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Luís Carlos Oliveira Lopes **Motor coordination in children: the associations with body composition, sedentary behaviour and academic achievement**

Universidade do Minho
Instituto de Educação

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Motor coordination in children: the associations with body composition, sedentary behaviour and academic achievement

Tese de Doutoramento em Estudos da Criança
Especialidade em Educação Física, Lazer e Recreação

Trabalho efectuado sob a orientação do
Professor Doutor Vítor Pires Lopes
e da
Professora Doutora Maria Beatriz Ferreira Leite de Oliveira Pereira

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Motor coordination in children: the associations with body composition, sedentary behaviour and academic achievement

Abstract

Introduction: This thesis focuses on the role of motor coordination in children's health-related behaviours and cognitive outcomes. Therefore, this study explores the relationships between motor coordination (MC) and body composition, sedentary behaviour (SB) and academic achievement (AA) in elementary school children. This work presents four papers in the body of the thesis and two papers in the annexes section as an integrated part of the PhD process. The specific objectives were: to evaluate the relationship between objectively measured SB and MC in Portuguese children (aged 9-10 years), accounting for physical activity (PA), accelerometer wear time, waist-to-height ratio, and mother's education level (PAPER I); to quantify maternal misclassification of child weight status in a sample of Portuguese children aged 9 to 12 years, according to gender, family income, maternal weight status, education level and age (PAPER II); to determine the ability (sensibility and specificity) of different measures of adiposity (body mass index, waist circumference, body fat percentage and waist-to-height ratio) to discriminate between low/high motor coordination in a sample of children aged 9–12 years (PAPER III); to evaluate the relationship between gross MC and AA in Portuguese children aged 9-12 years, accounting for cardiorespiratory fitness, body mass index, and socioeconomic status (PAPER IV).

Methods: Data for this exploratory cross-sectional school-based study are derived from the Bracara Study (2009/2010). The sample comprised 596 participants (281 girls) aged 9-to 12 years from 13 urban public elementary schools (4^{th} grade) in the north of Portugal. MC was assessed with Körperkoordination Test für Kinder (KTK). PA and SB were measured by accelerometry (Actigraph GT1M). Height, weight and waist circumference were measured with standardized protocols and instruments. Body fat percentage was estimated by a bioelectric impedance digital scale (Tanita TBF-300). Cardiorespiratory fitness was assessed with the Fitnessgram battery. The 4^{th} grade national exams were used as a measure of AA. Parents or guardians were also invited to participate through socio-biographic, PA and other health-related behaviour questionnaires.

Results: In paper I, a receiver operating characteristic (ROC) analysis showed that sedentary time significantly discriminated between children with low MC and high MC, with a best trade off between sensitivity and specificity being achieved at ≥77.29% and ≥76.48% for girls and boys respectively ($p<0.05$ for both). In both genders, the low sedentary group had significantly higher odds of having good MC than the higher sedentary group, independent of PA, accelerometer wear time, waist-to-height ratio, and mother's education level ($p<0.05$ for both). In paper II, the prevalence of underweight, overweight, and obesity in children were 4.6%, 25.5%, and 6.4%, respectively. 65.2% of underweight and 61.6% of overweight/obese children's were misclassified by their mothers. For the majority of variables presented, the values of agreement were fair (k ranged 0.257 to 0.486), but were statistically significant. Significant differences in the percentages of mothers who correctly classified their children's weight status were only found among the most educated in the overweight/obese group and among the normal weight mothers in the underweight group. In paper III, ROC curve analysis showed that all measures of adiposity performed well on average in identifying low MC, as indicated by the area under the curve greater than 0.6. The ROC performance of body fat percentage showed a slightly better discriminatory accuracy than body mass index, waist circumference and waist-to-height ratio in predicting low MC in girls. In boys, the ROC performance of waist circumference showed a slightly better discriminatory accuracy than body mass index, body fat percentage and waist-to-height ratio in predicting low MC. After adjustments, logistic regression analyses showed that body mass index, waist circumference, body fat percentage and waist-to-height ratio were positively and significantly associated with MC in both sexes, with the exception of waist-to-height ratio in girls. In paper IV, 51.6% of the sample exhibited MC disorders or MC insufficiency and none of the participants showed very good MC. In both genders, children with insufficient MC or MC disorders exhibited a higher probability of having low AA, compared with those with normal or good MC ($p<0.05$ for trend for both) after adjusting for cardiorespiratory fitness, body mass index and socioeconomic status.

Conclusions: Adequate levels of MC in children have essential importance since it were found to be positive related with health-related behaviours and cognitive outcomes. Our findings suggest that PA levels *per se* may not overcome the deleterious influence of high levels of SB on MC. Our data stress the importance of discouraging SB among children to improve MC (paper I). Many mothers do not properly recognize their children's weight status and frequently underestimate their children's body size (paper II). Body fat percentage and waist circumference showed a slightly better discriminatory accuracy in predicting low MC, for girls and for boys, respectively (paper III). Children of both genders with lower MC had higher odds of having low AA, after adjusting for potential confounding factors (paper IV).

Key-words: motor coordination, sedentary behaviour, physical activity, accelerometry, parental perceptions, body composition, academic achievement, children.

Coordenação motora em crianças: associações com a composição corporal, o comportamento sedentário e o desempenho académico

Resumo

Introdução: Esta tese centra-se no papel da coordenação motora (CM) nos comportamentos relacionados com a saúde e nos resultados cognitivos em crianças com idades compreendidas entre os 9 e os 12 anos. Neste sentido, este estudo explora as relações entre a CM e a composição corporal, o comportamento sedentário (CS) e o desempenho académico (DA) em crianças. Este trabalho apresenta quatro artigos no corpo da tese e dois artigos nos anexos como parte integrante do processo de doutoramento. Os objectivos específicos foram: avaliar a relação entre o CS objectivamente medido e a CM, ajustando para a actividade física (AF), o tempo de utilização do acelerómetro, o rácio cintura/altura e o nível de escolaridade da mãe (artigo I); quantificar os erros de classificação do peso corporal das crianças por parte das mães, de acordo com o sexo, o estatuto socioeconómico das crianças, o peso corporal, a escolaridade e a idade da mãe (artigo II); determinar a capacidade (sensibilidade e especificidade) de diferentes medidas de adiposidade (índice de massa corporal, perímetro da cintura, percentagem de massa gorda e o rácio cintura/altura) para descriminar entre baixa/elevada CM (artigo III); avaliar a relação entre a CM e o DA, ajustando para a aptidão cardiorrespiratória, índice de massa corporal e o estatuto socioeconómico (artigo IV).

Métodos: A amostra foi constituída de 596 participantes (281 meninas) do 4º ano de escolaridade, com idades compreendidas entre os 9 e os 12 anos, de 13 escolas públicas do 1º ciclo de carácter urbano do norte de Portugal, no ano lectivo 2009-2010. A CM foi avaliada pela bateria de testes Körperkoordination Test für Kinder (KTK). A AF e o CS foram medidos por acelerometria (ActiGraph GT1M). A altura, o peso foram medidos recorrendo a instrumentos e a protocolos standartizados. A percentagem de massa gorda foi aferida através de bioempedância (balança digital Tanita TBF-300). A aptidão cardio-respiratória foi determinada pela bateria de testes do Fitnessgram. As provas de aferição do 4º ano de escolaridade foram usadas como medidas do DA. Pais ou encarregados de educação participaram no estudo através do preenchimento de questionários socio-biográficos, de AF e outros comportamentos relacionados com a saúde.

Resultados: No artigo I, a análise das curvas (receiver operating characteristic – ROC) mostraram que o tempo em CS descriminou significativamente entre crianças com baixa CM e elevada CM, sendo o melhor equilíbrio (*trade off*) entre sensibilidade e especificidade alcançado com ≥77.29% e ≥76.48%, respectivamente para meninas e meninos ($p<0.05$ para ambos). Em ambos os sexos, o grupo com baixo CS teve uma probabilidade significativamente maior de ter uma boa CM do que o grupo com elevado CS, independentemente das variáveis de ajuste ($p<0.05$ para ambos). No artigo II, a prevalência de baixo peso, excesso de peso e obesidade foram, respectivamente 4.6%, 25.5%, e 6.4%. 65.2% das crianças com baixo peso e 61.6% das crianças com excesso de peso/obesidade foram incorrectamente classificadas pelas respectivas mães. Na maioria das variáveis apresentadas, os valores de concordância encontrados foram moderados (k entre 0.257 e 0.486), no entanto significativos. Diferenças significativas, nas mães que classificaram correctamente o peso corporal dos seus filhos, foram apenas encontradas nas mães com mais elevada escolaridade, no grupo de crianças com excesso de peso/obesidade, e nas mães com peso normal, no grupo de crianças com baixo peso. No artigo III, a performance das curvas ROC para a percentagem de massa gorda mostrou uma melhor precisão discriminatória do que as restantes, na predição de baixa CM em meninas. Nos meninos, a performance das curvas ROC para o perímetro da cintura mostrou uma melhor precisão discriminatória do que as demais, na predição de baixa CM. A análise de regressão logística mostrou que todas as medidas de adiposidade estavam positiva e significativamente associados com a CM em ambos os géneros, com a excepção do rácio cintura/altura nas meninas. No artigo IV, 51.6% dos participantes apresentaram distúrbios da CM ou insuficiências da CM e nenhuma criança foi classificada com boa CM. Em ambos os géneros, crianças classificadas com distúrbios da CM ou insuficiências da CM apresentaram uma maior probabilidade de manifestarem baixo DA, comparados com aqueles que foram classificados com CM normal ou CM boa ($p<0.05$ para a tendência em ambos).

Conclusões: Níveis adequados de CM em crianças têm uma importância crucial, quer para os comportamentos relacionados com a saúde quer nos resultados cognitivos/académicos. Os resultados sugerem que os níveis de AF *per se* podem não superar as influências prejudiciais que os elevados níveis de CS têm na CM. Estes resultados evidenciam a importância de desencorajar o CS nas crianças de forma a melhorar a CM (artigo I). Muitas mães não percepcionam correctamente o peso corporal dos filhos e frequentemente substimam-no (artigo II). A percentagem de massa gorda e o perímetro da cintura apresentaram uma melhor precisão discriminatória na predição de baixa CM, respectivamente em meninas e meninos (artigo III). Crianças de ambos os géneros com baixa CM tiveram uma maior probabilidade de serem classificados com baixo RA (artigo IV).

Palavras-chave: coordenação motora, comportamento sedentário, actividade física, acelerometria, percepções parentais, composição corporal, desempenho académico e crianças.

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Glossary

AA	Academic achievement
BF%	Body fat percentage
BMI	Body mass index
CI	Confidence intervals
FMS	Fundamental movement skills
DCD	Developmental coordination disorder
KTK	Körperkoordination Test für Kinder
MC	Motor coordination
OR	Odds ratio
PA	Physical activity
ROC	Receiver operating characteristic
SB	Sedentary behaviour
SES	Socioeconomic status
WHtR	Waist-to-height ratio
WC	Waist circumference

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1. Introduction

"A person's motor behaviour position at any point in his life reflects his past movement experiences and presages his future ones" (Clark, 2005).

Considering that most, if not all, measurable behaviour manifests itself in the form of movement, it is not surprising that movement is crucial for humans' survival. In our lives we produce a wide range of movements vital to our independence, interactions with the world and personal safety (Utley & Astill, 2008). Our capacity to move is an essential aspect of our evolutionary development as important as the evolution of our intellectual and emotional capacities (Schmidt, 1991).

Although motor development, motor learning and motor control are well establish in literature as different fields under the umbrella of motor behaviour, the lines separating these areas have become increasingly blurred (Thomas, 2006). According to Schmidt and Lee (2005) and Ulrich & Reeve (2005), there is no good explanation for separating the study of any of these fields from one another, because there is a significant overlap in scientific issues, theories, and methods. Furthermore, the artificial separation can hamper the understanding of issues across all three areas (Fischman, 2007). As Newell's (1986) model suggests, in any motor skill performance context, there are three interacting sources of constraint: the task, organism, and environment. Therefore, we share the perspective of Ulrich and Reeve (2005) that suggests that the field adopt the unifying name of motor behaviour defined as "understanding of the processes underlying motor performance across the lifespan".

When studying the motor behaviour, a developmental perspective is essential to our understanding of movement and mobility (Clark, 2005). Thus, it is important to understand the differences between growth (generally referring to physical growth) and development (changes occurring throughout the life span), as well as between learning (resulting in permanent changes in the ability to perform a skilled movement) and performance (changes in the observable product of movement).

In literature on motor skill development, the focus is mostly on the proficiency/competence level in movement skills. Motor competence can be defined as a person's ability to execute different motor acts, including coordination of both fine and gross motor skills (Henderson & Sugden, 1992). The development of motor competence during infancy and childhood is dependent upon and influenced according to the pattern that is established by two factors namely, biological factors which include genetics, gender and maturation, and environmental factors which include experience, opportunity, encouragement, demographics and social factors (Gallahue, 1982; Thomas, 2000; Thomas, 2001) and their interactions (Newell, 1986).

Multiple terms are used to describe a high motor skill performance (coordinated motor behaviour), including variations of the following: high motor competence, high motor proficiency, high motor skill competence, high motor skill proficiency, high motor coordination (MC), high fundamental movement skills proficiency, skilfulness. The terminology used for low motor skill performance (uncoordinated motor behaviour) include variations of the following: developmental coordination disorder, motor skills disorder, coordination disorder, incoordination, clumsiness, poor/low motor competence, poor/low MC, poor/low motor proficiency, poor/low fundamental movement skills proficiency, poor motor difficulties, and motor impairment. Although the terms are often interchangeable, the practice lacks precision, while there is considerable overlap between these concepts, because they do not always refer to the same thing. Given the lack of agreement on the use of one particular term to describe children with movement competency, the original terms that the authors used in their studies to identify the children with whom they were working will be used. Therefore, in this thesis, the original terms applied by each author/study were adopted in order to respect the study's origin, how the movement outcomes were assessed (product or process), the age group involved, and the objectives proposed. The term "motor coordination" (MC) used in this thesis is a general term that encompasses various aspects of movement competency. We used the term "motor coordination" (MC) in this study as it specifically aligns with the language used in the assessment implemented for this study (Kiphard-Schilling body coordination test) and with previous literature that has used the same assessment.

It is also important to define some other concepts used in this thesis, such as; physical activity (PA) is defined as any bodily movement produced by skeletal muscles that results in energy expenditure beyond basal metabolic rate (Caspersen, Powell, & Christenson, 1985). Physical fitness is a set of attributes related to a person's ability to perform physical activities that require aerobic fitness, endurance, strength or flexibility and is determined by a combination of regular activity and genetically inherited ability (Hussey, Bell, Bennett, O'Dwyer, & Gormley, 2007). Cardiorespiratory fitness reflects the overall capacity of the cardiovascular and pulmonary systems to supply oxygen during sustained exercise, as well as the ability to perform such exercise (Taylor, Buskirk, & Henschel, 1955).

One of the cornerstones of a physically active lifestyle is motor skill competence (Ennis, 2011). It has been suggested that an appropriate acquisition of MC contributes to children's physical, cognitive, and social development (Payne & Isaacs, 1995). A proper MC level is essential for strong general development, as well as for health, psychosocial development, and well-being (Haga, 2008b; Piek, Baynam, & Barrett, 2006). Since it is know that motor development is interrelated with cognitive development, because they share the same neuronal structures (cerebellum and the frontal lobe), when there are perturbations (genetic or environmental) that affect motor system or cognition it is often the case that both motor and cognitive functions are affected (Diamond, 2000). Therefore, children's development cannot be separated easily into disconnected developmental domains (Smith, Thelen, Titzer, & McLin, 1999), rather it is the whole child that needs our attention (Bowman, Burns, & Donovan, 2001). Furthermore, it is know that early school motor skills assessment may increased the predictability of later achievement and the probability of identifying children at risk for school failure (Son & Meisels, 2006). Additionally, a recent 9 years longitudinal study in children (7-9 until 16 years of age) showed for the first time that an intervention program with increased physical activity and motor skills training could improve school achievements (Ericsson & Karlsson, 2012).

The early childhood years are a critical time for the development of fundamental movement skills (FMS), which are considered the building blocks of more complex movements (Clark & Metcalfe, 2002) and a key factor in the promotion of lifelong active lifestyles (Clark, 2005; Stodden et al., 2008). Moreover, insufficiently developed movement skills have been identified as an important barrier to later participation in PA (Allender, Cowburn, & Foster, 2006), and it is known that motor skills have been observed to tracked during childhood (Malina, 1996). Likewise, these skills need to be learned, practiced and reinforced through developmentally appropriate movement programmes (Logan, Robinson, Wilson, & Lucas, 2011). According to Clark (2005) around the age of seven, children shift from the period of fundamental motor skills, in which they learn and practice through a variety of activities, to a new period in which they begin to implement skills in more complex contexts, such as games. This "context specific" period occurs about the same time as the qualitative shift occurs toward higher cognitive development. Therefore, this thesis focuses on assessing MC in fourth grade children, after the FMS period, because in this period, children are still mastering motor skills; consequently, their movement patterns are often extremely variable. The other reason was that the academic achievement (AA) was assessed using direct/objective indicators (scores on standardized tests) through the Portuguese Language and Mathematics National Exams which are mandatory for all 4th grade students. Also our interest emerges on the evidences that motor skill proficiency levels among young children have been described as suboptimal (Okely & Booth, 2004). Poor MC as become a growing issue of interest based on the fact that proficiency levels are tracked into childhood and adolescence (Branta, Haubenstricker, & Seefeldt, 1984; McKenzie et al., 2002) and are related to health outcomes such as adiposity (D'Hondt et al., 2011; Graf et al., 2004; Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2011; Okely, Booth, & Chey, 2004), self-esteem (Ulrich, 1987), cardiorespiratory fitness (Okely, Booth, & Patterson, 2001a), PA (Barnett, Morgan, Van Beurden, Ball, & Lubans, 2011; Burgi et al., 2011; Okely, Booth, & Patterson, 2001b; Williams et al., 2008; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006), sedentary behaviour (SB) (Williams et al., 2008; Wrotniak et al., 2006) and AA (Piek, Dawson, Smith, & Gasson, 2008; Son & Meisels, 2006), particularly in children who face unusual difficulties in performing motor skills, despite not having identifiable neurological or sensory problems and their being of normal intelligence (Venetsanou et al., 2011). These children are said to suffer from developmental coordination disorder (DCD). DCD is defined as a condition marked by a significant impairment in the development of MC, which interferes with AA and/or activities of daily living. These difficulties are not due to a general medical condition (psychiatric, neurological, or other medical condition) and are in excess of any learning difficulties, if present (APA, 1994, 2000).

Data for the present study are derived from the Bracara Study aimed to evaluate the relations between MC, PA, SB, physical fitness, body composition, AA and health behaviours among elementary school children (9 to 12 years old). Parents or guardians were also invited to participate through socio-biographic, PA and other health-related behaviour questionnaires as described in detail in the methods section of this thesis. The studies presented in this thesis four papers in the body of the thesis and two papers in the annexes section are an integrated part of the PhD process.

This thesis focuses on the role of motor coordination in children’s health-related behaviours and cognitive outcomes. Therefore the present study explores the relationships between motor coordination and body composition, sedentary behaviour and academic achievement in elementary school children.

The specific objectives on which this thesis was based are as follows:

1. to evaluate the relationship between objectively measured SB and MC Portuguese children (aged 9-10 years), accounting for PA, accelerometer wear time, waist-to-height ratio, and mother’s education level (PAPER I)

2. to quantify maternal misclassification of child weight status in a sample of Portuguese children aged 9 to 12 years, according to gender, family income, maternal weight status, education level and age (PAPER II)
3. to determine the ability (sensibility and specificity) of different measures of adiposity (body mass index, waist circumference, body fat percentage and waist-to-height ratio) to discriminate between low/high motor coordination in a sample of children aged 9–12 years (PAPER III)
4. to evaluate the relationship between gross MC and AA in Portuguese children aged 9-12 years, accounting for cardiorespiratory fitness, body mass index, and socioeconomic status (PAPER IV)

The two papers annexed in this thesis, as an integrated part of the PhD process, had the following aims:

5. to analyse the relation between usual PA and gross motor abilities and motor coordination in children aged 6 to 7 years (PAPER V)
6. to analyze the effects of an intervention strategy during school recess on physical activity levels by gender, age and body mass index (PAPER VI)

2. Background

According to Clark and Whitall (1989), the history of motor development could be divided into four periods: Precursor (1787-1928) (focus on product development, nature versus nurture argument), Maturational (1928-1946) (focus on maturation, which is genetically predetermined), Normative (1946-1970) (focus on the movement skills in school-age children), and Process-oriented (1970-present) (focus on hypothesis-driven research). During this last period, three major theoretical constructs emerge: the information-processing approach stated that movement is simple input-output relay information (the brain receives, processes, and interprets information in order to send signals to produce skilled coordinated movements); the ecological psychology perspective stated that actions are determined by many internal (of the individual) and external (from the environment) factors; the dynamic systems theory stated that movement emerges based on the interaction between the task, the environment, and the individual.

It is through movement that we interact with the world either by moving around in different contexts or handling objects, or by dealing with other people (Utley & Astill, 2008). However, it is required that these movements might be adaptive, goal-directed actions that are goal-achieving (Clark, 2005). In this context, literature has devoted some discussion to what is meant by the term “skill”. Most researchers agree with Schmidt’s definition that skills are movements that are learned and “dependent on practice and experience for their execution, as opposed to being genetically defined” (Schmidt & Lee, 2005). In this perspective, for Knapp (1963), skill is the learned ability to bring about a predetermined task outcome with maximal certainty and the minimum outlay of time and energy, or both. Someone is considered skilful if criterions of excellence are achieved and if high performance levels are achieved most of the time (Utley & Astill, 2008). In the area of sport, skills have been separated into three categories (Haibach, Reid, & Collier, 2011): cognitive skills, which involve the intellectual skills of the mover (enable a performer to make decisions and solve problems); perceptual skills, which include the interpreting and integrating of sensory information to determine the best movement outcome; and motor skills, which comprise the physical elements that make possible the movement. Motor skills have also been defined as activities that involve a chain of sensory responses (vision, central and motor mechanisms) whereby the performer is capable to maintain constant control of the sensory input in compliance with the goal of the movement (Argyle & Kendon, 1967).

According to Galhahue and Ozmun (2006), motor skills can be classified into three categories: non-locomotor stability, which is the ability to maintain body posture and to move the body voluntarily into a particular position; locomotor skills, which are gross motor skills in which the purpose of the movement is body transport (involving movement, such as running); and manipulative skills, which are fine motor skills in which individuals are enabled to explore the world through the manipulation of objects. This classification also involves the level of movement precision required to produce the movement. Therefore, skills in which large muscle groups produce the movement are classified as gross motor skills. Skills in which small muscles groups are critical to perform the skill with increased accuracy and control to produce precise movements are classified as fine motor skills.

There are in literature several authors proposing different periods of motor skill development across a life span. Clark (1994) described six major periods in the development of motor skill behaviour. These included: reflexive, which begins at the third gestational month when movement is first detected and lasts approximately two weeks after birth and is characterized by movements that are reflexive in nature, and pre-adapted, which starts when the infant's behaviours are no longer reflexive (approximately two weeks) and is characterized by the emergence of species-typical motor behaviours such as rolling over, sitting, crawling, feeding, and walking. Environments can speed up the appearance of some behaviours and suppress behaviours in others. Fundamental patterns are characterized by locomotor and manipulative coordination patterns that will provide the foundation (or "building blocks") for later emerging culturally specific motor skills. It is important to note that these are not maturationally-driven patterns but rather require substantial environmental support. The period ends when the fundamental pattern of coordination combines and elaborates into context-specific movements. Context-specific movements begin around seven years of age, when children show a qualitative shift in their cognitive development; it is the period where the developing mover begins to refine, elaborate, and combine movements into early forms of culturally specified motor skills. Skillful movements are characterized to be efficient both physiologically and psychologically, and adaptively versatile. To reach this period takes years of practice in one particular movement form. Compensation periods occur when an injury, disease, or other changes in our body require modifications to our movements and are characterized by the need to compensate for changes in our organism constraints (that is, our physiological systems).

Several theoretical models have emerged addressing the importance of motor skill development/competence to PA across time. To provide a heuristic model to situate the understanding of motor skill development, Clark & Metcalfe (2002) employed the metaphor of a mountain the "mountain of motor development". This metaphor is meant to assist the understanding of global changes that occur in our movement and mobility from birth to death. Climbing a mountain represents the sequential, cumulative, time-intensive challenge of working one's way to a peak (skilfulness). The individual's characteristics and environment interact in determining the final outcome in "mountain climbing". The model clearly illustrates that whilst all children are expected to progress to the fundamental pattern period, fewer are expected to progress to the context-specific and finally the skilful stage. The different-sized mountain peaks in the model represent different possible end points for individuals.

Seefeldt (1980) argued for the notion of a "proficiency barrier" and suggested there might be a "critical threshold" of motor skill competence, above which children will be active and successfully apply fundamental movement skills (FMS) competence to lifetime physical activities. Conversely, if children's skilfulness does not reach this threshold, the author hypothesized that they would ultimately drop out of physical activities, unable or unwilling to be physically active at the intensities and for the duration needed to maintain health and well-being. Indeed, the notion of a proficiency barrier leads to the question of the efficacy of critical or "sensitive" periods during which children may learn motor skills more easily (Clark, 2005).

The Bandura (1986) Social Learning Theory could also be applied to the understanding of motor skill development. Expectations of competence in this context refer to a child becoming engaged in activities requiring motor skills and behaving with confidence when he/she perceives him/herself as capable. Seeing others in exciting experiences of motor skills also gives a firm message to a child that 'someone else can do it, so I can too'. The role modelling and encouragement by teachers and parents (verbal persuasion) also plays an important role in developing a child's self-efficacy in motor skill performance. The motional arousal or anxiety involved in motor skill performance could also feasibly effect an individual's motivation.

Recently, Stodden et al. (2008) have hypothesized a developmental recursive and reciprocal model suggesting that children with a high motor skill proficiency will have higher levels of fitness and perceived sports competence, which in turn predicts greater participation in PA and vice-versa. The authors also postulated that the relationships between these variables may strengthen as children age, and that with age the direction of the association between motor skills competence and PA might change; that is, during early childhood, it is PA that may develop children's motor skills competence, but in middle and later childhood, the relations between both components might change; thus it is competence in motor skills that may be an important condition to engage in PA (Stodden et al., 2008).

Background

The mastery of a variety of motor skills is a requisite for children to engage in everyday activities and has important implications for different aspects of development in children and adolescents (Piek et al., 2006). Children's motor skill development is an expression of the integration of many body systems, including sensory, musculoskeletal, cardiorespiratory, and neurological systems (Dwyer, Baur, & Hardy, 2009) and is ability to interact with the environment (Riethmuller, Jones, & Okely, 2009). Consequently, the study of a child's motor development is a prerequisite for the full understanding of children's whole development (Payne & Isaacs, 1998).

The importance of promoting the development of MC at younger ages relies on the evidence that there are current and future benefits associated with the acquisition and maintenance of motor proficiency (Lubans, Morgan, Cliff, Barnett, & Okely, 2010). It has been suggested that an appropriate acquisition of MC contributes to children's physical, cognitive, and social development (Payne & Isaacs, 1995). A proper MC level is essential for strong general development, as well as for health, psychosocial development, and well-being (Haga, 2008b; Piek et al., 2006). Although a rudimentary form of movement pattern may naturally develop, a mature form of motor proficiency is more likely to be achieved with appropriate practice, encouragement, feedback and instruction (Gallahue & Ozmun, 2006). Likewise, these skills need to be learned, practiced and reinforced through developmentally appropriate movement programmes (Logan et al., 2011). The early childhood years are a critical time for the development of these skills, which are considered the building blocks of more complex movements (Clark & Metcalfe, 2002). Furthermore, it is known that motor skills have been observed to be tracked during childhood (Malina, 1996).

Regardless of the theoretical perspective or considered author to characterize or explain children's motor skill development, there seems to be a consensus of the key importance of the fundamental movement skills period. This is a period of development when children are thought to be able to acquire skills through structured and purposeful learning environments and is a crucial period for developing physically competent children. There is a general acceptance that the performances for a range of fundamental motor skills reflect a degree of learning to which the individual is exposed. Preschool and the early elementary years are crucial to a child's development and mastery of FMS. The acquisition of FMS is developmentally sequenced (Branta et al., 1984) and is dependent upon several internal and external factors (biological, psychological, social, motivational, cognitive, etc.), and the process of acquisition occurs while a range of active play experiences and structured programs takes place (Hardy, King, Farrell, Macniven, & Howlett, 2010). These skills enable children to interact with and explore their environment (Gallahue & Ozmun, 2006). Therefore, children at six/seven years of age should be at the 'mature' level of FMS performance proficiency.

It is important to note that sometimes there is confusion in literature regarding the operational definition of FMS. While some researchers use this term to describe general motor competence (Fisher et al., 2005; Ziviani, Poulsen, & Hansen, 2009), others reserve this term for the specific use of describing skills which directly apply to participation in PA (Clark & Metcalfe, 2002; Haywood & Getchell, 2009).

Motor skill proficiency levels among young children have been described as suboptimal (Okely & Booth, 2004). Indeed, Prätorius & Milani (2004) have shown that over the last 30 years, the percentage of German children with low MC has increased substantially, from 16% in 1974 to a level of 38% in contemporary children. Possible explanations may involve the decline of children's physical fitness (Tomkinson & Olds, 2007) and PA (Knuth & Hallal, 2009), and the increase of SB (Cui, Hardy, Dibley, & Bauman, 2011; Nelson, Neumark-Stzainer, Hannan, Sirard, & Story, 2006) and adiposity (Daniels et al., 2005; Lobstein, Baur, & Uauy, 2004). Therefore, as motor skills are positively associated with both physical fitness (Hands, Larkin, Parker, Straker, & Perry, 2009) and PA (Fisher et al., 2005; Okely et al., 2001b; Williams et al., 2008; Wrotniak et al., 2006) and inversely related to SB (Wrotniak et al., 2006) and to adiposity (Graf et al., 2004; Lopes, Stodden, et al., 2011; Okely et al., 2004) (as will be further explored in detail below), perhaps children's MC levels are decreasing as well.

Literature has also analysed age, gender and socioeconomic differences in MC. A debate exists in literature regarding the impact of gender on children's motor development and on possible differences in the ability to perform certain tasks. Results have shown that girls tend to perform better in balancing tasks (Engel-Yeger, Rosenblum, & Josman, 2010; Gabbard, 1996), whereas boys are generally known as more proficient than females in object-control skill performance (Ehl, Roberton, & Langendorfer, 2005; Hardy et al., 2010; Hume et al., 2008; Runion, Roberton, & Langendorfer, 2003; van Beurden, Zask, Barnett, & Dietrich, 2002). In locomotor skill performance, there are contradictory results, while some studies report no gender differences (Hume et al., 2008; van Beurden et al., 2002); others report boys (Cratty, 1986; Keogh & Sugden, 1985) or girls (Hardy et al., 2010; van Beurden et al., 2002) as more proficient.

In a study with German children aged 6-9 years old, Graf et al. (2004) found that boys showed an overall MC significantly better than the girls. Vandorpe et al. (2011), aiming to produce gender- and age-specific reference values for the gross MC of Flemish children between 6 and 12 years old, reported a significant gender difference for the subtests walking backwards and hopping for height; on balance, girls scored significantly better than boys for all but one age group (9 years old); on the hopping task, boys outscored the girls in every age group; however, those differences were only significant at ages 7, 8, 9 and 10 years; neither gender of all ages scored significantly different on moving sideways and jumping sideways.

Regarding age, it is well established that with increasing age, a gradual improvement in gross MC occurs; this improvement in MC is acknowledged as a general phenomenon during child development (Arceneaux, Hill, Chamberlin, & Dean, 1997; Chow, Hsu, Henderson, Barnett, & Lo, 2006). Vandorpe et al. (2011) in a study of Belgian children aged 6-11 years found that each age group scored significantly better than their one-year-younger counterparts on overall MC.

Indicators of socioeconomic status vary among studies (e.g., income, parental education and occupation, and neighbourhood of residence); therefore, results are not necessarily consistent across studies in school-age children. Nevertheless, there is some evidence which suggests socioeconomic status was positively associated with FMS among girls (Booth et al., 1999; Okely & Booth, 2004), and children from non-English-speaking backgrounds had lower levels of FMS mastery (Booth et al., 1997; Booth et al., 2006). Hardy et al. (2010) in 425 Australian preschool children found no significant differences in mastery of individual FMS according to socioeconomic status or language background among children, except in the hop test for boys. A higher proportion of boys from middle/high socioeconomic status demonstrated mastery of the hop compared with low socioeconomic status boys and boys from non-English-speaking backgrounds, compared with boys from an English-speaking background. Results in German and Flemish children were however equivocal, since one study noted no significant association between MC and socioeconomic status (Ahnert, 2005), while two reported lower levels of MC among children from low socioeconomic status families (Prätorius & Milani, 2004; Vandendriessche, Vandorpe, et al., 2012)

Lately, there has been increasing interest in the relationships between MC and health-related behaviours and outcomes. Indeed, a recent review (Lubans et al., 2010) of the relationship between MC and health benefits in children and adolescents indicated that MC levels are inversely correlated with weight status but positively correlated with PA, cardiorespiratory fitness, and perceived physical competence in both cross-sectional and longitudinal data. Another systematic review of literature conducted to synthesize the recent available data on physical fitness and PA in children with DCD, body composition, cardiorespiratory fitness, muscle strength and endurance, anaerobic capacity, power, and PA reveals that all have been negatively associated, to various degrees, with poor motor proficiency (Rivilis et al., 2011).

In recent years, a growing issue of interest has been the physical health of children with motor skill performance, particularly in children who face unusual difficulties in performing motor skills, despite not having identifiable neurological or sensory problems and their being of normal intelligence (Venetsanou et al., 2011). These children are said to suffer from DCD.

DCD is considered to be one of the major health problems among school-aged children worldwide (Cairney, Hay, Faught, Mandigo, & Flouris, 2005; Cairney, Hay, Faught, & Hawes, 2005; J. Cairney, J. A. Hay, B. E. Faught, T. J. Wade, et al., 2005; Henderson & Henderson, 2002; Polatajko & Cantin, 2006). DCD is defined, using the DSM-IV, as a condition marked by a significant impairment in the development of MC, which interferes with AA and/or activities of daily living. These difficulties are not due to a general medical condition (psychiatric, neurological, or other medical condition) (APA, 1994, 2000). DCD is a neurodevelopmental condition thought to affect a range from 1.4% to 19% in school-aged children (APA, 1994, 2000; Kadesjo & Gillberg, 1999; Lingam, Hunt, Golding, Jongmans, & Emond, 2009; Tsiotra et al., 2006; Wright & Sugden, 1996). However, agreement on the approximate prevalence is not universal. Although standardized assessments of motor problems have enabled researchers to consistently identify children with poor motor skills, the promotion of the 5% prevalence estimate has led to a somewhat tautological use of the 5^{th} percentile on these assessments as the cut-point for significant motor impairment (Cairney, Veldhuizen, & Szatmari, 2010).

In 1994, an international group of experts agreed to adopt the label ‘developmental coordination disorder’ to describe poor motor performance of unknown cause (APA, 1994). Research conducted in the past decade has provided evidence that children with DCD are demonstrated to be heavier (Cairney, Hay, Veldhuizen, Missiuna, Mahlberg, et al., 2010), less participant in PA (Rivilis et al., 2011), and less fit (Cairney, Hay, Veldhuizen, & Faught, 2010; Cairney, Hay, Faught, Flouris, & Klentrou, 2007; Cairney, Hay, Wade, Faught, & Flouris, 2006) than their normal-developed peers. In addition, they have poor AA (Losse et al., 1991), low self-esteem (Hay & Missiuna, 1998), poor social competence (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996) and are at risk of long-term psychological morbidity and educational failure (Lingam et al., 2009). Furthermore, they reported diminished perceptions of athletic competence, low levels of peer acceptance (J. Cairney et al., 2005; Cantell, Smyth, & Ahonen, 1994), greater anxiety than typically developed peers when faced with movement challenges (Rose, Larkin, & Berger, 1994; Skinner & Piek, 2001), and avoidance of PA (Bouffard et al., 1996).

Since this disorder can have various adverse effects on a child's life, it is important to emphasise early identification and intervention of young children suspect of, or at risk of, having DCD. Therefore, early identification can lead to education, guidance and encouragement to engage in typical childhood activities and hence decrease the risk of reduced self-esteem, self-efficacy and social participation (Missiuna, Rivard, & Bartlett, 2003). Early identification and intervention is both cheaper and more effective than therapy at an older age, narrowing (and in some cases minimizing) problems that associate with developmental delays (Berk & DeGangri, 1979; McIntosh, Gibney, Quinn, & Kundert, 2000). Moreover, planning, implementation, and evaluation of developmentally adequate movement programs depend on proper diagnosis of the child's level of motor development (Zimmer & Cicurs, 1993). Ultimately, the identification of children that may have developmental delays is the first step to impede later difficulties (Venetsanou, Kambas, Aggeloussis, Fatouros, & Taxildaris, 2009).

In this context, the main purpose of an MC test should not be only to measure performance of skills but rather the general traits underlying them (Burton and Miller, 1998).

Motor skill assessment can be performed using either a product or process. The decision of the way to measure children's performance, each with advantages and disadvantages, will be guided by the purpose of the information needed for example, to properly cluster a group of children, to identify those at risk, to plan intervention or educational programs, to monitor change over time, to provide feedback to the performer or to predict performance in the future (Burton & Miller, 1998).

A product-oriented assessment evaluates movement from a quantitative assessment approach. Product assessment is conducted in order to rate the outcome of skill execution such as time, distance or number of successful attempts and provides little information with regard to how the movement was performed (Burton & Miller, 1998). The result is generally compared to the performance of a normative group. The scores are converted or transformed into relative scores such as standard scores or percentiles. Such information allows the comparison of a child's performance to their chronological peers and could be used to monitor children with movement difficulties or to select participants eligible for a movement program (Hands, 2002). The objective nature of the measures usually ensures a high level of reliability over time and between assessors (Spray, 1987). Additionally, most tests can be done quickly and are capable of testing large groups. Because the tester does not require an extensive understanding of movement competencies to manage the test, this approach is useful for generalist teachers or professionals without a background in human movement (Hands & Larkin, 1998). On the other hand, the test outcomes do not inform the intervention or teaching program, while they do not provide direct information about the proficiency achieved (Branta et al., 1984). The validity of the test results depends on the appropriateness of the normative group for the child or group being tested. Finally, physical factors that impact performance such as height, weight and body composition, and differing cultural expectations and interests are not taken into account when interpreting the scores (Gabbard, 1996).

By way of contrast, process-oriented assessments are concerned with how the skill is performed rather than the outcome of the skill, and movement is evaluated based on the demonstration of behavioural criteria, which provides information of how the movement was performed (compared with an expert performer). For Hands (2002), the main advantages of qualitative assessment are that the information can be used to inform the teacher or other professional which specific components of a skill need to be practiced, and the assessment can be undertaken in a more meaningful context than quantitative methods. Observation records or checklists for each skill are usually generated to facilitate this assessment approach. The negative aspects comprise the difficulty of comparing results that have been gathered by different assessors. Assessors may interpret components of movement differently, unless intensive training has been undertaken. The inter-rater reliability is generally quite low. The time required to assess a large number of children is high. Further, it is difficult to interpret information gathered, since the results usually have no normative data (Burton & Miller, 1998). In addition, although these criteria comprise certain key aspects for a proficient performance, they do not represent the movement description on a developmental continuum (Stodden et al., 2008) or fully describe an instructional sequence. Ultimately, the use of the criterion of comparing a child to an expert performer could result in “ceiling effects”, make distinction between intermediate and advanced motor skill competence impossible, or result in “floor effects” that do not distinguish between a child with low-level skills and a child who is more skilled (Stodden et al., 2008).

In order to capture the inherent advantages of both approaches, some tests include both quantitative and qualitative test items. The combination of approaches takes into account the more erratic and variable movement patterns of beginners compared to the more consistent patterns of skilled performers. With the latter group, quantitative measures better discriminate between performers (Hands, 2002).

There are in literature several tests of motor skill proficiency, with a concise description of each going beyond the scope of this thesis. However, it is of importance to appropriately interpret the data accounting for types of assessments used and their reliability and validity to the aim purposed, once researchers have questioned the generalizability of results across studies that use different types (or parts of a battery test) of motor assessments (Stodden et al., 2008). In this thesis, MC was assessed with the Körperkoordination Test für Kinder (KTK) (Kiphard & Schiling, 1974), a well known product-oriented test that mainly focuses on gross MC of both normal children without motor problems and children with motor and/or mental problems. The KTK test battery is described in detail in the methods section of this thesis.

Regardless of how MC is assessed, evidence suggests that the development of FMS is a key factor in the promotion of lifelong PA. Moreover, insufficiently developed movement skills have been identified as an important barrier to later participation in PA (Allender et al., 2006). PA is defined as any bodily movement produced by skeletal muscles that results in energy expenditure beyond basal metabolic rate (Caspersen et al., 1985). PA is a complex multifactorial behaviour that is influenced by a variety of biological, behavioural and environmental factors and interactions among factors (Lopes, Rodrigues, Maia, & Malina, 2009; Sallis, Prochaska, & Taylor, 2000; Van Der Horst, Paw, Twisk, & Van Mechelen, 2007). Children's PA involve a mixture of school-based activities, organised team sports and unstructured play (Jago, Anderson, Baranowski, & Watson, 2005).

The importance of promoting active lifestyles from a young age is widely recognized, and the health benefits of regular PA are extensively acknowledged (Strong et al., 2005; WHO, 2010). The incorporation of PA into daily life and the achievement of recommended health-related levels of PA are major public health challenges. Indeed, many children and adolescents do not meet the current PA recommendations (Jago et al., 2005; Riddoch et al., 2007; Strong et al., 2005). Insufficient PA negatively impacts children's motor development and may affect their emotional and social development simultaneously (Huttenmoser, 1995; Waldron & Finn, 2005). Moreover, previous research has shown a decline in PA from childhood to adolescence (Goran, Gower, Nagy, & Johnson, 1998; Lopes, Vasques, Maia, & Ferreira, 2007), with the end of elementary school (9-11 years old) being a critical period of change (Goran et al., 1998; Nader, Bradley, Houts, McRitchie, & O'Brien, 2008).

Motor skills proficiency is sometimes described in literature as determinant (Hands et al., 2009; Wrotniak et al., 2006), while others describe it as an outcome of PA (Haga, 2008b; Hands et al., 2009). If, on the one hand, we can argue that motor skills proficiency is a consequence of the level of PA, on the other hand, it is also reasonable to accept that without some level of competence in a range of motor skills, children are limited in the amount and range of PA they can undertake (Bouffard et al., 1996). Although it is well established in literature that there is a positive albeit weak to moderate relationship between PA and different motor skills, the direction of the association is controversial, while some cross-sectional studies described that motor skills are related to PA in preschool (Fisher et al., 2005; Kambas et al., 2012; Williams et al., 2008) and elementary school children (Wrotniak et al., 2006) and adolescents (Okely et al., 2001b). Others found positive associations between PA and motor skills in preschool children (Burgi et al., 2011) and in adolescents (Barnett et al., 2011).

However, recent longitudinal evidence suggests that childhood object control skill proficiency (involving manipulation of an object, e.g., a ball) is predictive of subsequent PA during adolescence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009) and also that object control skill proficiency can be tracked from childhood to adolescence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010). Also in a longitudinal analysis, motor proficiency at age 6 was predictive of PA three years later, with significantly higher PA in the group with the highest motor skills (Lopes et al., 2009). Recently, Burgi et al. (2011) followed a group of preschoolers over 9 months and found that a higher baseline PA was predictive of improved motor skills at a follow-up but not vice versa, suggesting that PA enhances motor skill development and not the other way around.

As these observations yield inconsistent results, more studies are needed to clarify this relationship. Nevertheless, Barnett et al. (2011) suggested a reverse causality. Accordingly, Stodden et al. (2008) have hypothesized a recursive developmental model suggesting a reciprocal relationship between MC and PA. The authors postulated that children with high motor skill proficiency will have higher levels of fitness and perceived sports competence, which in turn predict greater participation in PA, and vice versa (Stodden et al., 2008). In this model is also argued that the relationship between motor skill competence and PA will emerge from early to late childhood and will continue to gain strength during adolescence. However, the authors also theorized that with age the direction of the association may change; that is, during early childhood, it is PA that may develop children’s motor skill competence, but in middle and later childhood, the relations between both components might change; thus, it is competence in motor skills that may be an important condition to engage in PA (Stodden et al., 2008).

Strongly related to PA is physical fitness. Physical fitness is a set of attributes related to a person's ability to perform physical activities that require aerobic fitness, endurance, strength or flexibility and is determined by a combination of regular activity and genetically inherited ability (Hussey et al., 2007). Cardiorespiratory fitness is the physical fitness component that has been studied most, because it is a health marker across the lifespan (Blair et al., 1989; Blair et al., 1996; Kodama et al., 2009; Ortega, Ruiz, Castillo, & Sjostrom, 2008). Cardiorespiratory fitness reflects the overall capacity of the cardiovascular and pulmonary systems to supply oxygen during sustained exercise, as well as the ability to perform such exercise (Taylor et al., 1955). Higher levels of cardiorespiratory fitness appear to delay all-cause mortality, primarily due to decreased rates of cardiovascular disease and cancer (Blair et al., 1989), and provide strong and independent prognostic information about the overall risk of illness and death, especially related to cardiovascular causes (LaMonte & Blair, 2006). Cross-sectional studies indicate that high cardiorespiratory fitness during childhood and adolescence is associated with a favourable plasma lipid profile (Mesa et al., 2006), total and central body fat (Ortega et al., 2007), features of the metabolic syndrome (Brage et al., 2004), novel cardiovascular disease risk factors (Ruiz et al., 2007), and arterial compliance (Reed et al., 2005). Longitudinal studies also suggest that higher cardiorespiratory fitness during childhood and adolescence is associated with a healthier cardiovascular profile later in life (Ruiz et al., 2009).

Despite the overwhelming evidence demonstrating that higher or improved physical fitness, including cardiorespiratory fitness, is associated with improved health in children and youth (Anderssen et al., 2007; Ekelund et al., 2007; Janssen, 2007; Strong et al., 2005), there is increasing evidence suggesting that the aerobic fitness performance of children is declining (Tomkinson & Olds, 2007). Furthermore, cardiorespiratory fitness tends to be tracked moderately from childhood to adulthood (Malina, 1996, 2001).

A recent review analysed the relations between cardiorespiratory fitness and MC in children. From the 19 studies provided, 18 of these studies reported that children with poor MC (DCD) demonstrated decreased aerobic power compared to their typically developing peers in both cross-sectional and longitudinal studies (Rivilis et al., 2011).

Therefore, children with MC problems are at greater risk for lower aerobic fitness than typically developing children (Cairney, Hay, Veldhuizen, & Faught, 2010). Given the importance of cardiorespiratory fitness, from a public health perspective, these results may hold implications for children's general development, health and well-being (Faught, Hay, Cairney, & Flouris, 2005; Haga, 2009; Tomkinson & Olds, 2007; Vandendriessche et al., 2011).

Current efforts to increase youth's PA have had limited success, with effective changes achieved only in smaller sub-groups or in the short term (Kipping, Jago, & Lawlor, 2008; van Sluijs, McMinn, & Griffin, 2007). One reason for this relative lack of success could be that most of the public health efforts to promote active lifestyles have focused mainly on PA and have paid little attention to the growing evidence that indicates that SB is a distinct health-related behaviour (Tremblay, Leblanc, Kho, et al., 2011). Additionally, neither interventions in PA or SB target improvements in MC (Salmon et al., 2005), and indicators of MC have not been systematically included in studies that consider correlates of PA (Lopes, Maia, Rodrigues, & Malina, 2011) or SB.

SB is defined as any activity that does not increase energy expenditure substantially above the resting level (less than 1.5 METs), such as sleeping, sitting, lying down, or watching television or other forms of screen-based entertainment (Pate, O'Neill, & Lobelo, 2008). In light of recent research, lack of PA is only one part of the public health problem, since various types of SB may occur through different behavioural mechanisms (Owen, Leslie, Salmon, & Fotheringham, 2000), have different determinants (Gordon-Larsen, McMurray, & Popkin, 2000), track differentially (Gordon-Larsen, Nelson, & Popkin, 2004), and have a distinct range of potentially adverse health consequences (Tremblay, Esliger, Tremblay, & Colley, 2007) independent of PA. Additionally, SB shows moderate stability during childhood and adolescence (Janz, Burns, & Levy, 2005).

In children and adolescents, self-reported leisure-time SB such as overall screen time (i.e., TV viewing, videogames, computer use) has commonly been studied; however, while these activities may represent a substantial portion of the time spent in total SB, they do not represent the total amount of everyday sedentary time. In this regard, as has been argued for PA (Ruiz & Ortega, 2009), objectively measuring total sedentary time by using devices such as accelerometers, may offer particular advantages, since these devices do not rely on subject recall and may capture the entire daily patterns of both PA and SB.

The negative effects of sedentary lifestyles on children's health and health-related behaviours and outcomes are a source of concern. Some studies have shown that children spend significant proportions of their waking time being sedentary between 50% and 80% (Colley et al., 2011; Martinez-Gomez et al., 2011; Matthews et al., 2008) and as a result may be at risk of detrimental health outcomes (Hinkley, Salmon, Okely, & Trost, 2010). Mounting evidence has suggested recently that time spent in SB is associated with adverse health outcomes, an association that may be independent of the protective contributions of PA, as it remained significant after adjustments (van Uffelen et al., 2010). In a recent review of SB and health indicators in school-aged children and youth, the authors concluded that spending more than two hours per day being sedentary was associated with unfavourable body composition, decreased fitness, lowered scores for self-esteem and pro-social behaviour, and decreased AA (Tremblay, Leblanc, Kho, et al., 2011).

Literature has paid little attention to the relationship between SB and MC (two studies reported no association) (Cliff, Okely, Smith, & McKeen, 2009; Graf et al., 2004), while the other two reported a negative association (Williams et al., 2008; Wrotniak et al., 2006), leaving the following questions unanswered: (i) Does SB predict MC and, if so, (ii) does this predictive relationship remain after considering the levels of PA that children undertake?

Recent studies have focused on understanding the relationships between MC and health-related behaviours and outcomes. Indeed, a recent systematic review identified eight potential benefits of MC: global self-concept, perceived physical competence, cardiorespiratory fitness, muscular fitness, weight status, flexibility, PA, and reduced SB (Lubans et al., 2010).

In the Stodden et al. (2008) model, the authors postulated that children with high motor skill proficiency will have higher levels of fitness and perceived sports competence, which in turn predict greater participation in PA and vice-versa. However, in this model, as in the general literature, the SB appears to be defined as the inverse of PA (i.e., insufficient levels of PA), instead of being considered as an independent behaviour. In fact, we only found four studies in literature linking SB to MC (Cliff et al., 2009; Graf et al., 2004; Williams et al., 2008; Wrotniak et al., 2006), and only three of them (Cliff et al., 2009; Williams et al., 2008; Wrotniak et al., 2006) were performed using objective measures. However, in those studies the relationship between PA and motor skills did not take into account the possible confounding effect of SB, and the associations between SB and motor skills were not adjusted for the influence of PA. PAPER I of this thesis attempts to push forward the literature on this subject by analysing associations between objectively measured SB and MC, taking into account PA levels in elementary school children.

Therefore, to establish healthy lifestyles from a young age, actions aiming to address the current inactivity crisis should attempt to both increase PA levels and decrease SB (Tremblay, Leblanc, Kho, et al., 2011). Indeed, the necessity for public health recommendations targeting SB has already been suggested (Hojbjerre et al., 2010). Based on the mounting evidence of the health-related benefits of low SB, the Canadian Society for

Exercise Physiology, in partnership with the Healthy Active Living and Obesity Research Group at the Children's Hospital of Eastern Ontario Research Institute, recently launched the Canadian Sedentary Behaviour Guidelines, which extend the American Academy of Paediatrics' guidelines for screen time (Education, 2001) to include transportation, sitting time, and time spent indoors. These guidelines suggest that for health benefits, children and adolescents should minimize the time they spend being sedentary each day by limiting recreational screen time to no more than two hours per day (lower levels are associated with additional health benefits) as well as limiting sedentary (motorized) transport, extended sitting time, and time spent indoors throughout the day (Tremblay, Leblanc, Janssen, et al., 2011); however, recommendations regarding limits on total time per day spent in sedentary activities are still lacking. Indeed, only a few studies have addressed links between total SB time and health outcomes in children and adolescents (Martinez-Gomez et al., 2011).

Closely linked to PA and SB is obesity. Childhood and adolescent obesity became an important public health problem, as its prevalence has increased significantly over the past years in several countries (Wang & Lobstein, 2006). Obesity is associated with a range of adverse health impacts, including metabolic, orthopaedic, cardiovascular, psychological, neurological, hepatic, pulmonary, gastroenterological and renal impairments (Daniels et al., 2005; Lobstein et al., 2004). The causes are multifactorial, and its development results from genetic and environmental factors to a variety of metabolic, behavioural, social and cultural interactions (Claessens, Beunen, & Malina, 2000; Dietz & Gortmaker, 2001). Although the relative importance of specific risk factors are not ordinarily specified at the level of the individual and population, a decline in PA, an increase in SB (Nelson et al., 2006; Sallis et al., 2000) and an excessive energy intake are often considered as primary mechanisms contributing to a potentially unhealthy weight gain and in turn to overweight and obesity (Lopes, Maia, et al., 2011). Additionally, the physical, social and emotional consequences of obesity may be evident in childhood and may persist into adult life (Dietz, 1998), as it is known that childhood obesity is tracked into adulthood (Magarey, Daniels, Boulton, & Cockington, 2003; Whitaker, Wright, Pepe, Seidel, & Dietz, 1997). Thus, identification of children at risk of developing overweight/obesity and its complications is essential, so that prevention and treatment strategies may be implemented early in life (Daniels et al., 2005).

Parental acknowledgment of a child's excess weight and an understanding of its health consequences are crucial primary steps in tackling obesity (Jeffery, Voss, Metcalf, Alba, & Wilkin, 2005). Indeed, it is supposed that those who correctly recognize their child's weight status and show concern may be more likely to act accordingly by setting up appropriate health behaviour changes (West et al., 2008). However, parents often do not accurately perceive their children's weight status, report low levels of concern, and are not aware of the health risks associated with excess fat accumulation (Baughcum, Chamberlin, Deeks, Powers, & Whitaker, 2000; Carnell, Edwards, Croker, Boniface, & Wardle, 2005; Eckstein et al., 2006; Jeffery et al., 2005; Maynard, Galuska, Blanck, & Serdula, 2003; Wake, Salmon, Waters, Wright, & Hesketh, 2002).

Parents play a key role for successful obesity-prevention interventions (Snethen, Broome, & Cashin, 2006), and they should be involved in such interventions for three main reasons: (i) Obesity runs in the family, and it is improbably a successful intervention if other family members will not cooperate with the intervention's goals; (ii) parents are a child's models that support the acquisition and maintenance of exercise and eating behaviours; (iii) it is necessary to teach parents specific behaviour-change strategies (Epstein, 1996). Interventions for prevention and treatment should work directly with parents from the very earliest stages of child development and growth (Lindsay, Sussner, Kim, & Gortmaker, 2006). Effective interventions require multifaceted strategies (Lindsay et al., 2006), including behaviour skills, behaviour change, and parental involvement to support healthy diet and nutrition and to increase PA (Snethen et al., 2006).

Literature on parental perceptions of children's weight status reports high rates of parental misperceptions (Eckstein et al., 2006; Maynard et al., 2003) and indicates that mothers are more likely than fathers to correctly assess their child's weight (Jeffery et al., 2005). It also states that older children are more likely to be accurately classified than younger ones (Campbell, Williams, Hampton, & Wake, 2006; Maynard et al., 2003). Results for socioeconomic status, race/ethnicity, and gender are contradictory (Baughcum et al., 2000; Carnell et al., 2005; Jeffery et al., 2005; Maynard et al., 2003; West et al., 2008). However, most of the research in this field has been carried out in the United States, Australia, and the United Kingdom; consequently, studies in other populations with different social and cultural backgrounds are necessary in order to understand if the associations found in those countries can be generalized.

In Portugal, about one third of children and adolescents are overweight or obese (Sardinha, Santos, Vale, Silva, et al., 2011), which emphasizes the need for a large variety of strategies to fight this epidemic. Knowing how Portuguese mothers view their children's weight status is an important step for intervention programs, an idea explored in PAPER II of this thesis.

In the Stodden et al. (2008) model, it is also suggested that obesity trajectories may be triggered by the cumulative effects that lower levels of motor proficiency have on reducing movement opportunities, physical fitness, and perceived physical competence during childhood. Overall, low motor proficiency will result in unsuccessful participation in movement play activities and/or sports in middle to late childhood, thus leading to a negative spiral of disengagement from an active lifestyle. Accordingly, the model proposes that motor proficiency levels will eventually lead to positive or negative obesity trajectories over time, as the recursive nature of the model effects compound over time.

It is reasonably well established in literature that there is an inverse association between adiposity and MC (D'Hondt et al., 2011; Graf et al., 2004; Lopes, Maia, et al., 2011; Lopes, Stodden, et al., 2011; Okely et al., 2004). Indeed, a recent review (Lubans et al., 2010) on the relationships between MC and health benefits in children and adolescents indicated that MC levels are inversely correlated with weight status both in cross-sectional and longitudinal studies. In this review, weight status was negatively correlated with MC in six of nine studies, with the remaining three demonstrating no relationship (Lubans et al., 2010). Rivilis et al. (2011), in a recent systematic review, concluded that an adverse body composition was associated with poor motor proficiency, regardless of the measure of adiposity considered.

However, overweight and obesity measurement issues may potentially play a role in obscuring the relationship between body composition and MC (Rivilis et al., 2011). There are some sophisticated methods to accurately measure body fat, such as computed axial tomography or dual-energy X-ray absorptiometric densitometry; however, such techniques are not feasible to apply in large epidemiological studies or even in clinical settings, because they are complex, time consuming and expensive.

Body fat percentage measurement techniques have been developed and validated for children; however, it has been used rarely in literature regarding the relationship between adiposity and MC. The existing studies have found significant associations between body fat percentage and MC, whether using skin folds (Lopes, Maia, et al., 2011), bioelectric impedance (J. Cairney, J. A. Hay, B. E. Faught, & R. Hawes, 2005) or whole-body air displacement plethysmography (Silman, Cairney, Hay, Klentrou, & Faught, 2011) methods. Using bioelectric impedance, Cairney et al. (2005) also found that children with poor MC had greater body weight and body fat compared to their normal MC peers. Certainly, bioelectric impedance is an appealing tool for assessing body composition due to its simplicity, painlessness, non-invasiveness and increasing low cost, making it highly suitable for survey and clinical use, particularly in school-age children (Wright et al., 2008). However, the resulting estimates of fat and fat-free mass actually agree poorly with more accurate methods, tending to be both biased and imprecise (Eisenmann, Heelan, & Welk, 2004).

Several anthropometric measures have been used in literature on associations between MC and adiposity, with the most common being the body mass index (BMI) (Lubans et al., 2010; Rivilis et al., 2011). D'Hondt et al. (2011), in a cross-sectional study with 954 Flemish primary school children stratified, found that less than 20% of healthy-weight participants was identified as being motor impaired, while that proportion increased to 43.3% and up to 70.8% in children with a BMI considered as overweight and obese, respectively. However, BMI is a suboptimal marker of body fat, because it does not distinguish fat from lean tissue or bone, and therefore classifying people as overweight or obese based on their BMI may lead to significant misclassification. Moreover, BMI is not a suitable method to assess body fat distribution (Brambilla et al., 2006), and it has been suggested that BMI may be a less-sensitive indicator of fat in children and adolescents than waist circumference or waist-to-height ratio (Brambilla et al., 2006).

Waist circumference is a simple, effective and inexpensive anthropometric tool to measure abdominal adiposity and related metabolic risks in children of different ethnicities (Brambilla et al., 2006; Lee, Bacha, Gungor, & Arslanian, 2006). Abdominal obesity seems to reflect intra-abdominal fat, including visceral adipose tissue (Clasey et al., 1999), and it is known that increased visceral adipose tissue is strongly correlated with cardiovascular disease risk factors (Soto Gonzalez et al., 2007). During childhood and adolescence, it is known that abdominal obesity is an important predictor for several cardiovascular disease risk factors (Moreno et al., 2002; Savva et al., 2000). For children and adolescents, there are no internationally accepted cut-off values for waist circumference; however, waist circumference centile charts have been developed for children and adolescents in some countries (Eisenmann, 2005; Fernandez, Redden, Pietrobelli, & Allison, 2004; Katzmarzyk, 2004; McCarthy, Jarrett, & Crawley, 2001). Faught et al. (2005), in a cross-sectional study with 571 elementary school students, found an association between poor MC with increased body fat and low cardio-respiratory fitness (PA was a significant mediator for both relationships). These authors concluded that poor MC is related to factors associated with increased risk for coronary vascular disease, including decreased cardiorespiratory fitness and increased body fat through the mediating influence of PA in children.

Waist-to-height ratio has been proposed as a convenient alternative measurement to assess central fatness in children (Savva et al., 2000). Similar to waist circumference, waist-to-height ratio has been shown to be strongly correlated with abdominal fat measured using imaging techniques (Soto Gonzalez et al., 2007). Correcting waist circumference to height may obviate the need for age-, sex- and ethnic-related reference values (Ashwell & Hsieh, 2005), while waist circumference requires population-specific cut-off values (WHO, 2000). Nevertheless, the gap that remains in literature is the ability of the different measures of weight status/adiposity to predict low MC, a research question explored in PAPER III of this thesis.

Besides health, academic success is an outcome most parents and schools prioritize and strive to help their children accomplish. AA can be accessed by direct indicators (grade point averages, scores on standardized tests, and grades in specific courses) or by indirect indicators (measurements of concentration, memory and classroom behaviour) (Strong et al., 2005).

The association between PA and AA in school-age children has received increased interest as of late. Most studies support the idea that children who are more physically active are more likely to achieve better academic results (Carlson et al., 2008; Coe, Pivarnik, Womack, Reeves, & Malina, 2006; Fox, Barr-Anderson, Neumark-Sztainer, & Wall, 2010; Hillman, Erickson, & Kramer, 2008; Kwak et al., 2009; Reed et al., 2010; Ruiz et al., 2010a; Strong et al., 2005; Taras, 2005; Trudeau & Shephard, 2008); however, no such relation was found in some studies (Ahamed et al., 2007; Carlson et al., 2008; Coe et al., 2006; Kwak et al., 2009; Sigfusdottir, Kristjansson, & Allegrante, 2007). Possible reasons for these mixed results may lie in the nature of the study. Variables include how PA was assessed (objective or self-reported), how AA was measured (direct or indirect indicators), whether results were controlled for socioeconomic status (Kwak et al., 2009; Trudeau & Shephard, 2008) and whether distinction was made among intensity levels of PA (Carlson et al., 2008; Coe et al., 2006; Kwak et al., 2009).

The discussion about a possible association between MC and AA has recently remerged. Studies suggest that neuronal structures (in the cerebellum and the frontal lobe) are responsible for coordination as well for cognition (Serrien, Ivry, & Swinnen, 2006), and that both functions seem to follow a similar developmental timetable with an accelerated development between 5 and 10 years of age (Anderson, 2002; Gabbard, 2008). Recent research also indicates that children’s development domains (motor, reading, and mathematics skills) are intercorrelated and cannot be separated (Smith et al., 1999; Son & Meisels, 2006); thus, it is the whole child that needs attention (Bowman et al., 2001). There is also evidence that working memory capacity and visual perceptual ability limit children’s AA

(Alloway, 2007; Alloway & Alloway, 2010; Sortor & Kulp, 2003). Besides, one cross-sectional and longitudinal study found that higher baseline motor skills (agility and dynamic balance) were related to better spatial working memory and/or baseline attention as well as their future improvements over the following nine months (only no association was found between dynamic balance and attention) (Niederer et al., 2011). Indeed, children with DCD tend to perform poorly in literacy and numeracy assessments (Alloway, 2007), while fine MC was found to positively correlate with AA (Sortor & Kulp, 2003); children with learning disabilities scored poorer in gross MC tests (both locomotor and object-control) (Westendorp, Hartman, Houwen, Smith, & Visscher, 2011). Additionally, other cross-sectional (Knight & Rizzuto, 1993; Nourbakhsh, 2006; Planinsec, 2002) and interventional studies (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008; Ericsson, 2008; Uhrich & Swalm, 2007) have shown that improved motor skill levels may be positively related to improvements in AA or other cognitive variables. Furthermore, longitudinal studies in preschool children found a relationship between early motor development and later cognitive function (Piek et al., 2008; Son & Meisels, 2006), suggesting that early assessment of school motor skills may increase the predictability of later achievement and the probability of identifying children at risk for school failure. The authors also concluded that well-developed gross motor skills are important to facilitate children’s cognitive development (Piek et al., 2008; Son & Meisels, 2006).

There are potential biological, psychological, and social mechanisms that may help explain this relationship. Coordinative exercise involves an activation of the cerebellum, which influences motor functions (Gao et al., 1996) as well as attention (Courchesne et al., 1994), working memory (Klingberg, Kawashima, & Roland, 1996), and verbal learning and memory (Andreasen et al., 1995). Additionally, the frontal lobes play an important role in mediating both MC (Hernandez et al., 2002) and cognitive functions (Miller & Cohen, 2001). An interventional study performed by Budde et al. (2008) aiming to investigate the effect of 10 minutes of physical exercise (coordination exercises vs. non-specific physical education lessons) on concentration and attention performance in a school setting, revealed enhanced attention and concentration performance in both groups, with significantly higher enhancement in the group that performed coordination exercises. Furthermore, they suggest that coordination exercises lead to a facilitation of neuronal networks that results in a pre-activation of cortical activities that are responsible for cognitive functions such as attention (Budde et al., 2008).

Better MC results may reflect better overall health, as has been suggested in the case of physical fitness (Chomitz et al., 2009) (i.e., better nutrition, more PA and healthier weight status), and good health may contribute positively to AA. As literature points out, high levels of motor competence/skill are positively associated with PA (Wrotniak et al., 2006). Cognitive facilitation by PA is presumably attributable to a direct improvement in cerebral circulation (of glucose, oxygen, and energetic substances) and the alteration of neurotransmitter actions in the central nervous system (acetycholine, dopamine, norepinephrine, epinephrine, adrenocorticotropic hormone and vasopressin) (Kashihara, Maruyama, Murota, & Nakahara, 2009). Taras (2005) indicates that PA increases blood flow to the brain and raises the levels of hormones (norepinephrine and endorphins) that reduce stress, improve mood, and induce a calming effect after exercise, possibly leading to an improvement in AA. Shephard (1996) has also suggested that increased PA may induce arousal and reduce boredom, leading to increased attention span and better concentration. Additionally, PA may increase feelings of self efficacy and self-esteem, which can improve class behaviour as well as AA. Furthermore, it is assumed that children who participate in PA, that promotes cooperation, sharing, and rule-following, learn skills that transfer to classroom settings (Taras, 2005).

Given the importance of assessment and evaluation in the education and health fields and the pressures that educational agents are under to achieve academic success for all students, indicators of educational achievement, health, and functional status may allow educators and policy makers to make more informed decisions (Lloyd, Colley, & Tremblay, 2010). Therefore, understanding the relationship between MC and AA is important for ensuring the appropriate assignment of resources as well as the implementation of programs to develop children's health-related behaviours.

Despite these findings, until now, to the best of our knowledge, no study has addressed the association between gross MC and direct/objective indicators for AA, namely scores on standardized tests for elementary school-age children, as assessed in PAPER IV of this thesis.

In summary, understanding the role of motor coordination in children's health-related behaviours and cognitive outcomes, namely whether or not SB is related to MC, how mothers perceived their offspring's weight status and which measure of adiposity best predicts MC, and whether or not MC can predict AA in elementary school-age children may provide useful information to public health policy makers and practitioners in the fields of education, health and motor behaviour for the prevention or reduction of the burden of MC impairment.

3. Methods

The schools' directors and children's parents/guardians received verbal and written description of the study and signed a written informed consent form. The protocol and procedures employed followed the Helsinki Declaration for Investigation in Human Subjects and were approved by the Curricular Development and Innovation Division (Portuguese Ministry of Education) and by the University's Ethics Committee.

All data was collected during regularly scheduled physical education classes by 2 assessors in full time. This graduated physical education professionals received specific training and had already participated in previous data collection. The assessors were helped by the physical education teachers.

The instruments used to perform this thesis were all validated and feasible in previous investigations published and were selected taking in account the aims purposed; the human, equipment and financial resources available; timeline disposed. The instruments characteristics and the description are in the methods section.

3.1 Study Design and Sampling

Data for the present study was derived from the Bracara Study aimed to evaluate the relations between Motor Coordination, Physical Activity, Physical Fitness, Body Composition, Academic Achievement, and Health Behaviors among elementary school children. The Bracara Study was conducted in a middle city located in the north of Portugal during the 2009/2010 academic year (September to June). All 21 public elementary schools in the city that qualified as urban (according to the Municipal Administration Registry) were considered and invited to participate in this study, corresponding to 846 children enrolling in the fourth grade; two schools decided not to take part in this study, corresponding to 90 children; six schools could not be evaluated on time to take part in this study, corresponding to 130 children; 30 children who failed the inclusion criteria (having a mental and/or physical disability or a health condition that did not allow them to participate in physical education classes) or had missing information on the variables of interest were excluded from this analysis. Therefore, the final sample included 13 urban public elementary schools, and 596 participants (281 girls) aged 9-12 years old (paper III and paper IV).

For Paper I - From the final sample (596 participants) due to temporal and material restrictions (accelerometers available) 383 children did not wear the accelerometer. However, drop out analysis showed that the 383 missing children had a similar mean values for height, waist circumference, WHtR and mother's education (data not showed). Therefore, the final sample included 213 participants (110 girls) aged 9-10 years old.

For Paper II - 596 questionnaires were sent out and 499 were returned (83.7% response rate). Drop out analysis showed that the missing 16.3% of children had a BMI that was no different from that of those included (mean BMI for excluded 19.01 ± 3.86 *vs* mean BMI for included 18.50 ± 3.10, p=0.122). Therefore, final sample included 499 participants (236 girls; 47.3%), aged 9-12 years old.

3.2 Measures

3.2.1 Sociodemographic Measures

Each child's date of birth, gender, and socioeconomic status was extracted from the schools' administrative record systems. The socioeconomic status records used by the Portuguese Ministry of Education are based on annual family income: children may be eligible for benefit A, eligible for benefit B, or not eligible. These categories were used as a proxy measurement of family socioeconomic status (Education, 2009). According to the Portuguese Ministry of Education, those eligible for benefit A receive books, school supplies, and meals for free; those eligible for benefit B receive 50 % of the books required and a 50% discount on meals. The questionnaire also included a question about mother's educational level and was also used as a measure of socioeconomic status. Mother´s were categorised according to the Portuguese Education Level: Low (mandatory education – 9 school years); Medium (secondary education – 12 school years); and High (college or university degree).

3.2.2 Children's weight status

Stature and body mass were measured using a stadiometer (Seca 220) and a scale (Tanita TBF-300) according to standardized procedures while the child was wearing light clothing without shoes. Values were recorded to the nearest 0.1 cm and 100 g, respectively. Body mass index (BMI) was calculated as body weight (kg), divided by height (m), squared. Weight status was determined according to the International Obesity Task Force (Cole, Bellizzi, Flegal, & Dietz, 2000; Cole, Flegal, Nicholls, & Jackson, 2007) cut-offs for BMI: underweight, normal weight, overweight, and obese. The overweight and obese categories were combined. Waist circumference measurements was taken as described by Lohman (Lohman, Roche, & Martorell, 1991).The waist and height were used to compute the WHtR.

Previous analyses (data not showed) showed that WHtR explain better MC than body mass index, fat mass percentage or waist circumference (R^2 – 0.22 for girls e 0.20 for boys) (Paper IV).

3.2.3 Maternal perceptions of weight status

A questionnaire was distributed to parents for assessing general child and parental health variables, divided in three sections: The first section collected information related to the child; the second section was related to parental characterization; and the third section addressed parental physical activity. For this study, only the mothers' perceptions of their child's weight status and the mothers' self-reported height and weight were used. The mother's appraisal of her child's weight was assessed with the question: "How would you describe your child´s weight at the moment? (underweight, normal weight, overweight or obese).".

3.2.4 Mother's weight status

The mothers' height and weight were assessed by the upper mentioned questionnaire and BMI was then calculated and defined according to the World Health Organization (2000) cut off points (WHO, 2000).

3.2.5 Motor Coordination

MC was evaluated with the body coordination test, Körperkoordination Test für Kinder (KTK), developed for German children (aged 5-15 years) (Kiphard & Schiling, 1974). The KTK battery has four items:

Balance: the child walks backward on three balance beams each 3 m in length, 5 cm in height, but with decreasing widths of 6, 4.5 and 3 cm. The child has three attempts at each beam; the number of successful steps is recorded; a maximum of 24 steps (eight per trial) were counted for each balance beam, which comprises a maximum of 72 steps.

Jumping laterally: the child makes consecutive jumps from side to side over a small beam (60 cm x 4 cm x 2 cm) as quickly as possible for 15 s. The child is instructed to keep his/her feet together; the number of correct jumps in two trials was summed.

Hopping on one leg over an obstacle: the child was instructed to hop on one foot at a time over a stack of foam blocks after a short run-up. After a successful hop with each foot (the child clears the block without touching it and continues to hop on the same foot at least two times), the height was increased by adding a block (50 cm x 20 cm x 5 cm). The child had three attempts at each height and on each foot; three, two or one point(s) was/were awarded for a successful performance on the first, second or third trial, respectively; a maximum of 39 points (12 stacks blocks) could be scored for each leg (maximum score 78).

Shifting platforms: the child begins by standing with both feet on one platform (25 cm x 25 cm x 2 cm) supported on four legs, 3.7cm in height and holding a second identical platform in his/her hands; the child is then instructed to place the second platform alongside the first and to step on to it; the first box is then lifted and placed alongside the second and the child steps on to it; the sequence continues for 20 s. Each successful transfer from one platform to the next earns two points (one for shifting the platform, the other for transferring the body); the number of points in 20 s is recorded and summed for two trials. If the child falls off in the process, he/she simply gets back on to the platform and continues the test.

Although some of the items in the KTK appear to measure specific components of motor performance, e.g., dynamic balance, speed and agility, balance and power, the four tests were loaded in a single factor when analyzed with other items (Kiphard & Schiling, 1974). Hence, the authors utilized the four items together as a global indicator of MC, the ‘‘motor quotient.’’ Each performance item was scored relative to gender- and age-specific reference values for the population upon which the KTK was established. The sum of the standardized scores for the four items provides the motor quotient. Using the motor quotient children were then categorized as having: MC disorders (<70 motor quotient); MC insufficiency (71≤ motor quotient ≤85); normal MC (86≤ motor quotient ≤115); good MC (115≤ motor quotient ≤130); or very good MC (131≤ motor quotient ≤145). In a normal population a motor quotient score below 85 represents a motor performance level below the 15th percentile and is considered problematic (Kiphard & Schiling, 1974). Therefore, in behalf of the child’s well-being, the authors suggested that motor therapy is recommended.

The psychometric characteristics of the KTK have been documented (Kiphard & Schiling, 1974). The test-retest reliability coefficient for the raw score on the total test battery was 0.97, while corresponding coefficients for individual tests ranged from 0.80 to 0.96. Factor analysis of the four individual tests resulted in a single factor labelled gross MC. The percentage of total variance in MC explained by the four tests varied from 81% at 6 years to 98% at 9 years (Kiphard & Schiling, 1974). Intercorrelations among the four tests varied from 0.60 to 0.81 for the reference sample of 1228 children. Both the factor analysis and intercorrelations thus indicated acceptable construct validity. Validity was further determined through differentiation of normal from disabled children. The KTK test differentiated 91% of children with brain damage from normal children. Participants were classified as having: MC disorders, MC insufficiency, normal MC, good MC or very good MC, according to the KTK reference values described above. Participants with good MC were recoded and combined with those with normal MC due to their small sample size (1.2%).

3.2.6 Academic Achievement

AA was assessed using the Portuguese Language and Mathematics *National Exams* which are mandatory for all 4th grade students. The exams were administered in May 2009 by two supervision teachers in the classroom. The Educational Evaluation Office from the Portuguese Ministry of Education performs management, analysis, and maintenance of student data and the National Exams database. The National Exams are criterion-referenced tests that provide scores to students, teachers and parents according to the performance levels: A (very good), B (good), C (fair), D and E (insufficient); the exams aim to evaluate how primary competences are appropriated by students in order to diagnose the educational system. For each exam 1, 2, 3, 4, or 5 points were attributed to scores of E, D, C, B, and A, respectively. An AA score was computed by summing the points attained for each of the exams. Participants were then categorized as having high AA (>8 points); middle AA (7-5 points); or lower AA (<4 points), based on the tertile values of this score.

3.2.7 Cardiorespiratory Fitness

Health-related components of physical fitness were evaluated using the Fitnessgram Test Battery, version 8.0. The Fitnessgram is included in the physical education curriculum, and the five tests recommended in the Portuguese National Program (curl-up, push-up, trunk lift, shuttle-run, and the modified back saver sit-and-reach) were used in this study. All tests were conducted according to the Fitnessgram measurement procedures (Welk & Meredith, 2008).

For the purpose of the present analysis we only considered the 20 m shuttle-run test as a way to evaluate cardiorespiratory fitness. This test requires participants to run back and forth between two lines set 20 m apart. Running speed started at 8.5 km/h and increased by 0.5 km/h each minute, reaching 18.0 km/h at minute 20. Each level was announced on the tape. The participants were told to keep up with the pacer until exhausted. The test was finished when the participant failed to reach the end lines concurrent with the audio signals on two consecutive occasions. Otherwise, the test ended when the subject stopped because of fatigue. Participants were encouraged to keep running as long as possible throughout the course of the test. The number of shuttles performed was recorded. Age- and sex-adjusted Z-scores were computed, because the age and sex-specific cut-off points of the Fitnessgram criteria are only developed for children aged 10 years old or older, and most participants in this study were nine years old.

The use of shuttle-run tests to assess aerobic fitness in children with motor problems is controversial, and has been criticized by Armstrong and Welsman (1997) and Hands and Larkin (2006) for being overly vulnerable to both motivational and environmental effects. Indeed, field-based measures of aerobic capacity rely on the internal motivation of the participants to perform to exhaustion (Rivilis et al., 2011), a circumstance that could be particularly challenging for children with developmental coordination disorders because they generally report less confidence in their physical abilities and may be unlikely to persist in their tasks (Cairney et al., 2006). Nevertheless, a recent study has shown that the shuttle-run test is moderately to fairly well correlated with lab based cycle ergometer tests for assessing cardiorespiratory fitness in children with and without developmental coordination disorders (Cairney, Hay, Veldhuizen, & Faught, 2010).

3.2.8 Physical Activity and Sedentary Time

The accelerometer GT1M Actigraph (ActiGraph, Pensacola, Florida, USA) was used to obtain detailed and objectively information about daily PA and sedentary behavior over 5 consecutive days. This lightweight, biaxial monitor was the latest model available by the manufacturer at the time of data collection, and studies have demonstrated that it is a technically reliable instrument, both within and across monitors (Rothney, Apker, Song, & Chen, 2008). The accelerometer was attached tightly in the hip, on the right side, with the notch faced upwards, and participants were instructed to use the accelerometer during waking hours and remove it during water-based activities; according to established procedures (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). The epoch length was set to 15 seconds to allow a more detailed estimate of PA intensity (Ward et al., 2005).

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

(Colley, Gorber, & Tremblay, 2010; Troiano et al., 2008). After screening was completed, the raw activity "counts" were processed for determination of time spent in the different PA intensities. Activity levels were expressed in mean counts.min-1 and also in estimates of the time spent in moderate-to-vigorous physical activity (MVPA). The established accelerometer cut-points proposed by Freedson and published by Trost et al (Trost et al., 2002) were used to determine PA intensities. Sedentary behavior was identified using a cut-point of <100 counts.min^{-1}, as this cut-off was shown to have an excellent classification accuracy (Trost, Loprinzi, Moore, & Pfeiffer, 2010).

3.3 Statistical analysis

Paper I - Descriptive data are presented as means and standard deviations, and two-sided t-tests were performed to assess gender differences.

Receiver-operating characteristic (ROC) curves were used to calculate the optimal sedentary time cut-off points that best discriminate between the participants with high and low MC. The area under the ROC curve (AUC) represents the ability of the test to correctly classify the participants with high or low MC. The values of AUC range between 1 (a perfect test) to 0.5 (a worthless test). ROC analyses were performed separately by gender.

Binary logistic regression models were constructed to verify the relationship between sedentary time percentage and normal/good MC, adjusting for PA, accelerometer wear time, WHtR, and mother's education level.

Data were analyzed using IBM SPSS Statistics v.19 (SPSS, Inc. IBM Company, USA) and MedCalc statistical software (MedCalc software, Mariakerke, Belguim). A p value lower than 0.05 denoted statistical significance.

Paper II - For the family income and for the mothers' weight status variables, due to the small size of participant's eligible for benefits A and B and of those in the overweight and obese categories respectively, the participants were grouped. Therefore, for the family income status analysis two groups were considered: those with school social benefits and those without. For the mothers' weight status two groups were considered: normal weight and overweight/obese. Mothers' ages were divided into two groups by the median value: ≤ 39 years old and ≥ 40 years old.

Methods

An analysis of variance (ANOVA) with Scheffé Post Hoc test for multiple comparisons was performed in order to test the differences between groups for continuous variables. Cross-tabulation examined unadjusted bivariate associations between child weight status categories and family income, gender, mother's weight status, age, and education level, with Chi-Square test or with Fisher's Exact test. Cohen's Kappa test was use to assess the inter-rater agreement between the percentages of participants in each one of the weight status categories (underweight, normal weight, overweight/obese). The Cohen's Kappa value can be interpreted by the strength of agreement: $k < 0.20$ poor; $0.21 < k < 0.40$ fair; $0.41 < k < 0.60$ moderate; $0.61 < k < 0.80$ good; $0.81 < k < 0.100$ very good (Altman, 1991).

All statistical analyses were performed using PASW Statistics 19 (Statistical Program for Windows).The level of significance for all analyses was set at 0.05.

Paper III - Comparisons between groups involved Student *t* test for continuous variables. Receiver operating characteristic (ROC) curves were used to analyse the potential diagnostic accuracy of the different measures of adiposity to discriminate between low and high MC. Logistic regression analyses were performed to further study the relationship between different measures of adiposity and MC. Data were analyzed using the IBM SPSS Statistics v.19 (SPSS, Inc. IBM Company, USA) and MedCalc statistical software (MedCalc software, Mariakerke, Belguim). A p value under 0.05 denoted statistical significance.

Paper IV - Two tailed t-test compared gender differences in continuous variables. Binary Logistic Regression was used to obtain to analyze the influence of MC on AA, adjusting for cardiorespiratory fitness, body mass index and socioeconomic status. In this regression analysis children belonging to the lower and middle tertiles of AA were grouped into one category – models were constructed separately for girls and boys. In each model all variables were tested simultaneously.

Statistics was performed using Predictive Analytics Software (IBM - PASW Statistics 18 - Statistical Program for Windows), former known as SPSS (Statistical Package for the Social Sciences. A p value <0.05 denoted statistical significance.

4. Results

Paper I

(Submitted)

Associations between Sedentary Behavior and Motor Coordination in Children

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Results

Abstract

Objectives: This study was conducted to evaluate the relationship between objectively measured sedentary behavior (SB) and motor coordination (MC) in Portuguese children, accounting for physical activity (PA), accelerometer wear time, waist-to-height ratio, and mother's education level.

Methods: A cross-sectional school-based study was conducted on 213 children (110 girls and 103 boys) aged 9-10 in the north of Portugal during the spring of 2010. Accelerometers were used to obtain detailed objective information about daily PA and SB over 5 consecutive days. Motor coordination was measured with a body coordination test (Körperkoordination Test für Kinder - KTK). Waist and height were measured by standardized protocols and the waist-to-height ratio (WHtR) was calculated. A questionnaire was used to assess mothers' educational levels. Receiver operating characteristic (ROC) and logistic regressions were used.

Results: ROC analysis showed that sedentary time significantly discriminated between children with low MC and high MC, with a best trade off between sensitivity and specificity being achieved at ≥77.29% and ≥76.48% for girls and boys respectively ($p<0.05$ for both). In both genders, the low sedentary group had significantly higher odds of having good MC than the higher sedentary group, independent of PA, accelerometer wear time, WHtR, and mother's education level ($p<0.05$ for both).

Conclusions: Our findings suggest that PA levels *per se* may not overcome the deleterious influence of high levels of SB on MC. Our data stress the importance of discouraging SB among children to improve MC.

Key-words: motor coordination, ROC analysis, physical activity, accelerometry.

INTRODUCTION

The importance of promoting active lifestyles from a young age is widely recognized and the health benefits of regular physical activity (PA) are extensively acknowledged (Strong et al., 2005). The incorporation of PA into daily life and the achievement of recommended health-related levels of PA are major public health challenges. Many children and adolescents do not meet the current PA recommendations (Jago et al., 2005; Riddoch et al., 2007; Strong et al., 2005). Moreover, previous research has shown a decline in PA from childhood to adolescence (Goran et al., 1998; Lopes et al., 2007), with the end of elementary school (9-11 years old) being a critical period of change (Goran et al., 1998; Nader et al., 2008).

The importance of promoting the development of motor coordination (MC) at younger ages relies on the evidence that there are current and future benefits associated with the acquisition and the maintenance of motor proficiency (Lubans et al., 2010). It has been suggested that an appropriate acquisition of gross MC contributes to children's physical, cognitive, and social development (Lopes, Rodrigues, Maia, & Malina, 2011; Payne & Isaacs, 1995). A proper MC level is essential for strong general development, as well as for health, psychosocial development, and well-being (Haga, 2008b; Piek et al., 2006). Although a rudimentary form of movement pattern may naturally be develop, a mature form of motor proficiency is more likely to be achieved with appropriate practice, encouragement, feedback and instruction (Gallahue & Ozmun, 2006). Likewise, these skills need to be learned, practiced and reinforced through developmentally appropriate movement programmes (Logan et al., 2011). The early childhood years are a critical time for the development of these skills, which are considered the building blocks of more complex movements (Clark & Metcalfe, 2002).

Lately there has been increasing interest in the relationships between MC and health-related behaviors and outcomes. Indeed, a recent review (Lubans et al., 2010) of the relationship between MC and health benefits in children and adolescents indicated that MC levels are inversely correlated with weight status, but positively correlated with PA, cardiorespiratory fitness, and perceived physical competence in cross-sectional and longitudinal data. In another systematic review of the literature conducted to synthesize the recent available data on fitness and physical activity in children with developmental coordination disorder (a neurodevelopmental condition characterized by poor motor proficiency that interferes with a child's activities of daily living). Body composition, cardiorespiratory fitness, muscle strength and endurance, anaerobic capacity, power, and physical activity have all been negatively associated, to various degrees, with poor motor proficiency (Rivilis et al., 2011).

Current efforts to increase youth's PA have had limited success, with effective changes achieved only in smaller sub-groups or in the short term (Kipping et al., 2008; van Sluijs et al., 2007). One reason for this relative lack of success could be that most of the public health efforts to promote active lifestyles have focused mainly on PA and have paid little attention to the growing evidence that indicates that sedentary behavior (SB) is a distinct health-related behavior (Tremblay, Leblanc, Kho, et al., 2011). Additionally, neither interventions in PA or SB target improvements in MC (Salmon et al., 2005), and indicators of motor coordination (MC) have not been systematically included in studies that consider correlates of PA (Lopes, Maia, et al., 2011) or SB.

Sedentary behaviour is defined as any activity that does not increase energy expenditure substantially above the resting level (less than 1.5 METs), such as sleeping, sitting, lying down, or watching television or other forms of screen-based entertainment (Pate et al., 2008). In light of recent research, lack of PA is only one part of the public health problem, since various types of SB may operate through different behavioural mechanisms (Owen et al., 2000), have different determinants (Gordon-Larsen et al., 2000), track differentially (Gordon-Larsen et al., 2004), and have a distinct range of potentially adverse health consequences (Tremblay et al., 2007) independently of PA. Additionally, SB shows moderate stability during childhood and adolescence (Janz et al., 2005).

In a recent review, the relationship between MC and SB was classified as uncertain due to an inadequate number of studies (only two were available). The review of associations (Lubans et al., 2010) between MC and aspects of physical and psychological attributes provides indirect evidence that MC may be an important antecedent/consequent mechanism for promoting healthier lifestyle-related behaviors (Lubans et al., 2010). Most studies assume that MC is the cause rather than the consequence of PA, although it is also reasonable to expect that greater PA opportunities might also provide the context to improve MC (Cliff et al., 2009). Nevertheless, the literature has paid little attention to the relationship between SB and MC (two studies reported no association) (Cliff et al., 2009; Graf et al., 2004), while the other two reported a negative association (Williams et al., 2008; Wrotniak et al., 2006), leaving the following questions unanswered: (i) does SB predict MC and, if so, (ii) does this predictive relationship remain after considering the levels of PA that children undertake.

In this context, the purpose of this study was to evaluate the relationship between objectively measured sedentary behavior and motor coordination in Portuguese children aged 9-10 years, accounting for physical activity levels, accelerometer wear time, waist-to-height ratio (WHtR), and mother's education level. We also examine the association between the amount of time spent on sedentary behaviors and low MC development.

METHODS

Study Design and Sampling

Data for the present study are derived from the Bracara Study aimed to evaluate the relations between MC, PA, physical fitness, body composition, academic achievement and health behaviors among elementary school children. The Bracara Study was conducted in a middle city located in the north of Portugal during the 2009/2010 academic year.

All 21 public elementary schools in the city that qualified as urban (according to the Municipal Administration Registry) were considered and invited to participate in this study, corresponding to 846 children enrolling in the fourth grade; two schools decided not to take part in this study, corresponding to 90 children; six schools could not be evaluated on time to take part in this study, corresponding to 130 children; 30 children who failed the inclusion criteria (having a mental and/or physical disability or a health condition that did not allow them to participate in physical education classes) or had missing information on the variables of interest were excluded from this analysis. The final sample of Bracara Study accounts for 596 participants (281 girls); due to temporal and material restrictions (accelerometers available) 383 children did not wear the accelerometer. However, drop out analysis showed that the 383 missing children had a similar mean values for height, waist circumference, WHtR and mother's education (data not showed). Therefore, the study included 13 urban public elementary schools, and 213 participants (110 girls) aged 9-10 years old.

The schools' directors and children's parents/guardians received verbal and written description of the study and signed a written informed consent form. The protocol and procedures employed followed the Helsinki Declaration for Investigation in Human Subjects and were approved by the Curricular Development and Innovation Division (Portuguese Ministry of Education) and by the University's Ethics Committee.

Data were collected during regularly scheduled physical education classes by 2 assessors in full time. Assessors were physical education graduates and received specific training, and had already participated in previous KTK and accelerometry data collection. The assessors were helped by the physical education teachers.

Results

Measures

Anthropometry

Height was measured to the nearest millimeter in bare or stocking feet with the children standing upright against a stadiometer (*Seca 220)*. Waist circumference measurements was taken as described by Lohman (Lohman et al., 1991).The waist and height were used to compute the WHtR. Previous analyses (data not showed) showed that WHtR explain better MC than body mass index, fat mass percentage or waist circumference (R^2 – 0.22 for girls e 0.20 for boys).

Physical Activity and Sedentary Time

The accelerometer GT1M Actigraph (ActiGraph, Pensacola, Florida, USA) was used to obtain detailed and objectively information about daily PA and sedentary behavior over 5 consecutive days. This lightweight, biaxial monitor was the latest model available by the manufacturer at the time of data collection, and studies have demonstrated that it is a technically reliable instrument, both within and across monitors (Rothney et al., 2008). The accelerometer was attached tightly in the hip, on the right side, with the notch faced upwards, and participants were instructed to use the accelerometer during waking hours and remove it during water-based activities; according to established procedures (Ward et al., 2005). The epoch length was set to 15 seconds to allow a more detailed estimate of PA intensity (Ward et al., 2005).

Accelerometer data were analyzed by an automated data reduction program (MAHUffe; see www.mrc-epid.cam.ac.uk) that provided options for screening the data and computing outcomes. Data files from individual participants were screened by detecting blocks of consecutive zeros. Periods with 60 minutes of consecutive zeros were detected and flagged as times in which the monitor was not worn (Troiano et al., 2008). Participants had to have at least 10 hours of data to count as a valid day and to have at least three valid days to be included (two weekdays and one weekend day). The screening procedures were consistent with current accelerometry studies and also similar to the screening used in NHANES (Colley et al., 2010; Troiano et al., 2008). After screening was completed, the raw activity “counts” were processed for determination of time spent in the different PA intensities. Activity levels were expressed in mean counts.min-1 and also in estimates of the time spent in moderate-to-vigorous physical activity (MVPA). The established accelerometer cut-points proposed by Freedson and published by Trost et al., (2002) were used to determine PA intensities. Sedentary behavior was identified using a cut-point of <100 counts.min^{-1}, as this cut-off was shown to have an excellent classification accuracy (Trost, Loprinzi, Moore, & Pfeiffer, 2011).

Motor Coordination

MC was evaluated with the body coordination test (Körperkoordination Test für Kinder -KTK), developed for German children (aged 5-15 years). The KTK battery has four items:

Balance: the child walks backward on three balance beams each 3m in length, 5cm in height, but with decreasing widths of 6, 4.5 and 3cm. The child has three attempts at each beam; the number of successful steps is recorded; a maximum of 24 steps (eight per trial) were counted for each balance beam, which comprises a maximum of 72 steps.

Jumping laterally: the child makes consecutive jumps from side to side over a small beam (60cmx4cmx2cm) as quickly as possible for 15s. The child is instructed to keep his/her feet together; the number of correct jumps in two trials was summed.

Hopping on one leg over an obstacle: the child was instructed to hop on one foot at a time over a stack of foam blocks after a short run-up. After a successful hop with each foot (the child clears the block without touching it and continues to hop on the same foot at least two times), the height was increased by adding a block (50cmx20cmx5cm). The child had three attempts at each height and on each foot; three, two or one point(s) was/were awarded for a successful performance on the first, second or third trial, respectively; a maximum of 39 points (12 stacks blocks) could be scored for each leg (maximum score 78).

Shifting platforms: the child begins by standing with both feet on one platform (25cmx25cmx2cm) supported on four legs, 3.7cm in height and holding a second identical platform in his/her hands; the child is then instructed to place the second platform alongside the first and to step on to it; the first box is then lifted and placed alongside the second and the child steps on to it; the sequence continues for 20s. Each successful transfer from one platform to the next earns two points (one for shifting the platform, the other for transferring the body); the number of points in 20s is recorded and summed for two trials. If the child falls off in the process, he/she simply gets back on to the platform and continues the test.

Although some of the items in the KTK appear to measure specific components of motor performance, e.g., dynamic balance, speed and agility, balance and power, the four tests are loaded toward a single factor when analyzed with other items. Hence, the authors utilized the four items together as a global indicator of MC, the ‘‘motor quotient’’. Each performance item was scored relative to gender- and age-specific reference values for the population upon which the KTK was established (Kiphard & Schiling, 1974). The sum of the standardized scores for the four items provides the motor quotient. Using the motor quotient children were then categorized as having: MC disorders (<70 motor quotient); MC insufficiency (71≤ motor quotient ≤85); normal MC (86≤ motor quotient ≤115); good MC (115≤ motor quotient ≤130); or very good MC (131≤ motor quotient ≤145). In this study participants were then categorized as having high MC if children has normal, good and very good MC (86≤ motor quotient ≤115); or low MC if children were classified has having MC disorders or insufficiency.

The psychometric characteristics of the KTK have been documented (Kiphard & Schiling, 1974). The test-retest reliability coefficient for the raw score on the total test battery was 0.97, while corresponding coefficients for individual tests ranged from 0.80 to 0.96. Factor analysis of the four individual tests resulted in a single factor labeled gross MC. The percentage of total variance in MC explained by the four tests varied from 81% at 6 years to 98% at 9 years (Kiphard & Schiling, 1974). Intercorrelations among the four tests varied from 0.60 to 0.81 for the reference sample of 1228 children. Both the factor analysis and intercorrelations thus indicated acceptable construct validity. Validity was further determined through differentiation of normal from disabled children. The KTK test differentiated 91% of children with brain damage from normal children.

Sociodemographics

A questionnaire was distributed to parents for assessing general child and parental health variables, divided in three sections: the first section collected information related to the child, the second section collected information to characterize the parents, and the third section addressed parental physical activity. The questionnaire included a question about the mother's educational level, used as a measure of socioeconomic status. Mothers were categorized according to the Portuguese Education Level: Low (mandatory education – 9 school years); Medium (secondary education – 12 school years); and High (college or university degree).

Statistical analysis

Descriptive data are presented as means and standard deviations, and two-sided t-tests were performed to assess gender differences.

Receiver-operating characteristic (ROC) curves were used to calculate the optimal sedentary time cut-off points that best discriminate between the participants with high and low MC. The area under the ROC curve (AUC) represents the ability of the test to correctly classify the participants with high or low MC. The values of AUC range between 1 (a perfect test) to 0.5 (a worthless test). ROC analyses were performed separately by gender.

Binary logistic regression models were constructed to verify the relationship between sedentary time percentage and normal/good MC, adjusting for PA, accelerometer wear time, WHtR, and mother's education level.

Data were analyzed using IBM SPSS Statistics v.19 (SPSS, Inc. IBM Company, USA) and MedCalc statistical software (MedCalc software, Mariakerke, Belguim). A p value lower than 0.05 denoted statistical significance.

RESULTS

The descriptive characteristics are shown in Table 1. Girls displayed lower levels of MC and fewer minutes of MVPA than boys, while boys spent less sedentary time than girls (p<0.001 for all). 46.3% of girls and 59.3% of boys showed normal or good MC (p<000.1).

TABLE 1. Participants' characteristics (means ± standard deviation).

	All (n=213)	Girls (n=110)	Boys (n=103)	p*
Age (years)	9.46±0.43	9.45 ± 0.37	9.48 ± 0.50	0.612
Sedentary time (min/day) †	453.62±32.75	463.17±27.71	443.32±34.42	<0.001
Sedentary time (%) †	75.60±5.46	77.20±4.62	73.90±5.79	<0.001
MC (motor quotient)	86.72±14.40	83.56±13.79	90.09±14.34	0.001
MVPA (mean min/day) †	82.45±24.18	74.12±19.30	91.35±25.75	<0.001
WHtR	0.48±0.05	0.48±0.05	0.48±0.05	0.341

Abbreviations: MVPA, Moderate, vigorous and very vigorous physical activity; MC, Motor coordination; WHtR – Waist-to-height ratio.

† – adjusted for wear time

* - t- test to compared gender differences.

As presented in Table 2, ROC analysis showed that sedentary time significantly discriminates between children with low MC and high MC, with a best trade-off between sensitivity and specificity being achieved at ≥77.29% and ≥76.48% for girls and boys respectively (p<0.05 for both).

Results

TABLE 2. Best trade-off between sensitivity and specificity for percentage of sedentary time to discriminate between motor coordination disorders/insufficiency and normal/good motor coordination by receiver-operating characteristics (ROC) analysis for each gender.

	Girls	Boys
Sedentary time cut-off (%)	77.29	76.49
Sensitivity	0.686 (0.541-0.809)	0.770 (0.645-0.868)
specificity	0.661 (0.526–0.779)	0.595 (0.433-0.744)
AUC	0.659 (0.562-0.746); p=0.0021	0.668 (0.569-0.758); p=0.0023

Abbreviations: AUC, area under the ROC curve.

To explore whether the association between this percentage of sedentary time threshold and MC is independent of PA, we performed a logistic regression analysis for each gender (Tables 3 and 4) according to the respective sedentary time cut-off (<77.29% and ≥77.29% for girls; <76.49% and ≥76.49% for boys). In both genders, the low sedentary group had significantly higher odds of having a good MC than the higher sedentary group, independent of PA, accelerometer wear time, WHtR, and mothers education level (OR = 5.065 for girls and OR = 9.149 for boys; p<0.05 for both; see Model 3).

TABLE 3. Odds Ratios and 95% confidence intervals from logistic regression model predicting normal/good motor coordination, for girls.

Girls		**Normal/Good Motor Coordination**		
		OR	**95% CI**	**p**
Model 1 Unadjusted	≥77.3% Sedentary time [a]	1		
	<77.3% Sedentary time	4.266	(1.916-9.496)	<0.001
Model 2 [b]	≥77.3% Sedentary time [a]	1		
	<77.3% Sedentary time	4.584	(1.764-11.915)	0.002
Model 3 [c]	≥77.3% Sedentary time [a]	1		
	<77.3% Sedentary time	5.065	(1.670-15.363)	0.004

Abbreviations: OR, Odds Ratio. CI, Confidence Intervals.

a – reference category.

b – adjusted for physical activity and accelerometer wear time.

c – adjusted for physical activity, accelerometer wear time , waist-to-height ratio and mother' education level.

TABLE 4. Odds Ratios and 95% confidence intervals from logistic regression model predicting normal/good motor coordination, for boys.

Boys		Normal/Good Motor Coordination		
		OR	95% CI	p
Model 1 Unadjusted	≥76.5% Sedentary time [a]	1		
	<76.5% Sedentary time	4.937	(2.094-11.641)	<0.001
Model 2	≥76.5% Sedentary time [a]	1		
	<76.5% Sedentary time	5.741	(2.132-15.457)	0.001
Model 3	≥76.5% Sedentary time [a]	1		
	<76.5% Sedentary time	9.149	(2.465-33.964)	0.001

Abbreviations: OR, Odds Ratio. CI, Confidence Intervals.

a – reference category.

b – adjusted for physical activity and accelerometer wear time.

c – adjusted for physical activity, accelerometer wear time , waist-to-height ratio and mother' education level.

Results

DISCUSSON

The main finding of this study indicates that for both genders the low sedentary group had significantly higher odds of having a good MC compared with the high sedentary group, independently of MVPA, accelerometer wear time, WHtR, and mother's education level.

In children and adolescents, self-reported leisure-time SB such as overall screen time (i.e. TV viewing, videogames, computer use) has commonly been studied; however, while these activities may represent a substantial portion of the time spent in total SB, they do not represent the total amount of everyday sedentary time. In this regard, as has been argued for PA (Ruiz & Ortega, 2009), objectively measuring total sedentary time by using devices such as accelerometers may offer particular advantages, since these devices do not rely on subject recall and may capture the entire daily patterns of both PA and SB. This study assessed both PA and SB using accelerometry.

The negative effects of sedentary lifestyles on children's health and health-related behaviors and outcomes are a source of concern. In this study we observed that children spent on average 75.6% of their time in SB. Results from other studies using objective methods (i.e. accelerometry) have also shown that children spend significant proportions of their waking time being sedentary, between 50% and 80% (Colley et al., 2011; Martinez-Gomez et al., 2011; Matthews et al., 2008) and as a result may be at risk of detrimental health outcomes (Hinkley et al., 2010). Mounting evidence has suggested recently that time spent in SB is associated with adverse health outcomes, an association that may be independent of the protective contributions of PA, as it remained significant after adjustments (van Uffelen et al., 2010). In a recent review of (both self-reported and objectively measured) SB and health indicators in school-aged children and youth, the authors concluded that spending more than 2 hours per day being sedentary was associated with unfavorable body composition, decreased fitness, lowered scores for self-esteem and pro-social behavior, and decreased academic achievement (Tremblay, Leblanc, Kho, et al., 2011).

In this study, ROC analysis showed the best trade-offs between sensitivity and specificity in discriminating between low and high MC using SB was achieved at 77.29% and 76.49% for girls and boys respectively. The values reported in the present study are in line with those reported by Martinez et al. (2011) who performed a similar ROC curve and accelerometer analysis. Martinez et al. (2011) showed that girls who spent more than 69% of their waking time in SB were less likely to have high cardiorespiratory fitness (Martinez-Gomez et al., 2011).

Recent studies have focused on understanding the relationships between MC and health-related behaviours and outcomes. Indeed, a recent systematic review identified eight potential benefits of MC (global self-concept, perceived physical competence, cardio-respiratory fitness, muscular fitness, weight status, flexibility, PA, and reduced SB) and found evidence for a positive association with PA and cardiorespiratory fitness and an inverse association with weight status. The remaining benefits, including SB, were classified as uncertain, due to an inadequate number of studies (Lubans et al., 2010). Rivilis et al. (2011) performed a systematically review and summarize the literature on the association between poor motor proficiency and fitness and physical activity outcomes in children. They concluded that body composition, cardiorespiratory fitness, muscle strength and endurance, anaerobic capacity, power, and physical activity have all been negatively associated, to various degrees, with poor motor proficiency. However, differences in flexibility were not conclusive because the results on this parameter are mixed. Recently, Stodden et al. (2009) have hypothesized a developmental recursive model suggesting a reciprocal relationship between MC and PA. The authors postulated that children with high motor skill proficiency will have higher levels of fitness and perceived sports competence, which in turn predict greater participation in PA and vice-versa. However, in this model, as in the general literature, the SB appears to be defined as the inverse of PA (i.e. insufficient levels of PA), instead of being considered as an independent behavior. In fact, we only found four studies in literature linking SB to MC (Cliff et al., 2009; Graf et al., 2004; Williams et al., 2008; Wrotniak et al., 2006), and only three of them (Cliff et al., 2009; Williams et al., 2008; Wrotniak et al., 2006) were performed using objective measures. However, in those studies the relationship between PA and motor skills did not take into account the possible confounding effect of SB, and the associations between SB and motor skills were not adjusted for the influence of PA.

Our study suggests that high time spent in SB was a predictor of low MC, regardless of PA levels and other confounders. Our findings, in combination with the studies of Wroniak et al. (2006) and Williams et al. (2008) that indicate a positive relationship between motor skill performance and PA and an inverse association with sedentary activity in children (Williams et al., 2008; Wrotniak et al., 2006), may suggest a reciprocal relationship between SB and MC. In this context, we could speculate that providing children with alternatives to SB, namely daily physical education classes, opportunities for sports participation in and outside school, and school recesses more conducive to activity, could have a positive impact on their MC, which could in turn increase PA and decrease time spent in SB. However, further longitudinal and intervention studies are necessary to confirm or disprove this hypothesis.

Our findings have important implications as they suggest that PA levels *per se* may not overcome the deleterious influence of high levels of SB on MC. Therefore, to establish healthy lifestyles from a young age, actions aiming to address the current inactivity crisis should attempt to both increase PA levels and decrease SB (Tremblay, Leblanc, Kho, et al., 2011). Indeed, the necessity for public health recommendations targeting SB has already been suggested (Hojbjerre et al., 2010). Based on the mounting evidence of the health-related benefits of low SB, the Canadian Society for Exercise Physiology, in partnership with the Healthy Active Living and Obesity Research Group at the Children's Hospital of Eastern Ontario Research Institute, recently launched the Canadian Sedentary Behavior Guidelines, which extend the American Academy of Pediatrics' guidelines for screen time (Education, 2001) to include transportation, sitting time, and time spent indoors. These guidelines suggest that for health benefits, children and adolescents should minimize the time they spend being sedentary each day by limiting recreational screen time to no more than 2 hours per day (lower levels are associated with additional health benefits) as well as limiting sedentary (motorized) transport, extended sitting time, and time spent indoors throughout the day (Tremblay, Leblanc, Janssen, et al., 2011); however, recommendations regarding limits on total time per day spent in sedentary activities are still lacking. Indeed, only a few studies have addressed links between total SB time and health outcomes in children and adolescents (Martinez-Gomez et al., 2011).

Strengths and limitations

Strengths of this study include the novelty of the analyses of the associations between SB and MC; the objective assessment of both total MVPA and total sedentary time (most previous studies have limited their analysis to self-reported leisure time SB and/or PA); and the use of a cut-point of <100 counts.min^{-1} to identify sedentary behavior, as this cut-off was shown to have an excellent classification accuracy (Trost et al., 2011).

This study has some limitations that must be considered when interpreting its results. First, accelerometers do not identify PA or sedentary patterns or contexts, and the accelerometers used in this study do not allow us to distinguish the type of sedentary behavior (i.e. lying, sitting or standing still). Second, the data has been derived from a cross-sectional study; therefore, results do not indicate causality. More research is needed to further study the relationship between SB and MC. Longitudinal and interventional studies would provide information on the direction of this association.

CONCLUSIONS

In conclusion, in both genders the percentage of time spent in SB was negatively associated with MC, independently of MVPA and other confounders. Our findings suggest that PA levels *per se* may not overcome the deleterious influence of high levels of SB on MC. Our data stress the importance of discouraging SB among children to improve MC.

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The authors have no conflict of interest to declare.

Results

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Paper II

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Maternal perceptions of children's weight status

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Abstract

Background Several studies have addressed mothers' perceptions of their children's weight status; however, there is no investigation on Portuguese children (a country with one of the highest levels of children's overweight and obesity in Europe). The aim of this study was to quantify maternal misclassification of child weight status in a sample of Portuguese children aged 9 to 12 years, according to gender, family income, and maternal weight status, education level and age.

Methods Data were collected in a school-based study (school year 2009/2010) in northern Portugal with 499 urban children (236 girls; 47.3%). Body mass index was calculated from measurements of height and weight [body mass (kg)/height (m^2)]. Mothers' perceptions of child's weight status, age, height and weight were accessed by a questionnaire. Children's age, gender and socio-economic status were extracted from the schools' administrative record systems. Cohen's Kappa was used to analyse the misperceptions and the agreement between children's objectively measured weight status and mothers' perception of their child's weight status.

Results The prevalence of underweight, overweight and obesity in children was 4.6%, 25.5% and 6.4%, respectively. A proportion of 65.2% of underweight and 61.6% of overweight/obese children were misclassified by their mothers. For the majority of variables presented, the values of agreement were fair (*k* ranged from 0.257 to 0.486), but were statistically significant. Significant differences in the percentages of mothers who correctly classified their children's weight status were only found among the most educated in the overweight/obese group and among the normal-weight mothers in the underweight group.

Conclusions Many mothers do not properly recognize their children's weight status and frequently underestimate their children's body size.

Keywords
children, parental perceptions, weight status

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Introduction

Parental acknowledgement of a child's excess weight and an understanding of its health consequences are crucial primary steps in tackling obesity (Jeffery *et al.* 2005). However, parents often do not accurately perceive their children's weight status, report low levels of concern and are not aware of the health risks associated with excess fat accumulation (Baughcum *et al.* 2000; Wake *et al.* 2002; Maynard *et al.* 2003; Carnell *et al.* 2005; Jeffery *et al.* 2005; Eckstein *et al.* 2006).

Literature on parental perceptions of children's weight status reports high rates of parental misperceptions (Maynard *et al.* 2003; Eckstein *et al.* 2006) and indicates that mothers are more likely than fathers to correctly assess their child's weight (Jeffery *et al.* 2005). It also states that older children are more likely to be accurately classified than younger ones (Maynard *et al.* 2003; Campbell *et al.* 2006). Results for socio-economic status, race/ethnicity and gender are contradictory (Baughcum *et al.* 2000; Maynard *et al.* 2003; Carnell *et al.* 2005; Jeffery *et al.* 2005; West *et al.* 2008). However, most of the research in this field has been carried out in the USA, Australia and the UK; consequently, studies in other populations with different social and cultural backgrounds are necessary in order to understand if the associations found in those countries can be generalized.

In Portugal, about one-third of children and adolescents are overweight or obese (Sardinha *et al.* 2011), which emphasizes the need for a large variety of strategies to fight this epidemic. Knowing how Portuguese mothers view their children's weight status is an important step for intervention programmes.

The aim of this study was to quantify maternal misclassification of child weight status in a sample of Portuguese children aged 9 to 12 years, according to gender, family income, and maternal weight status, education level and age.

Methods

Study design and sampling

Data for the present study were derived from the Bracara Study aimed to evaluate the relations between Motor Coordination, Physical Activity, Physical Fitness, Body Composition, Academic Achievement and Health Behaviours among elementary school children. The Bracara Study was conducted in a middle city located in the north of Portugal during the 2009/2010 academic year (September to June).

All 21 public elementary schools in the city that qualified as urban (according to the Municipal Administration Registry) were considered and invited to participate in this study, corresponding to 846 children enrolling in the fourth grade. Two schools, totalling 90 children, decided not to take part in this study; six schools (130 children) could not be evaluated on time to take part in this study; 127 children had missing information on the variables of interest or failed the inclusion criteria (because of a mental and/or physical disability or a health condition that did not allow them to participate in physical education classes) – all were excluded from this analysis. Therefore, the study included 13 urban public elementary schools and 499 participants (236 girls; 47.3%), aged 9–12 years old.

The schools' directors and the children's parents/guardians received a verbal and written description of the study and signed a written informed consent form. The employed protocol and procedures followed the Helsinki Declaration for Investigation in Human Subjects and were approved by the Curricular Development and Innovation Division (Portuguese Ministry of Education) and by the University's Ethics Committee.

Measures

Children's weight status

Stature and body mass were measured using a stadiometer (Seca 220) and a scale (Tanita TBF-300) according to standardized procedures in light indoor clothing, without shoes. Values were recorded to the nearest 0.1 cm and 100 g, respectively. Body mass index (BMI) was calculated as body weight (kg), divided by height (m), squared. Weight status was determined according to the International Obesity Task Force (Cole *et al.* 2000, 2007) cut-offs for BMI: underweight, normal weight, overweight and obese. The overweight and obese categories were combined. Data were collected during regularly scheduled physical education classes by a team of specialized examiners and with the help of physical education teachers.

Maternal perceptions of weight status

A questionnaire was distributed to parents for assessing general child and parental health variables, divided in three sections: the first section collected information related to the child; the second section was related to parental characterization; the third section addressed parental physical activity. For this study, only the mothers' perceptions of their child's weight status and the mothers' self-reported height and weight were used. The mother's appraisal of her child's weight was assessed with the question: 'How would you describe your child's weight at the moment? (underweight, normal weight, overweight or obese)'. A total of 596 questionnaires were sent out and 499 were returned (83.7% response rate). Dropout analysis showed that the missing 16.3% of children had a BMI that was not different from that of those included (mean BMI for excluded 19.01 ± 3.86 vs. mean BMI for included 18.50 ± 3.10, $P = 0.122$).

Mother's weight status

The mothers' height and weight were assessed by the above mentioned questionnaire and BMI was then calculated and defined according to the World Health Organization (2000) cut-off points.

Sociodemographic measures

Each child's family income was extracted from the schools' administrative record systems. The school's family income used by the Portuguese Ministry of Education is based on annual family income (eligible for benefit A, benefit B, or not eligible) and was used as a proxy measurement of family socio-economic status (Portuguese Ministry of Education 2009). The questionnaire also included a question about mothers' education level and was also used as a measure of socio-economic status. Mothers were categorized according to the Portuguese Education Level: Low (mandatory education – 9 school years), Medium (secondary education – 12 school years) and High (college or university degree).

Statistical analysis

For the family income and for the mothers' weight status variables, because of the small size of participants eligible for benefits A and B and of those in the overweight and obese categories respectively, the participants were grouped. Therefore, for the family income status analysis two groups were considered: those with school social benefits and those without. For the mothers' weight status two groups were considered: normal weight and overweight/obese. Mothers' ages were divided into two groups by the median value: ≤39 years old and ≥40 years old.

An analysis of variance (ANOVA) with Scheffé post-hoc test for multiple comparisons was performed in order to test the differences between groups for continuous variables. Cross-tabulation examined unadjusted bivariate associations between child weight status categories and family income, gender, mother's weight status, age and education level, with chi-squared test or with Fisher's exact test. Cohen's Kappa test was used to assess the inter-rater agreement between the percentages of participants in each of the weight status categories (underweight, normal weight, overweight/obese). The Cohen's Kappa value can be interpreted by the strength of agreement: $k < 0.20$ poor; $0.21 < k < 0.40$ fair; $0.41 < k < 0.60$ moderate; $0.61 < k < 0.80$ good; $0.81 < k < 0.100$ very good (Altman 1991).

All statistical analyses were performed using PASW Statistics 19 (Statistical Program for Windows). The level of significance for all analyses was set at 0.05.

Results

The prevalence of underweight, overweight and obese children was 4.6%, 25.5% and 6.4%, respectively. In girls, 5.9% were underweight, 27.1% were overweight, and 5.9% were obese; corresponding figures for boys were 3.4%, 24% and 6.8%, respectively.

Descriptive statistics for the age, weight, height and BMI of the child and mother by child weight status are summarized in Table 1. Mothers of the overweight/obese children were heavier and had a higher BMI than mothers of normal-weight children ($P < 0.001$ and $P = 0.03$ respectively).

Mothers' perceptions of their child's weight status are presented in Table 2; the percentage of the total agreement between the child's objectively measured weight status and mother's perception of the child's weight is 71.1%. The normal-weight category contributed more at a total agreement of 57.3%, followed by the overweight/obese category with 12.2%. A pro-

Table 1. Child and mother characteristics by child weight status (mean and standard deviation)

	Child weight status			
	Underweight $n = 23$ (4.6%) Mean (SD)	Normal weight $n = 317$ (63.5%) Mean (SD)	Overweight/obese $n = 159$ (31.9%) Mean (SD)	ANOVA
Child				
Age	9.74 (0.67)	9.55 (0.53)	9.61 (0.46)	$F(2,496) = 2.07; P = 0.127$
Weight	26.27 (3.10)*†	31.94 (4.55)†	44.64 (7.05)	$F(2,496) = 327.13; P < 0.001$
Height	1.37 (0.09)†	1.37 (0.07)†	1.41 (0.06)	$F(2,496) = 24.89; P < 0.001$
BMI (kg/m^2)	13.99 (0.75)*†	17.03 (1.41)†	22.31 (2.41)	$F(2,496) = 549.10; P < 0.001$
Mother				
Age	39.65 (4.73)	38.58 (5.53)	38.58 (6.35)	$F(2,492) = 0.388; P = 0.685$
Weight	61.66 (10.57)	63.06 (10.31)†	67.49 (9.80)	$F(2,459) = 9.85; P < 0.001$
Height	1.62 (0.06)	1.61 (0.07)	1.62 (0.07)	$F(2,457) = 1.97; P = 0.141$
BMI (kg/m^2)	23.39 (4.36)	24.43 (3.79)†	25.64 (3.70)	$F(2,445) = 5.96; P = 0.03$

*Significantly different from the normal weight group ($P < 0.05$).
†Significantly different from the overweight/obese group ($P < 0.05$).
BMI, body mass index.

Table 2. Percentages and Cohen's Kappa values of agreement between mother's perceptions of child weight status and objectively measured child weight status for total sample and by family income and gender

Maternal perception of child's weight status	Child weight status: Underweight	Normal weight	Overweight/obese	Cohen's Kappa coefficient (% total agreement)	95% CI
Total ($n = 499$)					
% perceived child as underweight	34.8	7.6	0		
% of the total agreement	1.6				
% perceived child as normal weight	65.2	90.2	61.6	0.352*	0.276–0.428
% of the total agreement		57.3		(71.1)	
% perceived child as overweight/obese	0	2.2	38.4		
% of the total agreement			12.2		
Family income ($n = 499$)					
High family income ($n = 302$)					
% perceived child as underweight	33.3	7.4	0		
% of the total agreement	1.0				
% perceived child as normal weight	66.7	89.9	59.0	0.366*	0.196–0.451
% of the total agreement		56.0		(71.2)	
% perceived child as overweight/obese	0	2.7	41.0		
% of the total agreement			14.2		
Low family income ($n = 197$)					
% perceived child as underweight	35.7	7.8	0		
% of the total agreement	2.5				
% perceived child as normal weight	64.3	90.7	66.7	0.324*	0.197–0.451
% of the total agreement		59.4		(71.0)	
% perceived child as overweight/obese	0	1.6	33.3		
% of the total agreement			9.1		
Children gender ($n = 499$)					
Girls ($n = 236$)					
% perceived child as underweight	28.6	4.9	0		
% of the total agreement	1.7				
% perceived child as normal weight	71.4	92.4	66.7	0.314*	0.204–0.424
% of the total agreement		56.4		(69.1)	
% perceived child as overweight/obese	0	2.8	33.3		
% of the total agreement			11.0		
Boys ($n = 263$)					
% perceived child as underweight	44.4	9.9	0		
% of the total agreement	1.5				
% perceived child as normal weight	55.6	88.4	56.8	0.390*	0.282–0.498
% of the total agreement		58.2		(73.0)	
% perceived child as overweight/obese	0	1.7	43.2		
% of the total agreement			13.3		

*$P < 0.001$.
CI, confidence intervals.

portion of 65.2% of underweight and 61.6% of overweight/obese children were misclassified by their mothers.

Higher values of agreement were observed for boys, and for those in the higher family income (Table 2), in the overweight/obese group, in the higher education level and the young mothers group (Table 3). For the majority of variables presented, the values of agreement were weak (k ranged from 0.257 to 0.486), but were statistically significant (Tables 2 & 3).

Table 4 presents the percentages of correct and incorrect mothers' classifications of the child's weight status, by child weight status.

Within the group of underweight children, a higher percentage of normal-weight mothers classified their child's weight status incorrectly ($P = 0.002$). Within the group of overweight/obese children, a higher percentage of mothers with a high education level classified their child's weight status correctly ($P = 0.042$).

Discussion

The results of this study indicate a high rate of maternal misclassification of child weight status; 65.2% of underweight and

Table 3. Percentages and Cohen's Kappa values of agreement between mother's perceptions of child weight status and objectively measured child weight status by mother's weight status, age and education level

Maternal perception of child's weight status	Child weight status			Cohen's Kappa coefficient (% total agreement)	95% CI
	Underweight	Normal weight	Overweight/obese		
Mothers' weight status ($n = 448$)					
Normal weight ($n = 259$)					
% perceived child as underweight	9.1	7.6	0		
% of the total agreement	0.4				
% perceived child as normal weight	90.9	89.7	63.5	0.291*	0.173–0.409
% of the total agreement		64.1		(73.4)	
% perceived child as overweight/obese	0	2.7	36.5		
% of the total agreement			8.9		
Overweight/obese ($n = 189$)					
% perceived child as underweight	85.7	7.4	0		
% of the total agreement	3.2				
% perceived child as normal weight	14.3	91.7	60.3	0.421*	0.303–0.539
% of the total agreement		52.9		(71.4)	
% perceived child as overweight/obese	0	0.9	39.7		
% of the total agreement			15.3		
Mothers' age ($n = 495$)					
≤39 years old ($n = 283$)					
% perceived child as underweight	16.7	8.1	0		
% of the total agreement	0.7				
% perceived child as normal weight	83.3	89.8	55.3	0.379*	0.275–0.483
% of the total agreement		59.0		(73.1)	
% perceived child as overweight/obese	0	2.1	44.7		
% of the total agreement			13.4		
≥40 years old ($n = 212$)					
% perceived child as underweight	54.5	7.0	0		
% of the total agreement	2.8				
% perceived child as normal weight	45.5	91.4	69.9	0.320*	0.206–0.434
% of the total agreement		55.2		(68.4)	
% perceived child as overweight/obese	0	1.6	30.1		
% of the total agreement			10.4		
Mothers' education level ($n = 489$)					
Low education level ($n = 279$)					
% perceived child as underweight	41.2	7.2	0		
% of the total agreement	2.5				
% perceived child as normal weight	58.8	91.0	63.0	0.358*	0.258–0.458
% of the total agreement		54.9		(69.8)	
% perceived child as overweight/obese	0	1.8	37.0		
% of the total agreement			12.4		
Medium education level ($n = 124$)					
% perceived child as underweight	33.3	7.8	0		
% of the total agreement	0.8				
% perceived child as normal weight	66.7	89.6	70.5	0.257*	0.108–0.406
% of the total agreement		55.6		(66.9)	
% perceived child as overweight/obese	0	2.6	29.5		
% of the total agreement			10.5		
High education level ($n = 90$)					
% perceived child as underweight	0	9.0	0		
% of the total agreement	0				
% perceived child as normal weight	100	88.1	38.1	0.486*	0.292–0.680
% of the total agreement		65.6		(80.0)	
% perceived child as overweight/obese	0	3.0	61.9		
% of the total agreement			14.4		

*$P < 0.001$.
CI, confidence intervals.

Table 4. Percentages of correct and incorrect mothers' classifications of child weight status, by child weight status

	Child weight status								
	Underweight			Normal weight			Overweight/obese		
	Incorrect	Correct	Test value† (*P* value)	Incorrect	Correct	Test value† (*P* value)	Incorrect	Correct	Test value† (*P* value)
Family income									
High income	9 (64.3%)	5 (35.7%)	0.014 (1.00)	19 (10.1%)	169 (89.9%)	0.056 (0.850)	36 (66.7%)	18 (33.3%)	1.056 (0.389)
Low income	6 (66.7%)	3 (33.3%)		12 (9.3%)	117 (90.7%)		60 (58.3%)	43 (41.7%)	
Children gender									
Boys	5 (55.6%)	4 (44.6%)	0.608 (0.657)	20 (11.6%)	153 (88.4%)	1.370 (0.261)	50 (65.8%)	26 (34.2%)	1.337 (0.257)
Girls	10 (71.4%)	4 (28.6%)		11 (7.6%)	133 (92.4%)		46 (56.8%)	35 (43.2%)	
Mothers' weight status									
Normal weight	10 (90.9%)	1 (9.1%)	10.568 (0.002)*	19 (10.3%)	166 (89.7%)	0323 (0.683)	40 (63.5%)	23 (36.5%)	0.264 (0.723)
Overweight/obese	1 (14.3%)	6 (85.7%)		9 (8.3%)	100 (91.7%)		42 (59.2%)	29 (40.8%)	
Mothers' age									
≤39 years old	10 (83.3%)	2 (16.7%)	3.630 (0.089)	19 (10.2%)	167 (89.8%)	0.231 (0.699)	46 (54.8%)	38 (45.2%)	3.531 (0.070)
≥40 years old	5 (45.5%)	6 (54.5%)		11 (8.6%)	117 (91.4%)		50 (69.4%)	22 (30.6%)	
Mothers' education level									
Low education level	10 (58.8%)	7 (41.2%)	1.039 (0.596)	15 (9.0%)	151 (91.0%)	0.465 (0793)	56 (62.2%)	34 (37.8%)	6.353 (0.042)*
Medium education level‡	4 (80%)	1 (20%)		8 (10.4%)	69 (89.6%)		31 (70.5%)	13 (29.5%)	
High education level				11 (11.9%)	59 (88.1%)		8 (38.1%)	13 (61.9%)	

*$P < 0.05$.

†Chi-squared or Fisher's exact test.

‡Mother's education levels: the medium and the high levels were combined in order to perform Fisher's exact test within the underweight category.

61.6% of overweight/obese children were inaccurately classified by their mothers as being a normal weight. The agreement between the objectively measured weight status and the mothers' perceptions of their child's weight status was fair, but statistically significant. These findings are consistent with earlier studies that show that most parents do not correctly recognize their child's weight status (Baughcum *et al.* 2000; Wake *et al.* 2002; Maynard *et al.* 2003; Carnell *et al.* 2005; Jeffery *et al.* 2005; Campbell *et al.* 2006; Eckstein *et al.* 2006; West *et al.* 2008). Also, a recent review shows that in 19 of 23 studies reviewed, fewer than 50% of parents of overweight children recognize their child as overweight (Parry *et al.* 2008). This is a concern because the physical, social and emotional consequences of obesity may be evident in childhood and may persist into adult life (Dietz 1998).

Although these systematic misclassifications are not fully understood, they may be explained by a number of reasons and methodological limitations: (1) the increasing prevalence of overweight children may have 'normalized' this condition, leading to an increased acceptance of body fat and reduced ability of mothers to recognize when their own child has excess weight; (2) stereotypes of overweight children in media reports tend to show images of severe obesity, which could give a distorted impression of the criteria for being overweight (Campbell *et al.* 2006); (3) differences in sampling (clinical vs. epidemiological), i.e. clinical samples may be made up of participants whose parents already recognize in some part their weight problem while healthy participants also comprise epidemiological samples; (4) most of the studies have small sample sizes (<100 children), which preclude multivariable analyses (Campbell *et al.* 2006) and make the results less precise (Parry *et al.* 2008). Larger and more diverse samples might help identify other correlates and allow comparisons among studies; (5) there are no uniform or standardized tools for evaluating parental perceptions of weight status across studies (Towns & D'Auria 2009); (6) children's weight status (and parental when it is the case) is calculated using different measurement instruments (questionnaires, interviews and objective and pictorial methods), and different standards are used to define childhood obesity (i.e. Centers for Disease Control and Prevention or International Obesity Taskforce cut-off points); (7) differences in the age range of the children studied. Some studies included children between 5 and 13 years old (Wake *et al.* 2002) and between 2 and 13 years old (Maynard *et al.* 2003) and compared what is incomparable because of their physical, psychological and social development differences; (8) socio-economic, cultural and social set differences. For example, Smith and colleagues (1999) observed cultural acceptance of larger body sizes among African Americans; (9) parents may want to avoid labelling because they fear it could stigmatize their child (Latner *et al.* 2005); (10) parents may avoid acknowledging their own weight status to avoid being blamed for their child's weight problem (Edmunds 2005); and (11) a lack of understanding of what *overweight* and *obese* mean (Maynard *et al.* 2003).

In the present study, 61.6% of overweight/obese children were classified by their mothers as being normal weight. These findings agree with West and colleagues (2008), indicating that the most common error is to underestimate the risk category, misclassifying overweight children as a normal or healthy weight (West *et al.* 2008). Our results highlight the need to educate parents about obesity and its health consequences in order to reduce misperceptions (Parry *et al.* 2008). Evidence suggests that parents who recognize their child's weight as a health problem are more likely to change their child's lifestyle habits (Rhee *et al.* 2005). Furthermore, a parental perception of a child being overweight is becoming a key variable in determining the family's readiness to modify the child's environment and lifestyle (Towns & D'Auria 2009).

Despite higher values of agreement being observed for boys, high family income, and for overweight/obese, high education level and younger aged mothers, significant differences in the percentages of mothers who correctly classified their children's weight status were only found among the most educated in the overweight/obese group, and among the normal-weight mothers in the underweight group. This result is in line with Baughcum and colleagues (2000), who found that the misperceptions were more common in mothers with less education, while others (Maynard *et al.* 2003; West *et al.* 2008) found that socio-economic status did not influence parental perceptions. Indeed, education is positively associated with health-related knowledge (Tur *et al.* 2005) and with a higher capacity to put it into practice (Ball & Crawford 2006).

Very little information is available on how parents perceive their underweight and normal-weight children. This study showed that 65.2% of underweight children are perceived as normal weight and 7.6% of normal-weight children are perceived as underweight. Although over-perception of thinness can lead to unhealthy dieting and eating disorders, underestimation on weight status can lead to overfeeding and may increase the risk of these children becoming overweight or obese. Consequently, it is important that parents have an accurate perception of their child's weight status.

Our findings have important public health implications, as the health-related behaviour (dietary practices, physical activity, sedentary behaviour) of school-aged children is mainly influenced and controlled by their parents (Lindsay *et al.* 2006).

Inaccurate recognition and lack of parental concern may contribute to the persistence of unhealthy lifestyles (Wardle *et al.* 2006) and probably leads to less active attempts at the management and exacerbation of obesity (Lobstein *et al.* 2004). Even though the media and public health professionals are trying to increase awareness, these systematic misperceptions raise an important problem, because the general public awareness may not translate into an individual level of concern (Campbell *et al.* 2006).

This study extends the existing literature on parental weight perceptions by including data on Portuguese children, one of the countries with the highest prevalence of overweight and obese children in Europe, for the first time (Sardinha *et al.* 2011), and by presenting results of the mothers' perceptions of their child's weight status by BMI categories (underweight, normal weight, overweight/obese) according to the child's gender, the mother's age, education level and weight status and family income. Another strength of our study is the high response rate (83.7%).

A limitation of this study is that the mothers' height and weight were self-reported and it is known that self-reported weight status underestimates the true prevalence of being overweight and obese, especially in women (Yun *et al.* 2006). Indeed, 58% of the mothers in our study were classified as normal weight, which is higher than the prevalence reported for Portuguese women (48.9%) using objectively measured weight and height (do Carmo *et al.* 2008).

Future studies should investigate effective strategies for increasing a parent's awareness of their child's weight status.

Conclusions

Many mothers do not properly recognize their children's weight status and frequently underestimate their children's body size.

Key messages

- This study found that mothers do not properly recognize their children's weight status and frequently underestimate their children's body size.
- Significant differences in the percentages of mothers who correctly classified their children's weight status were only found among the most educated in the overweight/obese group and among the normal-weight mothers in the underweight group.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

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Paper III

(Submitted)

The ability of different measures of adiposity to discriminate between low/high motor coordination

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Results

Abstract

Objective: The aim of this study is to determine the ability of different measures of adiposity to discriminate between low/high motor coordination (MC).

Methods: 596 elementary school children (age 9–12 years, 218 girls) participated in this cross-sectional school-based study. Weight, height and waist circumference (WC) were objectively measured by standardized protocols. Body fat percentage (BF%) was estimated by bioelectric impedance. Body mass index (weight/height^2) and waist-to-height ratio (WHtR) were computed. MC was assessed with the Körperkoordination Test für Kinder. Cardio-respiratory fitness was predicted by a maximal multistage 20m shuttle-run test of the Fitnessgram Test Battery. A questionnaire was used to assess the mothers' educational level. Receiver operating characteristic (ROC) and logistic regression were performed.

Results: ROC curve analysis showed that all measures of adiposity performed well on average in identifying low MC, as indicated by the area under the curve greater than 0.6. The ROC performance of BF% showed a slightly better discriminatory accuracy than BMI, WC and WHtR in predicting low MC in girls. In boys, the ROC performance of WC showed a slightly better discriminatory accuracy than BMI, BF% and WHtR in predicting low MC. After adjustments, logistic regression analyses showed that BMI, WC, BF% and WHtR were positively and significantly associated with MC in both sexes, with the exception of WHtR in girls.

Conclusions: BF% and WC showed a slightly better discriminatory accuracy in predicting low MC, for girls and for boys, respectively.

Key-words: Adiposity, motor coordination, KTK, cardiorespiratory fitness, children.

INTRODUCTION

Childhood and adolescent obesity has become an important public health problem, as its prevalence has increased significantly over the past years in several countries (Wang & Lobstein, 2006). In Portugal, about one-third of children and adolescents are overweight or obese (Sardinha, Santos, Vale, Silva, et al., 2011).

A proper motor coordination (MC) level is essential for strong general development, as well as for health, psychosocial development, and well-being (Haga, 2008b; Piek et al., 2006). Although rudimentary forms of movement patterns may naturally be developed, mature forms of motor proficiency are more likely to be achieved with appropriate practice, encouragement, feedback, and instruction (Gallahue & Ozmun, 2006). The early childhood years are a critical time for the development of these skills, which are considered the building blocks of more complex movements (Clark & Metcalfe, 2002).

It is reasonably well established in literature that an inverse association exists between adiposity and MC (D'Hondt et al., 2011; Graf et al., 2004; Lopes, Maia, et al., 2011; Okely et al., 2004). Indeed, a recent review(Lubans et al., 2010) on the relationship between MC and health benefits in children and adolescents indicated that MC levels are inversely correlated with weight status both in cross-sectional and longitudinal studies. In this review, weight status was negatively correlated with MC in six of nine studies, with the remaining three demonstrating no relationship (Lubans et al., 2010).

There are some sophisticated methods to accurately measure body fat, such as computed axial tomography or dual-energy X-ray absorptiometric densitometry; however, it is not feasible to apply such techniques in large epidemiological studies or even in clinical settings because they are complex, time consuming and expensive. Therefore, several anthropometric measures, indices and other techniques (such as bioelectric impedance) have been used in the literature on the association between adiposity and MC, with the most common being the body mass index (BMI). In a recent systematic review, Rivilis et al., (2011) concluded that an adverse body composition was associated with poor motor proficiency regardless of the measure of adiposity considered (Rivilis et al., 2011).

However, the gap that remains in the literature is on the ability of the different measures of weight status/adiposity to predict low MC. Therefore, the aim of this study was to determine the ability (sensibility and specificity) of different measures of adiposity (BMI, waist circumference, body fat percentage and waist-to-height ratio) to discriminate between low/high motor coordination in a sample of children aged 9–12 years.

METHODS

Study Design and Sampling

Data for the present study are derived from the Bracara Study aimed to evaluate the relations between MC, PA, physical fitness, body composition, academic achievement and health behaviors among elementary school children. The Bracara Study was conducted in a middle city located in the north of Portugal during the 2009/2010 academic year.

All 21 urban public elementary schools in the city were considered and invited to participate in this study, corresponding to 846 children enrolling in the fourth grade. Two schools declined the invitation, corresponding to 90 children; six schools could not be evaluated in time to take part in this study, corresponding to 130 children; and 30 children who failed the inclusion criteria (having a mental and/or physical disability or a health condition that did not allow them to participate in physical education classes) or had missing information on the variables of interest were excluded from this analysis. Therefore, the final sample included 596 participants (281 girls) aged 9–12 years.

The schools' directors and children's parents/guardians received verbal and written descriptions of the study and signed a written informed consent form. The protocol and procedures employed followed the Helsinki Declaration for Investigation in Human Subjects and were approved by the Portuguese Ministry of Education and by the University's Ethics Committee.

All data was collected during regularly scheduled physical education classes by a team of specialized examiners and with the help of physical education teachers.

Measures

Anthropometry

Weight was measured to the nearest 0.1 Kg using a regularly calibrated digital scale (Tanita TBF-300) with the children in light clothing and without shoes. Body fat percentage was estimated by a bioelectric impedance digital scale (Tanita TBF-300). Height was measured to the nearest millimeter in bare or stocking feet with the children standing upright against a stadiometer (*Seca 220)*. Waist circumference measurements were taken as described by Lohman (Lohman et al., 1991). Body mass index [body mass (kg)/height (m^2)] and waist-to-height ratio [waist (cm)/height (m)] were calculated.

Motor Coordination

MC was evaluated with the body coordination test, Körperkoordination Test für Kinder (KTK).(Kiphard & Schiling, 1974) The KTK battery has four items: balance; jumping laterally; hopping on one leg over an obstacle; and shifting platforms. The tests were applied following the original protocols described elsewhere (Lopes, Maia, et al., 2011).

Cardiorespiratory Fitness

The 20 m shuttle-run test was used to evaluate cardiorespiratory fitness according to the Fitnessgram Test Battery, version 8.0 protocol (Welk & Meredith, 2008).

Sociodemographics

Mother's educational level was assessed by a questionnaire distributed to the mothers of the participants in this study and was used as a proxy measure of socioeconomic status.

Statistical analysis

Comparisons between groups involved Student *t* test for continuous variables. Receiver operating characteristic (ROC) curves were used to analyze the potential diagnostic accuracy of the different measures of adiposity to discriminate between low and high MC. Logistic regression analyses were performed to further study the relationship between different measures of adiposity and MC. Data were analyzed using the IBM SPSS Statistics v.19 (SPSS, Inc. IBM Company, USA) and MedCalc statistical software (MedCalc software, Mariakerke, Belguim). A p value under 0.05 denoted statistical significance.

RESULTS

Descriptive statistics for the age, BMI, WC, BF%, WHtR and MC are summarized in Table 1. Girls had significantly lower MC and higher BF% than boys.

168 girls and 138 boys were classified has having low MC, whereas 112 girls and 176 boys were classified as having high MC.

Results

Table 1. Participants' characteristics.

	All (n=213)	Girls (n=110)	Boys (n=103)	p*
Age (years)	9.7±0.6	9.7 ± 0.5	9.7 ± 0.6	0.552
BMI	18.6±3.3	18.6±3.3	18.6±3.3	0.934
Waist Circumference (cm)	66.8±8.6	66.3±8.74	67.2±8.74	0.215
Waist Height Ratio	0.48±0.05	0.48±0.06	049±0.05	0.149
Body Fat percentage (%)	19.7±8.3	21.4±8.9	18.3±7.4	<0.001
Motor Coordination (motor quotient)	85.7±14.4	81.7±14.5	89.3±13.4	<0.001

* - t test to compared gender differences.

ROC curve analysis showed that all measures of adiposity performed well on average in identifying low MC, as indicated by AUCs greater than 0.6. The ROC performance of BF% showed a slightly better discriminatory accuracy than did BMI, WC and WHtR in predicting low MC in girls. In boys, the ROC performance of WC showed a better discriminatory accuracy than BMI, BF% and WHtR in predicting low MC. In boys, the ROC performance of BMI, WC and WHtR were slightly better than in girls. The AUCs of BMI, WC, and WHtR were significantly different from BF% ($p<0.05$) for the whole sample and for girls. A BMI of 18.0kg/m^2 for girls and 19.9kg/m^2 for boys, a WC of 69.50cm for girls and 68.50cm for boys, a BF% of 24.0% for girls and a 17.60%, and a WHtR of 0.497 for girls and 0.50 for boys were found to be optimal cut-offs for defining low MC in the participants (Table 2).

Table 2. Cut-off values, sensitivity, and specificity for the association of different measures of adiposity with motor coordination by sex.

	All	Girls	Boys
BMI			
BMI cut-off (kg/m^2)	>19.9	>18.0	>19.9
Sensitivity (%)	46.4 (40.7-52.2)	67.3 (59.6-74.3)	50.7 (42.1-59.3)
Specificity (%)	84.7 (80.0-88.7)	61.6 (51.9-70.6)	85.8 (79.7-90.6)
AUC	0.668 (0.629-0.706) p<0.001 ‡	0.660 (0.601 - 0.715) p<0.001‡	0.678 (0.623 - 0.729) p<0.001
WC			
WC cut-off (cm)	>69.5	>69.5	>68.5
Sensitivity (%)	49.7 (43.9-55.4)	47.6 (39.9-55.5)	54.3 (45.7-62.8)
Specificity (%)	83.7 (78.9-87.8)	83.0 (74.8-89.5)	83.0 (76.6-88.2)
AUC	0.675 (0.635 - 0.702) p<0.001†	0.660 (0.601 - 0.715) p<0.001 †	0.704 (0.650 - 0.754), p<0.001
WHtR			
WHtR cut-off	>0.50	>0.49	>0.50
Sensitivity (%)	47.7 (42.0-53.5)	47.0 (39.3-54.9)	52.9 (44.2-61.4)
Specificity (%)	85.1 (80.4-89.0)	81.2 (72.8-88.0)	85.2 (79.1-90.1)
AUC	0.663 (0.623-0.701) p<0.001*	0.643 (0.584-0.699) p<0.001*	0.701 (0.647 - 0.751), p<0.001
BF%			
BF% cut-off	>20.2	>24.0	>17.6
Sensitivity (%)	58.5 (52.8-64.1)	53.6 (45.7-61.3)	63.0 (54.4-71.1)
Specificity (%)	76.7 (71.4-81.5)	80.4 (71.8-87.3)	72.7 (65.5-79.2)
AUC	0.709 (0.670-0.745) p<0.001	0.701 (0.644-0.754) p<0.001	0.698 (0.644 - 0.749), p<0.001

AUC – Area Under the Curve; 95% CI in parentheses; ‡ AUC significantly different from BF% (p<0.05); † AUC significantly different from BF% (p<0.05); *AUC significantly different from BF% (p<0.05).

Logistic regression analyses showed that BMI, WC, BF% and WHtR were positively and significantly associated with MC in both sexes, with the exception of WHtR after adjustments for girls (Table 3).

Results

Table 3. Odds Ratios and 95% Confidence Intervals from logistic regression model predicting low motor coordination, for body mass index, waist circumference, waist-to-height ratio and fat mass percentage, for each gender.

	Low motor coordination					
Girls	unadjusted			Adjusted[a]		
	OR	CI	p	OR	CI	p
BMI<18.0	1					
BMI≥18.0	3.297	(2.002-5.429)	<0.001	2.155	(1.164-3.992)	0.015
WC<69.5	1					
WC≥69.5	4.450	(2.494-7.939)	<0.001	2.489	(1.242-4.988)	0.010
BF%<24.0	1					
BF%≥24.0	4.720	(2.707-8.231)	<0.001	2.395	(1.234-4.646)	0.010
WHtR<0.497	1					
WHtR≥0.497	2.733	(1.631-4.580)	<0.001	1.343	(0.713-2.528)	0.381
Boys						
	OR	CI	p	OR	CI	p
BMI<19.9	1					
BMI≥19.9	6.218	(3.627-10.658)	<0.001	3.255	(1.740-6.088)	<0.001
WC<68.5	1					
WC≥68.5	5.794	(3.457-9.709)	<0.001	3.296	(1.784-6.090)	<0.001
BF%<17.6	1					
BF%≥17.6	4.549	(2.817-7.345)	<0.001	2.603	(1.462-4.634)	<0.001
WHtR<0.5	1					
WHtR≥0.5	6.479	(3.799-11.051)	<0.001	3.840	(2.025-7.283)	<0.001

[a] - Adjusted for cardiorespiratory fitness and mothers' education levels.

OR – Odds ratio;

CI – Confidence Intervals;

DISCUSSION

The main findings of this study suggest that BF% provides a marginally superior tool for discriminating low MC for girls as compared with BMI, WC, and WHtR. In boys, WC showed a slightly better discriminatory accuracy in predicting low MC as compared with BMI, BF%, and WHtR. Slightly higher pooled AUCs were observed in boys as compared to girls (with an exception in BF%), suggesting that discrimination is more precise, on average, in boys. Logistic regression analyses showed that all different measures of adiposity were negatively and significantly associated with MC in both sexes, with the exception of WHtR for girls, after adjusting for cardio-respiratory fitness and mothers' education level.

A recent review of the associations between MC and aspects of physical and psychological attributes provides indirect evidence that MC may be an important antecedent or consequent mechanism for promoting health-related behaviors, including weight status (Lubans et al., 2010). However, measurement issues may potentially play a role in obscuring the relationship between body composition and MC (Rivilis et al., 2011).

Our study found that, in girls, BF% assessed by bioelectric impedance was the measure that best predicted low MC. BF% measurement techniques have been developed and validated for children; however, it has rarely been used in the literature regarding the relationship between adiposity and MC. The existing studies have found significant associations between BF% and MC, whether using skin folds (Lopes, Maia, et al., 2011), bioelectric impedance (J. Cairney, J. A. Hay, B. E. Faught, & R. Hawes, 2005) or whole body air displacement plethysmography (Silman et al., 2011) methods. Using bioelectric impedance, Cairney et al., (2005) also found that children with poor motor coordination had greater body weight and body fat compared to their normal MC peers. Bioelectric impedance is an appealing tool for assessing body composition due to the fact that it is simple, painless, non-invasive and increasingly cheap, making it highly suitable for survey and clinic use, particularly in school-age children (Wright et al., 2008). However, the resulting estimates of fat and fat-free mass actually agree poorly with more accurate methods, tending to be both biased and imprecise (Eisenmann et al., 2004).

BMI is the most common anthropometric measure used in studies relating to adiposity status and MC.(Lubans et al., 2010; Rivilis et al., 2011) In a cross-sectional study with 954 Flemish primary school children stratified, D'Hondt et al.,(2011) found that less than 20% of the healthy-weight participants was identified as being motor impaired, while that proportion increased to 43.3% and up to 70.8% in children with overweight and obesity, respectively. BMI is a suboptimal marker of body fat because it does not distinguish fat from lean tissue or bone, and therefore classifying people as overweight or obese based on their BMI alone may lead to significant misclassification. Moreover, BMI is not a suitable method to assess body fat distribution (Brambilla et al., 2006) and it has been suggested that BMI may be a less sensitive indicator of fat in children and adolescents than waist circumference (WC) or waist-to-height ratio (WHtR) (Brambilla et al., 2006).

In boys, we found that WC is the measure that best predicted low MC. In a longitudinal study, Cairney et al., (2010) also found associations between MC and WC. WC is a simple, effective and inexpensive anthropometric tool to measure abdominal adiposity and related metabolic risks in children of different ethnicities (Brambilla et al., 2006; Lee et al., 2006). For children and adolescents, there are no internationally accepted cut-off values; however, WC centile charts have been developed for children and adolescents in some countries (Eisenmann, 2005; Fernandez et al., 2004; Katzmarzyk, 2004; McCarthy et al., 2001; Sardinha, Santos, Vale, MJ, et al., 2011). Abdominal obesity seems to reflect intra-abdominal fat, including visceral adipose tissue (Clasey et al., 1999), and it is known that increased visceral adipose tissue is strongly correlated with CVD risk factors (Soto Gonzalez et al., 2007). During childhood and adolescence, it is known that abdominal obesity is an important predictor for several CVD risk factors (Moreno et al., 2002; Savva et al., 2000). Indeed, in a cross-sectional study with 571 elementary school students, Faught et al.(2005) found an association between poor MC with increased body fat and low cardio-respiratory fitness (physical activity was a significant mediator for both relationships). These authors concluded that poor MC is related to factors associated with increased risk for coronary vascular disease, including decreased cardiorespiratory fitness and increased body fat through the mediating influence of physical activity in children.

WHtR has been proposed as a convenient alternative measurement to assess central fatness in children (Savva et al., 2000). Similar to WC, WHtR has been shown to be strongly correlated with abdominal fat measured using imaging techniques (Soto Gonzalez et al., 2007). Correcting WC to height may obviate the need for age-, sex- and ethnic-related reference values (Ashwell & Hsieh, 2005), while WC requires population-specific cut-off values (WHO, 2000). To the best of our knowledge, there are no studies linking WHtR and MC; however, the good AUC found in this study may suggest that WHtR is a good measure for predicting low MC.

Strengths and limitations

This study has some limitations that need to be recognized. The data has been derived from a cross-sectional study; therefore results do not indicate causality. Our sample is not representative of the Portuguese population and therefore our findings are not generalizable.

Overall, the strengths of our study comprise the inclusion of potential confounding factors such as mother's education level (used as a proxy measure of socioeconomic status), which is recognized as having a powerful and synergistic relationship with obesity (Ulijaszek, 2012); the presence of cardio-respiratory fitness as a potential confounding element, due to its importance of being simultaneously linked to adiposity and MC (i.e., inversely associated with adiposity and positively related to MC) (Faught et al., 2005; Lopes, Maia, et al., 2011); and the novelty of the study, to determine the ability of different measures of adiposity to discriminate between low and high MC.

More research on other measures and techniques is needed to further study the accuracy of different measures of adiposity in discriminating between low and high MC.

CONCLUSIONS

BF% and WC showed a slightly better discriminatory accuracy in predicting low MC for girls and for boys, respectively. BMI, WC, BF% and WHtR were positively and significantly associated with MC in both sexes, with the exception of WHtR in girls after adjustments.

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Conflict of interest

The authors report no conflicts of interest.

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Paper IV

(Submitted)

Associations between Gross Motor Coordination and Academic Achievement in Elementary School Children

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Results

ABSTRACT

We aimed to evaluate the relationship between gross motor coordination (MC) and academic achievement (AA) in a sample of Portuguese children aged 9-12 years. The study took place during the 2009/2010 school year, using 596 urban children (281 girls) from the north of Portugal. AA was assessed using the Portuguese Language and Mathematics National Exams. Gross MC was evaluated with the Körperkoordination Test für Kinder. Cardiorespiratory fitness was predicted by a maximal multistage 20m shuttle-run test of the Fitnessgram Test Battery. Body weight and height were measured following standard procedures. Socioeconomic status was based on annual family income. Logistic Regression was used to analyze the association of gross MC with AA. 51.6% of the sample exhibited MC disorders or MC insufficiency and none of the participants showed very good MC. In both genders, children with insufficient MC or MC disorders exhibited a higher probability of having low AA, compared with those with normal or good MC ($p<0.05$ for trend for both) after adjusting for cardiorespiratory fitness, body mass index and socioeconomic status.

KEY WORDS

Motor coordination; academic achievement; cardiorespiratory fitness; socioeconomic status; body mass index.

INTRODUCTION

Mastery of a variety of motor skills is a requisite for children to engage in everyday activities and has important implications for different aspects of development in children and adolescents (Piek et al., 2006). Children's motor skill development incorporate many body systems, including sensory, musculoskeletal, cardiorespiratory, and neurological systems (Dwyer et al., 2009) and is ability to interact with the environment (Riethmuller et al., 2009). Consequently, the study of a child's motor development is a prerequisite for the full understanding of the children's whole development (Payne & Isaacs, 1998).

The importance of promoting the development of MC at younger ages relies on the evidence that there are current and future benefits associated with the acquisition and the maintenance of motor proficiency (Lubans et al., 2010). It has been suggested that an appropriate acquisition of MC contributes to children's physical, cognitive, and social development (Payne & Isaacs, 1998). Furthermore, a proper MC level is essential for strong general development, as well as for health, psychosocial development, and well-being (Haga, 2008a; Piek et al., 2006). Childhood years are a critical period for the development of these skills, which are considered the building blocks of more complex movements (Clark & Metcalfe, 2002) and a key factor in the promotion of lifelong active lifestyles (Clark, 2005; Stodden et al., 2008). It is also known that motor skills have been observed to track during childhood (Malina, 1996).

Recently, there is a re-emerged debate around the possible relations between physical activity (PA), physical fitness, motor coordination (MC) and cognitive development (Niederer et al., 2011), based on the decreased in children's PA (Knuth & Hallal, 2009), physical fitness (Tomkinson & Olds, 2007), MC (Prätorius & Milani, 2004), and the pressure of schools and parents to improve cognitive performance (Chomitz et al., 2009; Ertl, 2006).

While the relationship between PA and physical fitness with academic achievement (AA) has been thoroughly explored (Ahamed et al., 2007; Carlson et al., 2008; Castelli, Hillman, Buck, & Erwin, 2007; Chomitz et al., 2009; Coe et al., 2006; Etnier, Nowell, Landers, & Sibley, 2006; Eveland-Sayers, Farley, Fuller, Morgan, & Caputo, 2009; Fox et al., 2010; Grissom, 2005) (Hillman et al., 2008; Kwak et al., 2009; Niederer et al., 2011; Rasberry et al., 2011; Ruiz et al., 2010b; Sigfusdottir et al., 2007; Strong et al., 2005; Taras, 2005; Trudeau & Shephard, 2008), little, is known about the relation between of gross MC and AA in elementary school children.

Studies suggest that neuronal structures (in the cerebellum and the frontal lobe) are responsible for coordination as well for cognition (Serrien et al., 2006). There is also evidence that working memory capacity and visual perceptual ability limit children's AA (Alloway, 2007; Alloway &

Alloway, 2010; Sortor & Kulp, 2003). Besides, one cross-sectional and longitudinal study found that higher baseline motor skills (agility and dynamic balance) were related to better spatial working memory and/or baseline attention as well as their future improvements over the following nine months (only no association was found between dynamic balance and attention) (Niederer et al., 2011). Indeed, children with developmental coordination disorders tend to perform poorly in literacy and numeracy assessments (Alloway, 2007), while fine MC was found to positively correlate with AA (Sortor & Kulp, 2003); and children with learning disabilities scored poorer in gross MC test (both locomotor and object-control) (Westendorp et al., 2011). Additionally, other cross-sectional (Knight & Rizzuto, 1993; Nourbakhsh, 2006; Planinsec, 2002) and interventional studies (Budde et al., 2008; Erickson, 2008; Uhrich & Swalm, 2007) have shown that improved motor skill levels may be positively related to improvements in AA or other cognitive variables. Moreover, longitudinal studies in preschool children found relationship between early motor development and later cognitive function (Piek et al., 2008; Son & Meisels, 2006), suggesting that early school motor skills assessment may increased the predictability of later achievement and the probability of identifying children at risk for school failure (Son & Meisels, 2006).

It is important to note that the term “motor coordination” used in this study is a general term that encompasses various aspects of movement competency. There are many different test batteries that assess movement in a variety of ways using various movement tests. Specifically, process and product oriented movement assessments are used to examine differences in levels of MC. While it is outside the scope of this study to explain the differences and limitations in how movement and/or movement outcomes are assessed, we used the term “motor coordination” in this study as it specifically aligns with the language used in the assessment implemented for this study (Kiphard-Schilling body coordination test) and with previous literature that has used the same assessment.

Despite these findings, until now, to the best of our knowledge, no study has addressed the association between gross MC and direct/objective indicators for AA, namely scores on standardized tests, in elementary school children without intellectual disabilities, accounting for potential confounders such as physical fitness, body composition or socioeconomic status (Carlson et al., 2008; Coe et al., 2006; Etnier et al., 2006; Kwak et al., 2009; Rasberry et al., 2011; Trudeau & Shephard, 2008). In this context, understanding whether or not gross MC is related to AA among school age children may provide useful information about how to incorporate PA into daily life, helping to achieve recommended levels of PA and physical fitness and positively impacting academic success or progress. The purpose of the present study was to evaluate the relationship between gross MC and AA in urban Portuguese children aged 9-12 years, accounting for cardiorespiratory fitness, body mass index, and socioeconomic status.

METHODS

Study Design and Sampling

Data for the present study are derived from the Bracara Study aimed to evaluate the relations between gross MC, PA, physical fitness, body composition, AA and health behaviors among elementary school children. The Bracara Study was conducted in a middle city located in the north of Portugal during the 2009/2010 academic year.

Participants

All 21 public elementary schools in the city that qualified as urban (according to the Municipal Administration Registry) were considered and invited to participate in this study, corresponding to 846 children enrolling in the fourth grade; two schools decided not to take part in this study, corresponding to 90 children; six schools could not be evaluated on time to take part in this study, corresponding to 130 children; 30 children who failed the inclusion criteria (having a mental and/or physical disability or a health condition that did not allow them to participate in physical education classes) or had missing information on the variables of interest were excluded from this analysis. Therefore, the study included 13 urban public elementary schools, and 596 participants (281 girls) aged 9-12 years old.

Procedure

The schools' directors and children's parents/guardians received verbal and written description of the study and signed a written informed consent form. The protocol and procedures employed followed the Helsinki Declaration for Investigation in Human Subjects and were approved by the Curricular Development and Innovation Division (Portuguese Ministry of Education) and by the University's Ethics Committee.

Data were collected during regularly scheduled physical education classes by 2 assessors in full time. Assessors were physical education graduates and received specific training, and had already participated in previous KTK data collection. The assessors were helped by the physical education teachers.

Results

Measures

Academic Achievement

AA was assessed using the Portuguese Language and Mathematics *National Exams* which are mandatory for all 4th grade students. The exams were administered in May 2009 by two supervision teachers in the classroom. The Educational Evaluation Office from the Portuguese Ministry of Education performs management, analysis, and maintenance of student data and the National Exams database. The National Exams are criterion-referenced tests that provide scores to students, teachers and parents according to the performance levels: A (very good), B (good), C (fair), D and E (insufficient). For each exam 1, 2, 3, 4, or 5 points were attributed to scores of E, D, C, B, and A, respectively. An AA score was computed by summing the points attained for each of the exams. Participants were then categorized as having high AA (>8 points); middle AA (7-5 points); or lower AA (<4 points), based on the tertile values of this score.

Cardiorespiratory Fitness

Health-related components of physical fitness were evaluated using the Fitnessgram Test Battery, version 8.0. The Fitnessgram is included in the physical education curriculum, and the five tests recommended in the Portuguese National Program (curl-up, push-up, trunk lift, shuttle-run, and the modified back saver sit-and-reach) were used in this study. All tests were conducted according to the Fitnessgram measurement procedures (Welk & Meredith, 2008).

For the purpose of the present analysis we only considered the 20 m shuttle-run test as a way to evaluate cardiorespiratory fitness. This test requires participants to run back and forth between two lines set 20 m apart. Running speed started at 8.5 km/h and increased by 0.5 km/h each minute, reaching 18.0 km/h at minute 20. Each level was announced on the tape. The participants were told to keep up with the pacer until exhausted. The test was finished when the participant failed to reach the end lines concurrent with the audio signals on two consecutive occasions. Otherwise, the test ended when the subject stopped because of fatigue. Participants were encouraged to keep running as long as possible throughout the course of the test. The number of shuttles performed was recorded. Age- and sex-adjusted Z-scores were computed, because the age and sex-specific cut-off points of the Fitnessgram criteria are only developed for children aged 10 years old or older, and most participants in this study were nine years old.

Motor Coordination

MC was evaluated with the body coordination test, Körperkoordination Test für Kinder (KTK), developed for German children (aged 5-15 years) (Kiphard & Schiling, 1974). The KTK battery has four items:

Balance: the child walks backward on three balance beams each 3 m in length, 5 cm in height, but with decreasing widths of 6, 4.5 and 3 cm. The child has three attempts at each beam; the number of successful steps is recorded; a maximum of 24 steps (eight per trial) were counted for each balance beam, which comprises a maximum of 72 steps.

Jumping laterally: the child makes consecutive jumps from side to side over a small beam (60 cm x 4 cm x 2 cm) as quickly as possible for 15 s. The child is instructed to keep his/her feet together; the number of correct jumps in two trials was summed.

Hopping on one leg over an obstacle: the child was instructed to hop on one foot at a time over a stack of foam blocks after a short run-up. After a successful hop with each foot (the child clears the block without touching it and continues to hop on the same foot at least two times), the height was increased by adding a block (50 cm x 20 cm x 5 cm). The child had three attempts at each height and on each foot; three, two or one point(s) was/were awarded for a successful performance on the first, second or third trial, respectively; a maximum of 39 points (12 stacks blocks) could be scored for each leg (maximum score 78).

Shifting platforms: the child begins by standing with both feet on one platform (25 cm x 25 cm x 2 cm) supported on four legs, 3.7cm in height and holding a second identical platform in his/her hands; the child is then instructed to place the second platform alongside the first and to step on to it; the first box is then lifted and placed alongside the second and the child steps on to it; the sequence continues for 20 s. Each successful transfer from one platform to the next earns two points (one for shifting the platform, the other for transferring the body); the number of points in 20 s is recorded and summed for two trials. If the child falls off in the process, he/she simply gets back on to the platform and continues the test.

Although some of the items in the KTK appear to measure specific components of motor performance, e.g., dynamic balance, speed and agility, balance and power, the four tests were loaded in a single factor when analyzed with other items (Kiphard & Schiling, 1974). Hence, the authors utilized the four items together as a global indicator of MC, the ‘‘motor quotient.’’ Each performance item was scored relative to gender- and age-specific reference values for the population upon which the KTK was established. The sum of the standardized scores for the four items provides the motor quotient. Using the motor quotient children were then categorized as having: MC disorders (<70 motor quotient); MC insufficiency (71≤ motor quotient ≤85); normal MC

(86≤ motor quotient ≤115); good MC (115≤ motor quotient ≤130); or very good MC (131≤ motor quotient ≤145).

The psychometric characteristics of the KTK have been documented (Kiphard & Schiling, 1974). The test-retest reliability coefficient for the raw score on the total test battery was 0.97, while corresponding coefficients for individual tests ranged from 0.80 to 0.96. Factor analysis of the four individual tests resulted in a single factor labelled gross MC. The percentage of total variance in MC explained by the four tests varied from 81% at 6 years to 98% at 9 years (Kiphard & Schiling, 1974). Intercorrelations among the four tests varied from 0.60 to 0.81 for the reference sample of 1228 children. Both the factor analysis and intercorrelations thus indicated acceptable construct validity. Validity was further determined through differentiation of normal from disabled children. The KTK test differentiated 91% of children with brain damage from normal children. Participants were classified as having: MC disorders, MC insufficiency, normal MC, good MC or very good MC, according to the KTK reference values described above. Participants with good MC were recoded and combined with those with normal MC due to their small sample size (1.2%).

Sociodemographics

Each child's date of birth, gender, and socioeconomic status was extracted from the schools' administrative record systems. The socioeconomic status records used by the Portuguese Ministry of Education are based on annual family income: children may be eligible for benefit A, eligible for benefit B, or not eligible. These categories were used as a proxy measurement of family socioeconomic status (Education, 2009). According to the Portuguese Ministry of Education, those eligible for benefit A receive books, school supplies, and meals for free; those eligible for benefit B receive 50 % of the books required and a 50% discount on meals.

Anthropometrics

Weight was measured to the nearest 0.1 kg using a regularly calibrated digital scale (Tanita TBF-300), while the child was wearing light clothing without shoes. Height was measured to the nearest millimeter with a field stadiometer (*Seca 220)*. The body mass index ($kg.m^{-2}$) was calculated and defined according to Cole et al. (Cole et al., 2000) cut off points.

Statistical analysis

Two tailed t-test compared gender differences in continuous variables. Binary Logistic Regression was used to analyze the influence of MC on AA, adjusting for cardiorespiratory fitness, body mass index and socioeconomic status. In this regression analysis children belonging to the lower and middle tertiles of AA were grouped into one category – models were constructed separately for girls and boys. In each model all variables were tested simultaneously.

Statistics was performed using Predictive Analytics Software (IBM - PASW Statistics 18 - Statistical Program for Windows), former known as SPSS (Statistical Package for the Social Sciences. A p value <0.05 denoted statistical significance.

RESULTS

Boys had, on average, significantly higher levels of gross MC and fitness compared with girls ($p<0.001$ for both); Table 1.

Table 1 – Participants' characteristics.

	Whole Sample (n=596)	Girls (n=281)	Boys (n=315)	p*
Age (years)	9.7±0.6	9.7 ± 0.5	9.7 ± 0.6	0.552
Cardiorespiratory Fitness (number of laps)	19.9±11.3	16.6±8.0	22.8±13.0	0.000
Motor Coordination (motor quotient)	85.7±14.4	81.7±14.5	89.3±13.4	0.000
Body Mass Index ($kg.m^{-2}$)	18.6±3.3	18.6±3.3	18.6±3.3	0.934

Portugal, academic year 2009/2010.

* - t-test compared gender differences.

As shown in Table 2, 51.6% of the entire sample exhibited MC disorders or MC insufficiency and none of the participants showed very good MC. In both, Portuguese Language and Mathematics exams, none of the participants scored E, and more boys than girls scored A and D.

Results

Table 2 - Prevalence of Motor Coordination and Academic Achievement.

	Whole Sample (n=596)		Girls (n=281)		Boys (n=315)	
	n	%	n	%	n	%
Motor Coordination						
Motor coordination disorders	86	14.4	63	22.4	23	7.3
Motor coordination insufficiency	222	37.3	107	38.1	115	36.5
Normal motor coordination	281	47.1	110	39.1	171	54.3
Good motor coordination	7	1.2	1	0.4	6	1.9
Very good motor coordination	0	0	0	0	0	0
Portuguese Language Exam						
A	64	10.7	27	9.6	37	11.8
B	210	35.2	107	38.1	103	32.7
C	255	42.8	121	43.1	134	42.5
D	67	11.3	26	9.2	41	13.0
E	0	0	0	0	0	0
Mathematic Exam						
A	114	19.1	48	17.1	66	21.0
B	201	33.7	100	35.6	101	32.0
C	215	36.1	102	36.3	113	35.9
D	66	11.1	31	11.0	35	11.1
E	0	0	0	0	0	0

Portugal, academic year 2009/2010.

Children with MC insufficiency or MC disorders exhibited a higher probability of having low AA, compared with those with normal coordination ($p<0.05$ for trend in both genders); Tables 3 and 4.

Table 3 - Odds Ratios and 95% Confidence Intervals from binary logistic regression model predicting low academic achievement, for girls.

Boys	Low Academic Achievement Unadjusted model				Adjusted model[a]			
	OR	95% CI	p	p for trend	OR	95% CI	p	p for trend
Normal/good motor coordination [b]	1				1			
Motor coordination insufficiency	1.938	(0.778-4.828)	0.155	<0.001	2.496	(0.941-6.623)	0.066	<0.001
Motor coordination disorders	5.150	(2.087-12.711)	<0.001		7.861	(2.739-22.559)	<0.001	
Body mass index					0.916	(0.816-1.029)	0.139	
Cardiorespiratory fitness					1.223	(0.815-1.837)	0.331	
Socioeconomic status[b] (not eligible)					1			0.698
Socioeconomic status (benefit A)					0.678	(0.246-1.865)	0.451	
Socioeconomic status (benefit B)					0.744	(0.330-1.681)	0.477	

Portugal, academic year 2009/2010.

[a] - Adjusted for socioeconomic status, body mass index and cardiorespiratory fitness.

[b] - Reference category.

OR – Odds Ratio.

CI – Confidence Intervals.

Results

Table 4 - Odds Ratios and 95% Confidence Intervals from binary logistic regression model predicting low academic achievement, for boys.

Boys	Low Academic Achievement							
	Unadjusted model				Adjusted model[a]			
	OR	95% CI	p	p for trend	OR	95% CI	p	p for trend
Normal/good motor coordination [b]	1				1			
Motor coordination insufficiency	1.483	(0.769-2.862)	0.240	0.026	1.868	(0.902-3.865)	0.092	0.006
Motor coordination disorders	3.758	(1.428-9.886)	0.007		6.815	(2.075-22.379)	0.002	
Body mass index					0.841	(0.741-0.954)	0.007	
Cardiorespiratory fitness					1.021	(0.710-1.469)	0.910	
Socioeconomic status[b] (not eligible)					1			
Socioeconomic status (benefit A)					0.867	(0.360-2.090)	0.750	0.016
Socioeconomic status (benefit B)					0.369	(0.175-0.778)	0.009	

Portugal, academic year 2009/2010.

[a] - Adjusted for socioeconomic status, body mass index and cardiorespiratory fitness.

[b] - Reference category.

OR – Odds Ratio.

CI – Confidence Intervals.

DISCUSSION

The results of this study indicate that children of both genders with low gross MC had a higher probability of having low AA, after adjusting for cardiorespiratory fitness, body mass index, and socioeconomic status.

There are potential biological, psychological, and social mechanisms that may help explain this relationship. Coordinative exercise (exercises strengthening various coordination abilities) involve an activation of the cerebellum, which influences motor functions (Gao et al., 1996) as well as attention (Courchesne et al., 1994), working memory (Klingberg et al., 1996), and verbal learning and memory (Andreasen et al., 1995). Additionally, the frontal lobes play an important role in mediating both MC (Hernandez et al., 2002) and cognitive functions (Miller & Cohen, 2001). An interventional study performed by Budde et al. (2008) aiming to investigate the effect of 10 minutes of physical exercise (coordination exercises vs. non-specific physical education lessons) on concentration and attention performance in a school setting revealed enhanced attention and concentration performance in both groups, with significantly higher enhancement in the group that performed coordination exercises. Furthermore, they suggest that coordination exercises lead to a facilitation of neuronal networks that results in a pre-activation of cortical activities that are responsible for cognitive functions such as attention (Budde et al., 2008).

Better gross MC results may reflect better overall health, as has been suggested in the case of physical fitness (Chomitz et al., 2009) (i.e., better nutrition, more PA and healthier weight status), and good health may contribute positively to AA. As the literature points out, high levels of motor competence/skill are positively associated with PA (Wrotniak et al., 2006). Cognitive facilitation by PA is presumably attributable to a direct improvement in cerebral circulation (of glucose, oxygen, and energetic substances) and the alteration of neurotransmitter actions in the central nervous system (acetycholine, dopamine, norepinephrine, epinephrine, adrenocorticotropic hormone and vasopressin) (Kashihara et al., 2009). Taras indicates that PA increases blood flow to the brain and raises the levels of hormones (norepinephrine and endorphins) that reduce stress, improve mood, and induce a calming effect after exercise, possibly leading to an improvement in AA (Taras, 2005). Shephard has also suggested that increased PA may induce arousal and reduce boredom, leading to increased attention span and better concentration (Shephard, 1996). Additionally, PA may increase feelings of self efficacy and self-esteem, which can improve class behaviour as well as AA. Furthermore, it is assumed that children who participate in PA that promotes cooperation, sharing, and rule following learn skills that transfer to classroom settings (Taras, 2005).

Results

It of importance to note that children with poor MC report systematically less participation in organized and free-play activities than their typically developing peers (activity deficit) (Bouffard et al., 1996; J. Cairney et al., 2005), and these differences tend to persisted over time (Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010); therefore, it is possible that these children are not provided with the same opportunity to enhance AA given the benefits of PA on AA.

Our results also showed that boys had higher levels of gross MC and better performance on cardiorespiratory fitness tests than girls. This finding is supported by previous longitudinal research that found that boys had consistently higher results in both MC and physical fitness than girls at each observation (Lopes et al., 2009; Pereira et al., 2010). Perhaps the types of sports and PA in which boys are more often involved, i.e., those that require eye-hand (or foot) coordination (evident in a variety of ball games), give them more opportunities to improve their cardiorespiratory fitness and refine their MC.

Only 48.8% of our study participants were classified as having at least normal MC and none showed very good MC. These results are in line with those reported in a study with Portuguese children aged 6-10 years old (Maia & Lopes, 2002). However, our gross MC numbers are considerably lower than those observed by others (Graf et al., 2004; Vandorpe et al., 2011). In a study with German children aged 6-9 years old, Graf et al. (2004) found that only 31.3% of participants showed lower than normal MC. Vandorpe et al. (2011), in a study of Belgian children aged 6-11 years, found that only 21.1% demonstrated lower than normal MC. In the original German (1974) standardization sample with children aged 6-11, only 16% demonstrated lower than normal MC (Kiphard & Schiling, 1974). The low gross MC levels in Portuguese children may possibly be explained partially by the fact that Portuguese children have one of the highest rates of obesity in Europe (Sardinha et al., 2010). Indeed, several studies have described that overweight children have poor results on motor skill tests when compared with their normal-weight counterparts (Graf et al., 2004; Okely et al., 2004). Additionally, Portuguese children and adolescents have lower levels of PA (Baptista et al., 2011) compared to their European counterparts, a characteristic that correlates with low MC (Okely et al., 2001b). Furthermore, KTK norms and cut-off values are based on German children tested 36 years ago, while the literature has shown that children’s physical fitness (Tomkinson, Leger, Olds, & Cazorla, 2003) and PA (Knuth & Hallal, 2009) are declining; as motor skills are positively associated with both physical fitness (Hands et al., 2009) and PA (Williams et al., 2008; Wrotniak et al., 2006), perhaps MC levels are decreasing as well. Indeed, Prätorius & Milani (2004) have shown that over the last 30 years, the percentage of German children with low MC has increased substantially, from 16% in the KTK test’s original validation to a level of 38% in contemporary children.

Schools are excellent settings in which to provide students with the opportunity for daily PA, to teach the importance of regular PA for health, and to build skills that support active lifestyles. Promoting active lifestyles from a young age is widely recognized as beneficial, and the health benefits of regular PA are extensively acknowledged (Andersen et al., 2006; Strong et al., 2005). The incorporation of PA into daily life and the achievement of recommended PA levels for the maintenance of good health are major public health challenges. Physical education lessons and school recesses are ideal settings in which to develop children's fundamental movement skills and increase PA and fitness (van Beurden et al., 2003), while also contributing to one of the primary missions of schools, i.e. the promotion of academic performance (Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001).

Given the importance of assessment and evaluation in the education and health fields and the pressures that educational agents are under to achieve academic success for all students, indicators of educational achievement, health, and functional status may allow educators and policy makers to make better informed decisions (Lloyd et al., 2010). Therefore, understanding the relationship between MC and AA is important for ensuring the appropriate assignment of resources as well as the implementation of programs to develop children's health-related behaviors. This study highlights the necessity of providing opportunities for children to engage in PA structured and unstructured that promote a diversity of motor skills, since gross MC seems to play such an important role in AA.

Strengths and limitations

This study has some limitations that need to be recognised. The data has been derived from a cross-sectional study so the results do not indicate causality. Our sample is not representative of the Portuguese population and therefore our findings are not generalizable. The use of shuttle-run tests to assess aerobic fitness in children with motor problems is controversial, and has been criticized by Armstrong and Welsman (1997) and Hands and Larkin (2006) for being overly vulnerable to both motivational and environmental effects. Indeed, field-based measures of aerobic capacity rely on the internal motivation of the participants to perform to exhaustion (Rivilis et al., 2011), a circumstance that could be particularly challenging for children with developmental coordination disorders because they generally report less confidence in their physical abilities and may be unlikely to persist in their tasks (Cairney et al., 2006). Nevertheless, a recent study has shown that the shuttle-run test is moderately to fairly well correlated with lab based cycle ergometer tests for assessing cardiorespiratory fitness in children with and without developmental coordination disorders (Cairney, Hay, Veldhuizen, & Faught, 2010).

Results

Overall, the strengths of our study include the use of direct indicators of AA, namely, scores on standardized national exams; the inclusion of potential confounding factors such as socioeconomic status, which is recognized as a major factor in academic performance (Coe et al., 2006); the use of cardiorespiratory fitness, because it was suggested that this could mediate the relationship between PA and AA (Kwak et al., 2009); and the use of body mass index, which has been documented as inversely related with MC (Graf et al., 2004; Okely et al., 2004).

More research is needed to further study the relationship between MC and AA. Longitudinal and interventional studies would provide information on the direction of this association.

CONCLUSIONS

In this cross-sectional study, children of both genders with lower MC had higher odds of having low AA, after adjusting for potential confounding factors. The early identification of children with poor MC is crucial to implementing activities that develop health-related behaviors.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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5. Discussion

The main findings of the present work indicate that adequate levels of MC in children have essential importance since it were found to be positive related with health-related behaviours and cognitive outcomes. This study show that for both genders the low sedentary group had significantly higher odds of having a good MC compared with the high sedentary group, independently of MVPA, accelerometer wear time, WHtR, and mother's education level (paper I). The results also indicate a high rate of maternal misclassification of child weight status; 65.2% of underweight and 61.6% of overweight/obese children were inaccurately classified by their mothers as being a normal weight, and the agreement between the objectively measured weight status and the mothers' perceptions of their child's weight status was fair, but statistically significant (paper II). Moreover, regarding the relationship between adiposity measures and MC, this study suggest that BF% provides a marginally superior tool for discriminating low MC for girls as compared with BMI, WC, and WHtR. In boys, WC showed a slightly better discriminatory accuracy in predicting low MC as compared with BMI, BF%, and WHtR. Slightly higher pooled AUCs were observed in boys as compared to girls (with an exception in BF%), suggesting that discrimination is more precise, on average, in boys. Logistic regression analyses showed that all different measures of adiposity were negatively and significantly associated with MC in both sexes, with the exception of WHtR for girls, after adjusting for cardio-respiratory fitness and mothers' education level (paper III). Finally, this study indicates that children of both genders with low gross MC had a higher probability of having low AA, after adjusting for cardiorespiratory fitness, body mass index, and socioeconomic status (paper IV).

Motor behaviour is an essential aspect of children development. Excessive levels of sedentary time (Colley et al., 2011) and obesity (Sardinha, Santos, Vale, Silva, et al., 2011) along with, low levels of childhood physical activity (Baptista et al., 2011; Colley et al., 2011), physical fitness (Tremblay et al., 2010) and MC (Maia & Lopes, 2007; Prätorius & Milani, 2004; Vandorpe et al., 2011), are major public health issues that may threaten the future development, health and well-being of young people (Reilly & Kelly, 2011; Strong et al., 2005; WHO, 2010). Furthermore, since it is know that motor development is interrelated with cognitive development, when there are perturbations (genetic or environmental) that affect motor system or cognition it is often the case that both motor and cognitive functions are affected (Diamond, 2000). Therefore, children's development cannot be separated easily into disconnected developmental domains (Smith et al., 1999), rather it is the whole child that needs our attention (Bowman et al., 2001). Additionally, it is know that early school motor skills assessment may increased the predictability of later achievement and the probability of identifying children at risk for school failure (Son & Meisels, 2006).

Recently, researchers has been studying possible implications of MC for talent identification purposes (Fransen et al., 2012; Vandendriessche, Vaeyens, et al., 2012; Vandendriessche et al., 2011; Vandorpe, Vandendriessche, Vaeyens, Pion, Lefevre, et al., 2012) as well as potential health-related and developmental benefits in childhood throughout the lifespan (Lubans et al., 2010; Vandorpe, Vandendriessche, Vaeyens, Pion, Matthys, et al., 2012). However, children's MC levels have been described as suboptimal. Indeed, our results show that 51.7% of our study participants were classified as having MC disorders or insufficiencies and none showed very good MC, according to the normative values of KTK test battery. These results are in line with those reported in a study with Portuguese children aged 6-10 years (Maia & Lopes, 2002). However, our MC numbers are considerably lower than those observed by others (Graf et al., 2004; Vandorpe et al., 2011). In a study with German children aged 6-9 years, Graf et al. (2004) found that only 31.3% of participants showed lower than normal MC. Vandorpe et al. (2011), in a study of Belgian children aged 6-11 years, found that only 21.1% demonstrated lower than normal MC. In the original German (1974) standardization sample with children aged 6-11, only 16% demonstrated lower than normal MC (Kiphard & Schiling, 1974). The low MC levels in Portuguese children may possibly be explained partially by the fact that Portuguese children have one of the highest rates of obesity in Europe (Sardinha et al., 2010). Indeed, several studies have described that overweight children have poor results on motor skill tests when compared with their normal-weight counterparts (Graf et al., 2004; Okely et al., 2004). Additionally, Portuguese children and adolescents have lower levels of PA (Baptista et al., 2011) compared to their European counterparts, a characteristic that correlates with low MC (Okely et al., 2001b). Furthermore, KTK norms and cut-off values are based on German children tested 36 years ago, while the literature has shown that children's physical fitness (Tomkinson et al., 2003) and PA (Knuth & Hallal, 2009) are declining; as motor skills are positively associated with both physical fitness (Hands et al., 2009) and PA (Williams et al., 2008; Wrotniak et al., 2006), perhaps MC levels are decreasing as well. Indeed, Prätorius & Milani (2004) have shown that over the last 30 years, the percentage of German children with low MC has increased substantially, from 16% in the KTK test's original validation to a level of 38% in contemporary children.

Sedentary behaviour has been acknowledged as an important contributor to the premature development of non-communicable disease (Tremblay, Leblanc, Kho, et al., 2011), separate and distinct from a lack of moderate- to vigorous-intensity physical activity (van

Uffelen et al., 2010). In children and adolescents, self-reported leisure-time SB such as overall screen time (i.e. TV viewing, videogames, computer use) has commonly been studied; however, while these activities may represent a substantial portion of the time spent in total SB, they do not represent the total amount of everyday sedentary time. In this regard, as has been argued for PA (Ruiz & Ortega, 2009), objectively measuring total sedentary time by using devices such as accelerometers may offer particular advantages, since these devices do not rely on subject recall and may capture the entire daily patterns of both PA and SB. This study assessed both PA and SB using accelerometry.

In literature, the relationship between SB and MC has been rarely studied and no study has analyzed this relation accounting for PA levels. Only four studies have analyzed the association between MC with SB, Cliff et al., (2009) and Graf et al., (2004) reported no association, while Williams et al., (2008) and Wroniak et al., (2006) reported a negative association. The present study show that high time spent in SB was a predictor of low MC, regardless of PA levels and other confounders. Our findings have important implications as they suggest that PA levels *per se* may not overcome the deleterious influence of high levels of SB on MC. These findings, in combination with the studies of Wroniak et al. (2006) and Williams et al. (2008) that indicate a positive relationship between motor skill performance and PA and an inverse association with sedentary activity in children (Williams et al., 2008; Wrotniak et al., 2006), may suggest a reciprocal relationship between SB and MC. In this context, we could speculate that providing children with alternatives to SB, namely daily physical education classes, opportunities for sports participation in and outside school, and school recesses more conducive to activity, could have a positive impact on their MC, which could in turn increase PA and decrease time spent in SB. However, further longitudinal and intervention studies are necessary to confirm or disprove this hypothesis.

Despite recent studies suggesting a stabilization or a plateau in the prevalence of childhood overweight or obesity in some countries (Lissner, Sohlstrom, Sundblom, & Sjoberg, 2010; Ogden, Carroll, Curtin, Lamb, & Flegal, 2010; Olds, Tomkinson, Ferrar, & Maher, 2010; Salanave, Peneau, Rolland-Cachera, Hercberg, & Castetbon, 2009), many children still have excessive body weight. In Portugal, a representative study in children aged 10 to 18 years found that the prevalence of overweight/obesity were about a third, which is one of the higher prevalence rates in Europe (Sardinha, Santos, Vale, Silva, et al., 2011). Therefore, a large variety of strategies is needed to fight this epidemic, and parents have crucial importance for prevention and treatment programs.

Discussion

Our findings agree with earlier studies that show that most parents do not correctly recognize their child's weight status (Baughcum et al., 2000; Campbell et al., 2006; Carnell et al., 2005; Eckstein et al., 2006; Jeffery et al., 2005; Maynard et al., 2003; Wake et al., 2002; West et al., 2008). Also, a recent review shows that in 19 of 23 studies reviewed, fewer than 50% of parents of overweight children recognize their child as overweight (Parry, Netuveli, Parry, & Saxena, 2008). This is a concern because the physical, social and emotional consequences of obesity may be evident in childhood and may persist into adult life (Dietz, 1998).

This study extends the existing literature on parental weight perceptions by including data on Portuguese children, one of the countries with the highest prevalence of overweight and obese children in Europe, for the first time (Sardinha, Santos, Vale, Silva, et al., 2011), and by presenting results of the mothers' perceptions of their child's weight status by BMI categories (underweight, normal weight, overweight/obese) according to the child's gender, the mothers' age, education level and weight status and family income.

Childhood obesity may lead to impaired cognitive and physical development (Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012). In fact, it is relatively well established in literature a relationship between adiposity and MC independently of the age group, namely in pre-school (Castetbon & Andreyeva, 2012) and elementary school children (Lopes et al., 2012), and adolescents (Okely et al., 2004), or the measurements considered, namely product (D'Hondt et al., 2011) or process-oriented (Castetbon & Andreyeva, 2012; Okely et al., 2004), or the nature of the study, namely cross-sectional (Graf et al., 2004) or longitudinal (D'Hondt et al., 2012; Lopes, Maia, et al., 2011).

Although, in literature there is no study that aims to determine the ability of different measures of adiposity to discriminate between low/high MC, others studies have used the same measures of adiposity to evaluate the relationship with MC that were used in our investigation, with exception to WHtR. Our study found that, in girls, BF% assessed by bioelectric impedance was the measure that best predicted low MC. BF% measurement techniques have been developed and validated for children; however, it has rarely been used in the literature regarding the relationship between adiposity and MC. The existing studies have found significant associations between BF% and MC, whether using skin folds (Lopes, Maia, et al., 2011), bioelectric impedance (J. Cairney, J. A. Hay, B. E. Faught, & R. Hawes, 2005) or whole body air displacement plethysmography (Silman et al., 2011) methods. In boys, we found that WC is the measure that best predicted low MC. Similarly in a longitudinal study, Cairney et al., (2010) also found associations between MC and WC.

Faught et al., (2005) found an association between poor MC with increased body fat and low cardiorespiratory fitness (physical activity was a significant mediator for both relationships). These authors concluded that poor MC is related to factors associated with increased risk for coronary vascular disease, including decreased cardiorespiratory fitness and increased body fat through the mediating influence of physical activity in children.

While the relationship between PA and physical fitness with academic achievement (AA) has been thoroughly explored (Ahamed et al., 2007; Carlson et al., 2008; Castelli et al., 2007; Chomitz et al., 2009; Coe et al., 2006; Etnier et al., 2006; Eveland-Sayers et al., 2009; Fox et al., 2010; Grissom, 2005) (Hillman et al., 2008; Kwak et al., 2009; Niederer et al., 2011; Rasberry et al., 2011; Ruiz et al., 2010b; Sigfusdottir et al., 2007; Strong et al., 2005; Taras, 2005; Trudeau & Shephard, 2008), little, is known about the relation between of gross MC and AA in elementary school children without intellectual disabilities.

Our results suggest that low MC may be a predictor of low AA. This findings are corroborate by others cross-sectional (Knight & Rizzuto, 1993; Nourbakhsh, 2006; Planinsec, 2002) and longitudinal (Piek et al., 2008; Son & Meisels, 2006) studies, however, those studies were in different age group (i.e. pre-scholars) and/or with other cognitive variables. Recently a 9 years longitudinal study, in Swedish children followed from 7-9 years of age until they were 16 years old and left compulsory school, found that by including daily physical education and health in the school curriculum and one hour per week of motor skills training in pupils with specific needs, improvements could be achieved in motor skills, school results, and the proportion of pupils who qualify for upper secondary school. This study suggested for the first time that there is not only an association, but actually that a population-based intervention strategy with increased physical activity and motor skills training could improve school performance (Ericsson & Karlsson, 2012).

Given the importance of assessment and evaluation in the education and health fields and the pressures that educational agents are under to achieve academic success for all students, indicators of educational achievement, health, and functional status may allow educators and policy makers to make better informed decisions (Lloyd et al., 2010). Therefore, understanding the relationship between MC and AA is important for ensuring the appropriate assignment of resources as well as the implementation of programs to develop children's health-related behaviours. This study highlights the necessity of providing opportunities for children to engage in PA structured and unstructured that promote a diversity of motor skills, since gross MC seems to play such an important role in AA.

Discussion

Schools are excellent settings in which to provide students with the opportunity for daily PA, to teach the importance of regular PA for health, and to build skills that support active lifestyles. Promoting active lifestyles from a young age is widely recognized as beneficial, and the health benefits of regular PA are extensively acknowledged (Andersen et al., 2006; Strong et al., 2005). The incorporation of PA into daily life and the achievement of recommended PA levels for the maintenance of good health are major public health challenges. Physical education lessons and school recesses are ideal settings in which to develop children's fundamental movement skills and increase PA and fitness (van Beurden et al., 2003), while also contributing to one of the primary missions of schools, i.e. the promotion of academic performance (Dwyer et al., 2001).

5.1 Strengths and limitations

This study has some limitations that need to be recognized. First, the data has been derived from a cross-sectional study and therefore results do not indicate causality. Second, accelerometers do not identify PA or sedentary patterns or contexts, and the accelerometers used in this study do not allow us to distinguish the type of sedentary behaviour (i.e. lying, sitting or standing still). Third, mothers' height and weight were self-reported and it is known that self-reported weight status underestimates the true prevalence of being overweight and obese, especially in women (Yun, Zhu, Black, & Brownson, 2006). Indeed, 58% of the mothers in our study were classified as normal weight, which is higher than the prevalence reported for Portuguese women (48.9%) using objectively measured weight and height (do Carmo et al., 2008). Fourth, our sample is not representative of the Portuguese population and therefore our findings are not generalizable.

The strengths of our study comprise:

In paper I - the novelty of the analyses of the associations between SB and MC; the objective assessment of both total MVPA and total sedentary time (most previous studies have limited their analysis to self-reported leisure time SB and/or PA); and the use of a cut-point of <100 counts.min^{-1} to identify sedentary behaviour, as this cut-off was shown to have an excellent classification accuracy (Trost et al., 2011).

In paper II - the inclusion of data on Portuguese children, one of the countries with the highest prevalence of overweight and obese children in Europe, for the first time (Sardinha, Santos, Vale, Silva, et al., 2011); the insertion of results of the mothers' perceptions of their child's weight status by BMI categories (underweight, normal weight, overweight/obese) according to the child's gender, the mothers' age, education level and weight status and family income; and the high response rate (83.7%).

In paper III - the inclusion of potential confounding factors such as mother's education level (used as a proxy measure of socioeconomic status), which is recognized as having a powerful and synergistic relationship with obesity (Ulijaszek, 2012); the presence of cardiorespiratory fitness as a potential confounding element, due to its importance of being simultaneously linked to adiposity and MC (i.e., inversely associated with adiposity and positively related to MC) (Faught et al., 2005; Lopes, Maia, et al., 2011); and the novelty of the study, to determine the ability of different measures of adiposity to discriminate between low and high MC.

In paper IV - the use of direct indicators of AA, namely, scores on standardized national exams; the inclusion of potential confounding factors such as socioeconomic status, which is recognized as a major factor in academic performance (Coe et al., 2006); the use of cardiorespiratory fitness, because it was suggested that this could mediate the relationship between PA and AA (Kwak et al., 2009); and the use of body mass index, which has been documented as inversely related with MC (Graf et al., 2004; Okely et al., 2004).

6. Conclusions

Adequate levels of MC in children have essential importance since it were found to be positive related with health-related behaviours and cognitive outcomes.

In both genders the percentage of time spent in SB was negatively associated with MC, independently of MVPA and other confounders. Our findings suggest that PA levels *per se* may not overcome the deleterious influence of high levels of SB on MC. Our data stress the importance of discouraging SB among children to improve MC (paper I).

Many mothers do not properly recognize their children's weight status and frequently underestimate their children's body size. The results of this study highlight the need to educate parents about obesity and the negative impact of excess fat accumulation on their child's health and well-being (paper II).

BF% and WC showed a slightly better discriminatory accuracy in predicting low MC for girls and for boys, respectively. BMI, WC, BF% and WHtR were positively and significantly associated with MC in both sexes, with the exception of WHtR in girls after adjustments (paper III).

Children of both genders with lower MC had higher odds of having low AA, after adjusting for potential confounding factors. The early identification of children with poor MC is crucial to implementing activities that develop health-related behaviours (paper IV).

6.1 Future Directions

The importance of an adequate level motor coordination in childhood has recently re-emerged in literature. Well design cross-sectional studies should further describe motor coordination levels and correlates; and explore the associations with motor coordination and other variables (genetic and/or environmental) contributing to build and strengthen the existing knowledge on this topic. Relations between motor coordination, adiposity, physical activity, sedentary behaviour, physical fitness and academic achievement should be addressed with longitudinal and intervention studies to further explore the nature and the direction of associations.

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8. Annexes

Paper V

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Associações entre actividade física, habilidades e coordenação motora em crianças portuguesas

Association between physical activity and motor skills and coordination in Portuguese children

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Resumo – Actualmente, existe na literatura a evidência unânime, que a prática actividade física (AF) regular é benéfica para a saúde. A variação na AF nas crianças é resultado de vários factores, nos quais se incluem as habilidades motoras fundamentais (HMF) e a coordenação motora (CM). Analisar a relação entre a AF habitual e as HMF, e a CM em crianças de ambos os sexos com idades de 6 e 7 anos. A amostra foi constituída por 21 crianças com uma idade média de 6,38±0,50. A actividade física habitual foi avaliada por acelerometria, as habilidades motoras fundamentais usando o Test of Gross Motor Development (TGMD-2) e a coordenação motora através do Körperkoordination Test für Kinder (KTK). As crianças deste estudo cumprem as recomendações internacionais de AF regular. No KTK, a maioria das crianças (52,4%) apresentou perturbações da CM e insuficiências co-ordenativas, 47,6% valores correspondentes a uma CM normal, nenhum sujeito apresentou uma CM boa ou muito boa; no TGMD-2, para a avaliação locomotora, 76,2% das crianças situam-se acima do percentil 50 (P50), na avaliação do controlo de objectos, 28,6% atingem o P50 ou superior, e para o score total do teste, 38,1% alcançam o P50 ou superior. A AF habitual correlacionou-se positivamente com o TGMD-2 controlo de objectos. Estas crianças apresentaram resultados baixos, indiciadores de possíveis insuficiências do desenvolvimento coordenativo e de pobre desenvolvimento das HMF, pelo que se considera que deviam ser alvo de uma especial intervenção, nomeadamente na área da Educação Física.

Palavras-chave: Actividade Física; Habilidade Motoras Fundamentais; Coordenação Motora; Acelerómetros.

Abstract – *Nowadays, there is growing evidence in literature that Health benefits from regular physical activity (PA). The variance in PA among children is caused by a number of factors including their motor abilities and coordination. The aim of the study was to analyse the relation between usual PA and gross motor abilities and motor coordination in children aged 6 to 7 years. The sample comprised 21 children, aged in average 6,38±0,50 years. Physical activity was accessed by accelerometry, gross motor abilities by using the Test of Gross Motor Development (TGMD-2) and motor coordination by using the Körperkoordination Test für Kinder (KTK). Subjects met the international recommendations for daily PA; in motor coordination 47,6% of children met normal coordination, nobody reach good or very good coordination, the majority (52,4%) revelled disturbances or insufficiencies of coordination; in locomotion TGMD-2 76,2% of the children met percentile 50 or superior (P50), in object control TGMD-2 28,6% of the children reach P50 or superior, in total TGMD-2 38,1% of the children met P50 or superior. PA was positively correlated with TGMD-2 object control. Low performance attributed to the children in TGMD-2 and KTK tests could be an indicative of insufficient in the development of coordination and gross motor abilities; therefore we believe that this kind of intervention should be targeted at school children mainly in Physical Education classes.*

Key words: *Physical Activity; Gross Motor Abilities; Motor Coordination; Accelerometers.*

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INTRODUÇÃO

O processo do desenvolvimento motor revela-se basicamente por alterações no comportamento motor ao longo do ciclo de vida, proporcionado pela interacção entre as necessidades da tarefa, a biologia do indivíduo e as condições do ambiente[1].

Se o movimento serve como janela para o processo de desenvolvimento motor, então, a forma de o estudar é pelo exame da progressão sequencial das habilidades motoras ao longo de toda a vida[1]. Por conseguinte, habilidade representa a colecção de "equipamento" que uma pessoa tem ao seu dispor, determinando se uma tarefa motora pode ser bem ou mal desempenhada[2]. A execução de habilidades motoras, qualquer que seja o seu nível, requer um conjunto variado de aptidões que podem ser designadas genericamente por coordenação motora (CM), existindo, porém, alguma dificuldade na sua definição, dado que o uso de termos como agilidade, destreza ou controlo motor como seus sinónimos complicam a sua operacionalização[3].

De acordo com Newell[4], a CM deve ser analisada no contexto das acções motoras e não dos movimentos, uma vez que o movimento pode ser considerado condição necessária mas não suficiente para a acção, assim sendo, este apenas faz sentido no âmbito da acção motora[5]. Meinel e Schnabel[6] referem que, quando da realização de uma acção motora, devem ocorrer vários processos motores, sensoriais, verbais e de pensamento, sendo parcialmente visíveis, pelas características externas no decorrer do movimento. A CM é a harmonização destes processos, tendo em vista a realização da acção motora. Mesmo os mais simples movimentos (acções) requerem a organização de várias e independentes partes do sistema motor[2].

Estudos realizados têm-se revelado inconsequentes na tentativa de identificar as componentes da CM. Maia e Lopes[5] referem que cada tarefa ou acção motora requer uma combinação particular de componentes. Para Kiphard e Schiling[7] a CM é a interacção harmoniosa e económica do sistema músculo-esquelético, do sistema nervoso e do sistema sensorial a fim de produzir acções motoras precisas e equilibradas e reacções rápidas adaptadas à situação, exigindo: i) uma adequada medida de força que determina amplitude e velocidade do movimento; ii) uma adequada selecção dos músculos que influenciam a condução e orientação do movimento; iii) a capacidade de alternar rapidamente entre tensão e relaxamento musculares.

Segundo Meinel e Schnabel[6] a CM pode ser analisada segundo três pontos de vista: i) biomecânico, relativo à ordenação dos impulsos de força numa acção motora e a ordenação de acontecimentos em relação a dois ou mais eixos perpendiculares; ii) fisiológico, relacionando as leis que regulam os processos de contracção; iii) pedagógico, respeitante à ligação ordenada das fases de um movimento ou acções parciais e a aprendizagem de novas habilidades.

O papel do movimento no desenvolvimento das crianças é por vezes subestimado. Vários alertas têm chamado a atenção para o problema das crianças de hoje não encontrarem oportunidades suficientes para realizarem AF no dia-a-dia, quer em actividades escolares, quer em actividades de participação voluntária, espontâneas ou organizadas, de forma a obter benefícios para a saúde[8].

De uma forma geral, as actividades das crianças, como saltar, correr, dançar, andar de bicicleta, proporcionariam um grande volume de actividade e uma larga variedade de movimentos[9] onde a actividade vigorosa acontece de forma intermitente[10]. Mas tem-se verificado que o nível de AF durante o tempo livre tem declinado significativamente, apresentando-se abaixo das expectativas[11].

O ambiente e as condições de vida actuais tornam difícil para muitas crianças adquirirem experiências motoras, contrariando as suas necessidades específicas. Mudanças em termos da condição de vida implicam alterações nas condições para o desenvolvimento. A falta de movimento pode não só levar a um restringir do corpo e do desenvolvimento motor, como pode influenciar aspectos da personalidade como a percepção, a cognição, o discurso, as emoções, e o comportamento social[12].

Vários estudos mostram um deteriorar das habilidades motoras das crianças nas décadas mais recentes. Experienciar um grande e variado leque de movimentos ajuda as crianças não só ao desenvolvimento da auto-percepção, como também a perceber o ambiente que as rodeia[12]. Além do mais, aprendem mais facilmente novos movimentos, beneficiando-se dos movimentos anteriormente adquiridos, obtendo mais sucesso nas actividades realizadas e retirando delas mais prazer[13].

A AF começa na infância com o erguer, o virar, o gatinhar, o andar e progride para actividades mais complexas à medida que o controlo neuromuscular se desenvolve. Os padrões básicos de movimentos desenvolvem-se durante as idades pré-escolares, servindo de base para um leque variado de AF à medida que a idade avança. Com o crescimento, a maturação e a experiência os movimentos básicos são integrados e coordenados em movimentos e acções mais especializados e complexos que caracterizam as brincadeiras, os jogos, os desportos e outras actividades da adolescência[14].

Em idade escolar, a manutenção de níveis adequados de AF visa, sobretudo, o crescimento e desenvolvimento saudável e normal, para além da criação de hábitos de AF que se irão prolongar ao longo da vida[15].

De uma forma geral, quando realizados testes, as crianças activas em relação às inactivas (menos activas), apresentam melhores resultados, em termos motores, de força e ao nível da capacidade cardiovascular[16]. Num recente estudo longitudinal em crianças dos 6 aos 10 anos de idade, que relacionava CM, aptidão física e AF, os autores encontraram uma relação significativa da CM aos 6 anos com a AF aos 10 anos de idade, ou seja, o resultado encontrado indicou que a CM foi um importante preditor da AF[17].

Na literatura, são escassos os estudos que permitem aferir o grau de desenvolvimento das habilidades motoras fundamentais e da CM em crianças. A AF aferida objectivamente (acelerometria) é um fenómeno recente e de interesse crescente, apesar de existirem já alguns estudos nesta área, não conhecemos nenhuma investigação que relacione a AF à CM e as habilidades motoras fundamentais em crianças.

Neste contexto, os objectivos deste estudo foram verificar a relação entre a actividade física habitual, o desenvolvimento das habilidades motoras fundamentais e a coordenação motora, de crianças de ambos os sexos, com idades entre os 6 e os 7 anos.

PROCEDIMENTOS METODOLÓGICOS

O trabalho de campo foi realizado numa escola pública do norte de Portugal na primavera de 2006.

O protocolo e os procedimentos utilizados neste estudo respeitaram a Declaração de Helsínquia para a investigação em sujeitos humanos e foi aprovada pela Comissão Científica do Instituto de Educação da Universidade do Minho. Explicaram-se os objectivos do estudo, os procedimentos a adoptar e solicitou-se autorização para participar no estudo, ao Director da escola e aos Encarregados de Educação. Foi garantida a participação voluntária das crianças e assegurou-se a confidencialidade dos dados recolhidos.

Amostra

A amostra foi constituída por 21 alunos de duas turmas do 1º ano de escolaridade (13 meninas e 8 rapazes), com 6 e 7 anos de idade.

INSTRUMENTOS UTILIZADOS E VARIÁVEIS RECOLHIDAS

Actividade Física

A AF foi avaliada por acelerometria, utilizando o monitor de actividade MTI *ActiGraph* (*Manufacturing Technology Incorporated*, MTI).

A característica chave do programa é a conversão das contagens por segundo do MTI *ActiGraph* em unidades de dispêndio energético relativo (METs). As contagens são convertidas em unidades de dispêndio energético, utilizando a equação de regressão desenvolvida por Freedson et al.[18], para crianças dos 6 aos 18 anos de idade: METs = 2.757 + (0.0015 x *counts*/min) – (0.0896 x idade em anos) – (0.000038 x *counts*/min x idade) (r^2 = 0,90; SEE = 1,08 METs).

A equação é utilizada para derivar os valores de corte do número de contagens a que corresponde determinado valor de gasto energético em METs. De acordo com os valores de corte, o programa calcula para cada criança os minutos totais de cada uma das seguintes categorias de actividade física: AFM (3-5.9 METs); AFV (6-8.9 METs); AFMtoV (≥ 9 METs)[19], cujo somatório foi designado de AFtotal.

Para conseguir um quadro representativo da AF habitual e para uma maior fiabilidade dos resultados, os MTI *Actigraphs* foram utilizados sete dias consecutivos. Utilizou-se 1 minuto por *epoc*.

Habilidades Motoras Fundamentais

As habilidades motoras fundamentais foram avaliadas com o Teste de Desenvolvimento das Habilidades Motoras Fundamentais (grosseiras) (*Test of Gross Motor Development, Second Edition* – TGMD-2)[20].

O TGMD-2 é um teste adequado para a faixa etária dos 3 aos 10 anos de idade e consiste numa avaliação normativa das habilidades motoras globais comuns. O teste encontra-se dividido em dois tipos de avaliação, ou duas sub escalas (dividido em doze itens):

1) Avaliação locomotora: corrida (*run*), galope (*gallop*), pé-coxinho (*hop*), pulo/salto (*leap*), salto horizontal parado (*horizontal jump*), deslocamento lateral (*slide*);

2) Avaliação controlo de objectos: batimento numa bola estática (*striking a stationary ball*), drible sem deslocamento (*stationary dribble*), agarrar (*catch*), pontapear (*kick*), lançamento por cima do ombro (*overhand trow*), lançamento da bola por baixo (*underhand roll*).

Este teste permite uma avaliação separada para as duas sub escalas (locomoção e controlo de objectos), no entanto, não permite a avaliação separada de cada habilidade motora, dado que elas estão integradas num modelo estatístico que valida o teste.

O teste foi aplicado, de acordo com as descrições originais, tendo cada criança realizado três repetições em cada teste. A pontuação atribuída era de um ponto se atingisse o critério e zero se não o atingisse. De acordo com protocolo, foi usada uma câmara de vídeo para registo. Os resultados foram analisados por dois observadores previamente treinados, atendendo aos critérios de êxito e respectivas pontuações. Recorreu-se a um terceiro observador sempre que não havia concordância para um resultado.

De acordo com o protocolo do teste e usando as tabelas fornecidas pelo autor, a soma dos resultados obtida para cada avaliação (locomotora e controlo de objectos), atendendo à idade (avaliação locomotora e controlo de objectos) e ao sexo (avaliação controlo de objectos) de cada criança, foi convertia num *score* (resultado), cuja amplitude varia de 1 a 20. A soma desses *scores* (TGMD-2 total) converte-se em percentis ou quociente (baseado nas tabelas fornecidas pelo autor).

Para melhor compreensão dos resultados, optou-se por dividir os resultados em três percentis: habilidade motora baixa, menor que o percentil 50 (<P50); habilidade motora normal, entre o percentil 50 e o percentil 75 (≥P50 e < P75); e habilidade motora boa, acima do percentil 75 (≥P75).

Coordenação Motora

Para avaliar a CM, foi escolhido o Teste de Coordenação Corporal para Crianças (Körperkoordination Test für Kinder - KTK)[21].

Desenvolvido por Schilling[21], o KTK consiste numa bateria de testes que, no global, pretende avaliar a CM grosseira, e constitui-se por quatro itens: i) Equilíbrio em marcha à retaguarda; ii) Saltos monopedais; iii) Saltos laterais; iv) Transposição lateral.

O teste foi realizado, obedecendo às descrições originais. O quociente motor (QM) obtido a partir da bateria KTK resulta do somatório do QM obtido em cada item. O QM de cada item obtém-se transformando a pontuação obtida em cada item do teste, a partir da consulta das tabelas normativas respectivas que constam no manual da bateria. O QM permite classificar as crianças segundo o seu nível de desenvolvimento coordenativo: (1) Perturbações da coordenação (QM inferior a 70); (2) Insuficiência coordenativa (QM ≥71 e ≤85); (3) Coordenação normal (QM ≥86 e ≤115); (4) Coordenação boa (QM ≥116 e ≤130) (5) Coordenação muito boa (QM ≥131 e ≤145).

Medidas antropométricas

O Peso e a altura foram avaliados com a balança digital marca *Seca* modelo 708.

O peso foi registado com o aluno descalço e vestindo roupas leves, o resultado corresponde à média de duas avaliações efectuadas. Os resultados foram expressos em kg com aproximação a 0,1kg. Sempre que existia uma diferença entre os valores, superior a 0,2 kg, foi efectuada uma nova pesagem.

A altura foi retirada da medida entre o *vertex* (ponto acima da cabeça, no plano mediano-sagital) e o plano de referência do solo, mantendo a atitude antropométrica estável. As medidas foram registadas em centímetros com a aproximação à primeira casa decimal. Sempre que existia uma diferença entre medições, superior a 2 mm, era obtida uma terceira medição, através da qual se registava uma média dos valores verificados. As avaliações foram intercaladas entre peso e altura: à primeira avaliação do peso e altura seguiram-se as segundas avaliações de peso e altura.

Procedimentos Estatísticos

Foram avaliadas as distribuições das diferentes variáveis quanto à existência de *outliers* e quanto à normalidade. A variável AFMtoV utilizada para o cálculo da AF total sofreu uma transformação logarítmica uma vez que a sua distribuição não era normal.

Fez-se uma análise correlacional bivariada entre todas as variáveis estudadas, através da Correlação de Pearson.

O programa estatístico utilizado na análise dos dados foi o SPSS, versão *17.0* para o *Windows*. O nível de significância foi colocado a 5% ($p<0.05$).

RESULTADOS

Na Tabela 1, apresentam-se as medidas descritivas (valores mínimos, máximos, médias e desvios-padrão) da amostra total (n=21) para a idade, o tempo total em AF habitual (AFtotal em minutos

Tabela 1. Características da amostra das variáveis em estudo (valores mínimo, máximo, média e desvio padrão).

	Mín.	Máx.	Média ± DP
Idade	6	7	6,38 ± 0,50
AF Total (min/sem)	918	2 659	1 522 ± 501,21
KTK (quociente motor)	62	102	84,86 ± 12,44
TGMD-2 Av. Locomotora	32	48	41,43 ± 3,91
TGMD-2 Av. Controlo Objectos	23	44	32,86 ± 6,81
TGMD-2 Total	12	27	19,48 ± 3,44

Tabela 2. Percentagem de crianças por percentis no TGMD-2.

Variáveis	< P50	≥ P50 < P75	≥ P75
Locomotora	23,8	42,9	33,3
Controlo dos objectos	71,4	23,8	4,8
Total	61,9	23,8	14,3

por semana), o quociente motor (KTK), a avaliação locomotora (TGMD-2), a avaliação do controlo de objectos (TGMD-2) e o conjunto da avaliação locomotora e a avaliação do controlo de objectos (TGM-2 total).

Relativamente à AFtotal, todos os sujeitos da amostra cumprem as recomendações internacionais de AF diária para crianças (420 min/sem de AF moderada a vigorosa).

Ao analisar os dados do KTK, verifica-se que apenas 47,6% das crianças apresentam um QM correspondente a uma CM normal. Salienta-se, ainda, o facto de nenhum sujeito apresentar uma coordenação boa ou muito boa. A maioria das crianças (52,4%) apresentou perturbações da coordenação e insuficiências coordenativas (figura 1).

Na Tabela 2, apresentam-se os resultados do TGMD-2, em valores percentuais, para a amostra total, TGMD-2 avaliação locomotora e TGMD-2 avaliação do controlo de objectos, definidos pelos percentis: menor que o percentil 50 (< P50); entre o percentil 50 e menor que o percentil 75 (≥ P50 < P75) e maior ou igual ao percentil 75 (≥ P75).

No que respeita à avaliação locomotora do teste TGMD-2, observa-se que a maioria (76,2%) das crianças se situa acima do percentil 50 (P50) (Tabela 2).

Na avaliação do controlo de objectos do teste TGMD-2, apenas 28,6% dos sujeitos atingem o P50 ou superior (Tabela 2).

Quando se analisa o TGMD-2 total, constata-se que 38,1% das crianças alcançam o P50 ou superior (Tabela 2).

Para a amostra total, fez-se uma análise correlacional entre a AF total e o KTK e a AF total e o TGMD-2 (Tabela 3). Verificaram-se correlações positivas, estatisticamente significativas, entre: a AF total e o TGMD-2 (avaliação controlo de objectos).

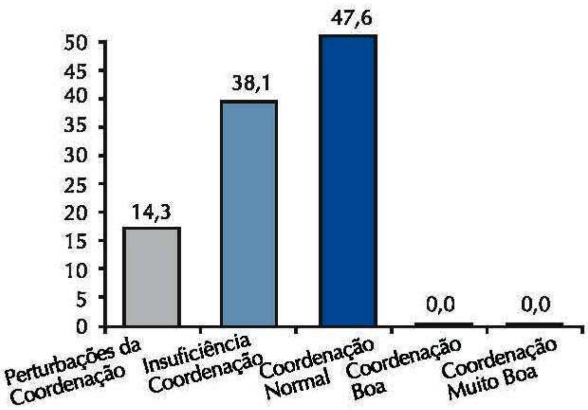

Figura 1. Percentagem de crianças por nível de desempenho no KTK.

Tabela 3. Matriz de correlação *de Pearson* entre a AF total e o KTK; a AF total e o TGMD-2.

		AF total (min/sem)
TGMD-2 Locomotora	Correlação	0.201
	Sig.	0.382
TGMD 2 Controlo Objectos	Correlação	0.593*
	Sig.	0.005
TGMD 2 Total	Correlação	0.331
	Sig.	0.143
KTK (quociente motor)	Correlação	0.171
	Sig.	0.460

DISCUSSÃO

Os objectivos do presente estudo foram analisar a existência de uma relação entre a AF habitual as habilidades motoras fundamentais e a CM.

Relativamente à AF habitual, todos os sujeitos da amostra realizam mais de 420 min/sem de AF moderada a vigorosa, cumprindo as recomendações internacionais de AF diária para crianças necessária para a manutenção de um bom estado de saúde. O que vai ao encontro a outros estudos realizados com crianças portuguesas, nomeadamente, Mota et al.[22] e Mota et al.[23]. No entanto, estes resultados são contrários a outras investigações, nomeadamente em Portugal por Maia e Lopes[5], em Inglaterra por Armstrong e Welsman[24] e nos Estados Unidos da América pelo CDC[25] em que a generalidade das crianças não cumpre as recomendações de AF.

No que se refere as habilidades motoras fundamentais, aferidas através do TGMD-2, na avaliação Locomotora, apenas 23,8% dos sujeitos se situa abaixo do P50. Na avaliação controlo de objectos, 71,4% situam-se abaixo do P50, no TMGD total, 61,9% das crianças estão abaixo do P50. Estes resultados são inferiores aos encontrados em Bonifacci[26], onde só 10,4% das crianças estavam abaixo do P50, no TGMD total.

Quando comparados os resultados da avaliação locomotora e da avaliação controlo de objectos, no que concerne à percentagem de crianças abaixo do P50, observa-se uma grande disparidade entre eles (23,8% e 71,4%, respectivamente). Estes dados poderão ser indiciadores de uma falta de experiências com a manipulação de objectos.

Os resultados do KTK permitiram verificar que apenas 47,6% das crianças apresentam uma CM normal (ninguém apresentou coordenação boa ou muito boa), o que significa que na sua maioria (52,4%) os alunos apresentaram insuficiência coordenativa e perturbações da coordenação. Quando comparados com outros estudos que também utilizam o KTK, verificamos que os nossos resultados são inferiores aos encontrados por Lopes et al.[3], que apresentavam já resultados inferiores aos de Kiphard e Schilling[7] na década de 70. O que corrobora a ideia e as evidências da literatura de que as crianças vêm apresentando cada vez mais baixos resultados.

Tal como seria de esperar, verificam-se correlações significativas entre a AF habitual e o TGMD-2 (avaliação controlo de objectos). Contrariamente às nossas expectativas iniciais, não se encontraram correlações significativas entre a AF habitual e o KTK, o TGMD-2 (avaliação Locomotora), o TGMD total. Num estudo com 25 crianças com uma idade média de 12,4 anos, Schmucker et al.[27] encontraram correlações significativas entre a AF habitual e o KTK e as habilidades motoras básicas. Refira-se, no entanto, que a amostra do nosso estudo tem uma idade média inferior à de Schumucker et al.[27] e que quer as habilidades motoras, quer a AF foram avaliadas com instrumentos diferentes, daí que as comparações se tornem difíceis. De facto, será sempre de esperar que as crianças mais activas sejam aquelas que apresentem um maior reportório motor e, consequentemente, uma melhor CM e um desempenho mais elevado das habilidades motoras fundamentais, desde que a qualidade e quantidade de AF sejam adequadas às suas idades e ao seu desenvolvimento. Ora, no nosso estudo, parece-nos que o facto de 62% da nossa amostra estar abaixo do P50 no TGMD-2 total e de 52,4% apresentarem perturbações da coordenação ou insuficiências coordenativas no KTK, poderá ser explicado não pela falta de AF (em termos de quantidade), uma vez que todas as crianças deste estudo fazem pelo menos 60 min/dia em média de AF, mas provavelmente pela falta de riqueza (em termos de qualidade dos estímulos). Importa, contudo, ressalvar a pequena dimensão da nossa amostra, bem como, o facto de os acelerómetros nada nos dizer sobre a qualidade e riqueza dos estímulos da AF.

Este estudo tem como limitação a pequena dimensão da amostra.

CONCLUSÃO

As crianças deste estudo cumprem as recomendações internacionais de AF habitual.

No que diz respeito às habilidades motoras fundamentais e à CM, os sujeitos deste estudo apresentam resultados baixos, indiciadores de possíveis insuficiências do desenvolvimento coordenativo e de pobre desenvolvimento das habilidades motoras fundamentais, pelo que se considera que deviam ser alvo de uma especial intervenção na área da Educação Física. Apenas foram encontradas correlações significativas entre a AF habitual e o TGMD-2 (avaliação controlo de objectos). Neste contexto, parece ser importante recorrer a materiais de jogo e estratégias, no sentido de aumentar, adequar e diversificar a riqueza dos estímulos, nomeadamente nas aulas de EF e nos recreios escolares, garantindo um desenvolvimento motor integral das crianças.

Em termos de indicações para o futuro, salienta-se a necessidade da realização de mais estudos, com amostras representativas e de carácter longitudinal, cujos resultados sirvam de suporte para a definição de programas de intervenção que visem o incremento da quantidade e qualidade da AF na infância.

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Paper VI

(Published)

Physical Activity Levels in Normal Weight and Overweight Portuguese Children: an Intervention Study during an Elementary School Recess

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Abstract

This study aimed to analyze the effects of an intervention strategy during the school recess on physical activity (PA) levels, by gender, age and body mass index (BMI). The sample comprises 158 Portuguese children aged 6 to 12 years. Weight and height were objectively measured. PA was assessed by accelerometry during the recess in pre-intervention and post-intervention periods. Introduction of extra outdoor play equipment was used as an intervention strategy. Significant interaction effects were found for the following areas: percentage of time spent in PA ($F_{(1,150)}$=70.157;p<0.001), intervention X age group ($F_{(1,150)}$= 24.416;p<0.001) and gender X age group ($F_{(1,150)}$=6.919;p=0.009); the time spent in Moderate PA for intervention X gender ($F_{(1,150)}$=15.290;p<0.001) and BMI X gender ($F_{(1,150)}$=6.411;p=0.012); the time spent in Vigorous and Very Vigorous PA ($F_{(1,150)}$=54.790;p=0.001), intervention X age group ($F_{(1,150)}$=9.490; p=0.002), intervention X gender ($F_{(1,150)}$=14.161;p<0.001) and BMI X gender ($F_{(1,150)}$=5.049;p=0.026). It appears that successful recess interventions to improve PA for children in elementary scholars are possible by providing relatively inexpensive play equipment.

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Key words: *Physical Activity; Accelerometry; School Recess; Children; Intervention.*

Introduction

The health and behavioral benefits of Physical Activity (PA) in childhood and adolescence are well known.[1] Current PA guidelines for children recommend moderate-to-vigorous physical activity (MVPA) for at least 60 min a day.[1-3] Although, some authors suggest 90 min of MVPA a day to prevent clustering of cardiovascular disease risk factors.[4]

The increased prevalence of overweight and obesity among children in developed countries,[5-7] including Portugal,[8, 9] combined with the large proportion of children that do not accomplish PA recommendations are important public health concerns.[4,10,11]

Schools are potential environment to develop and promote healthy behaviors among children, since children spent a considerable amount of their waking hours in school. In the school setting, recess provides important daily opportunity for children to be physically active and has additional educational and developmental benefits,[12] including social (e.g., sharing, cooperation, communication, problem solving, conflict resolution, and self-discipline), emotional (e.g., stress relief, self-esteem, character development), and cognitive (e.g., creativity, problem solving, and vocabulary) aspects.[13]

Recently, some studies have objectively examined PA levels, PA patterns, and the effects of interventions during the school recess. Yet, little is known about how PA levels are affected by an intervention, according to children's weight status.

Literature in school recess shown that boys usually engage in more PA than girls regardless of the age and method used to assess PA.[14-21] However, Mota et al [22] found the opposite; and they also found that PA during school recess may contribute to the achievement of the daily PA recommendations in 6% up to 9% in MVPA.[20, 22] One study also found a significant interaction between BMI category and sex for the percent of recess time spent in moderate PA (MPA) and vigorous PA (VPA).[23]

A limited number of studies have examined intervention programs for the purpose of promoting PA during the school recess. Supervision,[24] encouragement,[25] multicolor playground markings,[26, 27] play equipment,[19, 28] and, increasing time spent in recess[18, 29] are examples of successful low-cost interventions for increasing children's daily PA. Playground redesign, which utilizes both multicolor playground markings and changes in the physical structures, is another example of a successful intervention.[30]

In order to build more activity-friendly playgrounds it is necessary to know more about the factors that influence PA in this young age group[28] and, at the same time, to understand how children respond to different types of interventions.

Purpose of Study

The purpose of this study was to examine the effects of an intervention during the school recess on PA levels, by gender, age and body mass index (BMI), in children. Studies designed to increase PA during recess with Portuguese children are lacking. This study will help to better understand how PA levels (objectively measured) during the school recess are affected by an intervention, according to children's weight status. This new study will be able to add to the literature since most studies have limited their examination to differences between genders and age groups only.

Methods

Subjects

For this study, the sample included all children (n=182) from two elementary schools, with comparable outdoor playground space (about 400 m^2 area without play structures and equipment) and school schedule (from 8.00 to 13.00 am). Twenty-four children were excluded from the analysis due to sickness or absence in one of the two measurements. Therefore, the final sample included 158 children (81 from one school and 87 from the other) aged 6 to 12 years old (92 girls and 66 boys). Data was collected in two consecutive weeks in the spring of 2006, baseline information in the first week and post intervention in the second week.

Children were grouped according to their age in two groups: 6-7 years old; 8 or older than 8 years old.

The protocol and procedure employed in this study followed the Helsinki Declaration for investigation in Human Subjects and was approved by the University Ethic Committee. Data was kept confidential and informed written consent was obtained from the schools principals as well as from the children's parents or guardians.

Instruments

PA was assessed with Actigraph accelerometer (The Actigraph, LLC., Pensacola, FL, USA, formerly the Manufacturing Technology Incorporated (MTI) Actigraph, and the Computer Science Applications accelerometer). The validity of the Actigraph has been established with indirect calorimetry[31] (r = 0.86) and doubly labeled water [32] (r = 0.39 to r = 0.58) as criterion measures. The Actigraph (5.1 x 4.1 x 1.5 cm, 43g) measures uni-axial accelerations within the dynamic range of 0.5 to 2.00 G with a frequency from 0.25 to 2.75 Hz. Measurements are made 10 times per second and summed over a user-defined time period (*epoch period*) for data storage. In this study the epoch period was set to 1 minute. Although shorter sampling interval periods are sometimes used for estimating activity in young children, 1-min intervals are widely used in older children. In order to have a common interval for the entire sample as has been done in previous studies with this type of accelerometer a 1-min time sampling interval was used.[33] The limitation is a possible underestimation of vigorous activity in the younger children. The Actigraph was firmly attached over the child's non-preferred hip with an elastic belt.

Accelerometer count analysis

Accelerometer counts were transferred to a computer and treated with specific software developed for the study by the Department of Computer Science of Polytechnic Institute of Bragança. A key feature of the software was the conversion of MTI actigraph counts into units of relative energy expenditure (METs). The counts were converted to METs using the regression equation developed by Freedson *et al* [34] for children 6-to-18 years of age: METs = 2.757 + (0.0015 x counts/min) – (0.0896 x age[years]) – (0.000038 x counts/min x age), with r^2 = 0.90 and SEE = 1.08 METs. The equation was then used to derive cut-offs for the number of counts that corresponded to a specific MET. Based on the cut-offs points, the software calculated for each child the number and average time (in minutes) of the periods in each of the following categories of PA intensity: rest or mild (≤ 2.9 METs), moderate (3.0-5.9 METs, MPA), vigorous (6.0-8.9 METs, VPA), and very vigorous (≥ 9.0 METs, VVPA).

Body Mass Index

Measurements of weight (to the nearest 0.1 Kg) and height (to the nearest 0.1 cm) were taken and the BMI was calculated [(weight (kg)/height^2 (m^2)].

Students were divided into normal weight and overweight, according to Cole's cut off points for BMI.[35]

Procedure

Children' PA was evaluated during the school recesses in two distinct periods: 1) pre-intervention (first week); 2) post-intervention (second week). In both periods, each student was measured for 30 minutes (recess period between 10:30 and 11:00 am). In a normal school day recess did not have play structures and equipment available.

The intervention consisted of the introduction of extra outdoor play equipment, in the playground, such as: balls', skipping ropes, arches, hood horses and the floor was painted for playing traditional games. Equipment was set in the playground during classes' time, so it can be available when the recess period starts. During the intervention children were allowed to play freely with the equipment. No stimuli to its utilization or explanations on how to play with the equipments were given.

Data analysis

To evaluate the effects of the intervention on children's PA levels during recess periods, repeated measures of ANOVA were used, with interactions between gender, age group, and BMI. The statistic level of significance was set at $p < 0.05$. Data were analyzed using SPSS for Windows (15.0).

Results

Participants' characteristics are presented in Table 1. Total sample was divided in Boys and Girls, than were grouped by age, height and weight, and body mass index. Mean values for age ranged between 6.6 ± 0.5 and 8.7 ± 0.8 years and for BMI between 16.4 ± 3.0 and 17.8 ± 3.2 kg/m^2.

Table 2 shows the pre-intervention and pos-intervention results from the percentage of PA and minutes in MPA and VVVPA, in accordance with participant's classification in normal or overweight/obese.

In pre-intervention, mean values for the percentage of PA ranged between 51.3 ± 4.7 (in overweight/obese girls with 6 and 7 years old) and 84.7 ± 2.7 (in normal weight boys ≥ 8 years old), for MPA ranged between 12.7 ± 1.9 min (in overweight/obese boys with 6 and 7 years old) and 16.6 ± 1.5 min (in overweight/obese boys ≥ 8 years old), and for

VVVPA ranged between 2.1 ± 1.9 min (in overweight/obese girls with 6 and 7 years old) and 13.1 ± 1.1 min (in normal weight boys ≥ 8 years old).

In post-intervention, mean values for the percentage of PA ranged between 79.5 ± 1.9 (in normal weight girls ≥ 8 years old) and 94.3 ± 4.3 (in overweight/obese boys with 6 and 7 years old), for MPA ranged between 12.3 ± 0.9 min (in normal weight boys ≥ 8 years old) and 16.6 ± 1.5 min (in overweight/obese boys ≥ 8 years old), and for VVVPA ranged between 5.4 ± 2.1 min (in overweight/obese girls with 6 and 7 years old) and 20.4 ± 2.5 min (in overweight/obese boys with 6 and years old).

Table 3 presents all results from ANOVA analysis of the effects of the intervention.

Percentage of time in Physical Activity

Significant intervention effects were found for the percentages of time spent in total PA ($F_{(1, 150)}$ = 70.157; $p<0.001$), meaning that, the percentage of time spent for children's on PA increased significantly with intervention. It was found that the younger group (6 to 7 years old) benefited significantly more from the intervention ($F_{(1, 150)}$ = 24.416; $p<0.001$). Significant interaction between gender and age group were found ($F_{(1, 150)}$ = 6.919; p=0.009), suggesting that the percentages of time spent in PA increased significantly more in the younger group of girls. No significant intervention effects were found for the percentages of time spent PA regarding BMI.

Time in Moderate Physical Activity (MPA)

No significant intervention effects were found for the time spent in MPA. Significant interaction effects for gender and intervention were found for the time spent in MPA ($F_{(1, 150)}$ = 15.290; $p<0.001$). The time spent in MPA increased in girls and decreased in boys. Significant interaction between BMI and gender were found ($F_{(1, 150)}$ = 6.411; p=0.012), suggesting that the time spent in MPA increased significantly more in the overweight/obese group of girls.

Time in Vigorous and Very Vigorous Physical Activity (VVVPA)

The time spent in VVVPA increased significantly with intervention ($F_{(1, 150)}$ = 54.790; p=0.001). Younger children (6 to 7 years old) benefited significantly more from intervention ($F_{(1, 150)}$ = 9.490; p=0.002) than the older ones (≥ 8 years old). Boys benefited significantly more than girls ($F_{(1, 150)}$ = 14.161; $p<0.001$) with intervention. Overweight/obese boys increased significantly more the amount of time spent in VVVPA ($F_{(1, 150)}$ = 5.049; p=0.026) than the normal weight boys.

Discussion

The purpose of the present study was to examine the intervention effects of providing play equipment during school recess on children's PA levels.

Results of the study indicated that providing play equipment during school recess was effective in increasing children's PA level. This result was in agreement with others studies.[19, 28] The effects of the intervention showed a significant increase in the percentage of time spent in PA, regardless of gender, age group and BMI status. This result also supported previous findings that 50% time in MVPA during the school recess is a reachable target [19, 21, 28]. However, other studies indicated different results.[14, 15, 27]

Consistent with previous intervention school recess studies [18, 19, 26, 28, 30], on average boys in the current study spent higher percentage of time in PA (pre-intervention 81.97% ± 12.59 and pos-intervention 91.61% ± 7.89) than girls (73.47% ± 17.91 pre and 82.79% ± 13.94 pos-intervention). Although, the younger group of girls was the one who benefited more from the intervention, both genders have benefited from the play equipment. This was indicated by both boys and girls significantly increased the percentages of time spent in total PA. This is a positive and significant finding from a public health perspective, since girls systematically exhibit lower PA levels than boys, and that such trend tends to track into adolescence and adulthood.[36]

No significant effects were found for the time spent in MPA. With intervention MPA decreased in boys and increased in girls. However, the overall percentage of time in PA increased in boys and in girls. This may suggest that boys increased their time spent in VPA and VVPA to help increase the overall time spend in PA. This is further explained by significant gender differences of time spent on MPA and VVVPA. It can be speculated that if this effect became a long time trend, it might translate into cardiovascular and energy expenditure benefits.[37] Nevertheless, previous school recess intervention studies found the opposite results, where boys engaged in more MPA than girls. Future studies are needed to further examine this effect.

Regarding age group differences, the results showed that younger girls and boys benefited more from the intervention. This result was in consistent with Ridgers et al [18] findings. They found significant intervention effect related to MVPA was stronger for the younger group compared to the older elementary school children.[18] Although Stratton and Mullan [26] found the opposite. These contradictory results may be due to the type of intervention. In the present study the play equipment used was probably more appropriated for the younger students.

The intervention also had a significant improvement in PA levels of obese/overweight children. Overweight/obese girls increased significantly more in MPA and overweight/obese boys significantly in VVVPA than normal weight children. Despite of these results, it seems that BMI had low impact on the results overall. This may suggest that play equipment used in this intervention may attract all children, but that BMI in early ages is not yet a predictor for PA. This interesting finding led us to speculate that early age PA interventions may have similar results for both overweight/obese and normal weight children. Probably, the extra weight in children at these ages does not affect motor skills and fitness levels necessary to play with equipment that was provided, but it may happen later in life.[37-39]

Future studies should consider evaluate large samples and assess other variables including motor skills and fitness levels in order to better understand it's association with children's PA. Future intervention may also include a control group.

Conclusions and Recommendations

There are some limitations in this study. We only measured once during pre-intervention and one post-intervention, and we do not know if the increase of PA observed was affected by the novelty effect of the intervention. It was not clear if the effects will remain the same with longer time period. Also, we did not include a control group. Nevertheless, the PA was measured objectively and the play equipment chosen was attractive and relatively inexpensive. Due to small sample size, generalizations cannot be assumed. Further studies with larger Portuguese samples are needed in order to confirm or refute these findings.

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Annexes

Table 2. Pre-intervention and Post-intervention Physical Activity values (mean ± SD).

		Girls (n= 92)				Boys (n= 66)			
		(6 and 7 years old) (n= 40)		(8 ≥ years old) (n= 52)		(6 and 7 years old) (n= 26)		(8 ≥ years old) (n= 40)	
		Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Percentage in Physical Activity (%)	Normal	73.8±2.7	89±2.1	76.2±2.4	79.5±1.9	79.5±3.4	93.2±2.6	84.7±2.7	90.6±3.1
	Overweight/obese	51.3±4.7	79.7±3.6	80.9±3.8	80.4±3.0	80±5.6	94.3±4.3	80.3±4.5	90±3.5
Moderate Physical Activity (min)	Normal	13.9±0.9	12.9±1.1	13.6±0.8	12.8±0.9	12.9±1.2	10.1±1.3	12.3±0.9	10±1.1
	Overweight/obese	13.3±1.6	18.5±1.8	13.1±1.3	15±1.5	12.7±1.9	7.9±2.2	16.6±1.5	13.1±1.7
Vigorous to Very Vigorous Physical Activity (min)	Normal	8.2±1.1	13.8±1.2	9.3±0.9	11±1.1	10.9±1.3	17.8±1.5	13.1±1.1	17.1±1.2
	Overweight/obese	2.1±1.9	5.4±2.1	11.1±2.2	9.1±1.7	11.3±2.2	20.4±2.5	7.5±1.7	13.9±1.9

Table 3. Effects of the intervention - ANOVA

	Percentages of time in PA(a)		Time in MPA(b)		Time in VVVPA(c)	
	F (gl)	p	F (gl)	p	F (gl)	p
Intervention	70.157	<0.001**	2.934	0.089	54.790	<0.001**
Intervention x Age group	24.416	<0.001**	0.069	0.792	9.490	0.002*
Intervention x Gender	0.074	0.786	15.290	<0.001**	14.161	<0.001**
Intervention x BMI(d)	1.643	0.202	1.337	0.249	0.089	0.765
Gender x Age group	6.919	0.009*	1.019	0.314	0.582	0.447
Intervention x Age Group x BMI(d)	1.616	0.206	0.334	0.564	0.077	0.782
Intervention x Gender x BMI(d)	0.208	0.649	6.411	0.012*	5.049	0.026*
Intervention x Age Group x Gender x BMI(d)	3.509	0.063*	0.856	0.356	0.112	0.738

Notes: (a) – Physical Activity; (b) – Moderate Physical Activity; (c) - Vigorous to Very Vigorous Physical Activity; (d) – Body Mass Index.

* indicates .05 and ** indicates .01 level of significance.