the participants lived within

the optimum distance to school (1.5km) while 72% lived within 2.2km, with a mean distance between home and school of 2.14km.

In line with this premise, our findings revealed that 96.7% of walking school journeys occurred within 2km as well as 92% of cycling trips. So it is likely that in Portuguese adolescents the criterion and reasonable maximum distance for walking to school is 2km. Our results reinforce the ones of Van Dyck et al. (2.0km) (Van Dyck et al., 2010) and Nelson et al. (2.4km) (Nelson and Woods, 2010). In our opinion, it seems that studying correlates of walking to school should be done within this distance removing it as a potential confounder. And intervention efforts to increase walking should target students living within this distance.

One possible explanation for the 2km distance criterion found can be the urban planning policies mentioned above. This could be the evidence needed for authorities to replicate this school siting policies in other settings for ACS proliferation. Another example is a study from the Netherlands, where the average distance to an elementary school was smaller than 2 kilometer, which showed that 79% of the trips to school were made by active (Dessing et al., 2014).

On the other hand, maximum cycling distances were different comparing our study (2.0km) and the other two studies conducted in Belgium (8.0km) and Ireland (4.0km). The difference might be due to difference in the built environment, e.g. Porto is quite hilly, and a closer look at the built environment in these three cities might help explain the differences; further research into this is needed. Another possible reason may be related to cycling not being a particular popular means of travel in Portugal, especially in the northern region (Instituto Nacional de Estatística, 2012). In fact, until recently cyclists were required by traffic laws to cycle on the edge of the road and cycling was considered unsafe. Despite a possible overestimation (see in limitations of the study), only 8% of the school trips made by bike were over 2km. According to other studies, that leaves an opportunity for increasing ACS in our population by encouraging more young people to cycle for a distance of up to 4 or 8km. In order to increase ACS, policies that remove barriers and promote the conditions necessary for choosing active modes of transportation are needed (Cooper et al., 2010; Jensen, 2008). These may include: 1) cycling-friendly infrastructures like separate bike lanes, traffic calming measures, car free zones; 2) bike parking and end of the trip facilities such as showers, bicycle stations, bike lockers; and 3) legal interventions as speed limits (Pucher et al., 2010). Moreover, research identified policies to increase walking and bicycling as an effective way of improving the safety of people involved in these behaviors. As more people walk or bicycle the less likely any of them are to be injured. The most likely mechanism which underlies safety for cyclists and walkers is modification of motorists behavior as this influences the likelihood of collisions (Jacobsen, 2003).

In Portugal, only in January 2014 an established law ended the obligation to cycle on the roadside (sometimes non existing) and allowed bikers to take their place on the roads as any other vehicle (2013), giving them vehicle priorities in order to promote safer bicycle riding and increase the rates of this behavior. This can be a turning point in the transportation system and further research

is needed to understand the implication of this modification on rates of active transport to school for children and adolescents.

More minutes in MVPA were recorded during walking trips compared to during vehicle trips, as expected. An average of 12 minutes, corresponding to 20% of recommended daily MVPA, were observed during walking trips while vehicle trips only represented 2%. This observation emphasizes the meaningful role that the trip to school may play in youth achieving recommended PA guidelines, and the associated potential for achieving health benefits. So, strategies aimed to increase this behavior are a relevant approach for increasing physical activity levels. To our knowledge only two other studies objectively assessed time spent in MVPA during a walking trip to school among adolescents. Comparable to our results, Southward et al. (Southward et al., 2012) observed approximately 11 minutes of MVPA during home-school trips, while in the study by Voss et al. (Voss et al., 2014) walking trips only contributed with 9.2 min of MVPA on average. Interestingly, the results by Voss et al. were comparable to ours in terms of distance and duration of the walking trips. Differences in time in MVPA during school trips may be related to features of the built environment, for example slope, and further research is needed.

Significant differences between trips to school and from school were found, with more active transport taking place during the school-home trip. One may speculate that these differences could be related to the pressure youth are submitted to get to school on time, first at home and due to the traffic congestion also during their trip to school. Longer trip duration and more time spent in MVPA during school-home walking trips may be related to the absence of a schedule to accomplish allowing adolescents to spend more time on the trip. It may also be that adolescents travel home with friends and may be involved in some kind of play during these trips. A significant higher rate of walking was found for school-home trips when compared with home-school trips. Although only few studies looked at this difference, similar results were found by other researchers (Larsen et al., 2009; Schlossberg et al., 2006) taking us to believe that this is may be a common trend. Explanations for this trend are usually related to the parental time schedule that allows parents to drive their children in the morning, while they are usually at work when their children leave school. Therefore, on one hand opportunities may exist to increase ACS on the home-school trip; on the other hand more attention should be given to the school-home trip when studying the relations between environmental features and active transport.

Finally, according to our results larger distances are likely to increase the odds of motorized travel. In fact, distance is the strongest environmental predictor of school travel mode choice (Wong et al., 2011). As changing school locations is unlikely in most countries, the implications of this finding include increasing the number of households within 2km of the schools (i.e. urban densification), building new schools closer to where students live, and more feasible interventions like changing traffic directions, building paths, connecting public transport and other travel planning practices that enable more direct routes to school shortening the home-school distance.

This research contributes to increase the understanding of geographical variation of the relation between the environment and active transportation. Strengths of this study include the use of

objective measures of activity and location that were automatically combined to assess trips to school and classify trip mode. This methodology reduces common bias of self-reporting and measures the actual route taken between home and school, instead of common approximations such as Euclidean distances and shortest route approaches. Moreover, all trips between home and school are included and not only trips before and after school, i.e., trips over lunch time are also included.

Integration of accelerometer and GPS data is a relatively new and not enough is known about the optimal methods for manipulation of this type of data. In fact, no consensus exist for guidance in dealing with these type of data issues (McCrorie et al., 2014). However, PALMS is a free, simple and intuitive software that may be particularly helpful in future research as it uses several methods to reduce the error in data, allowing researchers to manipulate protocols and quickly processes the complex datasets.

This study has some limitations that should be mentioned. GPS signal acquisition time when leaving school and home buildings might have influence the number of trips included in our study as the first data point may have occurred outside the inclusion criterion distance. Trip underestimation may also have occurred if journeys had intermediate stops longer than 5 minutes as our inclusion criteria did not account these trips as home-school trips. Exploring pause time is therefore recommended for future studies particularly in school to home trips, where children have more freedom to explore their environment.

The objective method used to categorize trips is based on GPS-derived travel speeds and may be, in our particular context, an overestimation of cycling trips. Despite, previous studies found a 73% agreement between PALMS bicycling and sensecam trips (Carlson et al., 2014) few adolescents from our sample self-reported cycling (data not shown). Moreover, unlike in the US where bus average speed is around 21km/h (American public transportation association, 2013), in Portugal, the average speed during public transportation is 15.7km/h (STCP, 2013), similar to bicycle trips (Carlson et al., 2014). So, more research is needed in order to improve bicycle differentiation in the Portuguese context.

CONCLUSION

Our study explored the school travel behavior among adolescents providing important data that could assist urban planners and public health professionals in developing initiatives to increase rates of ACS and physical activity among youth.

The main findings suggest that 1) walking is the most frequent means of transport to and from school and a round trip home-school-home represents on average 40% of recommended daily MVPA; 2) 2.0 km seems to be a reasonable maximum distance for walking between home and school, so planning and policy efforts should be made in order to achieve this distance; 3) cycling is uncommon and to reach higher rates of active travel to school special attention should be given to cycling particularly in trips over 2km; 4) Increasing distance is associated with higher levels of

passive transportation to school; 5) a distinction should be made between the home-school and school-home trips when implementing strategies to increase ACS.

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CHAPTER 3 – Overall Discussion

This thesis was grounded on knowledge gaps identified by literature. The studies included in this dissertation tested different research questions, used different datasets and methods, yet addressed a unifying theme of built environment, active living and health. These studies expanded the knowledge in the field but also raised more questions about the conceptualization and methodology of current research. Our conclusions provide support for the important role the built environment and ACS may play in increasing PA levels and subsequently health in young people.

Findings from our studies suggest that transport domains is the most important contributor to MVPA and 43.6% of the time in MVPA bouts were found in this domain. In addition, ACS alone, particularly walking, is responsible for 45% of youth's MVPA. Walking is indeed of significant relevance not only for MVPA but also for metabolic health. In this concern results from our research showed walking to school to be related with improved waist circumference and HDL-C profiles and has the volume needed to significantly act on these markers. Moreover, our results corroborates studies supporting built environmental correlates to be domain specific so, environmental interventions aiming at increasing ACS should include decreasing distances between home and school and increased safety.

The first paper explored the association between built environment perceptions with PA in adolescents as mixed findings commonly describe this association (Ferreira et al., 2007) and only few factors were found to be consistently related or unrelated to PA. Our results showed different environmental perceptions to be related with different PA domains. Our results corroborate previous studies that suggest correlates to be domain specific and blame research fails to study behavior specific correlates for the inconsistencies in the literature (Giles-Corti et al., 2005; Sallis et al., 2006). From the 21 built environment items explored only 4 were somewhat predictive of active living and varied by gender. Gender differences have previously been identified as main moderators that may alter the strength of association between environment and active travel (Panter et al., 2008), so these differences between boys and girls were somewhat expected. Facilities and aesthetics were associated with PA, respectively among both boys and girls and among boys only. Our study also found safety perceptions to be

important for ACS among girls, but found no significant correlates for boys. Similar results for girls were also found in another investigation. Safety concerns may be, according to Nelson & Woods (2010), intuitively explained by the lower levels of independent mobility traditionally seen in girls which might result in increased fear and learned helplessness surrounding navigation of the physical environment. These findings suggest that certain attributes of the neighborhood are important to youth active living but it remains unknown why so many others were unrelated to different PA behaviors. A possible cause may be linked to the early stage of built environment research, particularly in children and adolescents, and most of the potential correlates for youth investigation are determined based on adult research. Though, it could be that among youth other built environment attributes different from the ones tested are conducive to an active lifestyle (De Meester et al., 2012). Moreover, our items regarding transport dimension were mostly based on parental perceptions of the neighborhood related to their children's' independent mobility. While this can be particularly relevant for children (Schoeppe et al., 2013), our older sample (16.6 years old) may have higher independent mobility turning this questions less relevant for our sample. Additionally, inconsistencies in the definition and understanding of the concept of neighborhood have been commonly reported and this may be more significant in children and adolescents (Feng et al., 2010). Another important aspect worth noted is that most consistent associations found in the literature of built environment and PA were based on objectively measured environmental attributes, because of the lower measurement error associated, and our paper results, as most of the literature, relies on self-reports (Ding et al., 2011). On the other hand, in paper IV where objective methods were used, distance emerged as an important built environment attribute predicting walking to school, alike repeatedly emphasized within the literature (Pont et al., 2009; Wong et al., 2011). Distance of 2.0 km were found to be critical for walking trips as 96.7% of these ACS where within this distance.

If on one turn, objective methods of the environment are likely to reduce self-report bias, on the other hand increased specificity with respect to where PA occurs may help to overcome misestimating associations between PA and built environment features (Troped et al., 2010). So far, body of research objectively examining relationships between built environment and PA uses an analytic

approach that assumes activity occurs within a designated defined area through GIS buffers. However, this approach may put on misclassification bias in the context of PA research as built environmental features are often associated to an individual without direct knowledge of real exposure. To strengthen our investigation we went further in this methodological aspects and for our second and fourth studies, besides accelerometers and GIS, we've included GPS technology assuring both the spatial and temporal aspects were present and giving real exposure measures to context specific PA.

In paper II we meant to spatially identify the proportion of time spent at different domains in order to identify the most important targets for PA promotion, as each is relevant to and driven by different built environmental features and policies. According to our results, despite activity exposure was higher in leisure domain, most of the MVPA activity was found on transport domain. Results differed by gender and most important contributors to MVPA were the transport domain in girls and school domain for boys. Concerning gender differences in PA domains, irrespectively of the direction, they were already reported in previous studies (Klinker et al., 2014; Rainham et al., 2012) and were expected as adolescents have different preferences and are usually involved in different types of PA (Kuo et al., 2009) particularly in contexts for self-organized play (Nielsen et al., 2011); Moreover, it may be that features of the built environment may privilege boys as they are prepared with equipment of their interest like pitches, goals, etc (Nielsen et al., 2011). Variations in results found in the scarce literature on the topic are probably related to the different data processing approaches undertaken typical from a new field that is starting to build its body of research. For example, one approach exclude all weekend data, included only physical education classes and recess (based on classes' timetables) in the school domain and classified all other PA in school grounds as leisure; other included in MVPA every single count, irrespectively of bouts. Regardless discrepancies' in methodologies all research seems to assign the largest proportion of time spent in MVPA to transport domain, which is in line with our results. Moreover, ACS alone, particularly walking, could contribute with for 45% of daily MVPA as results from paper IV revealed each trip direction (home-school or school-home) to have 12 minutes of MVPA. Other studies support findings from our research and have found that active transport to school can contribute to children's overall PA (Klinker et al., 2014; Southward

et al., 2012). So, strategies targeting ACS are a relevant approach for increasing physical activity levels. In addition to our results, Sallis et al. (2012) had already consider active transportation and active recreation domains to be most amenable to environment and policy intervention and therefore the ones to bet on for PA promotion.

Given the importance of the transport domain for MVPA and because most sustained exercise is the one incorporated into daily routine activities (Larkin, 2003) we have restricted our interest in travelling to school. School travel is important for several motives. First, school is the most common destination for children and adolescents (Timperio et al., 2004) and it is a regular behavior that takes place all over the year. Secondly, due to their regularity they become easier to target with intervention programs as well as the efficiency with which interventions can be delivered increases due to the big amount of people travelling to the same place at the same time. Thirdly, students can be easily targeted in the interventions programs via school. Last but not least, due to the few transportation options available for children and adolescents they are more likely to rely on active transportation to school and therefore be more environment dependent. Moreover, according to Frank Lawrence (2012) “the built environment relates with public health indirectly, largely through individual transportation choices and environmental exposures that result from different built environment patterns”.

Although conceptually, transport related PA could contribute to the daily overall amount of energy expenditure, and help prevent the development of chronic diseases (Faulkner et al., 2009; Tudor-Locke et al., 2001) lack of research on this topic led us to our third paper. Until then current evidence had not revealed the importance of travel to school behavior for children’s health (Sirard & Slater, 2008) and it was unclear whether this type of physical activity had enough potential to improve metabolic health. Results, adjusted for MVPA, showed that ACS could indeed be of particular relevance for health promotion initiatives. Walking to school is likely to positively impact health and eventually decrease metabolic and cardiovascular disease as it was associated with a better waist circumference and HDL-C profile. Despite this paper did not address directly if ACS had enough volume for metabolic improvements, according to paper IV each trip to school takes about 15 minutes to travel 0.94 km, if students are usually

involved in home-school-home journeys then they fit evidence regarding favorable dose–response relationship between the amount of exercise performed and HDL-changes reach statistical significances. So, maximizing the number of youth actively commuting to school can therefore be seen also as a promising public health strategy. Adding relevance to our results, interventions to encourage ACS are becoming a priority in some countries (Active Healthy Kids Canada, 2013; National Safe Routes to School Taskforce, 2008).

As there is limited evidence to guide interventions designed to increase ACS, insertions to better understand this common behavior are an essential step for the development of evidence-based and effective interventions. This process isn't without challenges. First, most research on transport-related PA relies on self-reported data or GIS based estimates of routes taken than may not be representative of actual route as stated earlier. Second, no direct measures of active transportation are available and no clear standards for classifying students as active or passive commuters have been established. Nonetheless, to promote a strong evidence base it is important that uniform methods are used, making it possible to compare results across studies (Chillon et al., 2011). In an attempt to overcome these issues in our last paper we've used GPS devices together with accelerometer data to objectively classify trip modes. Other studies have already tested this methodology successfully (De Vries et al., 2011; Southward et al., 2012) however given the complexity of data and time consuming process, the procedures are only hardly replicable. Integration of accelerometry and GPS data is relatively new and no consensus exist for guidance in dealing with these type of data (McCrorie et al., 2014). Given this, we decided to handle data on a brand new software for data processing (PALMS) ("Personal Activity Location Measurement System (PALMS).") that automatically detects trips between two points of interest (home, school) reducing and simplifying the process (Carlson et al., 2014). These approach is likely to be particularly helpful for future research as it uses several methods to reduce the error in data, allows researchers to manipulate protocols and quickly processes the complex datasets; furthermore it is available to everyone. Nonetheless, these methodology needs to be refined in future research, particularly bicycle trips definition, it has already been used in a couple of studies for trip detection (Carlson et al., 2014; Carlson et al., 2015). Future research regarding data collection should include other members of the

social environment important for youth as friends and parents influence on school travel; also individual and school factors should be taken into account in future studies. Other confounders include car and bicycle ownership. Moreover, newer research should assess mediators and use appropriate statistical procedures to deal with all information.

In summary, data from our study suggest the potential role ACS may play to increase PA levels and health in children and adolescents and related built environment features. Findings also give a closer insight of travel to school behavior in Portuguese adolescents which may be of particular relevance for successful health strategies.

While contributing to substantial health benefits, active transport brings benefits across several sectors including reduced traffic congestion, reduced air and noise pollution, improved safety and increased social interactions (Litman, 2009). With the right conditions, policies and education, more children would undoubtedly walk/bike to school and there are many possible ways to encourage active transportation. Encouragement programs such as Safe routes to School or Walking School Bus, complemented by improved infrastructures such as sidewalks, crosswalks and bike paths, reduced traffic speed, easy-to-rent bikes, secure bike storages, improved road connectivity, among others, may be successful strategies (Chillon et al., 2011; Garrard, 2011). However, in the situation of limited resources for public health initiatives, like the one we are in, it is particularly important to identify and prioritize subgroups of the population to whom environmental interventions are the most effective and where they should be applied. The key for successful health promotion strategies includes an inter-sectorial partnership including community participation, health and urban design professionals and government members working together to create the social and environmental conditions under which car trips are replaced by walking and cycling to school (Garrard, 2011).

CHAPTER 4 – Conclusions

The current dissertation adds to an increasingly active field of research in built environment and active living, employing new and objective methods of measurements. Considering the overall findings that emerged from the original studies we highlight the following conclusions:

- Perceptions of environment correlates are gender and behavior specific:
 - a) Higher levels of overall PA are predicted by better perceptions of sports equipment at home, both in boys and girls;
 - b) Boys PA is significantly associated with aesthetics within the neighborhood;
 - c) Active transport to school is associated with safety issues in girls;
- The most important predictors of daily MVPA are the transport domain in girls and leisure domain for boys; nevertheless, a higher proportion of MVPA bouts were found in the school domain for boys;
- Walking is the most frequent means of transport to and from school and a round trip home-school-home represents, on average, 40% of recommended daily MVPA;
- Walking to/from school is associated with higher odds of having a better waist circumference and HDL-C profile when compared to using passive means of transport;
- Cycling to school is unusual in Portuguese adolescents;
- Increasing distance is associated with higher levels of passive transportation to school; 2.0 km seems to be a reasonable maximum distance for walking between home and school, so planning and policy efforts should be made in order to achieve this distance;
- GPS, GIS and accelerometer data can be the response to subjectiveness of measures of active travel.

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