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Human Growth, Biological Maturation, Motor Performance and Contextual Factors in Madeira Children

DOCTORAL THESIS

António Manuel Marques Antunes
DOCTORATE IN SPORTS SCIENCES

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SUPERVISOR
Duarte Luís de Freitas

CO-SUPERVISOR
José António Ribeiro Maia

‘Keep your thoughts positive
because your thoughts become your words.

Keep your words positive
because your words become your behavior.

Keep your behavior positive
because your behavior becomes your habits.

Keep your habits positive
because your habits become your values.

Keep your values positive because
your values become your destiny.’

Mohandas Karamchand Gandhi

Dedicatory

To my parents,
Angelina and António

‘Parents can only give good advice or put them on the right paths, but the final forming of a person's character lies in their own hands’
Anne Frank

In the meanwhile, throughout my studies
‘One father is more than a hundred schoolmasters.’
George Herbert

your love warms me each and every day…

To my wife,
Elisabete

‘Love is the only game where two can play and both win.’
Eva Gabor

Particularly when
‘Few things are as hot as receiving the kisses, the smile and the warmth from the person one loves after an exhausting day at work.’
Augusto Branco

the splendor of an I Love You…

To my son,
Bernardo

‘I Love you to the moon... and back.’
Sam McBratney

And I know,
‘While we try to teach our children all about life, our children teach us what life is all about.’
Angela Schwindt

your smile fills my heart with Love and Life…

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Ponta do Sol, September 2014
António Manuel Antunes

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List of abbreviations

AAHPERD	American Alliance for Health, Physical Education, Recreation and Dance
AIC	Akaike information criterion
ARM	Autonomous Region of Madeira
BMI	Body mass index
CDC	Centers for Disease Control and Prevention
CITMA	Centro de Ciência e Tecnologia da Madeira
CRES	Healthy Growth of Madeira Children Study
F	Female
FMS	Fundamental motor skills
Gr	Age group
HH	Hopping for height
JS	Jumping sideways
KTK	Körperkoordinations Test für Kinder
M	Male
MC	Motor coordination
MCGS	Madeira Child Growth Study
MET	Standard metabolic equivalent
MS	Moving sideways
p	Points
P	Percentile

PE	Physical Education
POPRAM	Programa Operacional Plurifundos da Região Autónoma da Madeira
PTB	Preschool Test Battery
RUS	Radius, ulna and short bones
SAsr	Standardized residuals of skeletal age on chronological age
SES	Socioeconomic status
Ta	Total assessed
TaD	Total assessed by district
Tf	Total of females
TGMD-2	Test of Gross Motor Development
Tm	Total of males
TW2	Tanner-Whitehouse 2 Method
TW3	Tanner-Whitehouse 3 Method
WB	Walking backwards
WHO	World Health Organization

Abstract

The central aims of this study were: (1) to construct age- and gender-specific percentiles for motor coordination (MC), (2) to analyze the change, stability, and prediction of MC, (3) to investigate the relationship between motor performance and body fatness, and (4) to evaluate the relationships between skeletal maturation and fundamental motor skills (FMS) and MC.

The data collected was from the 'Healthy Growth of Madeira Children Study' and from the 'Madeira Child Growth Study'. In these studies, MC, FMS, skeletal age, growth characteristics, motor performance, physical activity, socioeconomic status, and geographical area were assessed/measured. Generalized additive models for location, scale and shape, mixed between-within subjects ANOVA, multilevel models, and hierarchical regression (blocks) were some of the statistical procedures used in the analyses.

Scores on walking backwards and moving sideways improved with age. It was also found that boys performed better than girls on moving sideways. Normal-weight children outperformed obese peers in almost all gross MC tests. Inter-age correlations were calculated to be between 0.15 and 0.60. Age was associated with a better performance in catching, scramble, speed run, standing long jump, balance, and tennis ball throwing. Body mass index was positively associated with scramble and speed run, and negatively related to the standing long jump. Physical activity was negatively associated with scramble. Semi-urban children displayed better catching skills relative to their urban peers. The standardized residual of skeletal age on chronological age (SAsr) and its interaction with stature and/or body mass accounted for the maximum of 7.0% of variance in FMS and MC over that attributed to body size per se. SAsr alone accounted for a maximum of 9.0% variance in FMS and MC over that attributed to body size per se and interactions between SAsr and body size.

This study demonstrates the need to promote FMS, MC, motor performance, and physical activity in children.

Key words: growth, maturation, motor performance, children

Resumo

Os objetivos centrais deste estudo foram: (1) construir cartas centílicas da coordenação motora (MC) em função da idade e sexo, (2) analisar a mudança, a estabilidade e os preditores da MC, (3) investigar a relação entre a performance motora e a gordura corporal, e (4) avaliar as relações entre a maturação esquelética, as habilidades motoras fundamentais (FMS) e a MC.

A MC, as FMS, a idade esquelética, as características somáticas, a performance motora, a atividade física, o estatuto socioeconómico e a área geográfica foram avaliados no âmbito do 'Healthy Growth of Madeira Children Study' e 'Madeira Child Growth Study'. Os 'Generalized additive models for location, scale and shape', a 'mixed between-within subjects ANOVA', os modelos multinível e a regressão hierárquica (blocos) foram os procedimentos estatísticos utilizados na análise dos dados.

Os resultados nos testes 'equilíbrio à retaguarda' e 'transposição lateral' aumentaram com a idade e os meninos apresentaram melhores desempenhos do que as meninas no teste de 'transposição lateral'. As crianças normoponderais foram mais proficientes do que os colegas obesos, na maioria dos testes de MC. As auto-correlações estavam compreendidas entre 0,15 e 0,60. A idade estava associada a uma melhor performance no 'agarrar', 'corrida de ida-e-volta', 'corrida de velocidade', 'impulsão horizontal', 'equilíbrio' e 'lançamento da bola de ténis'. O índice de massa corporal estava positivamente associado à 'corrida de ida-e-volta' e 'corrida de velocidade', e negativamente relacionado com a 'impulsão horizontal'. A atividade física estava negativamente associada com a 'corrida de ida-e-volta'. As crianças residentes na área suburbana apresentaram melhores desempenhos no 'agarrar' do que os seus pares residentes na área urbana. A interação dos resíduos estandardizados da idade óssea (SAsr) com a estatura e/ou o peso corporal explicou um máximo de 7,0% de variância nas FMS e MC, acima daquela atribuída ao tamanho corporal per si. Os SAsr sozinhos foram responsáveis por um máximo de 9,0% de variância nas FMS e MC, acima daquela atribuída ao tamanho corporal per si e interações entre os SAsr e o tamanho corporal.

Este estudo demonstrou a necessidade de promover as FMS, a MC, a performance motora e a atividade física em crianças.

Palavras-chave: crescimento, maturação, desempenho motor, crianças

Résumé

Les principaux objectifs de cette étude ont été: (1) construire des cartes centiliques de la coordination moteur (MC) en fonction de l'âge et du sexe, (2) analyser le changement, la stabilité et les prédictions de la MC, (3) étudier la relation entre la performance motrice et la graisse corporelle, et (4) évaluer les relations entre la maturation squelettique, les habiletés motrices fondamentales (FMS) et la MC.

La MC et les FMS, l'âge squelettique, les caractéristiques somatiques, la performance motrice, l'activité physique, le statut socioéconomique et l'aire géographique ont été évalués dans le cadre de deux projets de recherches: 'Healthy Growth of Madeira Children Study' et 'Madeira Child Growth Study'. Les procédures statistiques utilisées dans l'analyse des données ont été les 'Generalized additive models for location, scale and shape', la 'mixed between-within subjects ANOVA', les modèles multi-niveaux et la régression hiérarchique (blocs).

Les résultats obtenus aux tests 'équilibre en arrière' et 'transposition latérale' ont augmenté avec l'âge. Les garçons ont de meilleurs performances que les filles au test de la 'transposition latérale'. Les enfants normo-pondéraux ont été plus compétents que les camarades obèses dans la plupart des tests de MC. Les auto-corrélations se sont situées entre 0,15 et 0,60. L´âge était associé à une meilleure performance dans les domaines d'activité suivantes: 'attraper', 'course en aller-retour', 'course de vitesse', 'impulsion horizontale', 'équilibre' et 'lancer de la balle de tennis'. L'indice de masse corporelle était, d'une part, positivement associé à la 'course en aller-retour' et à la 'course de vitesse'; d'autre part, il était relié négativement à l'impulsion horizontale'. L'activité physique était négativement associée à la 'course en aller-retour'. Les enfants résidant en milieu suburbain ont présenté de meilleures performances dans l'exécution du mouvement ('attraper') que ses camarades vivant en milieu urbain. C'est l'interaction entre les résidus standardisés de l'âge osseux par rapport à l'âge chronologique (SArs) et la stature et/ou le poids corporel qui explique un maximum de 7,0% de variance dans les FMS et la MC, au-dessus de celle attribuée à la taille corporelle per se. Les SAsr sont seuls responsables d'un maximum de 9,0% de variance dans les FMS et MC, au-dessus de celle attribuée à la taille corporelle per se ainsi que des interactions entre les SAsr et la taille corporelle.

Cette étude a montré qu'il convient de promouvoir les FMS, la MC, la performance motrice et l'activité physique chez l'enfant.

Mots-clés: croissance, maturation, performance du moteur, enfants

Resumen

Los objetivos principales de este estudio fueron: (1) construir cartas centílicas de coordinación motora (MC) en base a la edad y el sexo, (2) analizar el cambio, la estabilidad y los predictores de MC, (3) investigar la relación entre el rendimiento motor y la grasa corporal, y (4) evaluar la relación entre la madurez esquelética y las habilidades motoras fundamentales (FMS) y el MC.

La MC, las FMS, la edad esquelética, las características somáticas, el rendimiento motor, la actividad física, el nivel socioeconómico y la zona geográfica se evaluaron en el ámbito ‘Healthy Growth of Madeira Children Study’ y ‘Madeira Child Growth Study’. Para el análisis de datos los procedimientos estadísticos utilizados fueron: ‘Generalized additive models for location, scale and shape’, la ‘mixed between-within subjects ANOVA’ y los modelos multinivel y de regresión jerárquica (bloques).

Los resultados de la prueba ‘equilibrio a la retaguardia’ y ‘transposición lateral’ aumentaron con la edad y los niños tuvieron mejores resultados que las niñas en la prueba ‘transposición lateral’. Los niños de peso normal fueron más competentes que sus colegas obesos en la mayoría de pruebas MC. Las auto-correlaciones se situaron entre 0,15 y 0,60. La edad estuvo asociada con un mejor rendimiento en ‘agarrar’, ‘carrera de ida y vuelta’, ‘carrera de velocidad’, ‘impulso horizontal’, ‘equilibrio’ y lanzamiento de una pelota de tenis. El índice de masa corporal se asoció positivamente con la ‘carrera de ida y vuelta’ y ‘carrera de velocidad’, y negativamente con el ‘impulso horizontal’. La actividad física estuvo negativamente asociada con la ‘carrera de ida y vuelta’. Los niños que viven en la zona suburbana mostraron mejores resultados en ‘agarrar’ que sus pares que viven en el área urbana. La interacción de los residuos estandarizados de edad ósea (SAsr) con la altura y/o peso corporal explicó un máximo de 7,0% de la varianza en el FMS y MC, por encima de la que se atribuye al tamaño del cuerpo per se. Los SAsr fueron aisladamente responsables por un máximo de 9,0% de la varianza en las FMS y MC, superior a aquella atribuida al tamaño corporal per se y las interacciones entre el SAsr y el tamaño corporal.

Este estudio demostró la necesidad de promover la FMS, el MC, el rendimiento motor y la actividad física en los niños.

Palabras clave: crecimiento, maduración, rendimiento motor, niños

Chapter 1

Introduction and outline of the thesis

1 Introduction

1.1 Why study human physical growth, biological maturation, and motor performance?

The study of the human physical growth, biological maturation, and motor performance relies, necessarily, in the description and interpretation of what constitutes their nuclear expression – its variation and co-variation. Humans are a very successful species and much of this success comes from the human design, the extended period of childhood, and the plasticity of response to environmental conditions (Freitas et al., 2002 and Ulijaszek et al., 1998). Although much is known about human physical growth, biological maturation and motor performance, understanding these phenomena is far from complete.

It is well known that fundamental motor skills (FMS) are basic forms of movement (Malina et al., 2004) or the ABCs of movement (Goodway and Robinson, 2006) that are considered the building blocks or the foundation for more advanced skills, i.e., those required in sport-specific activities (Lubans et al., 2010; Clark and Metalfe, 2002; Seefeldt, 1980). Recently, the literature has suggested a link between FMS, physical activity and health-related physical fitness. Good development of FMS seems to be associated with high levels of physical activity (Cliff et al., 2009; Hume et al., 2008; Williams et al., 2008; Raudsepp and Päll 2006; Wrotniak et al., 2006; Okely et al., 2001), better proficiency on physical fitness test performances (Stodden et al., 2009; Barnett et al., 2008) and a decrease of body fatness (Foley et al., 2008; Hume et al., 2008; Okely et al., 2004; Reeves et al., 1999).

A possible correlate of FMS, motor coordination (MC), and motor performance is biological maturation. Children of the same chronological age and sex can vary in biological maturity (Malina et al., 2004). Although a theoretical frame of reference is available for maturity-associated variation in human physical growth, strength, and motor performance in adolescents, little is known about the maturity-associated variation in FMS, MC and motor performance in middle childhood. Skeletal maturity seems to be a factor of little consequence in explaining individual differences in FMS, strength and motor proficiency in childhood (Kerr, 1975; Rarick and Oyster, 1964; Seils, 1951). Given the link between FMS, physical activity and health-related physical fitness, it is timely to investigate the maturity-associated variation in FMS in early childhood and childhood, using the best method for the assessment of biological maturity, i.e. skeletal maturity, and assessing FMS in terms of process and product (Freitas, 2011).

It is also important to point out that prior research remains inconclusive regarding to the association of body mass index (BMI) to gross MC in late childhood and adolescence. In fact, apart from the recent progress in constructing normative values for gross MC tests, the previous studies are confined to some countries and a need exist for well-constructed centile curves. In addition, whilst the previous research explored the associations of MC with physical fitness, human physical growth, physical activity and SES, our study extended the multivariate analysis to FMS and biological maturation. Moreover, very little is known about stability and childhood predictors of MC at early adolescence. It is crucial to explore the longitudinal relationship between motor performance and body fatness in preschool children and to consider the simultaneous effect of physical activity, socioeconomic status (SES) and geographical area. In light of the essential research examining the longitudinal relationship between motor performance and body fatness in early childhood, two issues have to be highlighted: first, motor performance was largely assessed via FMS and a recent study has given some evidence that process- and product-assessments measure different aspects and/or levels of motor performance (Logan et al., 2014); second, no studies have explored this association in a relatively healthy weight group. Lastly, developments of FMS and MC have received less attention in the context of growth and maturation. So, this study focuses in MC growth curves, tracking, and interrelationships between human physical growth, biological maturation, motor performance, and contextual factors.

1.2 Frame of reference

A model developed from ‘Second International Consensus Symposium on Physical Activity, Fitness, and Health’ (Bouchard et al., 1994) provides a clear understand of the relationships between levels of physical activity, health-related fitness, and health. The model proposes that physical activity can influence fitness, which in turn may modify the level of habitual physical activity, i.e., with increasing fitness, people tend to become more active while the fittest individuals tend to be the most active. The model also specifies that fitness not only influences health, but health status also influences both habitual physical activity level and fitness level. Environmental and genetic factors are associated with individual variation in physical activity, health-related fitness and health (Bouchard and Shephard, 1994) (Figure 1.1).

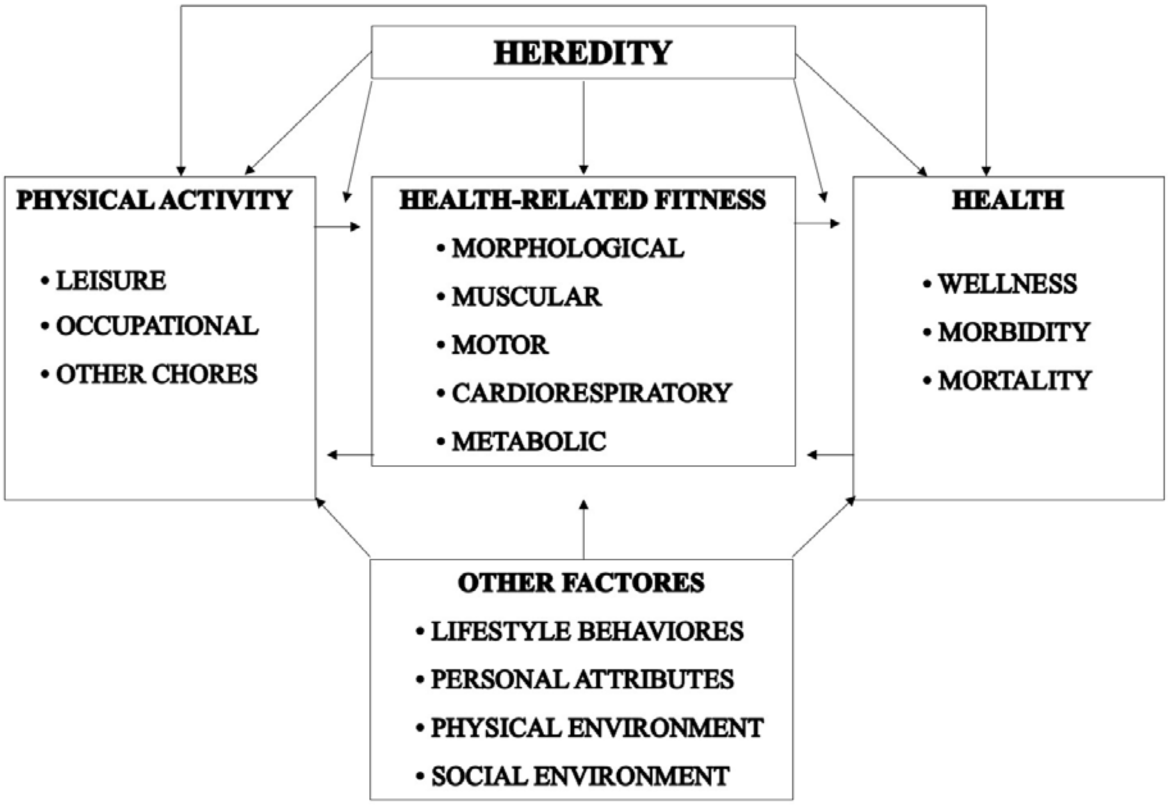

Figure 1.1 A model describing the relationships among habitual physical activity, health-related fitness, and health status (Bouchard and Shephard, 1994).

1.3 Key terms and concepts

1.3.1 Human physical growth

Human physical growth is the dominant biological activity for about the first 2 decades of human life, including prenatal life (Malina et al., 2004). Human physical growth is the increase in size or mass (Bogin, 1988 and Scott, 1986); is a geometric process of self-multiplication of living substance involving hyperplasia, hypertrophy and accretion (Tanner, 1990 and Malina, 1975); is a dynamic process that is characterized by an increase in body size and changes in physique, body composition and proportions (Malina, 1980).

Human physical growth is described, i.e., measured, by the technique of anthropometry and may be visualized in terms of a few ‘clusters’ (Johnston, 1986). Height and body mass are the two most often used measurements of human physical growth and expresses the overall body size. Skeletal breaths or width measurements provide an indication of the robustness of the skeleton. Four commonly used skeletal breadths are the biacromial, bicristal, biepicondilar femur and biepicondilar humerus. Limb circumferences or girths are indicators of relative muscularity. The two more commonly used limb measurements are arm and calf circumferences. Waist circumference is an indicator of adipose tissue (body fatness) in the abdominal area. Skinfold thicknesses are indicators of subcutaneous adipose tissue. Most often, 5 skinfolds are used in growth studies, namely, triceps, subscapular, medial calf, suprailiac and abdominal, Measurements may be related to each other as indices or ratios. BMI is the relationship between body mass (weight) and height (stature), where body mass is in kilograms (kg) and height is in meters (m) squared [BMI = body mass (kg)/height^2)] and is widely used as an indicator of overweight and obesity (American College of Sports Medicine, 2006; Malina et al., 2004; Norton and Olds, 1996).

1.3.2 Biological maturation

Biological maturation is a process that has been operationalized in many ways (Bielicki, 1975); is a time marker that goes away from chronologic age; it measures the progress made along the road of life, anatomically, and mentally (Prahl-Andersen and Roede, 1979). Biological maturation is the process of becoming fully mature or completely developed (Beunen, 1996 and Roche, 1986); is a dynamic process towards a target, the adult state; is a process of cellular organization that requires specialization and differentiation; is a process limited in time and common to all the individuals; is a process regulated by a specific internal clock – genes and influences of the environment (Malina et al., 2004; Tanner et al., 2001; Bailey and Garn, 1986; Gessel, 1945; Weiss, 1939). Biological maturation marks the progress towards the adult state: individuals vary in timing and tempo of indicators of biological maturity (Beunen, 1996). Three systems are generally used in the assessment of biological maturation: skeletal, sexual and somatic approaches. Dental maturity is also used occasionally (Beunen, 1996). In the assessment of skeletal maturity, two main techniques are presently in use: the atlas technique (Greulich and Pyle, 1959) and the bone specific approach developed by Tanner et al., (2001; 1983). The Tanner-Whitehouse method (TW3) (Tanner et al., 2001) entails matching 20 individual bones of the hand and wrist, namely the radius and ulna, the carpals, and the metacarpals and phalanges, to a set of written criteria. Two overall maturity scores are obtained, by summing the 13 RUS (radius, ulna and short bones) scores and the seven carpal scores respectively. Each of these has been scaled to pass from 0 (invisible) to 1000 (full maturity). The summed maturity scores are then converted to bone age (Tanner et al., 2001 and Beunen, 1996).

1.3.3 Fundamental motor skills, motor coordination and motor performance

Fundamental motor skills are elementary forms of movement involved in the performance of a particular task. Skill emphasizes the accuracy, precision, and economy of performance (Malina et al., 2004). FMS are often divided into locomotor (run, gallop, hop, leap, horizontal jump and slide) and object control (striking a stationary ball, stationary dribble, catch, kick, overhead throw and underhand roll) skills (Ulrich, 2000). FMS can be assessed in terms of process (the technique of performing a specific movement in terms of its components) and/or product (the result or the outcome). Three tools are commonly used in assessing the movement performance in childhood: the Preschool Test Battery (PTB) (Morris et al., 1981), the Test of Gross Motor Development (TGMD-2) (Ulrich, 2000) and the Körperkoordinations Test für Kinder (KTK) (Kiphard and Schilling, 1974). The movement patterns for most FMS ordinarily develop by 6 or 7 years of age. As the FMS are refined through practice, quality of performance improves, and the fundamental patterns are integrated into more complex movement sequences, such as those required for specific games and sports (Malina et al., 2004). Note that, the term MC, is a general term that encompasses various aspects of movement competency (see also Chaves et al., 2012 and Lopes et al., 2012).

The study of the performance in this variety of specific motor skills, from infancy to adolescence, is traditionally conducted in the context of physical fitness (Malina et al., 2004). Physical fitness can be defined as a state; a plural characteristic. Physical fitness was traditionally viewed in terms of strength and muscular endurance, cardiorespiratory endurance and motor capacities. Now, morphological and metabolic components have been added. The concept of physical fitness has since evolved from a primary focus on its motor and strength components (performance-related fitness) to more emphasis on health (health-related fitness). Performance can be defined as the individual capacity in competition, in a motor test or at work. Health-related physical fitness is a state characterized by (a) an ability to perform daily activities with vigour, and (b) demonstration of traits and capacities that are associated with low risk of premature development of hypokinetic diseases (Pate, 1988). The components of health-related fitness are the morphological, muscular, motor, cardiorespiratory and metabolic (Bouchard and Shephard, 1994). Physical fitness is currently assessed with a variety of tests batteries, for example: the American Alliance for Health, Physical Education, recreation, Recreation and Dance [AAHPERD] (1988), the Fitnessgram (Cooper Institute for Aerobics Research, 1999) and the Eurofit (Adam et al., 1988).

1.3.4 Physical activity

Physical activity is defined as any body movement produced by the skeletal muscles that result in a substantial increase over the resting energy expenditure (Bouchard and Shephard, 1994 and Caspersen et al., 1985). A general procedure used in the decomposition or division of physical activity consists of identifying separate characteristics of daily live. The most common are: sport-fitness, Physical Education, exercise-training, leisure-time, work-job, household chores and transportation; these overlap to some extent depending on the purpose for performing the activity (LaMonte et al., 2006 and Welk, 2002).

Physical activity is traditionally defined in terms of frequency (number of sessions, for example, daily, weekly,…), intensity (walking at 5 km/h; absolute energy cost), type of activity (walking, jogging,…) and time spent or duration of the activity (minutes per session, for example, 10', 30', 1 hour,…) (LaMonte et al., 2006 and Welk, 2002). As a movement, physical activity can be operationalized into two measurable variables: physical activity and energy expenditure. Direct and indirect measures of physical activity and energy expenditure are available. The selection or choice of a measure of physical activity should take into account the sample size, the study design and the target population (LaMonte et al., 2006). The predominant tendency is to combine methods, such as, heart rate and accelerometry, to obtain a comprehensive picture of the habitual level of physical activity and energy expenditure of an individual (Montoye et al., 1996).

1.4 Geographic, economic and social aspects of Madeira Island, Portugal

The Madeira Archipelago is situated in the Atlantic Ocean and comprises the islands of Madeira, Porto Santo and the uninhabited islands of Selvagens and Desertas. The Madeira Archipelago is one of Europe’s ultra-peripheral regions (Trujillano et al., 2006) situated about 900 km from mainland Portugal. The Madeira Island, which covers only 780km2, is the top of a volcano and is very mountainous with steep slopes throughout the island with a central mountain range at 1,200 m above sea level. It has a population of some quarter of a million of which 100 thousand live in the regional capital of Funchal., The population of the island is one of relative homogeneity; there is no aboriginal population that preceded the Portuguese settlement of the early fifteenth century, although there is evidence of people with sub-Saharan origins, a likely direct import of slaves from West Africa (Brehm et al., 2003). Since the 1980’s the economy has changed from one based on subsistence production (fishing and agriculture based on small farms) into an off-shore tourist/business centre (Almeida and Correia, 2010) with agriculture increasingly focused on the export of bananas and wine, and in the increment and pulverization of services related to tourism. This recent rapid economic growth has been aided since 1986 by European community structural fund monies for modernization which by 1994 had committed US $400 million to infrastructural projects (Porter, 1994). Substantial investment has been focused on roads, bridges, tunnels and the development of the airport in an attempt to ensure that tourism would not be limited to the Funchal region. In 1988 Madeira was one of the poorest regions in the Union with GDP per head being only 40% of the European average; 10 years later this has risen to 58% (InfoRegio, 2011). This economic transformation and very much improved accessibility have had a profound effect on the population, particularly the children and adolescents.

1.5 Aims and hypothesis of the thesis

This study was undertaken in Madeira and Porto Santo Islands, at a time of rapid and substantial social and economic change. Portugal lacks a convincing body of knowledge about the interrelationships between FMS, biological maturation, motor performance, and contextual factors. There is also a need to provide MC reference values. In this context, the general purpose of this study was threefold:

1.º To provide age- and gender-specific percentiles for gross MC tests based on a large representative sample of children;

2.º To analyse change, stability, and prediction of MC in a longitudinal Portuguese sample from Madeira and Porto Santo islands;

3.º To investigate the relationship between motor performance and body fatness, and between skeletal maturation and FMS and MC.

The purposes seek to answer the following questions: (1) what is the age- and gender-associated variation in gross MC tests? (2) Are there differences in MC among normal-weight, overweight and obese children? (3) Is MC stable during childhood and early adolescence? (4) What are the predictors of MC at early adolescence? (5) What is the relationship between motor performance and body fatness in early childhood? (6) Controlling for potential effects of body size per se, what is the contribution of the interaction of skeletal age and body size to the variance in FMS and MC? (7) Controlling for the potential effects of body size per se and interactions with skeletal age, what is the contribution of skeletal age to the variance in FMS and MC?

Based on the available literature, the following groups of hypotheses were formulated:

1.º Boys and girls improved the MC scores with increasing age and showed a large interindividual variability; normal-weight children outperform their obese peers in all gross MC tests and that these differences will be more marked in late childhood; overweight children also surpassed their obese peers in some gross MC tests;

2.º Stability of MC during childhood and early adolescence was low-to-moderate across the different cohorts; MC, human physical growth, biological maturation, physical fitness, FMS, physical activity, and SES in childhood were predictors of MC at early adolescence; and predictors of MC changed over time and the relative contribution of these predictors also changed with age;

3.º Body fatness has a negative influence in weight-bearing tests; boys outperform girls in motor tests that require power and speed, whereas girls excel boys in balance; physical activity, SES and geographical area have little influence in motor performance;

4.º Interactions of skeletal age and body size would contribute negligibly to the variation in FMS and MC over and above body size per se; skeletal age alone would contribute negligibly to the variation in FMS and MC over and above body size and interactions of skeletal age with body size.

1.6 Outline of the thesis

This thesis is structured according to the Scandinavian model and comprises 8 chapters. Chapter 1 is the current introduction. Chapter 2 deals with the general methodology. The sample and sampling procedures, the 'Healthy Growth of Madeira Children Study', and the 'Madeira Child Growth Study' are described for a better understanding of the following chapters. Chapters 3-6 provide four original papers with a similar structure, namely, introduction, material and methods, results, discussion and references. The first one (chapter 3) is centred in the 'Healthy Growth of Madeira Children Study' and centiles curves for gross MC were obtained for boys and girls separately using generalized additive models for location, scale and shape. The second one (chapter 4) combines data from the 1st (2006) and 2nd (2012) phases of the 'Healthy Growth of Madeira Children Study'. A mixed between-within subjects analysis of variance was conducted to assess the effect of age, sex and its interaction on each MC test, across the two time periods. The third one, (chapter 5) uses data from the 'Madeira Child Growth Study'. A two-level regression model with repeated measurements nested within individuals was used to estimate the longitudinal effect of age and body fatness on motor performance, controlling for physical activity, SES and geographical area. The forth one (chapter, 6) deals with data from the 'Healthy Growth of Madeira Children Study'. Hierarchical multiple regression analyses were used to estimate the contribution of skeletal age alone or interacting with stature and/or mass to the unique variance in FMS and MC over and above that explained by covariates. Chapter 7 summarizes the main results and presents future prospects. Finally, chapter 8 gives the appendices.

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Chapter 2

General methodology

2 Methodology

Data are from the ‘Healthy Growth of Madeira Children Study’ (CRES) and from the ‘Madeira Child Growth Study’ (MCGS).

2.1 The ‘Healthy Growth of Madeira Children Study’

2.1.1 First phase

2.1.1.1 Sample and sampling procedures

The sample of the CRES (1^{st} phase) comprised 1637 subjects, 801 boys and 836 girls, aged 3 to 15 years, sampled according to formula 2.1. Thirty schools were first selected, but this number extended to 40 schools. Around 50 boys and 50 girls were observed in the age interval 3-10 year, and about 100 boys and 100 girls, from 10 to 14 years old. Subjects were selected with a stratified sampling procedure with the number of districts, the educational level and school facilities as stratification factors. Demographic data were provided by the Regional Secretary of Education and Human Resources and the sampling procedures were developed by a member of the Statistics Portugal.

$$n_{ij} = n_j \frac{N_{ij}}{N_j} \qquad (2.1)$$

Where,

j	index of the school year (j = 01, 02, 03, 1, 2, 3, 4, 5, 6, 7, 8 and 9)
i	index of the district (i = 1,…, 11)
$n_j = 100^{\dagger}$	size of the sample for each school year j
n_{ij}	size of the sample for district i and school year j

N_j total number of students of the Autonomous Region of Madeira (ARM) of school year j.

N_ij total number of students of the ARM from district i and school year j

†At 10-14 years old, the sample size was fixed at 200 subjects.

The population and the number of subjects assessed by district are shown in Figure 2.1.

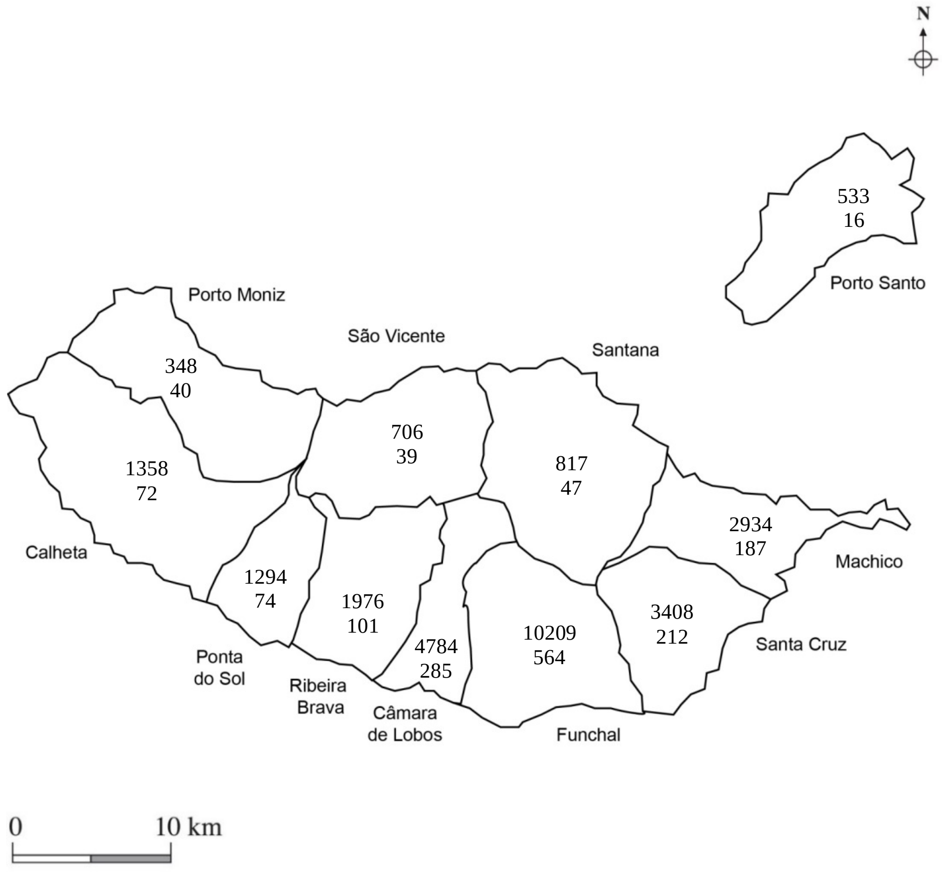

Figure 2.1 Distribution of the total number of subjects by district of the Autonomous Region of Madeira and number of subjects assessed.

Table 2.1 shows the number of predicted and assessed subjects by district, school, cohort, birth year, and sex. The sample was assessed during 2005 and 2006.

Table 2.1 Sample size by district, school, cohort, birth year and sex in the 'Healthy Growth of Madeira Children Study'.

District	School	Cohort 1		Cohort 2		Cohort 3		Cohort 4		Cohort 5		Cohort 6		Cohort 7		Cohort 8		Cohort 9		Cohort 10		Cohort 11		Cohort 12		Tm	Tf	Ta	TaD
	Birth year	2002		2001		2000		1999		1998		1997		1996		1995		1994		1993		1992		1991					
	Age, years	3		4		5		6		7		8		9		10		11		12		13		14					
	Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Tm	Tf	Ta	TaD
Funchal	Infantário Os Louros	13	10	14	5																					27	15	42	564
	Infantário O Sapatinho	2	5		7		1																			2	13	15	
	Escola Básica do 1.º Ciclo com Pré-Escolar de São Martinho			4	1	12	15	15	18	17	13	20	16	17	16		2									85	81	166	
	Escola Básica do 1.º Ciclo com Pré-Escolar do Lombo Segundo					3	2	2			1		2	2	2											7	7	14	
	Escola Básica do 1.º Ciclo com Pré-Escolar da Chamorra					2					2															2	2	4	
	Escola Básica dos 2.º e 3.º Ciclos dos Louros															11	12	10	12	6	8	5	9	12	9	44	50	94	
	Escola Básica dos 1.º, 2.º e 3.º Ciclos Bartolomeu Perestrelo															6	6	6	8	3	7	3	7	7	5	25	33	58	
	Escola Básica dos 2.º e 3.º Ciclos de Santo António																	3	1			3	1	1		7	2	9	
	Escola Básica dos 2.º e 3.º Ciclos Dr. Horácio Bento de Gouveia															6	6	2	3	15	8	5	13	8	13	36	43	79	
	Escola Básica e Secundária Gonçalves Zarco															14	11	10	13	2	12	7	7	3	4	36	47	83	
Câmara de Lobos	Jardim de Infância O Pião	2	2	6	8	3																				11	10	21	285
	Escola Básica do 1.º Ciclo com Pré-Escolar de Estreito de Câmara Lobos			3	2	7	9	10	10	9	10	10	10	8	10	4										51	51	102	
	Escola Básica do 1.º Ciclo com Pré-Escolar Romeiras															1										1		1	
	Escola Básica do 1.º Ciclo com Pré-Escolar de Câmara de Lobos													2						2						4		4	
	Escola Básica dos 2.º e 3.º Ciclos da Torre															8	11	9	8	8	10	7	7	7	9	39	45	84	
	Escola Básica dos 2.º e 3.º Ciclos do Estreito de Câmara Lobos															6	8	8	8	8	8	10	8	5	4	37	36	73	
Santa Cruz	Escola Básica do 1.º Ciclo com Pré-Escolar de Santa Cruz	6	6																							6	6	12	212
	Escola Básica do 1.º Ciclo com Pré-Escolar das Figueirinhas			7	7	6	7	6	6	6	6	5	6	5	5											35	37	72	
	Escola Básica dos 2.º e 3.º Ciclos do Caniço															9	6	6	9	6	6	7	6	6	6	34	33	67	
	Escola Básica dos 2.º e 3.º Ciclos Dr. Alfredo Ferreira Nóbrega Júnior															6	7	6	5	4	6	7	7	6	7	29	32	61	
Machico	Escola Básica do 1.º Ciclo com Pré-Escolar de Machico	6	5	5	5	5	6	5	6	6	5	5	6	5	5	3	5									40	43	83	187
	Escola Básica dos 2.º e 3.º Ciclos do Caniçal															2	2	3	1	3	1	3	1	2	2	13	7	20	
	Escola Básica e Secundária de Machico															9	6	5	13	10	9	11	12	6	3	41	43	84	
Ribeira Brava	Infantário O Balão	1			2																					1	2	3	101
	Escola Básica do 1.º Ciclo com Pré-Escolar de São Paulo	3	5	4	3	3	4	3	3	3	4	3	4	4	4											23	27	50	
	Escola Básica e Secundária Padre Manuel Álvares															3	3	6	6	5	5	5	5	5	5	24	24	48	
Ponta do Sol	Escola Básica do 1.º Ciclo com Pré-Escolar do Lombo dos Canhas	4	1	2	3	3	2	3	3	2	2	2	3	2	2											18	16	34	74
	Escola Básica do 1.º Ciclo com Pré-Escolar da Lombada		2																								2	2	
	Escola Básica e Secundária da Ponta do Sol															4	5	4	4	3	3	3	4	4	4	18	20	38	
Calheta	Escola Básica do 1.º Ciclo com Pré-Escolar de Ladeira e Lamaceiros	4	3	4	3	3	3	3	2	4	2	3	2	2	3											23	18	41	72
	Escola Básica e Secundária da Calheta															3	3	3	4	3	3	2	3	4	3	15	16	31	
Santana	Escola Básica do 1.º Ciclo com Pré-Escolar de São Roque do Faial	3	3	2	2	1	1	1	2	1	2	2	2	2	2		1									12	15	27	47
	Escola Básica e Secundária Bispo Dom Manuel Ferreira Cabral															2	2	2	2	2	3	2	2	1	2	9	11	20	
São Vicente	Escola Básica do 1.º Ciclo com Pré-Escolar da Boaventura	3	2	1	2	2	2	1	1	1	2	1	1	1	1											10	11	21	39
	Escola Básica e Secundária Dona Lucinda Andrade															1	2	2	2	1	1	3	2	2	2	9	9	18	
Porto Santo	Infantário O Moinho	2	2																							2	2	4	16
	Escola Básica do 1.º Ciclo com Pré-Escolar do Porto Santo			1	1	1	1	1	1	1	1	1	1	1	1											6	6	12	
	Escola Básica e Secundária Professor Doutor Francisco de Freitas Branco															1	2	1	2	2	2	2	1	1	1	7	8	15	
Porto Moniz	Escola Básica do 1.º Ciclo com Pré-Escolar do Porto Moniz	1	1	1	1	1	1			1	1			1	1											5	5	10	40
	Escola Básica e Secundária do Porto Moniz															1	1	1	2	2	1	1	2	2	2	7	8	15	
Total		50	47	54	52	52	54	50	52	51	51	52	53	52	52	100	101	87	103	85	93	86	97	82	81	801	836	1637	

Legend: M, male; F, female; Tm, total of males; Tf, total of females; Ta, total assessed; TaD, total assessed by district.

2.1.1.2 Study design

A graphical representation of the design adopted in the CRES is given in Figure 2.2. The CRES is a cross-sectional design with 12 birth cohorts [1.ª (2002), 2.ª (2001), 3.ª (2000), 4.ª (1999), 5.ª (1998), 6.ª (1997), 7.ª (1996), 8.ª (1995), 9.ª (1994), 10.ª (1993), 11.ª (1992) e 12.ª (1991)] measured/assessed once only.

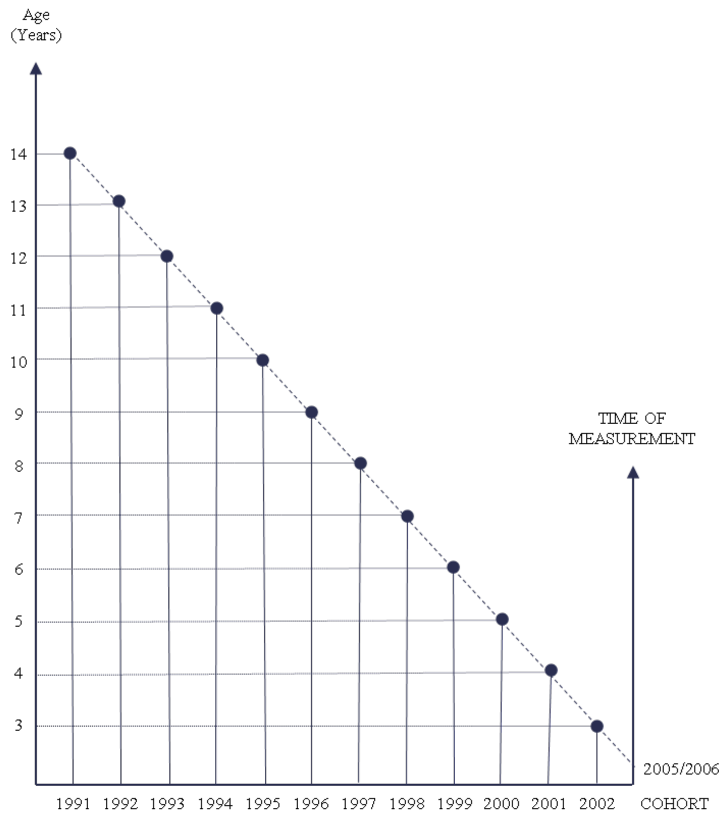

Figure 2.2 Design of the 'Healthy Growth of Madeira Children Study': first phase.

2.1.1.3 Tests and measurements

2.1.1.3.1 Fundamental motor skills

Fundamental motor skills were assessed through the 'Test of Gross Motor Development (TGMD-2) (Ulrich, 2000) (Appendix A). The TGMD-2 is composed of two subtests of 6 skills each. The locomotor part includes: run (the ability to advance steadily by springing steps so that both feet leave the ground for an instant with each stride), gallop (the ability to hop a minimum distance on each foot), leap (the ability to perform all of the skills associated with leaping over an object), horizontal jump (the ability to perform a horizontal jump from a standing position) and slide (the ability to slide in a straight line from one point to another). The object control subtest comprises: striking a stationary ball (the ability to strike a stationary ball with a plastic bat), stationary dribble (the ability to dribble a basketball a minimum of four times with the dominant hand before catching the ball with both hands, without moving feet), catch (the ability to catch a plastic ball has been tossed underhand), kick (the ability to kick a stationary ball with the preferred foot), overhand throw (the ability to throw a ball at a point on a wall with the preferred hand) and underhand roll (the ability to roll a ball between two cones with the preferred hand) (Table 2.2). Each motor skill includes 3, 4 or 5 performance criteria. If the child performs a behavioural component correctly, the examiner marks a 1 and otherwise 0. The child has to perform each skill twice. The sum of the scores of the two trials represents the final score for each skill. The skill scores add up to a subset score for locomotor and object control. The maximum raw total subtest score is 48. Raw scores in locomotor and object control subtests were used in this study as recommended by Ulrich (2000). Test-retest reliability in the pilot study was comprised between 0.65 and 0.95 if 1 item was deleted.

Table 2.2 Test of Gross Motor Development (TGMD 2) (Ulrich, 2000).

Locomotor subtest	Control subtest
Run	Striking a stationary ball
Gallop	Stationary dribble
Hop	Catch
Leap	Kick
Horizontal jump	Overhand throw
Slide	Underhand roll

2.1.1.3.2 Human physical growth

Growth characteristics were assessed according to procedures used in the 'Leuven Growth Study – Growth and Fitness of Flemish Girls' (Claessens et al., 1990) and from Norton and Olds (1996) (Appendix B). In 2005/2006, children were evaluated on 21 human physical growth characteristics divided by general body dimensions (height, body mass and sitting height), bone diameters (biacromial bicristal, femur and humerus) circumferences [arm (relaxed and flexed), calf, forearm, hip, thigh and waist] and skinfolds (abdominal, biceps, calf, subscapular, suprailiac, thigh, and triceps) (Table 2.3). The ICC for human physical growth characteristics were comprised between 0.85 and 1.00, in the pilot study, and between 0.89 and 1.00, in the 1st phase of the study.

Table 2.3 Human growth characteristics (Norton and Olds, 1996; Claessens et al., 1990).

Group/cluster	Growth characteristic
Body size	Height
	Body mass
	Sitting height
Bone diameters (lengths)	Biacromial
	Bicristal
	Femur
	Humerus
Circumferences (girths)	Arm relaxed
	Arm flexed and tensed
	Calf
	Forearm
	Hip
	Thigh
	Waist
Skinfolds	Abdominal
	Biceps
	Calf
	Subscapular
	Suprailiac
	Front thigh
	Triceps

2.1.1.3.3 Motor coordination

Gross motor coordination (MC) was assessed through ‘Körperkoordinations Test Für Kinder’ (KTK) (Kiphard and Schilling. 1974) (Appendix C). The KTK includes four specific tasks: (1) balance while moving backwards – the child is required to walks backward on balance beams 3 m in length but of decreasing widths: 6 cm, 4.5 cm, 3 cm; the number of successful steps is recorded; (2) jumping laterally – with the feet together, the child is required to make consecutive jumps as rapidly as possible from side to side over a small beam (60 cm x 4 cm x 2 cm) for 15 seconds; the number of correct jumps is recorded; (3) hopping on one leg over an obstacle – the child is required to hop on one foot over a stack of foam squares; after a successful hop (the child clears the foam square without touching it and continues to hop on the same foot at least two times) with each foot, the height is increased by adding a square (50 cm x 20 cm x 5 cm); three attempts at each height and with each foot are given, and the height of the final successful jump was recorded as the score; (4) shifting platforms – with the child standing with both feet on one platform (25 cm x 25 cm x 2 cm supported on four legs 3.7 cm high) and holding a second identical platform in his/her hands, he/she is required 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 (if the child falls off in the process, he/she simply gets back on to the platform and continues the test); the sequence continues for 20 seconds; each successful transfer from one platform to the other is given two points (one for shifting the platform, the other for transfer the body), and the number of points in 20 seconds was recorded. Raw scores for each of the four tests were used in the current analysis. Test-retest reliability, via ICC, carried out in the pilot study ranged between 0.64 and 0.90.

2.1.1.3.4 Physical activity

The Baecke questionnaire (Baecke et al., 1982) was used to assess physical activity (Appendix D). The questionnaire presents 16 questions, 8 of them related to physical activity at work (questions 1 to 8), 4 related to sport practice (questions 9 to 12) and 4 related to leisure-time physical activity (questions 13 to 16). Answers to the different items of the questionnaire were quantified in a likert scale, with the exception of the parental occupation and sports. Three indices were operationalized: physical activity at work, physical activity in sports and physical activity in leisure time. In this study, no information was collected in the first 8 questions because all the participants were students. The sum of sport and leisure-time indices was used as the total physical activity of the child.

2.1.1.3.5 Physical fitness

Physical fitness was assessed using the Eurofit test battery (Adam et al., 1988), which includes nine motor tests, namely, flamingo balance, plate tapping, shuttle run, sit ups, flexed arm hang, sit and reach, handgrip and stand long jump (Appendix B). The endurance shuttle run was replaced by the 12-minute run/walk test from the AAHPERD (1988) (Table 2.4). In the pilot study, ICCs were comprised between 0.76 and 0.99.

Table 2.4 Eurofit tests battery (Adam et al., 1988).

Factor	Test
Cardiorespiratory endurance	12-minute run/walk
Strength	
Static	Handgrip
Explosive power	Standing long jump
Muscular endurance	
Functional strength	Bent arm hang
Trunk strength	Sit ups
Speed	
Running speed - agility	Shuttle run 10 × 5 meters
Speed of limb movement	Plate tapping
Flexibility	Sit and reach
Balance	
Total body balance	Flamingo balance

2.1.1.3.6 Skeletal maturation

Radiographs of the left hand and wrist were taken with a portable X-ray apparatus (Top 25, For you, Belgian) using Kodak films (OMAT MA, Ready Pack). The portable unit was built according the indications supplied by Greulich-Pyle (1959) atlas and recommendations made by Tanner et al. (1962). Skeletal age was assessed with the Tanner-Whitehouse bone method (TW3 or TW2) (Tanner et al., 2001; 1983). The radius, ulna, seven carpals (excluding the pisiform) and metacarpals and phalanges of the 1st, 3rd and 5th rays were compared to written criteria for each bone; maturity scores were summed and converted to skeletal age.

All the x-rays were rated by a member of the Laboratory of Human Physical Growth and Motor Development, University of Madeira, with a large experience in rating x-rays. Inter-observer agreement between the rater and Professor Gaston Beunen was 85.3% (see also Freitas et al., 2012).

2.1.1.3.7 Socioeconomic status

The SES of the family was based on parental occupation, educational level, income, housing conditions and residential area features (Appendix E). Questions were taken from Census 1991 questionnaires (Statistics Portugal, 1995) and a modified version of the Graffar´s method (Graffar, 1956) was use to operationalize the household SES. In this method, each item is assessed in a five-point scale and then all responses are summed producing a scale ranging from 5 (most affluent) to 25 (less affluent). The operationalization of the social and economic parameters was the following:

- Parental occupation: nominal variable were occupations were coded according to the Portuguese Classification of Occupations (Instituto de Emprego e Formação Profissional, 2001). The 10 major groups of occupations to one digit (0-9) were recoded into five groups (1-5) using the following aggregation: code 1 – occupations from groups 1 and 2; code 2 – occupations from group 3; code 3 – occupations from groups 0, 4, 5 and no-qualified workers from these groups; code 4 – occupations from group 6 and no-qualified workers from this group; code 5 – occupations from groups 7 and 8, and no-qualified workers from these groups. The occupation of the father or mother of greater importance was retained in this study. In the SES scale, 1 includes the occupations of highest social prestige and 5 the lowest.

- Educational level: nominal variable that identifies the education level of the father and mother grouped in 5 categories (1 – licensee, master, post-graduate, and bachelor degree; 2 – technological education/technological specialization course; 3 – secondary school; 4 – primary and/or basic school; 5 – incomplete primary school). The highest educational level (father or mother) entered in the classification.

- Income: nominal variable with 5 levels (1 – live from incomes [inherited or acquired fortune]; 2 – fixed monthly salary; 3 – hasn't own salary [monthly salary of relatives]; 4 – payment per week or hour or task; 5 – the family is sustained by public or private charity.

- Housing conditions: nominal variable with 5 categories (1 – luxury houses or large apartments offering the maximum comfort to its residents; 2 - houses or apartments that aren't so luxury and large as the ones from the previous category but are spacious and comfortable; 3 - modest houses or apartments, well-constructed and in good condition; bright and airy, with kitchen and bathroom; 4 - intermediate category between 3 and 5; houses in good condition but without bathroom inside of the house or illegal building; 5 - accommodation unfit for a decent life: huts and apartments devoid of all comfort, ventilation, lighting or also those where too many people live in overcrowded condition.

- Residential area features: nominal variable with 5 categories (1 - elegant residential quarter (neighbourhood) where the land value or rent is high; green areas, footpaths, safe areas and sports facilities; 2 - good residential quarter (neighbourhood), with wide streets and comfortable houses and apartments; green areas, footpaths, safe areas and good access to sport facilities; 3 - shopping streets or narrow streets; old houses with generally less comfortable or social quarter; mixed between the urban and rural area; 4 - poor area with houses in disrepair, lack of sewerage system, roads in disrepair, unsafe areas, little access to sport facilities; 5 - degraded and dangerous area.

2.1.1.4 Testing procedures

A team of 6 teachers of Physical Education collected the data between February and July 2006. To ensure accurate measurements and ratings, the examiners followed an intensive training for a period of 3 months (October to December 2005).

First, the field team was trained in anthropometry by an expert from the University of Leuven, Belgium. Theoretical classes and lab sessions were ministered in the University of Madeira.

Second, the scientific coordinator of the CRES gave a verbal description of 'Preschool Test Battery' [PTB], TGMD-2 and KTK tests to the field staff, according to the procedures stated in the manuals. Equipment, performance criteria, administration and scoring system were extensively reviewed. After this stage, examiners watched a variety of DVDs and video-tape lessons in the lab. The scientific coordinator also scored the children and his scores served as criteria during the training sessions. Any discrepancy was dissipated through close observation of the images and protocols.

Finally, a pilot study was carried out in 46 children, age 3-10 year, from one public primary school. Children completed the items twice within a 8-day period.

In January of 2006, all the schools were visited by the field staff and an assessment plan was outlined together with the Director. Anthropometry, x-ray and motor tests were assessed/administered in the morning. Height and body mass were measured in the gymnasium or empty classroom. Whenever as possible, motors tests were conducted in an outside area, for example, the school playground. The field members worked in pairs. Children received a verbal description followed by a visual demonstration of each skill/test.

All study protocols were reviewed and approved by the Scientific Board of the University of Madeira and permission was granted from the Regional Secretary of Education and Culture (Appendix F). The whole process was also approved by the Ethics Committee of the Hospital of Funchal (Appendix G).

Participants were informed about the procedures, nature and relevance of the study and permissions were granted from their parents or tutors (Appendix H).

2.1.2 Second phase

2.1.2.1 Sample

A subsample of 158 children, 83 boys and 75 girls, aged 6, 7 and 8 years, in the 1st phase, was reassessed in 2012 (follow-up). The number of subjects assessed by district is shown in Figure 2.3.

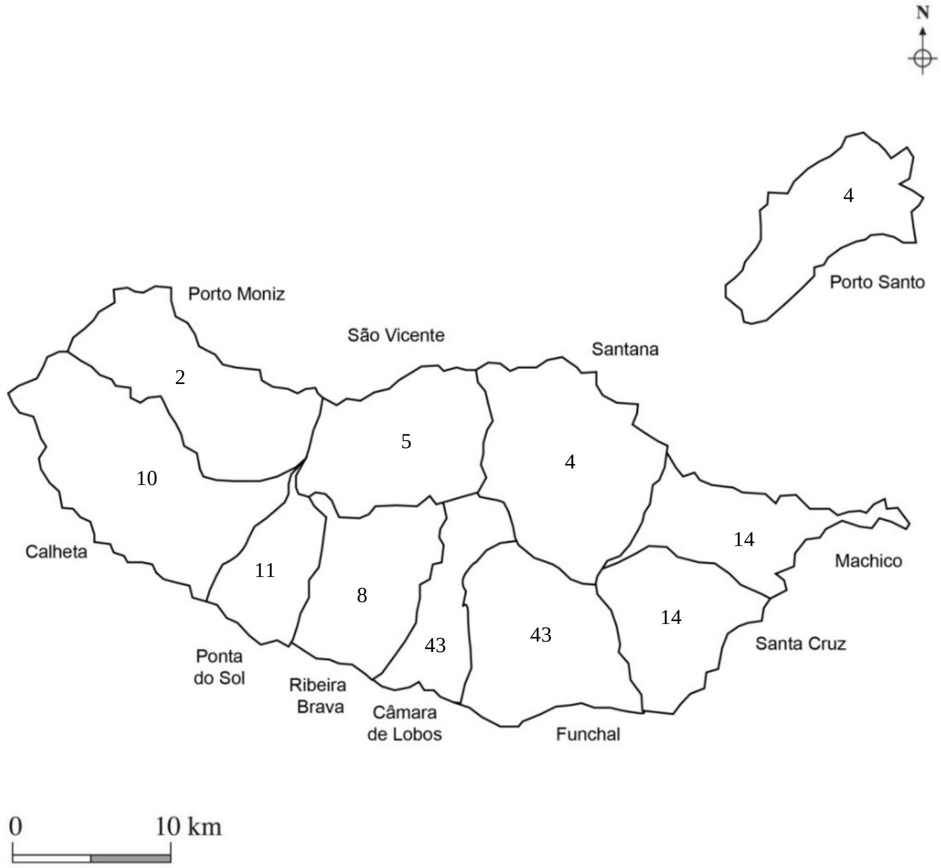

Figure 2.3 Distribution of the sample by district of the Autonomous Region of Madeira: 2nd phase of the 'Healthy Growth of Madeira Children Study'.

The sample size by district, school, cohort, age and sex is presented in Table 2.5.

2.1.2.2 Study design

A graphical representation of the 1st (subsample) and 2nd phases of the CRES is given in Figure 2.4. The participants came from 3 birth cohorts born in 1998, 1999 and 2000. At the start of the study, in 2006, children were aged 6, 7 and 8. Subsequently, the same children were observed in 2012 (follow-up), when they were, respectively, 12, 13 and 14 years.

Table 2.5 Sample size by district, school, cohort, age and sex in the 'Healthy Growth of Madeira Children Study': 2nd phase.

District	School	Cohort 4		Cohort 5		Cohort 6					
		Age, years 12		13		14					
		Sex									
		M	F	M	F	M	F	Tm	Tf	Ta	TaD
Funchal	Escola Básica e Secundária Gonçalves Zarco	2	4	3	0	4	2	9	6	15	43
	Escola Básica dos 2.º e 3.º Ciclos Bartolomeu Perestrelo	0	1	1	0	2	0	3	1	4	
	Escola Básica dos 2.º e 3.º Ciclos de São Roque	0	0	1	0	0	0	1	0	1	
	Escola Básica dos 2.º e 3.º Ciclos dos Louros	1	1	0	0	0	0	1	1	2	
	Escola Básica dos 2.º e 3.º Ciclos Dr. Horácio Bento de Gouveia	5	3	2	4	3	2	10	9	19	
	Escola Básica dos 2.º e 3.º Ciclos de Santo António	0	0	0	2	0	0	0	2	2	
Câmara de Lobos	Escola Básica dos 2.º e 3.º Ciclos do Estreito de Câmara de Lobos	7	8	6	6	5	6	18	20	38	43
	Escola Básica dos 2.º e 3.º Ciclos da Torre	0	0	2	0	0	1	2	1	3	
	Escola Básica e Secundária do Carmo	0	0	2	0	0	0	2	0	2	
Santa Cruz	Escola Básica dos 2.º e 3.º Ciclos do Caniço	1	2	2	4	2	1	5	7	12	14
	Escola Básica e Secundária de Santa Cruz	0	0	0	0	1	1	1	1	2	
Machico	Escola Básica e Secundária de Machico	3	1	2	2	3	3	8	6	14	14
Ribeira Brava	Escola Básica e Secundária Padre Manuel Álvares	1	0	1	4	1	1	3	5	8	8
Ponta do Sol	Escola Básica e Secundária da Ponta do Sol	3	1	1	2	1	3	5	6	11	11
Calheta	Escola Básica e Secundária da Calheta	2	1	3	1	2	1	7	3	10	10
Santana	Escola Básica dos 1.º, 2.º e 3.º Ciclos com Pré-Escolar do Porto da Cruz	0	0	1	1	1	1	2	2	4	4
São Vicente	Escola Básica e Secundária Dona Lucinda Andrade	1	0	1	1	1	1	3	2	5	5
Porto Santo	Escola Básica e Secundária Professor Dr. Francisco de Freitas Branco	1	1	0	0	1	1	2	2	4	4
Porto Moniz	Escola Básica e Secundária do Porto Moniz	0	0	1	1	0	0	1	1	2	2

Legend: M, male; F, female; Tm, total of males; Tf, total of females; Ta, Total assessed; TaD, total assessed by district.

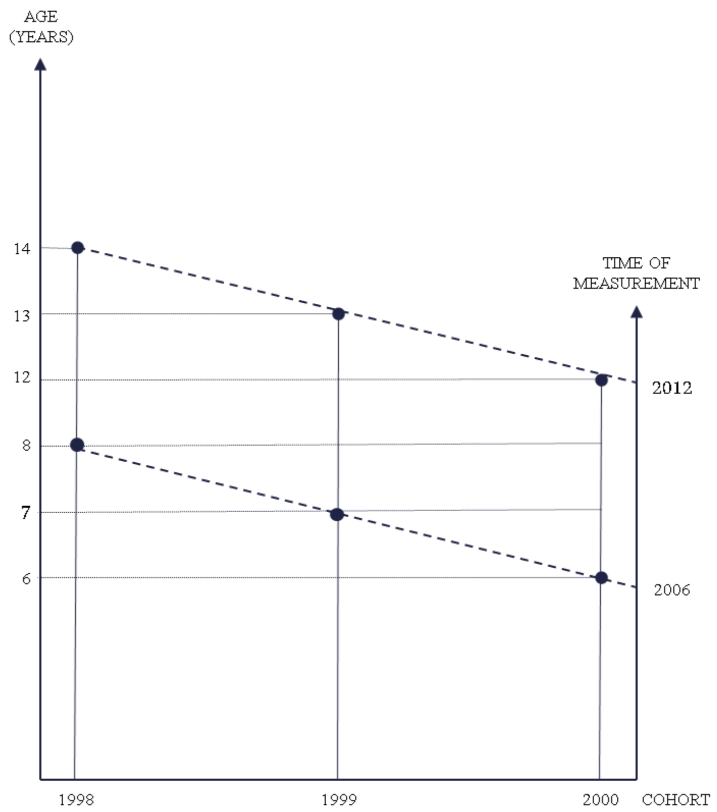

Figure 2.4 Design of the 'Healthy Growth of Madeira Children Study': 1st and 2nd phases.

2.1.2.3 Tests and measurements

Fundamental motor skills and skeletal maturation were not assessed/measured in the 2nd phase of the CRES. Height, body mass and waist circumference were the human physical growth characteristics re-measured in 2012.

Gross motor coordination was assessed with the same protocol of the 1st phase, i.e., the KTK battery (Kiphard and Schilling, 2007; 1974) (Appendix I). For physical fitness, 12-minute run/walk, standing long jump, sit ups, sit and reach, and flamingo balance were re-administered to the children (Appendix J). Physical activity (Appendix K) and SES (Appendix J) questionnaires were the same of the 1st phase.

2.1.2.4 Testing procedures

The author of this thesis and member of the field team of 1st phase of the CRES collected the data between January and March 2012. Fist, participants were located through a 'computing platform' called 'place 21' of the Regional Secretary of Education and Culture. The children's name, birth date and parent/legal guardian's names were entered in the platform; a total of 19 schools were identified. Second, all the schools were visited and an assessment plan was outlined together with the Director. Third, an invitation was sent to all participants. Forty-nine percent of the children agreed to participate in the 2nd phase.

Testing was done in the morning in the following sequence: human physical growth, motor coordination, physical fitness and questionnaires. Growth characteristics were measured in a gymnasium or unused classroom and motor tests were conducted outdoors (school playground). All variables were administered in a single day (~ 1 to 12 participants/day).

The study protocols were reviewed and approved by the Scientific Board of the University of Madeira and permission was granted from the Regional Secretary of Education and Culture (Appendix L). Participants were informed about the procedures, nature and relevance of the study and permissions were granted from their parents or tutors (Appendix M).

2.2 The 'Madeira Child Growth Study'

2.2.1 Sample and sampling procedures

Two hundred seventy-two healthy children, 143 boys and 129 girls, aged 3-yr-old, were recruited from 29 public/private preschools and participated in the 'Madeira Child Growth Study' [MCGS]. A multistage stratified sampling procedure, based on records of Regional Secretary of Education and Human Resources, was used to ensure a representative sample. Sampling procedures were equal to those used in CRES (see formula 2.1). The population and the number of children assessed by district are shown in Figure 2.5.

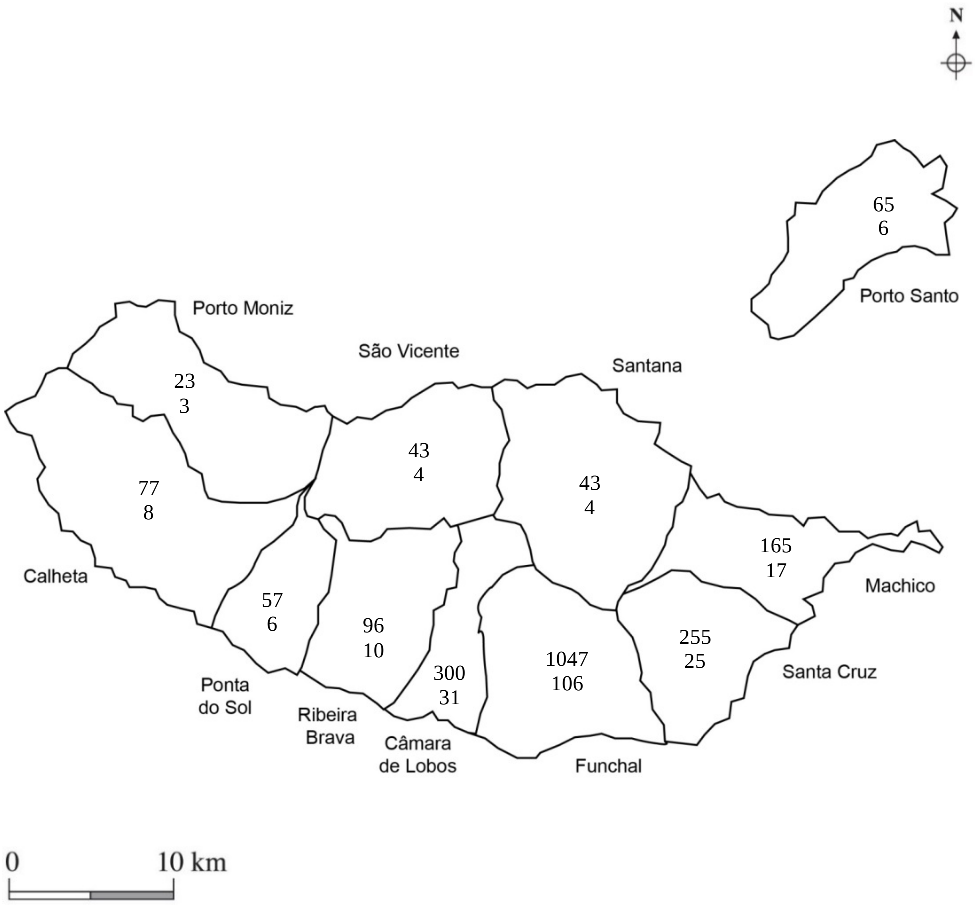

Figure 2.5 Distribution of the total number of subjects by district of the Autonomous Region of Madeira and number of subjects assessed: 'Madeira Child Growth Study'.

Table 2.6 shows the number of assessed children by district, school and sex.

2.2.2 Study design

A graphical representation of the MCGS is presented in Figure 2.6. The MCGS is a longitudinal design with one birth cohort born in 2009. At the start of the study in 2012 children were aged 3 years and they were observed at annual intervals (two years follow-up). In 2013 and 2014 children were, respectively, 4 and 5 years old.

Table 2.6 Number of children by district, school, and sex in the ‘Madeira Child Growth Study’.

District	School	M	F	TaD
Funchal	Canto dos Reguilas	16	14	118
	Centro Social Paroquial da Graça	3	12	
	Infantário Cidade dos Brinquedos	4	3	
	Escola Básica do 1.º Ciclo com Pré-Escolar da Nazaré	12	6	
	Externato Adventista do Funchal	3	2	
	Jardim de Infância Padre Angelino Barreto	3	0	
	Jardim de Infância O Polegarzinho	5	5	
	Infantário Quinta dos Traquinas	9	2	
	A Quintinha dos Janotas - Infantário, Lda	10	9	
Santa Cruz	Escola Básica do 1.º Ciclo com Pré-Escolar de Santa Cruz	6	12	38
	Escola Básica do 1.º Ciclo com Pré-Escolar da Camacha	5	7	
	Escola Básica do 1.º Ciclo com Pré-Escolar da Terça de Cima	2	1	
	Escola Básica do 1.º Ciclo com Pré-Escolar Dr. Clemente Tavares	5	0	
Câmara de Lobos	Escola Básica do 1.º Ciclo com Pré-Escolar da Lourencinha	10	6	33
	Escola Básica do 1.º Ciclo com Pré-Escolar da Quinta Grande	3	2	
	Escola Básica do 1.º Ciclo com Pré-Escolar do Covão	1	8	
	Escola Básica do 1.º Ciclo com Pré-Escolar da Fonte da Rocha	2	1	
Machico	Escola Básica do 1.º Ciclo com Pré-Escolar do Caniçal	3	3	24
	Infantário A Gaivota	11	7	
Ribeira Brava	Escola Básica do 1.º Ciclo com Pré-Escolar da Ribeira Brava	4	3	14
	Escola Básica do 1.º Ciclo com Pré-Escolar do Lombo de São João	3	4	
Calheta	Escola Básica do 1.º Ciclo com Pré-Escolar do Estreito da Calheta	3	6	10
	Escola Básica do 1.º Ciclo com Pré-Escolar do Lombo do Autoguia	1	0	
Porto Santo	Escola Básica do 1.º Ciclo com Pré-Escolar do Campo de Baixo	6	4	10
Ponta do Sol	Escola Básica do 1.º Ciclo com Pré-Escolar da Ponta do Sol	1	2	7
	Escola Básica do 1.º Ciclo com Pré-Escolar da Lombada	2	2	
São Vicente	Escola Básica do 1.º Ciclo com Pré-Escolar da Vila de São Vicente	4	3	7
Santana	Escola Básica do 1.º Ciclo com Pré-Escolar de Santana	3	3	6
Porto Moniz	Escola Básica do 1.º Ciclo com Pré-Escolar do Porto Moniz	3	2	5
Total		143	129	272

Legend: M, male; F, female; TaD, total assessed by district.

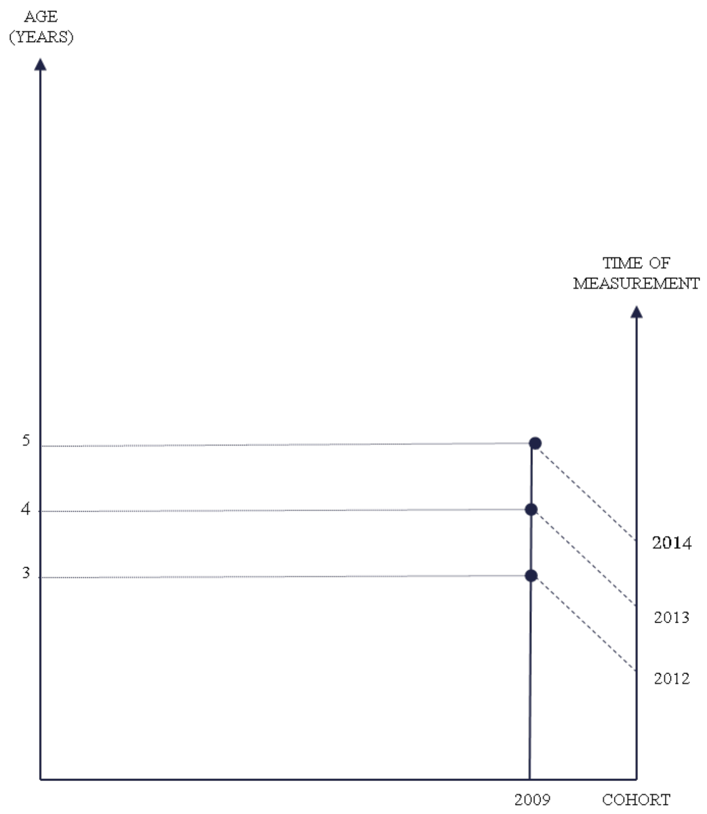

Figure 2.6 Design of the ‘Madeira Child Growth Study’.

2.2.3 Tests and measurements

2.2.3.1 Human physical growth

Height, body mass, skinfolds (abdominal, biceps, calf, subscapular, suprailiac and triceps) and waist circumference were measured according to standardized procedures (Claessens et al., 2008; Norton and Odds, 1996) (Appendix N). Test-retest reliability in the second year of measurement (2013) (random subsample of n = 45) ranged from 0.979 to 1.000.

2.2.3.2 Physical activity

The leisure time exercise questionnaire (Godin and Shephard, 1985) was used to assess physical activity (Appendix O). The questionnaire includes 3 questions measuring strenuous, moderate and mild exercise, over a typical 7-day period. The children were asked to recall how many times, on the average, they did several kinds of exercise for more than 15 minutes during their free time. A leisure-time physical activity score was computed by multiplying weekly frequencies of strenuous, moderate and mild exercise by nine, five, and three, respectively; these latter values correspond to MET value categories of the activities listed. Then the total weekly leisure time activity score was computed by summing the products of the separate components (Godin, 2011).

2.2.3.3 Motor performance

Motor performance was assessed using the PTB (Morris et al., 1981) (Appendix N). The PTB comprises 6 motor performance items, namely, catching (child's ability to catch an aerial ball), scramble (how fast the child could move from the supine to the vertical, run a short distance, pick up a fleece ball, and return to a horizontal position), speed run (how fast the child could run a distance of 40 feet), standing long jump (how far the child could jump horizontally, using a two-foot take-off and landing), balance (how long the child could balance while standing on one foot) and tennis ball throw for distance (how far the child could throw a tennis ball).

2.2.3.4 Socioeconomic status

The SES of the family was based on parental occupation, educational level, income, housing conditions and residential area features (Appendix O). Questions were taken from Census 2011 questionnaires (Statistics Portugal, 2013) and a modified version of the Graffar´s method (Graffar 1956) was use to operationalize the household SES. In this method, each item is assessed in a five-point scale and then all responses are summed producing a scale ranging from 5 (most affluent) to 25 (less affluent). Parental occupation was coded according to the Portuguese Classification of Occupations (Statistics Portugal, 2011). The 10 major groups were recoded in five groups. This task was performed by a member of the Statistics Portugal.

2.2.3.5 Geographical area

Three types of geographical areas were obtained following the criteria developed by the Statistics Portugal (2004). Urban area (centrality index ≥ 3.81) comprises the municipality of Funchal. Semi-urban area (centrality index between 3.46 and 3.80) covers the municipalities of Machico, Porto Santo, Câmara de Lobos and Santa Cruz. Rural area (centrality index ≤ 3.45) includes the municipalities of Ribeira Brava, São Vicente, Santana, Calheta, Ponta do Sol and Porto Moniz. The centrality index is based on the functions provided by an urban centre, the degree of specialization, and the number of functional units. Regarding to the population, the intervals are the following: urban area (≥ 12001 inhabitants), semi-urban area (6000 ≤ n.º of inhabitants < 12000) and rural area (< 5999 inhabitants).

2.2.4 Testing procedures

Data were collected by the author of this thesis and a team of 17 physical education (PE) teachers. All PE teachers completed 32 hours of theoretical classes and field sessions (Appendix P). Training focused on equipment, performance criteria, and administration and scoring of motor tests. Practical procedures were administrated in a sample of 8 children, aged 4-5 years old. A pilot study was then carried out in 72 children, age 4 years, before data collection. Children completed the motor tests twice within a 8-day period. Test-retest reliability, via intraclass correlation coefficient, ranged from 0.92 (catching) to 0.99 (balance).

In November of 2012, the preschools were visited by the author of this thesis and an assessment plan was outlined together with the Director. Data were collected between December and July of each year. Anthropometry and motor tests were assessed/administered in a single day (~1 to 12 participants/day) during the morning and early afternoon. The sequence was anthropometry and then motor tests. Anthropometry was performed by the author of this thesis in the gymnasium or empty classroom. Motor tests were conducted by the author of this thesis and the PE teacher in the school playground. Therefore, data collection involved two testers: the author of this thesis and the PE teacher of each preschool. Based on the number of students, some PE teachers gave classes in more than one school. Children received a verbal description followed by a visual demonstration of each motor test and were highly motivated when performing the motor tests. The author of this thesis and/or the PE teacher administered the questionnaires at baseline to the parents/legal guardians at the end of the school day. During the two-year of the follow-up the 17 PE teachers remained in the study.

Permissions were obtained from the Scientific Committee of the University of Madeira and the Regional Secretary of Education and Human Resources (Appendix Q). Parents or tutors were informed about the procedures, nature and relevance of the study and permissions were granted for all the participants (Appendix R).

2.3 References

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Chapter 3

Gross motor coordination and weight status of Portuguese children aged 6-14 years

António M. Antunes, José A. Maia, Mikis D. Stasinopoulos, Élvio R Gouveia, Martine A. Thomis, Johan A. Lefevre, Alexandra Q. Teixeira, Duarte L. Freitas

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Abstract

Purposes: To construct age- and gender-specific percentiles for gross motor coordination (MC) tests and to explore differences in gross MC in normal-weight, overweight and obese children.

Methods: Data are from the 'Healthy Growth of Madeira Study', a cross-sectional study carried out in children, aged 6-14 years, in 2005 and 2006. In all, 1276 participants, 619 boys and 657 girls, were assessed in gross MC ('Körperkoordinations Test für Kinder'), anthropometry, physical activity and socioeconomic status (SES). Centiles curves for gross MC were obtained for boys and girls separately using generalized additive models for location, scale and shape.

Results: Scores on walking backwards [$F(8, 1258) = 41.45$, $p < 0.001$, $\eta^2 p = 0.21$] and moving sideways [$F(8, 1258) = 167.01$, $p < 0.001$, $\eta^2 p = 0.52$] improved with age among Portuguese children. Boys performed better than girls on moving sideways [$F(1, 1258) = 34.39$, $p < 0.001$, $\eta^2 p = 0.03$]. Centile curves revealed large interindividual variation. After adjustment for age, physical activity and SES, normal-weight children outperformed their obese peers in almost all gross MC tests. Overweight boys displayed better scores than obese counterparts in walking backwards (6-8 years), hopping on one leg (12-14 years) and moving sideways (12-14 years). Additionally, overweight girls surpassed obese colleagues in walking backwards (9-11; 12-14 years), hopping on one leg (all age groups) and jumping sideways (12-14 years).

Conclusions: In general, Portuguese children improved their scores on gross MC with age and demonstrated a large interindividual variation. Gender differences vary over age and gross MC test. Normal-weight children outperformed obese peers on gross MC even controlling for age, physical activity and SES.

Key words: motor coordination, centiles, weight status, children

3.1 Introduction

Given the link between gross motor coordination (MC), physical activity and health-related fitness, a number of academics have gathered factual evidence related to age- and gender-associated variation in gross MC tests (Vandorpe et al., 2011; Ahnert et al., 2009; Largo et al., 2001a,b,c; Kiphard and Schilling, 1974). From these studies, MC seems to improve with age during middle childhood and adolescence, while gender-associated differences are not consensual over age range and among MC test.

A more comprehensive picture of the developmental trajectory of gross MC has recently been provided by Chaves et al. (2013) and Vidal et al. (2009) in Portuguese children, aged 6-11 years. Gross MC was assessed via the ‘Körperkoordinations Test für Kinder’ (KTK) (Kiphard and Schilling, 1974) and LMS method (Cole and Green, 1992) was used to derive the age- and gender-specific percentiles. Boys and girls not only improved the MC scores with increasing age, but also showed a large interindividual variability, i.e., a wide absolute range between the 3^{rd} and 97^{th} percentiles. Similar results were found by Valdivia et al. (2008) in Peruvian children, aged 6-11 years, using KTK and the same statistical method to derive the gross MC curves.

The aforementioned interrelationships and the developmental trajectories of gross MC are strongly intermediated by other variables including weight status, physical activity and socioeconomic status (SES) (Lubans et al., 2010 and Stodden et al., 2008). Specifically, overweight and obese children were found to perform poorer on gross MC than their normal-weight peers, with an obvious effect of body mass index (BMI) on weight-bearing gross MC tasks (Gentier et al., 2013; Krombholz, 2013; D’Hondt et al., 2013; 2011). In addition, the BMI-related differences in gross MC seem to be more pronounced in late childhood (D’Hondt et al., 2011) than in beginning of adolescence (Lopes et al., 2012). Sport club participation was also associated with higher levels of gross MC (Fransen et al., 2012; Vandorpe et al., 2012; Zahner et al., 2009) and played a central role in children’s future level of gross MC (D’Hondt et al., 2013). Likewise, SES was a predictor of gross MC in Peruvian children (Valdivia et al., 2008).

Apart from the recent progress in constructing normative values for gross MC tests, the previous studies are confined to some countries and a need exist for well-constructed centile curves. In effect, these studies did not embrace the age band recommended for KTK battery, i.e., 5-15 years, and did not use statistical modelling that allow to derive growth curves dealing with truncated data, as are the cases of walking backwards and hopping on one leg. The current study provided age- and gender-specific percentiles for gross MC tests based on a large representative sample of children. It overcomes some of the earlier failings, namely, an extension of the age interval and a statistical novel approach to derive the centiles curves. Based on the available literature, it was hypothesized that gross MC improved with increasing age and that gender-association variation was dependent of the gross MC test. It is our expectance that these centile values could provide a better understanding of the general pattern of gross MC tests and be used by professionals for screening, control and research purposes.

It is also worth to emphasize that prior research remains inconclusive regarding to the association of BMI to gross MC in late childhood and adolescence. Therefore, we also investigated the differences in gross MC among normal-weight, overweight and obese children after controlling for age, physical activity and SES. It is hypothesized that normal-weight children outperform their obese peers in all gross MC tests and that these differences will be more marked in late childhood. Furthermore, it is hypothesized that overweight children surpassed their obese peers in some gross MC tests.

3.2 Subjects and methods

3.2.1 Participants

This study uses data from the 'Healthy Growth of Madeira Study' (CRES), a cross-sectional study of children, aged 3 to 15 years, conducted by the University of Madeira and the Government of the Autonomous Region of Madeira in 2005 and 2006. Briefly, 40 public/private schools were randomly selected and stratified according to geographical location (11 districts), school grade (nursery schools/kindergartners and grades 1 to 9) and school facilities (gym and/or school sports hall). Approximately 50 boys and 50 girls were sampled in each age interval from 3 to 9 years and about 100 boys and 100 girls from 10 to 14 years. The number of children sampled was proportional to the number of children enrolled in the education system, matched by district, age and sex. A list of schools and students was provided by the Secretary of Education and Culture. Sampling procedures were carried out with the assistance of ‘Statistics Portugal’ and have been reported in detail elsewhere (Freitas et al., 2013).

The Director of each school selected the children randomly until the required number of boys and girls was obtained. Any child with a known disability was excluded. In all, the CRES comprises a sample of 1637 voluntary children, 801 boys and 836 girls. The current study involves a subsample of 1276 children, 619 boys and 657 girls, which correspond to the total number of children aged 6 to 14 years who performed KTK. Parents/legal guardians and children gave their informed consent/assent. The CRES received approval from the ethics committee of the University of Madeira, educational authorities and local hospital.

3.2.2 Data collection

Data was collected between January and June 2006 by 6 teachers of Physical Education under the supervision of the leader of the research team. The field team members underwent theoretical classes and lab sessions during a period of 3 months. A pilot study was carried out in 46 children, age 3-10 years, from a primary school. Children were assessed twice with an interval of 1 week (1^{st} evaluation, 6 and 7 December; 2^{nd} evaluation, 13 and 15 December, 2005) aiming to assess test-retest reliability and to refine the assessment procedures. Anthropometric measurements took place in the gym and MC tests were assessed in the school sports hall. Both, anthropometry and MC tests were assessed/performed in a single day (~20 participants/day).

3.2.2.1 Anthropometry

The field team members of the CRES assessed children’s stature and body mass following to the guidelines of Claessens et al. (1990). Participants wore a swimming costume (two-piece for females), without shoes and jewellery removed. Stature was measured with a portable stadiometer (Siber-Hegner, GPM) to the nearest millimetre. Body mass was measured on a balance-beam scale accurate to 100 g (Seca Optima 760, Germany). Children were classified as normal-weight, overweight or obese according to the age- and sex-specific BMI [calculated by dividing body mass (kg) by height (m^2)] cut-off points developed by the International Obesity Task Force (Cole et al., 2000). The intraclass test-retest correlation coefficient (ICC) for stature and body mass was 0.996 and 1.000 in the pilot study, and was 1.00 in the CRES.

3.2.2.2 Gross motor coordination

The “Körperkoordinations Test für Kinder” (KTK) (Kiphard & Schilling, 1974) includes four specific tasks: (1) balance while moving backwards – the child is required to walks backward on balance beams 3 m in length but of decreasing widths: 6 cm, 4.5 cm, 3 cm; the number of successful steps is recorded; (2) jumping laterally – with the feet together, the child is required to make consecutive jumps as rapidly as possible from side to side over a small beam (60 cm x 4 cm x 2 cm) for 15 seconds; the number of correct jumps is recorded; (3) hopping on one leg over an obstacle – the child is required to hop on one foot over a stack of foam squares; after a successful hop (the child clears the foam square without touching it and continues to hop on the same foot at least two times) with each foot, the height is increased by adding a square (50 cm x 20 cm x 5 cm); three attempts at each height and with each foot are given, and the height of the final successful jump was recorded as the score; (4) shifting platforms – with the child standing with both feet on one platform (25 cm x 25 cm x 2 cm supported on four legs 3.7 cm high) and holding a second identical platform in his/her hands, he/she is required 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 (if the child falls off in the process, he/she simply gets back on to the platform and continues the test); the sequence continues for 20 seconds; each successful transfer from one platform to the other is given two points (one for shifting the platform, the other for transfer the body), and the number of points in 20 seconds was recorded. Raw scores for each of the four tests were used in the current analysis. Test-retest reliability, via ICC, carried out in the pilot study ranged between 0.64 and 0.90.

3.2.2.3 Physical activity and socioeconomic status

Physical activity was assessed by means of a questionnaire developed by Baecke et al. (1982). In this study, physical activity indices were calculated for sport and leisure time. A sport score (one or two main sports) was also calculated from a combination of the intensity of the sport which was played, the amount of time per week playing that sport, and the proportion of the year in which the sport was played regularly. The sum of sport and leisure-time indices was used as the total physical activity of the child. Socioeconomic information was collected via a standardized questionnaire developed by the ‘Statistics Portugal’ (Instituto Nacional de Estatística, 1995). The questionnaire encompasses five characteristics (parental occupation, education, income, housing, and residential area features), but only education, i.e., the highest educational attainment of the father or mother, was used in the current study. The team members filled out the questionnaires by means of a face-to-face interview with the subjects before the anthropometric measurements were taken. Children under 11 years of age had the assistance of a parent or legal guardian.

3.2.3 Centiles curves

Centiles curves for gross MC tests were obtained for boys and girls separately using generalized additive models for location, scale and shape (GAMLSS) (Rigby & Stasinopoulos, 2005) and its R implementation (Stasinopoulos & Rigby, 2007). Different distributions were selected using the Akaike information criterion (AIC). For walking backwards and hopping on one leg tests, truncated versions were used because these tasks had an upper limit. For boys, the Normal (or Gaussian) (NO) (truncated), Skew *t* type 3 (ST3) (truncated), Box-Cox power exponential (BCPE), and Box-Cox *t* (BCT) distributions were used to fit the growth curves of walking backwards, hooping on one leg, jumping sideways and moving sideways tests, respectively. For girls, the distributions chosen to model gross MC tests were: Power Exponential (PE) (truncated) (walking backwards), *t* family (TF) (truncated) (hopping on one leg), and Box-Cox Cole and Green (BCCG) (jumping sideways and moving sideways).

The parameters to be estimated for each distribution were: NO (μ, σ), PE, TF and BCCG (μ, σ, υ), and ST3, BCPE and BCT ($\mu, \sigma, \upsilon, \tau$). The parameter μ is interpreted as relating to location (median), while σ is a scale parameter (approximate coefficient of variation). The other two, υ and τ, are shape parameters (transformation to symmetry). All parameters were modelled as smooth functions of age using penalized splines (P-splines) (Eilers & Marx, 1996). In each case, the smoothing parameters were selected using local maximum likelihood as described by Stasinopoulos and Rigby (2013).

3.2.4 Data analysis

Data were entered once in the computer by two different people - each person entered the data once, in a total of two entries - and cross-referenced in STATA, version 11 (StataCorp, 2009) to detect input errors. Outliers and the normality of the data were first explored. Descriptive statistics were calculated to determine the means, standard deviations and/or frequencies for age, anthropometry, gross MC, physical activity and SES. A two-way between-groups analysis of variance (ANOVA) was used to test simultaneously for the effect of age and gender on each gross MC test and to explore the possibility of any interaction effect; the effect size was reported as partial eta squared (η^2_p). Analysis of covariance (ANCOVA) was used to explore differences between BMI categories (normal-weight, overweight and obese) on each gross MC tests, while controlling for age, age squared, physical activity and SES. The raw scores of the current sample were compared with national and international samples using one-sample *t*-tests. All analyses were performed using STATA, version 11 (StataCorp, 2009) and SPSS 19.0 (IBM Corp, Released 2010). The minimal statistical significance was set at $p < 0.05$.

3.3 Results

3.3.1 General characteristics

Means, SDs, frequencies (absolute and relative) and ranges for the socio-demographic and health variables are presented in Table 3.1. In all, 48.5% of the children are boys and 51.5% girls. The prevalence of overweight and obesity is 17.69% and 7.47%, respectively, for the boys, and 20.70% and 5.02% for the girls. Approximately 50% of the parents have the secondary education or polytechnic/university level, which parallels the data from 2001 Census.

Table 3.1 Socio-demographic and health characteristics of the sample, aged 6-14 years, CRES (2006).

	Boys		Girls	
Characteristics	n	Mean ± Sd	n	Mean ± Sd
Age (years)	619	11.20 ± 2.39	657	11.26 ± 2.38
Height (cm)	616	146.71 ± 15.52	657	145.98 ± 13.84
Body mass (Kg)	616	42.39 ± 14.30	657	41.84 ± 13.16
Body mass index (kg/m2)	616	19.14 ± 3.61	657	19.14 ± 3.62
Normal-weight		461 (74.84)		488 (74.28)
Overweight		109 (17.69)		136 (20.7)
Obese		46 (7.47)		33 (5.02)
Physical activity				
Sport index (range 1-5)	614	3.04 ± 0.63	650	2.64 ± 0.58
Leisure-time index (range 1-5)	614	2.74 ± 0.59	650	2.55 ± 0.57
Total (range 2-10)	614	5.77 ± 0.99	650	5.19 ± 0.94
Socioeconomic status†				
Elementary school (grades 1 to 6)		280 (45.53)		317 (49.07)
Secondary school (grades 7 to 12)		213 (34.63)		238 (36.84)
Post-secondary (polytechnic and university)		122 (19.84)		91 (14.09)

†High qualification of the father or mother; data are mean ± standard deviation or frequencies [absolute and relative (in brackets)].

3.3.2 Reference values and centile curves for gross motor coordination tests

Means, SDs and age-, and gender-specific smoothed percentiles (10th, 25th, 50th, 75th and 90th) for gross MC tests are shown in Table 3.2. Graphical representation is given in Figures 3.1 to 3.4. Scores on walking backwards [$F(8, 1258) = 41.45$, $p < 0.001$, $\eta^2_p = 0.21$] and moving sideways [$F(8, 1258) = 167.01$, $p < 0.001$, $\eta^2_p = 0.52$] improve with age among our children, aged 6-14 years. Furthermore, boys perform better than girls on moving sideways [$F(1, 1258) = 34.39$, $p < 0.001$, $\eta^2_p = 0.03$]. A significant interaction effect between the age group and the gender is found on hopping on one leg [$F(8, 1258) = 2.66$, $p = 0.007$, $\eta^2_p = 0.02$] and jumping sideways [$F(8, 1258) = 2.53$, $p = 0.010$, $\eta^2_p = 0.02$] indicating that the influence of age on these gross MC tests is dependent on sex and, therefore, we cannot safely interpret the main effects.

Age-, and gender-specific differences described earlier are seen in the growth curves. Additionally, for walking backwards (Figure 3.1), interindividual variability is similar at 6 and 14 years olds. For hopping on one leg, boys show analogous variability at the extremes, but interindividual variability is higher in girls at 14 years (Figure 3.2). A greater variability at the upper limit is also seen for jumping sideways and moving sideways in boys and girls (Figures 3.3 and 3.4).

3.3.3 Gross motor coordination and weight status

Age-, and gender-specific means and SDs for gross MC testes of normal-weight, overweight and obese children, aged 6-14 years, are shown in Table 3.3. The results of ANCOVAs, controlling for age, age squared, physical activity and SES are presented as well. Children classified as normal-weight outperform their obese peers in all gross MC tests. Overweight boys also score better than obese peers in walking backwards (6-8 years), hopping on one leg (12-14 years) and moving sideways (12-14 years). Additionally, overweight girls surpass obese colleagues in walking backwards (9-11; 12-14 years), hopping on one leg (all age groups) and jumping sideways (12-14 years).

3.4 Discussion

This study provided age- and gender-specific percentiles for gross MC tests and investigated differences in gross MC among normal-weight, overweight and obese children. In detail, raw scores on walking backwards and moving sideways improved with age and boys performed better than girls on moving sideways. Furthermore, normal-weight children outperformed their obese peers in all gross MC tests. Overweight children also surpassed obese colleagues on walking backwards, hopping on one leg, moving sideways (boys), and jumping sideways (girls) in some age groups.

Although centile curves for gross MC tests have been published for Portuguese (Chaves et al., 2013 and Vidal et al., 2009) and Peruvian (Valdivia et al., 2008) children, the growth curves representing developmental changes from 6 to 14 years have apparently not been provided.

Table 3.2 Age-, and gender-specific smoothed percentiles for gross motor coordination: walking backwards, hopping on one leg, jumping sideways and moving sideways.

		Walking backwards†							Hopping on one leg‡							Jumping sideways							Moving sideways						
Age, years	n	x̄	Sd	P10	P25	P50	P75	P90	x̄	Sd	P10	P25	P50	P75	P90	x̄	Sd	P10	P25	P50	P75	P90	x̄	Sd	P10	P25	P50	P75	P90
Boys																													
6	33	37.8	12.1	19.1	26.0	33.7	41.4	48.3	19.6	11.4	4.6	9.2	15.1	21.7	27.8	30.8	8.6	16.9	21.3	26.6	32.4	38.1	30.2	5.3	21.9	24.4	27.2	30.2	33.3
7	52	42.1	11.0	24.9	32.0	39.9	47.8	54.9	27.3	12.2	8.8	14.9	22.0	29.1	35.3	33.6	8.9	21.7	26.6	32.3	38.3	44.2	33.2	4.9	25.3	28.0	31.2	34.4	37.7
8	55	48.6	11.4	30.3	37.6	45.7	53.7	60.6	35.4	9.3	13.4	20.9	29.2	36.8	43.1	43.8	9.7	26.4	31.8	37.9	44.2	50.3	37.1	4.9	28.6	31.7	35.0	38.5	42.0
9	48	53.5	11.2	34.4	41.9	50.0	58.0	64.4	37.8	10.8	18.1	27.0	36.5	44.7	51.0	48.1	11.7	30.2	36.4	43.3	50.3	57.0	40.3	6.4	31.5	34.8	38.4	42.1	45.6
10	82	51.0	11.6	36.4	44.1	52.3	60.1	66.1	42.7	16.4	22.7	33.0	43.8	52.7	58.9	50.1	13.9	32.9	40.2	48.3	56.6	64.3	42.7	6.3	33.9	37.4	41.1	44.8	48.4
11	92	53.7	11.9	38.0	45.7	54.1	61.7	67.3	47.2	14.2	26.9	38.6	50.5	60.0	65.9	54.3	12.1	36.4	44.3	53.2	62.1	70.0	43.8	5.8	35.9	39.6	43.4	47.1	50.6
12	87	56.8	10.6	40.5	48.3	56.5	63.7	68.5	53.3	13.7	29.8	42.6	54.9	64.1	69.2	59.2	13.1	40.6	48.6	57.9	67.2	74.9	46.5	6.0	37.9	41.7	45.5	49.2	52.7
13	87	57.9	9.8	43.1	50.9	58.8	65.4	69.5	59.7	15.3	37.2	50.4	60.7	67.3	70.5	66.0	14.1	44.3	52.5	62.8	72.8	80.4	49.6	6.5	40.4	44.3	48.2	52.0	55.5
14	83	60.0	8.6	45.5	53.1	60.7	66.7	70.1	67.9	7.6	58.2	64.9	68.9	71.0	71.9	69.6	11.5	50.1	57.6	67.5	77.1	83.8	53.2	6.5	43.3	47.4	51.4	55.2	58.8
Girls																													
6	35	35.4	12.8	19.2	25.9	35.2	44.6	51.2	18.3	11.4	4.7	9.4	15.5	22.1	28.6	31.2	8.8	16.3	21.2	27.3	34.1	40.9	28.5	5.3	21.7	24.8	27.9	30.8	33.2
7	51	43.9	12.1	23.8	30.8	40.3	49.7	56.7	29.1	10.8	9.4	15.7	22.8	30.1	37.1	38.3	13.5	21.0	26.7	33.6	41.1	48.3	32.4	5.0	24.4	27.6	30.9	34.0	36.7
8	49	47.1	13.6	28.3	35.5	45.1	54.5	61.6	31.6	12.8	14.4	21.5	29.3	37.2	44.8	43.0	12.7	26.1	32.4	39.9	47.8	55.3	35.1	5.5	27.1	30.3	33.8	37.1	40.1
9	55	50.7	11.0	32.1	39.6	49.0	58.2	64.9	35.2	11.9	18.2	26.1	34.5	42.9	50.9	48.3	10.1	31.1	37.9	45.7	53.8	61.3	38.3	5.2	29.7	33.0	36.6	40.1	43.3
10	83	50.8	11.5	35.1	42.8	51.9	60.6	66.7	40.9	14.1	20.9	29.4	38.4	47.3	55.6	54.7	13.2	35.8	42.8	50.8	58.9	66.3	41.0	6.1	32.1	35.4	39.2	42.9	46.3
11	103	54.5	12.7	37.4	45.4	54.2	62.3	67.8	43.3	14.7	23.6	32.7	42.2	51.5	59.7	55.3	10.7	39.8	47.0	54.9	62.9	70.0	42.3	5.2	34.2	37.7	41.6	45.5	48.9
12	97	55.8	11.2	39.1	47.4	56.0	63.6	68.5	47.9	14.0	27.5	37.2	47.2	56.6	64.0	60.2	11.7	43.3	50.6	58.5	66.2	73.1	45.3	5.9	36.2	39.9	43.9	47.8	51.3
13	89	56.8	10.6	40.3	48.9	57.4	64.5	69.0	52.7	13.7	32.4	42.6	52.7	61.5	67.4	62.4	12.2	46.4	54.0	61.9	69.4	75.9	45.7	6.8	37.9	41.9	46.1	50.1	53.5
14	95	56.5	11.1	41.1	50.0	58.5	65.2	69.4	57.1	12.6	37.0	47.5	57.4	65.0	69.4	65.4	11.5	49.2	56.9	64.8	72.1	78.3	49.1	6.4	39.6	43.9	48.2	52.2	55.5

†Maximum score is 72 points; ‡maximum score is 78 points; x̄, mean; Sd, standard deviation; P, percentile.

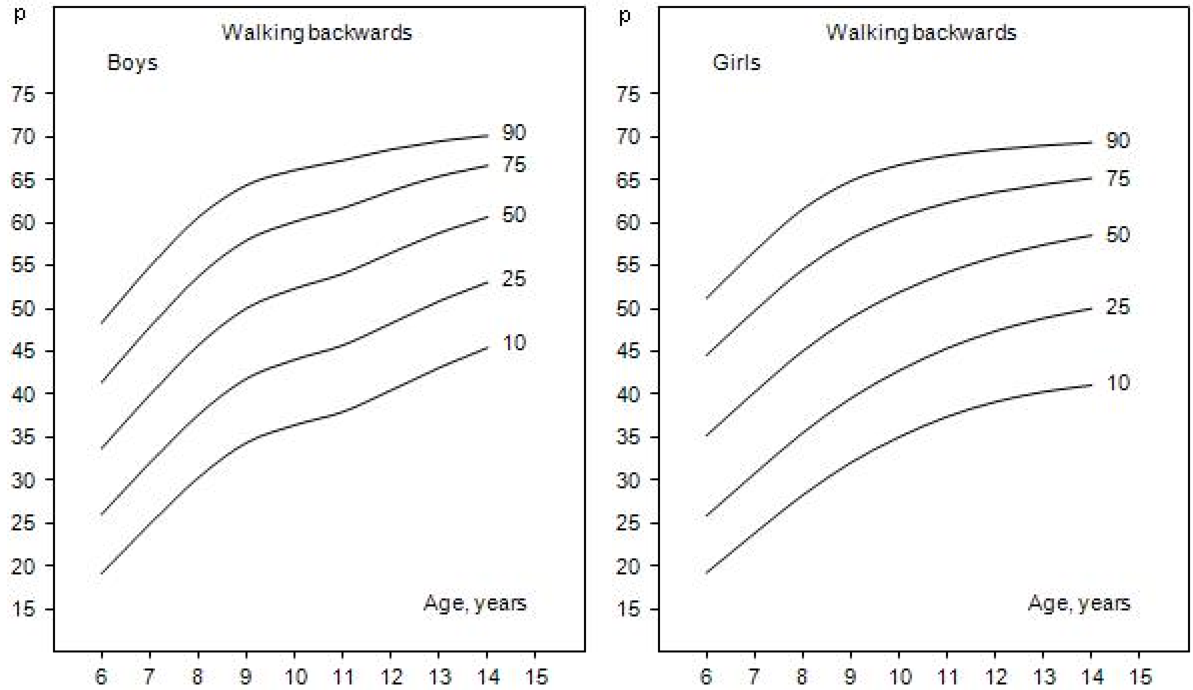

Figure 3.1 Centile curves of Portuguese children, aged 6 to 14 years: walking backwards. (Note: p is points)

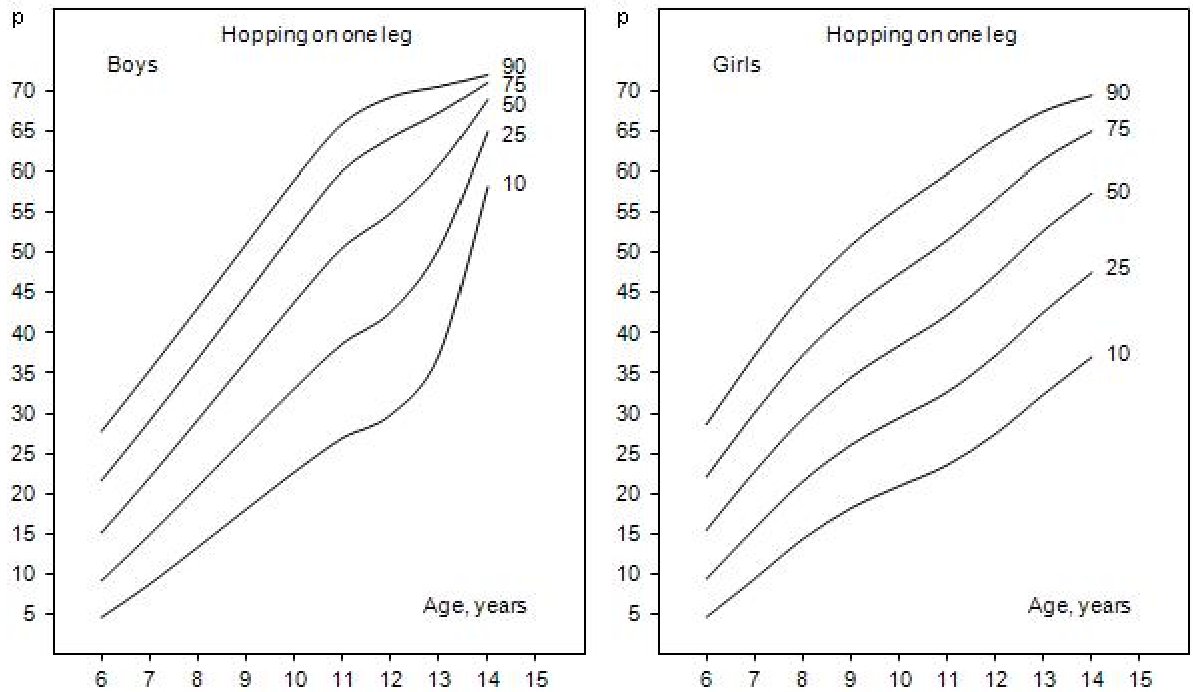

Figure 3.2 Centile curves of Portuguese children, aged 6 to 14 years: hopping on one leg. (Note: p is points)

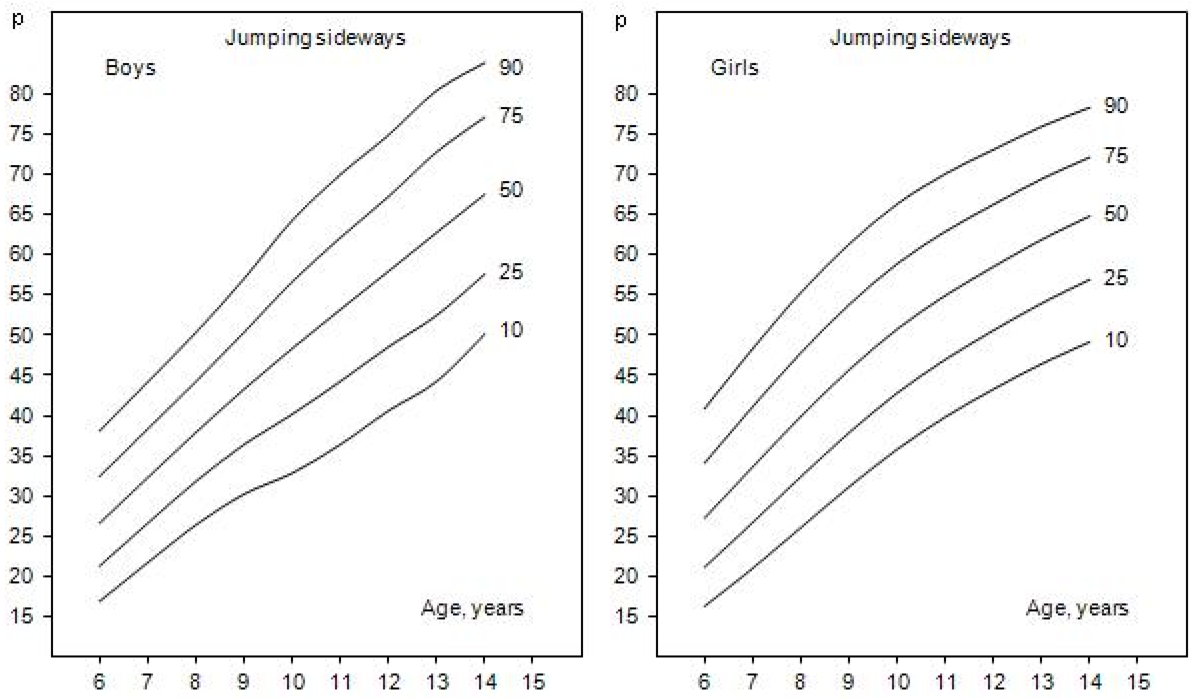

Figure 3.3 Centile curves of Portuguese children, aged 6 to 14 years: jumping sideways. (Note: p is points)

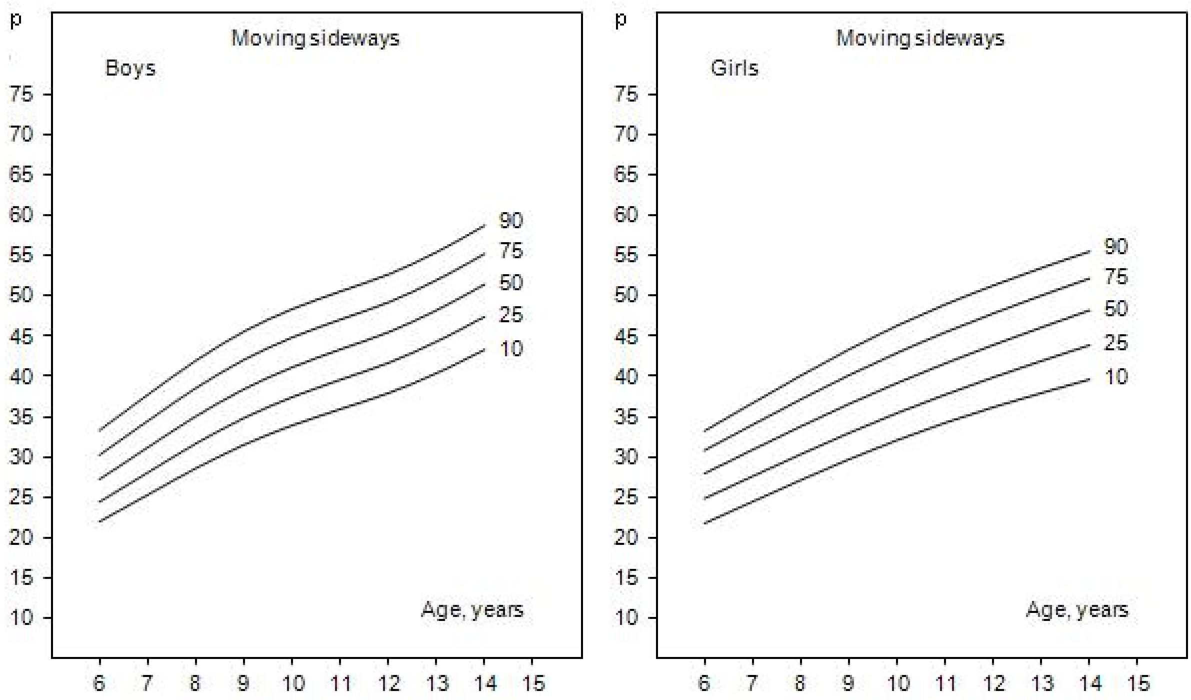

Figure 3.4 Centile curves of Portuguese children, aged 6 to 14 years: moving sideways. (Note: p is points)

Table 3.3 Gross motor coordination tests (KTK) of normal-weight, overweight and obese children, age 6 to 14 years.

	Weight status†							
MC tests	n	Normal-weight (1)	n	Overweight (2)	n	Obese (3)	p	Contrast
Boys								
6-8 years								
Walking backwards	114	43.75 ± 12.14	14	48.50 ± 10.78	10	35.90 ± 8.80	0.01	1 and 2 > 3
Hopping on one leg	114	29.77 ± 12.50	14	26.64 ± 11.69	10	18.30 ± 10.04	< 0.001	1 > 3
Jumping sideways	114	37.18 ± 10.62	14	38.43 ± 12.65	10	30.20 ± 5.83	< 0.001	1 > 3
Moving sideways	114	34.12 ± 5.53	14	34.71 ± 5.90	10	31.40 ± 5.66	< 0.001	1 > 3
9-11 years								
Walking backwards	154	56.06 ± 9.84	50	47.26 ± 10.02	16	41.31 ± 10.38	< 0.001	1 > 2 and 3
Hopping on one leg	154	48.01 ± 12.70	50	35.96 ± 12.26	16	28.88 ± 15.95	< 0.001	1 > 2 and 3
Jumping sideways	154	54.03 ± 11.77	50	47.04 ± 12.92	16	44.00 ± 12.76	< 0.001	1 > 2 and 3
Moving sideways	154	44.21 ± 5.80	50	39.88 ± 5.50	16	38.00 ± 4.32	< 0.001	1 > 2 and 3
12-14 years								
Walking backwards	190	59.25 ± 9.20	44	55.70 ± 11.18	19	53.32 ± 10.19	ns	-
Hopping on one leg	190	63.31 ± 11.24	44	54.95 ± 16.38	19	42.95 ± 15.96	< 0.001	1 > 2 and 3; 2 > 3
Jumping sideways	190	66.67 ± 13.17	44	61.70 ± 14.41	19	53.89 ± 10.18	< 0.001	1 > 3
Moving sideways	190	50.66 ± 6.27	44	48.59 ± 8.18	19	42.74 ± 3.28	< 0.001	1 and 2 > 3
Girls								
6-8 years								
Walking backwards	98	45.01 ± 12.79	22	37.09 ± 11.51	10	31.70 ± 8.65	< 0.001	1 > 2 and 3
Hopping on one leg	98	31.20 ± 10.87	22	17.64 ± 8.62	10	10.80 ± 9.51	< 0.001	1 > 2 and 3
Jumping sideways	98	40.05 ± 12.43	22	34.45 ± 12.79	10	27.30 ± 9.60	< 0.001	1 > 3
Moving sideways	98	33.63 ± 5.34	22	29.82 ± 4.97	10	27.00 ± 5.83	< 0.001	1 > 2 and 3
9-11 years								
Walking backwards	160	53.69 ± 11.58	64	50.91 ± 11.75	13	40.62 ± 12.82	< 0.001	1 and 2 > 3
Hopping on one leg	160	43.37 ± 13.84	64	37.47 ± 12.69	13	23.77 ± 10.54	< 0.001	1 > 2 and 3; 2 > 3
Jumping sideways	160	54.88 ± 11.78	64	52.08 ± 10.51	13	44.62 ± 13.10	< 0.001	1 > 3
Moving sideways	160	42.12 ± 5.53	64	39.09 ± 5.10	13	35.38 ± 4.65	< 0.001	1 > 2 and 3
12-14 years								
Walking backwards	220	57.51 ± 10.25	49	53.98 ± 11.84	10	42.30 ± 11.41	< 0.001	1 and 2 > 3
Hopping on one leg	220	54.95 ± 12.65	49	46.47 ± 13.42	10	31.80 ± 17.54	< 0.001	1 > 2 and 3; 2 > 3
Jumping sideways	220	63.59 ± 11.37	49	62.39 ± 11.63	10	46.00 ± 13.89	< 0.001	1 and 2 > 3
Moving sideways	220	47.70 ± 6.23	49	44.29 ± 6.40	10	38.60 ± 5.08	< 0.001	1 > 2 and 3; 2 > 3

†ANCOVA is adjusted for age, age squared, physical activity and educational level of the father or mother; MC, motor coordination; data are mean ± standard deviation.

Notwithstanding, age and gender effects on gross MC tests, via two-way ANOVA, were given in a Belgian sample, aged 6 to 11 years. Vandorpe et al. (2011) observed that performance on the four subtests improved significantly with increasing age and *post hoc* analysis revealed that each age group scored significantly better than their 1-year younger counterparts. Belgian girls also scored better than boys on walking backwards, while boys outperformed girls on hooping on one leg. These data parallel our sample on walking backwards and hopping on one leg for the age-related developmental patterns, but are contradictory for gender-related differences.

It is well known that attained levels of performance in a variety of fundamental motor skills, strength and performance improve with age during childhood and adolescence (Malina et al., 2004) and, therefore, the gradual improvement in gross MC tests is not surprising as it appears to be a general phenomenon (D'Hondt et al., 2011 and Vandorpe et al., 2011). Of note, is the lack of consensus regarding to gender-related differences. In the original sample, Kiphard and Schilling (1974) reported no differences between boys and girls on walking backwards and moving sideways. These results corroborate what was found in the present study for walking backwards, but not for moving sideways. German girls also showed a general advantage over boys on hooping on one leg and jumping sideways. These results did not parallel our sample. In fact, it was expected that boys scored better than girls on jumping or hopping since these tasks require strength, endurance and explosiveness (D'Hondt et al., 2011). Nonetheless, girls were also found to be better than boys in jumping tasks, considering the gender-specific leisure activities (Vandorpe et al., 2011). Hence, biological and environmental forces might enhance the raw scores observed in these MC tasks favouring either boys or girls.

In a further attempt to assign a meaning to our results, data from the current study was compared with Belgian (Vandorpe et al., 2011) and German (Kiphard and Schilling, 1974) children. One-sample *t*-test revealed that Portuguese boys and girls showed lower scores than Belgian counterparts on hopping on one leg and jumping sideways, while the opposite was found for walking backwards (*t*-statistic and p-values not shown). In moving sideways, our boys performed significantly better than Belgian peers at 6, 8, 9 and 10 years old, but girls scored lower than Belgian colleagues. A similar trend was observed when using one-sample *t*-tests with the German mean as the reference value. Portuguese children scored significantly lower than the German sample for walking backwards (girls), hopping on one leg, jumping sideways, and moving sideways.

This comes as a revelation, given the temporal gap between our study and the German sample (~32 years). It was expected that the increased standard of living, opportunity for practice and instruction, and learning, experienced by the Portuguese children in the last decades, could lead to similar or higher scores of gross MC. However, recent papers also demonstrated that changes in fat mass (Krombholz, 2013), physical activity (Vandorpe et al., 2012), sedentary behaviour (Lopes et al., 2012), and physical fitness (Tomkinson et al., 2012) operated in the last years might potentially explain our findings. Interestingly, scores from the current study were similar or slightly above the Portuguese peers from Azores (Vidal et al., 2009) and Viseu (Chaves et al., 2013). It is also noteworthy that the large interindividual variation found in this study was corroborated by Chaves et al. (2013) and Vidal et al. (2009) in all gross MC tests.

In order to explore the effect of fat mass in attained levels of gross MC, children of different weight status were compared. Our findings of decreased gross MC with increased BMI and the different relationships according to age, gender and gross MC test were consistent with previous research. A negative association of BMI on hooping on one leg, jumping sideways and moving sideways has been reported by D'Hondt et al. (2011) in Belgian children, aged 5-12 years. BMI-related differences in gross MC were also more pronounced with increasing age (D'Hondt et al., 2013; 2011). This trend was not observed in our data. Overweight and/or obesity was also associated with lower scores on gross MC in German (Krombholz, 2013 and Graf et al., 2004) and Portuguese (Lopes et al., 2012) children. It was suggested that overweight and/or obese children perform worse in weight-bearing gross MC tasks because a greater proportion of fat mass has to be supported or moved against gravity (Gentier et al., 2013).

This study has a number of distinctive and innovative features. It uses a novel fitting approach to derive the gross MC curves. A previous use by the World Health Organization Multicentre Growth Reference Study Group (Borghi et al., 2006) provided good results in the construction of the world standard child growth curves. The setting of the study is also important. It was undertaken in Madeira and Porto Santo islands at a time of rapid and substantial social and economic change. Since the 1980's the economy has changed from one based on fishing and agriculture into an off-shore tourist/business center. The population is relatively homogenous; there is no aboriginal population that preceded the Portuguese settlement of the early fifteenth century. Therefore, the large sample size and the random sampling procedure ensure the representativeness of the Portuguese population. In addition, the number of health characteristics available allows a clear description of the sample. Finally, the small prevalence of overweight and obese children is an added value when deriving the gross MC curves. However, there are some shortcomings that apply to the current research. First, the cross-sectional nature of this study cannot provide a real picture of the trajectories across time. Second, although physical activity was addressed, it was self-reported and questionnaire responses depend on the perception, encoding, storage, and retrieval of information (Shephard, 2003).

In conclusion, this study presents age- and gender-specific percentiles for gross MC of Portuguese children. Raw scores improved with age, but a main effect was simply observed on walking backwards and moving sideways. Similarly, boys performed better than girls in the majority of gross MC tests; however, a main effect was only found on moving sideways. Children from this study showed a tendency to lower scores on hopping on one leg and jumping sideways compared to Belgian and German counterparts, and similar or higher scores than their Azores and Viseu peers. Patterns of gross MC showed a large interindividual variability. Finally, normal-weight and/or overweight children outperformed their obese peers in almost the totality of gross MC tests. These results are generally consistent with the hypotheses that gross MC improves with age and that gender-related differences depends of age and MC test. Additionally, our hypotheses about BMI and gross MC are partially supported by our findings. These centile curves can be used as reference data for Portuguese children. Our study also highlights the importance of normal-weight status in the performance of gross MC. It is suggested longitudinal studies to capture real developmental changes across time.

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Chapter 4

Change, stability and prediction of gross motor coordination in Portuguese children

António M. Antunes, José A. Maia, Élvio R. Gouveia, Martine A. Thomis,

Johan A. Lefevre, Alexandra Q. Teixeira, Duarte L. Freitas

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Abstract

Purpose: To analyze change, stability, and prediction of motor coordination (MC) in a longitudinal Portuguese sample from Madeira and Porto Santo islands.

Methods: A total of 158 children, 83 boys and 75 girls, aged 6, 7 and 8 years, were evaluated in 2006 and reevaluated in 2012 at 12, 13 and 14 years of age. MC was assessed through the Kiphard-Schilling's body coordination test (KTK). Twenty-one human physical growth characteristics were taken in 2006. Skeletal maturity was estimated using the Tanner-Whitehouse 3 method. Physical fitness was assessed using the Eurofit test battery. Fundamental motor skills (FMS) were assessed through the 'Test of Gross Motor Development' (TGMD-2). The Baecke questionnaire was used to assess physical activity and socioeconomic status (SES) was quantified via a questionnaire developed by the National Institute of Statistics.

Results: The mixed between-within subjects ANOVA indicated that boys performed better than girls in walking backwards (WB), hopping for height (HH) and moving sideways (MS). Group 1 (6-12 years) performed less proficiently than group 2 (7-13 years) and/or group 3 (8-14 years) in all MC tests. A time effect was observed for WB and MS. Inter-age correlations between the 1st and 2nd measurements for MC tests were between 0.15 and 0.60. Correlations above 0.60 were found for WB, HH and jumping sideways (JS). Childhood predictors of MC at early adolescence were MC tests, human physical growth characteristics, physical fitness, FMS and SES. The total variance explained by the models was between 17% and 79%. Physical activity and biological maturation in childhood did not contribute to MC prediction in early adolescence.

Conclusions: MC tracks at low-to-moderate levels during childhood and early adolescence, and childhood predictors of MC at early adolescence were MC, human physical growth characteristics, physical fitness, FMS and SES.

Key words: Tracking, biological maturation, skills, coordination, children

4.1 Introduction

One of the purposes of assessing gross motor coordination (MC) of children, aged 5 to 15 years, is to explore age- and sex-association variation. In a classical study, Kiphard and Schilling (1974) observed that MC increased with age and girls performed significantly better than the boys in hopping for height (HH) and jumping sideways (JS). More recent studies (Vandorpe et al., 2011; Ahnert et al., 2009; Valdivia et al., 2008; Deus et al., 2008) confirm the pattern of age-associated variation, but there is some inconsistency regarding to sex-associated variation in MC tests.

Tracking of MC has been examined in a small number of studies (Vandorpe et al., 2011; Ahnert et al., 2009; Deus et al., 2008; Willimczik, 1980). Tracking refers to the tendency for an individual to maintain the same relative position within an age and sex group over a period of time (Malina et al., 2004), and the ability to discover specific ages or variables where prediction becomes reasonable accurate (Foulkes and Davies, 1981). In Belgian (Vandorpe et al., 2011) and German (Ahnert et al., 2009 and Willimczik, 1980) children, the stability of MC was high (inter-age correlations above 0.60). Deus et al. (2008) reported correlations coefficients between 0.16 and 0.74 in Portuguese children. Consequently, there is some heterogeneity of tracking of MC across studies. In terms of prediction, MC has been linked to physical fitness (Vandendriessche et al., 2011), human physical growth (D'Hondt et al., 2012; 2011; Lopes et al., 2012; Wrotniak et al., 2006), physical activity (Lopes et al., 2011; Vandorpe et al., 2011; Fisher et al., 2005), and socioeconomic status (SES) (Vandendriessche et al., 2012 and Valdivia et al., 2008). Evidences from these studies were: (1) high levels of physical fitness and physical activity were associated with high scores on MC; (2) body fatness was inversely associated with MC; and (3) the association of SES with MC was inconsistent across studies.

Since MC, together with fundamental motor skills (FMS), are determinants of the children's general development (Haga, 2008 and Henderson and Sugden, 1992) and are associated with health-related parameters (Stodden et al., 2008) it is crucial to promote MC during childhood and adolescence. According to Branta et al. (1984), longitudinal research that describes change serves as standard against which individuals of certain ages, grades, programs and populations can be compared, and the knowledge about a general pattern of change can stimulate attempts at explanation, intervention, and prediction. In this line, the extent to which MC is stable over time is of interest because of its significance in the prediction of human performance, identification of clumsy and motor-impaired children, and application of preventive measures (Ahnert et al., 2009).

This study considers change, stability, and prediction of MC in a longitudinal sample of Portuguese children, from Madeira and Porto Santo Islands. Whilst the previous research explored the associations of MC with physical fitness, human physical growth, physical activity and SES, the current study extended the multivariate analysis to FMS and biological maturation. Moreover, very little is known about stability and childhood predictors of MC at early adolescence, i.e. at 12, 13 and 14 years. Specifically, we hypothesized that: (1) MC improved with age and differences in scores among boys and girls were test- and age-specific; (2) stability of MC during childhood and early adolescence was low-to-moderate across the different cohorts; (3) MC, human physical growth, biological maturation, physical fitness, FMS, physical activity and SES in childhood were predictors of MC at early adolescence; and (4) predictors of MC changed over time and the relative contribution of these predictors also changed with age.

4.2 Subjects and methods

4.2.1 Study design, sampling procedures and participants

In 2006, 1369 subjects, 664 boys and 705 girls, were sampled in the scope of the 'Healthy Growth of Madeira Study' (CRES). The CRES is a cross-sectional study with 12 birth cohorts, assessed at the ages of 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. A proportional stratified random sampling was conducted with geographical location, school grade and school facilities, as stratification factors. A total of forty public schools were selected from the 11 districts of Autonomous Region of Madeira (ARM), i.e., Madeira and Porto Santo islands. The Secretary of Education and Culture provided a list of schools and students. In each district, at least 1 kindergarten, 1 primary school and 1 high school participated in the study. Approximately 50 boys and 50 girls were randomly sampled in each age interval from 3 to 10 years. For the age intervals 10 to 14 years, each cohort comprised around 100 boys and 100 girls. The number of subjects sampled in each district was proportional to the number of children enrolled in the compulsory education system, matched by age and sex. Sampling procedures were carried out with the collaboration of a member of the National Institute of Statistics (Statistics Portugal) and have been reported in detail elsewhere (Freitas et al., 2013).

In the current study, a subsample of 158 subjects, 83 boys and 75 girls, aged 6, 7 and 8 years, was used and corresponds to 49.4% of the original sample for these age intervals (n = 320; 162 boys and 158 girls). The distribution of the subsample, by district, was similar to the original sample. In 2012, this subsample was reevaluated when children were 12, 13 and 14 years, respectively. Therefore, the longitudinal sample comprised children from three cohorts: 1 (6-12 years), 2 (7-13 years) and 3 (7-14 years). The use of 158 subjects in the follow up reflected the human and financial constraints that are common in longitudinal studies. Overall, there were no significant differences between those who were followed and the rest of the sample on the main clusters including MC, human physical growth, biological maturation, physical fitness, FMS and physical activity. The number of participants, by age group and sex, at baseline (2006) and follow-up (2012), as well as the mean length of follow-up are presented in Table 4.1.

Table 4.1 Number of subjects (n), age at baseline [mean and standard deviation (Sd)], age group (Gr), age at follow-up (mean and Sd), and mean length of the follow-up in boys and girls from the Healthy Growth of Madeira Study.

	Baseline			Follow-up			
Sample characteristics	n	x̄±Sd	Age group	n	x̄±Sd	Age group	Mean length of follow-up
Boys							
Gr 1	27	6.72±0.2	6	27	12.49±0.2	12	5.77
Gr 2	29	7.62±0.2	7	29	13.39±0.2	13	5.77
Gr 3	27	8.59±0.3	8	27	14.38±0.2	14	5.79
Total	83			83			
Girls							
Gr 1	23	6.64±0.2	6	23	12.40±0.2	12	5.76
Gr 2	28	7.58±0.2	7	28	13.34±0.2	13	5.77
Gr 3	24	8.68±0.3	8	24	14.46±0.3	14	5.77
Total	75			75			
Grand total	158			158			

Gr 1, 6-12 years; Gr 2, 7-13 years; Gr 3, 8-14 years.

4.2.2 Data collection and measurements

All study protocols were reviewed and approved by the Scientific Board of the University of Madeira and permission was granted from the Regional Secretary of Education and Culture. The whole process was also approved by the Ethics Committee of the Hospital of Funchal. Participants were informed about the procedures, nature and relevance of the study and (written) consent was granted from their parents or tutors.

In 2006, data was collected by 6 teachers of Physical Education under the supervision of one of the study coordinators. The team members underwent theoretical classes and lab sessions during a period of 3 months prior to data collection.

A pilot study was carried out in 46 children, age 3-10 years, from a primary school. Children were assessed twice with an interval of 1 week (1st evaluation, 6 and 7 December; 2nd evaluation, 13 and 15 December, 2005) in order to assess test-retest reliability and to refine assessment procedures.

Baseline data was collected between January and June of 2006. The assessment of anthropometry and skeletal maturation (x-ray) took place in the gym. FMS, physical fitness and MC tests were assessed in the school sports hall. The field members worked in pairs. Children received a verbal description followed by a visual demonstration of each skill/test. Motor tests were administered in a single day (~20 participants/day).

In 2012, data was collected by one member of the previous team who followed strictly the assessment procedures. Data collection took place between January and March of 2012.

4.2.2.1 Gross motor coordination

MC was evaluated by means of the ‘Körperkoordinations Test Für Kinder’ (Body Coordination Test for Children) (KTK) developed by Kiphard and Schilling (1974) and recently revised by the same authors (Kiphard and Schilling, 2007). The KTK comprises 4 test items: (1) walking backwards (WB) three times along each of three balance beams (6 cm, 4.5 cm and 3 cm width, 3 m length, 5 cm height) (the number of successful steps is recorded); (2) hopping for height (HH) on one leg over a pile of pillows increasing in height with consecutive steps of 5 cm per pillow (60 cm × 20 cm × 5 cm each) (the height of the final successful jump is recorded); (3) jumping sideways (JS) with both feet as many times as possible over a wooden slat (60 cm × 4 cm × 2 cm) in 15 s (the number of jumps over two trials is summed); and (4) moving sideways (MS) on wooden boxes (25 cm × 25 cm × 5.7 cm) during 20 s (the number of relocations is counted and summed over two trials). Raw scores for each test were used in the present data analysis. Test-retest reliability, via intraclass correlation coefficient (ICC), carried out in the pilot study were between 0.64 and 0.90.

4.2.2.2 Anthropometry

Twenty-one human physical growth characteristics subdivided in general body dimensions (height, body mass and sitting height), bone diameters (biacromial, bicristal, femur and humerus) circumferences [arm (relaxed and flexed), calf, forearm, hip, thigh and waist] and skinfolds (abdominal, biceps, calf, subscapular, suprailíaca, thigh, and triceps)] were taken in all participants in 2006. Children were assessed according to procedures used in the ‘Leuven Growth Study – Growth and Fitness of Flemish Girls’ (Claessens et al., 1990). Height and body mass were related to each other in the body mass index (BMI) [BMI = ratio of body mass (in kilograms) and height squared (in meters)]. The ICCs of test and retests were between 0.85 and 1.00 in the pilot study. Test-retest reliability during the 1st phase of the study (2006) ranged from 0.89 and 1.00. Height, body mass, waist circumference and abdominal skinfold were also assessed in 2012, but these variables were not included in the present analysis.

4.2.2.3 Biological maturation

Skeletal maturity was estimated using the Tanner-Whitehouse 3 method (Tanner et al., 2001). Briefly, the radius, ulna and short bones (RUS) entails matching 13 individual bones of the hand and wrist, namely the radius and ulna, the metacarpals and the phalanges, to a set of written criteria. The summed maturity scores are converted to bone age. In 2006, an x-ray from the left hand and wrist was taken with a portable unit [Model TOP 25 (140 kvp; 25 mA); For You Company, Belgium]. The portable unit was built according the indications supplied by Greulich-Pyle (1959) atlas and recommendations made by Tanner et al. (1962). All the x-rays were rated by one of the co-authors of this study with a large experience in rating x-rays. Inter-observer agreement between the rater and Gaston Beunen was 85.3%. Reliability analyses for skeletal maturity assessments have been reported in detail elsewhere (Afonso et al., 2013 and Freitas et al., 2012).

4.2.2.4 Physical fitness

Physical fitness was assessed using the Eurofit test battery (Adam et al., 1988), which includes nine motor tests, namely, flamingo balance, plate tapping, shuttle run, sit ups, flexed arm hang, sit and reach, handgrip and stand long jump. The endurance shuttle run was replaced by the 12-minute run/walk test from the AAHPERD (1988). In the pilot study, ICCs were between 0.76 and 0.99. In 2012, some of these motor tests were reassessed, but these data were not included in this analysis.

4.2.2.5 Fundamental motor skills

FMS were assessed through the 'Test of Gross Motor Development' (TGMD-2) (Ulrich. 2000). The TGMD-2 comprises 12 motor skills divided into two subsets: locomotor and object control. The first assesses motor skills that are involved in moving the centre of gravity and include: run, gallop, hop, leap, horizontal jump and slide. The second assesses motor skills associated with throw/manipulation of objects and included: striking a stationary ball, stationary dribble, catch, kick, overhand throw and underhand roll. The sum of scores of the 6 motor skills originates a score for locomotor and object control skills, separately (Ulrich. 2000). Data regarding to FMS were only collected in 2006. Test-retest reliability in the pilot study was between 0.65 and 0.95 if 1 item was deleted.

4.2.2.6 Physical activity

Physical activity was assessed through the Baecke questionnaire (Baecke et al., 1982). The questionnaire presents 16 questions, 8 of them related to physical activity at work (questions 1 to 8), 4 related to sport practice (questions 9 to 12) and 4 related to leisure-time physical activity (questions 13 to 16). Answers to the different items of the questionnaire are quantified in a likert scale, with the exception of the parental occupation and sports. Three indices are operationalized: physical activity at work, physical activity in sports and physical activity in leisure time. In the 1st phase of the study, no information was collected in the first 8 questions because all the participants were students. The questionnaire was administered through a face-to-face interview. At earlier ages and whenever necessary, the questionnaire was filled with the assistance of the school's teacher, parents or tutors.

4.2.2.7 Socioeconomic status

SES was quantified via a standardized questionnaire developed by the National Institute of Statistics (Statistics Portugal, 1995). The questionnaire comprises 5 groups of questions, namely, parental occupation, education, income, housing and residential area. The Graffar framework (Graffar, 1956) was used in the social stratification. Participants were grouped in three socioeconomic levels: high (children and adolescents whose sum of scores was between 5 and 13), average (sum of scores between 14 and 17) and low (sum of scores between 18 and 25).

4.2.3 Statistical analysis

Data were double entered and screened for outliers and normality. Means and standard deviations were calculated at baseline and/or follow-up for MC, human physical growth characteristics, biological maturity, physical fitness, FMS, physical activity and SES.

An independent-samples *t*-test was used to investigate the differences between those who were followed and the rest of the sample. Intraclass correlation coefficients (R) were used in the reliability analyses.

A mixed between-within subjects analysis of variance (or split-plot ANOVA) with three independent variables [two between-group variables (age and sex) and one repeated measure (time 1 and time 2)] was conducted to assess the effect of age, sex and its interaction on each MC test (dependent variable), across two time periods.

Tracking of human physical growth characteristics and MC tests was estimated with inter-age Pearson product-moment correlations between the first (baseline) and last (follow-up) measurements.

Predictors of MC were identified via stepwise multiple linear regression. First, zero-order correlations were calculated between MC tests assessed at 12, 13 and 14 years, and human physical growth characteristics, MC, skeletal maturation, physical fitness, FMS, physical activity and SES at 6, 7 and 8 years, respectively. Second, items with statistical significance were entered in the stepwise regression.

A *p*-value of 0.05 was set as the level of statistical significance.

All analyses were conducted using Stata, version 11 (Stata. 2009) and SPSS 19.0 (IBM Corporation, 2012).

4.3 Results

4.3.1 Descriptive statistics

Table 4.2 presents the descriptive statistics for MC, human physical growth, biological maturity, physical fitness tests, FMS, physical activity and SES of the Madeira children and adolescents. For human physical growth, physical fitness, FMS and SES, only predictors of MC are presented. Biological maturity and physical activity are included in Table 4.2 for a better description of the sample.

Developmental progress in MC tests was quantified for boys and girls, separately. In WB, there is a substantial main effect for time, Wilks' Lambda = 0.45, F (1, 152) = 183.84, $p < 0.001$, partial eta squared = 0.55, with the three groups showing an increase across the two time periods.

There is also a main effect of age group on WB, *F* (2, 152) = 8.13, p < 0.001, partial eta squared = 0.10. Contrasts reveal that group 1 (6-12 years) performs worse than group 3 (8-14 years). Sex is also statistically significant, *F* (1, 152) = 7.40, p = 0.007, partial eta squared = 0.05; boys show higher scores than girls in WB (*F*, *p* value, partial eta squared and contrasts are not shown in Table 4.2).

In HH, there is a significant interaction effect between time and group, *F* (2, 152) = 8.65, p < 0.001, partial eta squared = 0.12, and time and sex, *F* (1, 152) = 27.08, p < 0.001, partial eta squared = 0.15. This indicates that changes in scores of HH differ over time for the three different age groups and between boys and girls. In HH, there is also a main effect of age group, *F* (2, 152) = 10.27, p < 0.001, partial eta squared = 0.12, with group 1 showing lower scores than groups 2 and 3. Likewise, there is a main effect of sex, indicating that scores in HH are higher in boys than in girls.

In JS, there is a significant interaction effect between time and group, and time and sex, i.e., the impact of time is influenced by the level of group and/or sex, and vice-versa. In JS, there is also a main effect of group [*F* (2, 152) = 11.29, p < 0.001, partial eta squared = 0.13, groups 1 and 2 < 3)].

In MS, all effects are reported as significant at *p* < 0.05. There is a main effect of time, Wilks' Lambda = 0.15, *F* (1, 152) = 833.7, p < 0.001, partial eta squared = 0.85, showing a change in MS scores across the two different time periods. The main effect comparing the three age groups [*F* (2, 152) = 14.35, p < 0.001, partial eta squared = 0.16] and the contrasts suggest that group 1 performs less proficiently than groups 2 and 3, and that group 2 scores less than 3. The main effect for sex, [*F* (1, 152) = 7.66, p = 0.006, partial eta squared = 0.05], shows that boys perform better than girls in MS.

Table 4.2 Descriptive statistics for motor coordination, human physical growth, biological maturation, physical fitness, fundamental motor skills, physical activity and socioeconomic status at baseline (6, 7 and 8 years old) and 6 years later (12, 13 and 14 years old).

	Baseline			Follow-up		
	Gr 1 (6 y)	Gr 2 (7 y)	Gr 3 (8 y)	Gr 1 (12 y)	Gr 2 (13 y)	Gr 3 (14 y)
Variables†	x̄±Sd	x̄±Sd	x̄±Sd	x̄±Sd	x̄±Sd	x̄±Sd
Boys						
Motor coordination						
Walking backwards	40.0±11.3	44.5±11.1	49.1±12.1	59.9±12.1	55.8±13.0	64.2±9.4
Hopping for height	21.4±10.2	29.4±12.4	35.2±7.7	61.1±14.4	60.9±16.0	70.0±9.6
Jumping sideways	31.0±8.8	34.3±7.8	42.1±7.3	70.8±11.4	68.7±15.0	78.1±7.3
Moving sideways	30.7±4.8	34.1±4.7	37.4±4.2	50.0±6.4	49.1±7.5	54.2±5.2
Human physical growth						
Height(cm)	121.3±5.4	127.2±5.8	131.4±7.0	154.3±7.7	159.1±7.9	165.2±8.9
Body mass (kg)	23.3±3.7	26.9±4.0	31.9±7.9	45.6±8.0	51.1±11.3	61.2±16.6
Body mass index (kg/m^2)	15.8±1.8	16.6±1.0	18.3±3.2	19.0±2.0	20.1±3.4	22.3±5.1
Abdominal skinfold (mm)	9.0±5.8	10.51±8.2	16.1±10.2	16.54±8.9	18.0±11.1	19.1±12.4
Bicristal diameter (cm)	19.4±1.2	20.±1.03	21.1±1.5	-	-	-
Biological maturity						
Rus (TW3) (scores)	185.3±34.7	226.4±28.9	250.5±32.3	-	-	-
Physical fitness						
Flexed arm hang (sec)	5.1±6.6	4.8±4.0	5.7±7.0	-	-	-
Handgrip (kg)	10.1±2.3	12.4±2.1	13.8±3.4	-	-	-
Sit ups (n)	15.0±4.8	16.9±4.1	16.2±4.0	22.4±5.1	23.1±4.7	24.1±3.7
Stand long jump (cm)	111.1±14.9	116.8±16.5	120.3±12.9	157.6±22.5	159.31±20.90	180.1±21.0
Fundamental motor skills						
Hop	6.4±1.9	7.0±1.6	7.1±1.5	-	-	-
Leap	2.5±1.2	2.0±1.3	2.6±1.0	-	-	-
Run	5.9±1.7	7.2±1.5	7.5±0.9	-	-	-
Stationary dribble	5.0±2.3	6.4±2.3	7.3±1.3	-	-	-
Object control subtest	30.7±5.2	32.8±5.7	35.9±3.9	-	-	-
Locomotor subtest	32.0±5.8	35.4±5.1	37.6±4.1	-	-	-
Physical activity						
Sport score	1.5±0.8	1.5±0.6	1.7±0.7	2.1±0.9	1.7±0.8	1.9±0.9
Sport index	2.8±0.8	2.8±0.6	2.9±0.4	3.1±0.7	2.9±0.6	3.0±0.6
Leisure-time index	2.6±0.8	2.5±0.6	2.8±0.6	2.9±0.5	2.7±0.5	2.8±0.5
Girls						
Motor coordination						
Walking backwards	34.3±12.3	44.0±10.4	46.3±12.7	49.0±16.9	56.9±9.6	56.5±13.8
Hopping for height	19.4±11.1	29.3±8.8	33.2±13.9	51.7±12.9	54.8±10.6	52.4±11.7
Jumping sideways	31.1±7.2	41.7±13.1	42.6±12.2	64.2±14.6	67.6±11.2	69.7±11.6
Moving sideways	28.5±5.5	32.9±4.9	34.5±5.5	45.7±10.5	50.4±7.1	50.3±6.7
Human physical growth						
Height(cm)	120.6±4.7	125.9±4.7	132.4±6.4	153.2±5.9	158.2±4.6	160.1±6.6
Body mass (kg)	23.3±5.4	26.5±5.2	30.5±6.7	47.2±12.9	50.0±8.3	54.5±10.4
Body mass index (kg/m^2)	15.9±2.7	16.6±2.4	17.3±3.3	19.9±4.6	20.0±2.9	21.3±4.1
Bicristal diameter (cm)	19.1±1.2	20.0±1.1	20.8±1.3	-	-	-
Calf circumference (cm)	25.4±3.0	25.7±2.9	27.9±3.2	-	-	-
Biological maturity						
Rus (TW3) (score)	297.6±35.0	319.6±37.7	398.9±67.6	-	-	-
Physical fitness						
Shuttle run (sec)	26.1±2.7	25.0±2.0	23.9±2.1	-		
Sit and reach (cm)	21.3±4.7	22.1±4.8	18.6±5.7	24.1±8.6	24.4±5.5	24.2±8.1
Stand long jump (cm)	96.9±16.8	105.2±15.6	109.1±15.0	138.6±21.6	146.3±18.3	141.6±24.7
Fundamental motor skills						
Gallop	5.1±3.0	6.4±2.4	7.5±1.1	-	-	-
Physical activity						
Sport score	1.3±0.5	1.4±0.7	1.2±0.5	1.7±0.8	1.6±0.6	1.8±0.9
Sport index	2.4±0.5	2.6±0.5	2.5±0.4	2.6±0.6	2.5±0.6	2.7±0.7
Leisure-time index	2.6±0.5	2.6±0.4	2.7±0.7	2.4±0.6	2.5±0.7	2.5±0.5
Socioeconomic status						
Parental occupation	3.8±1.5	3.7±1.3	3.6±1.2	4.3±1.2	3.9±1.3	3.9±1.4

†Biological maturation and physical activity were not predictors of motor coordination. For human physical growth, physical fitness, fundamental motor skills and socioeconomic status characteristics, only predictors of motor coordination are presented.

4.3.2 Tracking of MC tests

Table 4.3 shows the Pearson product-moment inter-age correlation coefficients among the Madeira participant's performances on MC tests at baseline and their performance six years later, separately for boys and girls.

Table 4.3 Tracking of motor coordination tests between ages at baseline (6, 7, and 8 years old) and corresponding ages 6 years later (12, 13 and 14 years old) in boys and girls from the Healthy Growth of Madeira Study.

	Pearson product-moment correlation coefficient (*r*)		
Motor coordination tests	Gr1 (6 and 12 years)	Gr2 (7 and 13 years)	Gr3 (8 and 14 years)
Boys			
Walking backwards	0.25	0.74	0.28
Hopping for height	0.36	0.55	0.34
Jumping sideways	0.29	0.59	0.51
Moving sideways	0.35	0.45	0.16
Girls			
Walking backwards	0.68	0.38	0.15
Hopping for height	0.58	0.65	0.64
Jumping sideways	0.60	0.65	0.41
Moving sideways	0.40	0.15	0.41

Gr, group.

Overall, MC throughout childhood and early adolescence exhibit low to moderate tracking (r in the range of 0.15-0.60). Some exceptions are observed in WB (group 1 and 2, boys or girls), HH (group 2 and 3, girls) and JS (group 2, girls) where correlations are higher than 0.60, indicating reasonably good tracking. The range of correlations for MC tests is similar for boys (r between 0.16 and 0.74) and girls (r between 0.15 and 0.68). However, girls show better stability than boys in all MC tests [r in the ranges of 0.40-0.68 (girls) and r in the ranges of 0.25-0.36 (boys)] at 6-12 years old. A more stable pattern of boys comparing to girls is seen in

WB (r = 0.74, boys and r = 0.38, girls) and MS (r = 0.45, boys and r = 0.15, girls) at 7-13 years. On the contrary, girls showed higher tracking than boys in HH (r = 0.55, boys and r = 0.65, girls) and JS (r = 0.59, boys and r = 0.65, girls) at 7-13 years. In the older age group, 8-14 years, boys display higher stability coefficients than girls in WB (r = 0.28, boys and r = 0.15, girls) and JS (r = 0.51, boys and r = 0.41, girls), and the opposite is true for HH (r = 0.34, boys and r = 0.64, girls) and MS (r = 0.16, boys and r = 0.41, girls). Generally, WB, HH and JS are slightly more stable at 7-13 years (r in the range of 0.38-0.74) than at 6-12 (r in the range of 0.25-0.68) and 8-14 years (r in the range of 0.15-0.64). MS shows better tracking at 6-12 years (r in the range of 0.35-0.40) than in 7-13 years (r in the range of 0.15-0.45) and 8-14 years (r in the range of 0.16-0.41). Of the 24 correlations, 10 are above 0.50, 4 in boys and 6 in girls. The highest number of correlations above 0.50 is located in the age group 7-13 years.

4.3.3 Predictors of motor coordination

Multiple linear regressions models for MC tests at 12, 13 and 14 years with predictors of MC observed at 6, 7 and 8 years are shown in Table 4.4.

For boys, 17 to 73% of the variance in the MC tests at 12, 13 and 14 years is explained by MC tests, human physical growth, physical fitness, FMS and SES at 6, 7 and 8 years, respectively. By age group, the model R^2 is comprised between 17-42% (6-12 years), 45-73% (7-13 years) and 36-55% (8-14 years). WB at 13 years is best explained (partial R^2) by WB (26%) at 7 years. Bicristal diameter and height at 6 and 7 years are predictors of JS at 12 years and WB at 13 years. Abdominal skinfold at 8 years is also a predictor of HH (37%) and MS (36%) at 14 years. At 7 years, JS is a predictor of WB (9%) and MS (21%) at 13 years. HH at 8 years explain 23% of the WB at 14 years. Stationary dribble, leap and run at 6 or 7 years are predictors of WB and/or HH and/or JS at 12 or 13 years. The percentage of explained variance of these FMS on MC tests is between 12% and 24%. Object control subtest at 8 years is also predictor of WB (10%) at 14 years. At 13 or 14 years, JS is predicted by flexed arm hang at 7 or 8 years. Explained variance is comprised between 15% and 28%. Flexed arm hang at 7 years is the second more important predictor of HH (8%) at 13 years. Standing long jump at 7 years and handgrip at 8 years are also predictors of HH and WB, respectively.

Table 4.4 Multiple linear regression for motor coordination tests at 12, 13 and 14 years with predictors observed at 6, 7 and 8 years, respectively.

6-12 years				7-13 years				8-14 years			
Predictors of MC[†]	Regression coefficients[‡]	Partial R^2	Model R^2	Predictors of MC	Regression coefficients	Partial R^2	Model R^2	Predictors of MC	Regression coefficients	Partial R^2	Model R^2
Boys											
Walking backwards at 12y			0.17	Walking backwards at 13y			0.73	Walking backwards at 14y			0.55
Stationary dribble	-0.412	0.17		Walking backwards	0.560	0.26		Hop	0.489	0.23	
				Jumping sideways	0.326	0.09		Object control subtests	0.317	0.10	
				Height	-0.285	0.08		Handgrip	-0.301	0.08	
Hopping for height at 12y			0.24	Hopping for height at 13y			0.62	Hopping for height at 14y			0.37
Leap	0.488	0.24		Run	0.484	0.21		Abdominal skinfold	-0.610	0.37	
				Flexed arm hang	0.307	0.08					
				Standing long jump	0.291	0.07					
Jumping sideways at 12y			0.42	Jumping sideways at 13y			0.70	Jumping sideways at 14y			0.53
Bicristal diameter	0.466	0.21		Flexed arm hang	0.442	0.18		Locomotors subtests	0,604	0.36	
Run	0.357	0.12		Sit ups	0.530	0.28		Sit ups	-0.382	0.15	
				Run	0.403	0.15					
Moving sideways at 12y			0.24	Moving sideways at 13y			0.45	Moving sideways at 14y			0.36
Walking backwards	0.487	0.24		Jumping sideways	0.474	0.21		Abdominal skinfold	-0.598	0.36	
				Locomotors subtests	0.371	0.13					
Girls											
Walking backwards at 12y			0.64	Walking backwards at 13y			0.43	Walking backwards at 14y			0.26
Walking backwards	0.553	0.28		Shuttle run	-0.515	0.27		Body mass index	-0.508	0.26	
Gallop	0.443	0.18		Jumping sideways	0.408	0.17					
Hopping for height at 12y			0.63	Hopping for height at 13y			0.54	Hopping for height at 14y			0.67
Bicristal diameter	-0.554	0.29		Hopping for height	0.630	0.39		Hopping for height	0.348	0.08	
Hopping for height	0.447	0.19		Gallop	-0.336	0.11		Sit and reach	0.435	0.18	
								Body mass index	-0.377	0.10	
Jumping sideways at 12y			0.79	Jumping sideways at 13y			0.58	Jumping sideways at 14y			0.48
Hopping for height	0.402	0.10		Standing long jump	0.455	0.16		Sit and reach	0.518	0.27	
Parental occupation	0.349	0.09		Jumping sideways	0.434	0.15		Calf circumference	-0.442	0.20	
Walking backwards	0.355	0.09									
Moving sideways at 12y			0.70	Moving sideways at 13y			0.53	Moving sideways at 14y			0.53
Walking backwards	0.586	0.30		Walking backwards	0.602	0.36		Hopping for height	0.589	0.34	
Parental occupation	0.419	0.15		Calf circumference	-0.385	0.15		Sit and reach	0.339	0.11	

[†]MC, motor coordination, [‡]Standardised coefficients

For girls, the total variance explained by the models is between 26 and 79%. The model R^2 for age groups 6-12, 7-13 and 8-14 years is between 63-79%, 43-58%, and 26-67%, respectively. WB at 12 years and HH at 13 and 14 years are best explained by the same MC tests at younger ages. HH at 6 years and JS at 7 years are also predictors of HH at 12 years and JS at 13 years, respectively. Human physical growth characteristics, such as bicristal diameter, calf circumference and BMI are also predictors of MC tests. 29% of the variance in HH at 12 years is explained by bicristal diameter at 6 years; MS and JS at 13 and 14 years are also explained by calf circumference at younger ages; and WB (26%) and HH (10%) are explained by BMI at 8 years. As for boys, MC tests at older ages in girls are explained by other MC tests at younger ages. For example, JS and MS at 12 and 14 years are explained by HH at 6 and 8 years, respectively. The same is true for WB and MS at 13 years, where JS and WB at 7 years explained 17 and 36% of the variance, respectively. Among FMS, only gallop is a predictor of MC tests. WB at 12 years and HH at 13 years are explained by gallop at younger ages. Explained variance is comprised between 11 and 18%. Shuttle run, standing long jump and sit and reach are predictors of MC tests. The best predictor of WB at 13 years is shuttle run (27%) at 7 years, while the best predictor of JS at 13 years is standing long jump (16%) at 7 years. The sit and reach test at 8 years is also a predictor of HH, JS and MS at 14 years. Around 9-15% of the variance in JS and MS at 12 years is explained by parental occupation at 6 years.

4.4 Discussion

The central aim of this longitudinal study was to investigate tracking of MC from childhood to early adolescence in a Portuguese sample from Madeira and Porto Santo islands. Over a time frame of approximately 6 years, we observed a low to moderate tracking of MC tests and that predictors of MC were, predominantly, FMS, the same MC tests at baseline and/or physical fitness tests. Moreover, human physical growth characteristics and SES showed low correlations with MC tests, whilst biological maturation and physical activity did not contribute to prediction of MC.

The patterns of age-associated and sex-associated variation in MC tests of the current study are similar to other samples, although there is inconsistency across studies. In Flemish children, Vandorpe et al. (2011) reported that each age group scored significantly better than their 1-year younger counterparts on all four subtests. These results are in line with our study since group 1 (6-12 years) has showed a lower score than groups 2 (7-13 years) and 3 (8-14 years), and that a time effect (within-subject effect) was observed for HH and MS. Significant sex differences were also found in the Flemish sample. In WB, girls scored significantly better than boys for all but on age group. On the HH, boys outscored the girls in every age group; both, boys and girls, did not score significantly different on JS and MS. These data parallels the Madeira sample in HH and JS, but differ in WB and MS. Two other studies documented these patterns in Portugal. A paper by Deus et al. (2008) followed longitudinally 285 children, aged 6 to 10 years, from Azores islands, and found an increase in MC scores, in both sexes. Also in Azores, but using a large cross-sectional sample, Lopes et al. (2003) observed that boys outscored the girls in all MC tests. These results were partially achieved by our sample. In the scope of the Munich Longitudinal Study on the Ontogenesis of Individual Competencies, Ahnert et al. (2009) observed that MC tests generally increased from ages 8 to 12, with no reliable sex differences. Also in German children, aged 6 to 10 years, Willimczik (1980) did not find significant differences between the sexes in MC scores. On the contrary, significant age changes and some sex differences were found in 4007 Peruvian children, aged 6-11 years (Valdivia et al., 2008).

It was expected that proficiency in MC will improve throughout childhood and early adolescence since some of the MC tasks require speed, agility or muscular power. However, this pattern was not observed in certain of the previous studies. In this regard, Branta et al. (1984) reported that although children become taller, broader, and stronger during middle childhood and early adolescence it ignores the dependence of motor development on exposure to skills, opportunity for practice, and interest and motivation, and for these reasons the development of motor skills cannot be automatic. Biased sampling, secular changes, contamination of off-setting groups, and changes in the test administration can also be responsible for the age changes reported by different studies. Interestingly, in the current study, boys displayed better MC scores than girls in WB, HH and MS. Again, these differences during middle childhood are likely to be environmental rather than biological. Thomas and French (1985) suggested that prior to puberty most gender differences in motor performance are socially induced by parents, peers, teachers, and coaches, although differences are by no means uniform and may include some type of sex-related predisposition toward certain motor tasks.

At puberty, sex differences in motor performance appear to be influenced by both biological and environmental factors.

Tracking or stability of MC is another issue addressed in this study. Overall, stability of MC tests was low to moderate indicating that Madeira children proceeded at about different pace. Similar findings were found in Azorean children. Deus et al. (2008) reported correlations between 0.16 and 0.74 depending on the intervals over which MC tests were assessed. On the contrary, MC was found to be highly stable in Belgian (Vandorpe et al., 2011) and German (Ahnert et al., 2009) school children. Vandorpe et al. (2011) observed correlations comprised between 0.66 (age 6-8 years) and 0.88 (age 7-9 years)], whilst Ahnert et al. (2009) found correlations of 0.76 (boys) and 0.72 (girls). Also in Germany, Willimczik (1980) reported correlations between 0.63 and 0.83 in MC tests. These three studies showed higher correlations than in Madeira and confirm the heterogeneity of MC over time. In this respect, Ahnert et al. (2009) stated that any comparison across studies should take into account the MC test, the age of the subjects, the achievement level and the measurement time interval to adequately access stability. As for change over time, inconsistency in stability coefficients of MC across studies is probably due to the study design, assessment strategies, variation in neuromuscular maturation, changes in body size and proportions, opportunity for practice, motivation, and cooperation of the children to perform in the test situation (Ahnert et al., 2009 and Malina et al., 2004).

The last issue dealt in this study concerned the prediction of MC. Of interest, FMS, MC and physical fitness tests in middle childhood were the main predictors of MC in early adolescence. It was not a surprise that FMS were predictors of MC given the moderately high correlation reported in the literature between the two motor tasks. In the Netherlands, Smits-Engelsman et al. (1998) observed an overall correlation between the Movement ABC (Henderson and Sugden, 1992) and KTK batteries of 0.62, and suggested a general ‘motor ability’ factor which underlies motor tasks of all types. The finding that a MC test at a younger age was a predictor of the same MC test 6 years later was not expected, considering the general low to moderate correlations observed in the current study. However, as stated before, a reasonably good tracking was observed in WB, HH and JS. The close association between MC and physical fitness found in Madeira children is also in agreement with previous research. Recently, Vandendriessche et al. (2011) reported a strong association (r in the range of 0.79-0.87) between physical fitness and MC tests. Similarly, Haga (2008) found a close relationship between motor competence and physical fitness suggesting a relatively strong covariance between the two set of variables. Also, Barnett et al. (2008) found that object control proficiency in childhood was associated with adolescent cardiorespiratory fitness, accounting for 26% of fitness variation. Overall, the results of these studies support the idea that children with good FMS and high levels of physical fitness are more likely to become well coordinated adolescents and vice-versa. The causal mechanism responsible for these associations is unclear (Marshall and Bouffard, 1997).

In Madeira children, abdominal skinfold and BMI at 8 years were also predictors of MC tests at 14 years. The regression coefficients were negative meaning that higher levels of body fatness were associated with poorer performance in MC. An inverse relationship between skinfolds and/or BMI with MC tests, mostly in HH and JS, was also observed in Azorean (Lopes et al., 2012), Peruvian (Valdivia et al., 2008), Belgian (D'Hondt et al., 2012; 2011; Vandendriessche et al., 2011) and North-American (Wrotniak et al., 2006) children. A reasonable explanation is that excess body fatness represents an inert load that must be moved (Malina et al., 2004). Interestingly, BMI-differences in MC were more pronounced in Madeira children that belonged to the older group (8-14 years) as was also reported by D'Hondt et al. (2011) in Flemish children.

The finding that physical activity was not a predictor of MC in Madeira children was unexpected since recent reports have suggested a positive relationship between physical activity and MC. For example, Vandorpe et al. (2011) reported that children who consistently practiced sports in a club environment over the three years of testing displayed better coordination levels than children who only partially participated or did not participate in a club environment at all. Also D'Hondt et al. (2012) reported that the participation in organized sports within a sports club was a positive predictor of MC. Lopes et al. (2011) found that MC was an important predictor of physical activity in Azorean children. We could argue that the discrepancy between the findings of our study and the previous ones could be allocated to the questionnaire, i.e., the Baecke questionnaire (Baecke et al., 1982) was not sensitive enough to capture the subject's physical activity. In order to minimize this possibility, the team members filled out the questionnaires by means of a face-to-face interview and children under 10 years of age had the assistance of the teacher of physical education or a parent. In addition, evidence is accumulating that the Baecke questionnaire and modifications of this questionnaire provide reliable and valid information (Philippaerts et al., 2006).

SES, through the parental occupation, only entered into two regression models and explained 9% and 15% of the variance of JS and MS, respectively. The regression coefficients were positive, so low SES had a better performance than high SES in MC, since a lower score in the SES scale represents a higher SES. Our finding did not support a previous research by Vandendriessche et al. (2012) who observed that high SES girls were more proficient than their peers from middle SES in JS, WB and HH. Valdivia et al. (2008) reported that SES was not a relevant predictor of differences in MC profiles of Peruvian children. One plausible explication for the Madeira data is that low SES children had a more permissive rearing atmosphere that might be conducive to greater freedom of activity and opportunity for practice and, in turn, compensate the higher MC noted in low SES (Malina et al., 2004).

Skeletal maturation in childhood was not a predictor of MC in early adolescence. Few other studies have considered maturity-associated variance in MC in these age intervals. Seils (1951) found low to moderate correlations between skeletal age and gross motor skill performance in primary-school children. Kerr (1975) used a serial tapping task to analyse movement control in 60 participants, age 5-, 7- and 9 years. No significant relationship was found between the fine motor task and skeletal age. In Belgian girls, 6-16 years old, the correlation coefficients between skeletal age and balance were low or non-significant (Beunen et al., 1997). The absence of a clear association between skeletal maturation and MC supports the idea that neuromuscular maturation could be dominant at earlier ages and this may not be related to skeletal maturation.

There are some weaknesses that need to be addressed when interpreting our results. First, physical activity was self-reported and questionnaire responses depend on the perception, encoding, storage, and retrieval of information (Shephard, 2003). Second, the three cohorts did not cover the entire growth period. On the other hand, this study was built on previous research (D’Hondt et al., 2012; 2011; Lopes et al., 2012; 2011; Vandendriessche et al., 2012; 2011; Vandorpe et al., (2011); Valdivia et al., 2008) by including FMS and biological maturation as predictors of MC, in addition to human physical growth, physical fitness, physical activity and SES. Other strengths lie in the stratified sampling procedure, a relatively large sample size, and the high quality control of the data.

In summary, the present findings indicate that boys, on average, show better MC scores than girls, and younger children tend to perform less proficiently than older peers. MC tracks at low-to-moderate levels during childhood and early adolescence, and childhood predictors of MC at early adolescence are MC tests, human physical growth characteristics, physical fitness, FMS and SES. Furthermore, predictors of MC change over time and the relative contribution of these predictors also change with age. Given that FMS and physical fitness in childhood are predictors of MC in early adolescence it is crucial to enhance them to promote MC. Future longitudinal research using biological and environmental variables is justified to gain greater insight in the tracking of MC.

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Chapter 5

Motor performance and body fatness in 3- to 5-yr-old children

António M. Antunes, José A. Maia, Élvio R. Gouveia, Martine A. Thomis,

Johan A. Lefevre, Alexandra Q. Teixeira, Donald Hedeker, Duarte L. Freitas

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Abstract

Purpose: To investigate the relationship between motor performance and body fatness in 3- to 5-year-old children, controlling for physical activity, SES and geographical area.

Methods: Two hundred seventy-two healthy children, 143 boys and 129 girls, participated in the ‘Madeira Child Growth Study’, a longitudinal study over two years. Motor performance was assessed using the Preschool Test Battery, while body fatness was estimated through body mass index (BMI), sum of skinfolds and waist circumference. Physical activity and socioeconomic status (SES) were assessed via questionnaire. Geographic area was defined according to Statistics Portugal. A two-level regression model with repeated measurements (level one) nested within individuals (level two) was used to estimate the longitudinal effect of age and body fatness on motor performance, controlling for several correlates at baseline.

Results: Age was associated to a better performance in all motor tests. Boys outperformed girls in scramble (p = 0.018), speed run (p = 0.001), and standing long jump (p = 0.003). The BMI was positively associated with scramble (β = 0.047; p = 0.030) and speed run (β = 0.038; p < 0.001), and negatively (β = -0.009; p = 0.012) related to the standing long jump. Physical activity in leisure-time was negatively (β = -0.006; p = 0.031) associated with scramble. No statistical significance was found for the association between socioeconomic status and motor tests. Semi-urban children were fitter in catching than urban peers (p = 0.003).

Conclusion: Body fatness was associated to a poor performance in scramble, speed run and standing long jump. Physical activity, SES and geographical area had a negligible influence on motor tests in this sample of preschool children.

Key Words: motor performance, body fatness, early childhood

5.1 Introduction

More than ever, it is crucial to explore the longitudinal relationship between motor performance and body fatness in preschool children and to consider the simultaneous effect of physical activity, socioeconomic status (SES) and geographical area. Interest in this relationship and covariates has been intensified by a report showing high rates of overweight (26.7%) and obesity (12.1%) among US children, aged 2-5 years (Odgen et al., 2012). In Portugal, data for this age range are not available but Rito et al. (2012) found a similar prevalence (28.1% and 8.9%, respectively) in 6- to 8-year-old children.

Overall, body fatness has a negative influence in motor performance in early (Krombholz, 2013; Castetbon and Andreyeva, 2012; Roberts et al., 2012; Nervik et al., 2011) and late (Gentier et al., 2013; Morrison et al., 2012; Sacchetti et al., 2012) childhood. Moreover, being overweight or obese has a negative effect on health status during childhood and adolescence (Willis, 2004 and Reilly et al., 2003). Motor performance in early childhood is also related to motor performance in late childhood (Branta et al., 1984) and physical activity or fitness in adolescence (Barnett et al., 2009; 2008). Thus, if a poor motor performance is seen early in life, there is a greater chance to perform poorly and display low levels of physical activity later (Jones et al., 2013).

The relationship between SES and motor performance has emerged with an inconsistent pattern. Children of higher SES performed better than children from lower SES (Chow and Louie, 2013; Giagazoglou et al., 2008; Mészáros et al., 2008; Krombholz, 1997); however, other studies described no SES differences (Krombholz, 2006) or reported varying trends (Okely and Booth, 2004). Research dealing with the effect of geographical area on motor performance has not, to our knowledge, been considered in early childhood. Rural children showed a healthier profile in cardiorespiratory and muscular fitness than their urban peers, while the opposite was found for speed-agility and flexibility (Chillón et al., 2011). Notwithstanding, no difference was found between rural and urban children in cardiopulmonary and motor fitness (Özdirenç et al., 2005).

In light of the crucial research examining the longitudinal relationship between motor performance and body fatness in early childhood, two issues have to be highlighted: first, motor performance was largely assessed via fundamental motor skills and a recent study has given some evidence that process- and product-assessments measure different aspects and/or levels of motor performance (Logan et al., 2014); second, no studies have explored this association in a relatively healthy weight group. Therefore, the primary aim of this study was to investigate the relationship between motor performance and body fatness in 3- to 5-year-old children, controlling for physical activity, SES and geographical area. Two additional aims were: (1) to examine age- and sex-related differences on motor performance; (2) to explore the individual influence of environmental variables on motor tests. It was hypothesized that: (1) body fatness has a negative influence in weight-bearing tests, (2) boys outperform girls in motor tests that require power and speed, whereas girls excel boys in balance; and (3) physical activity, SES and geographical area, at baseline, have little influence in motor performance.

5.2 Methods

5.2.1 Study and sample

In 2012, a two-year follow-up study was initiated in Madeira and Porto Santo, Islands, Portugal. Two hundred seventy-two healthy children, 143 boys and 129 girls, aged 3-yr-old, were recruited from 29 public/private preschools and participated in the 'Madeira Child Growth Study' [MCGS]. Permissions were obtained from the Scientific Committee of the University of Madeira and the Regional Secretary of Education and Human Resources.

A multistage stratified sampling procedure, based on records of the Ministry of Education, was used to ensure a representative sample. The number of participants in each district was proportional to the number of inhabitants of that age and gender. Children were randomly selected according to several steps. First, an oral presentation of the study was given to the school authorities. Second, a selection of the preschools was made and a meeting was carried out with the PE teacher of each school aiming to explain the study. Third, an invitation was delivered to the parent/legal guardian of the children; the invitation included the purposes of the study as well as a summary of the procedures. The sample size was initially set in 220 subjects, but 272 children (12.5% of the target population) had agreed to participate and were included in the MCGS.

In 2013 and 2014, the children were reassessed at 4 and 5 years old, respectively. During the follow-up, 58 children dropped out of the study (23 children in 2013 and 35 in 2014). The main reason for the dropping out was the emigration. A description of the sample size, dropouts and period of measurement is given in Table 5.1.

Table 5.1 Sample size (n), dropouts and period of measurement of the 'Madeira Child Growth Study'.

	Period of measurement					
	2012		2013		2014	
Age, years†	Boys	Girls	Boys	Girls	Boys	Girls
3	143	129				
4			127	122		
5					109	105
Total	272		249		214	
Dropouts			23		35	
Total dropouts			58			

†In the age group 3-year-old, ages from 3.0 up to 3.99.

5.2.2 Testers, training and data collection

Data were collected by the lead author and a team of 17 physical education (PE) teachers. All PE teachers completed 32 hours of theoretical classes and field sessions. Training focused on equipment, performance criteria, and administration and scoring of motor tests. Practical procedures were administrated in a sample of 8 children, aged 4-5 years old. A pilot study was then carried out in 72 children, age 4 years, before data collection. Children completed the motor tests twice within a 8-day period. Test-retest reliability, via intraclass correlation coefficient, ranged from 0.92 (catching) to 0.99 (balance). In November of 2012, the preschools were visited by the lead author and an assessment plan was outlined together with the Director. Data were collected between December and July of each year. Anthropometry and motor tests were assessed/administered in a single day (~1 to 12 participants/day) during the morning and early afternoon.

The sequence was anthropometry and then motor tests. Anthropometry was performed by the lead author in the gymnasium or empty classroom. Motor tests were conducted by the lead author and the PE teacher in the school playground. Therefore, data collection involved two testers: the lead author and the PE teacher of each preschool. Based on the number of students, some PE teachers gave classes in more than one school. Children received a verbal description followed by a visual demonstration of each motor test and were highly motivated when performing the motor tests. The lead author and/or the PE teacher administered the questionnaires at baseline to the parents/legal guardians at the end of the school day. During the two-year of the follow-up the 17 PE teachers remained in the study.

5.2.3 Measures

5.2.3.1 Motor performance

The Preschool Test Battery [PTB] (Morris et al., 1981) was chosen because it is a reliable tool for assessing motor skills in preschool age children (Morris et al., 1982). The PTB comprises 6 motor performance items, namely, catching (child’s ability to catch an aerial ball), scramble (how fast the child could move from the supine to the vertical, run a short distance, pick up a fleece ball, and return to a horizontal position), speed run (how fast the child could run a distance of 40 feet), standing long jump (how far the child could jump horizontally, using a two-foot take-off and landing), balance (how long the child could balance while standing on one foot) and tennis ball throw for distance (how far the child could throw a tennis ball).

5.2.3.2 Anthropometry

Height, body mass, skinfolds and waist circumference were measured according to standardized procedures (Claessens et al., 2008 and Norton and Odds, 1996). Height was measured with a portable stadiometer (Siber-Hegner, GPM) to the nearest 0.1 cm and body mass on a balance-beam scale to the nearest 0.1 kg (Seca Optima 760, Germany). Body mass index (BMI) was calculated as body mass (kg) divided by height (m^2). Abdominal, biceps, calf, subscapular, suprailiac and triceps skinfold thicknesses were measured using a caliper (Siber-Hegner, GPM). Waist circumference was taken at the level of the narrowest point between the lower costal border and the iliac crest using a flexible steel tape (Holtain LTD). Participants wore a swimming costume, without shoes and jewellery removed. Height, skinfold thicknesses and waist circumference were performed twice and a third measurement was done if the first two measurements differed by more than 5 mm (height and waist circumference) and 10% (skinfolds). The average of the two closest readings was considered as the final value. Measurements were taken on the left side of the body. Test-retest reliability in the second year of measurement (2013) (random subsample of n = 45) ranged from 0.979 to 1.000. All anthropometric measurements were performed by the lead author with the same instruments over the two-year of follow-up.

5.2.3.3 Physical activity

The leisure time exercise questionnaire (Godin and Shephard, 1985) was used to assess physical activity. Briefly, the questionnaire includes 3 questions measuring strenuous, moderate and mild exercise, over a typical 7-day period. The children were asked to recall how many times, on the average, they did several kinds of exercise for more than 15 minutes during their free time. A leisure-time physical activity score was computed by multiplying weekly frequencies of strenuous, moderate and mild exercise by nine, five, and three, respectively; these latter values correspond to MET value categories of the activities listed. Then the total weekly leisure time activity score was computed by summing the products of the separate components (Godin, 2011). The questionnaire was administrated through a face-to-face interview to the parents/legal guardian (usually the mother) at the end of the school day. Two studies have investigated the validity of the leisure time exercise questionnaire in children, aged 7-10 years, by comparisons with the Caltrac accelerometer, and reported low-to-moderate correlations (r = 0.40-0.62) (Eisenmann et al., 2002 and Scerpella et al., 2002).

5.2.3.4 Socioeconomic status

The SES of the family was based on parental occupation, educational level, income, housing conditions and residential area features. Questions were taken from Census 2011 questionnaires (Statistics Portugal, 2013) and a modified version of the Graffar´s method (Graffar 1956) was use to operationalize the household SES. In this method, each item is assessed in a five-point scale and then all responses are summed producing a scale ranging from 5 (most affluent) to 25 (less affluent). Parental occupation was coded according to the Portuguese Classification of Occupations (Statistics Portugal, 2011). The 10 major groups were recoded in five groups. This task was performed by a member of the Statistics Portugal. As for physical activity, the questionnaire was administrated by the lead author via a face-to-face interview to the parents/legal guardian at the end of the school day.

5.2.3.5 Geographical area

Three types of geographical areas were obtained following the criteria developed by the Statistics Portugal (2004). Urban area (centrality index ≥ 3.81) comprises the municipality of Funchal. Semi-urban area (centrality index between 3.46 and 3.80) covers the municipalities of Machico, Porto Santo, Câmara de Lobos and Santa Cruz. Rural area (centrality index ≤ 3.45) includes the municipalities of Ribeira Brava, São Vicente, Santana, Calheta, Ponta do Sol and Porto Moniz. The centrality index is based on the functions provided by an urban centre, the degree of specialization, and the number of functional units. Regarding to the population, the intervals are the following: urban area (≥ 12001 inhabitants), semi-urban area (6000 ≤ n.º of inhabitants < 12000) and rural area (< 5999 inhabitants).

5.2.4 Statistical analysis.

Data were entered once in the computer by two different people - each person entered the data once, in a total of two entries - and cross-referenced in specific software to detect input errors. Microsoft Excel 2010, Stata version 13 (StataCorp, 2013) and SuperMix 1 (Scientific Software International, 2005-2013) were used for data analysis. Outliers and the normality of the data were first explored. Descriptive statistics (mean±standard deviation) were calculated for chronological age, anthropometry, motor performance, physical activity (total weekly leisure-time) and SES (total), according to sex and period of measurement. Absolute and relative frequencies were also used to summarize weight status, physical activity, SES and geographical area. Children were classified into healthy weight, overweight and obese categories according to the 'International Obesity Task Force' cut-off points (Cole et al., 2000). A two-level regression model with repeated measurements or occasions (level one) nested within individuals (level two) was used to estimate the longitudinal effect of age and BMI or sum of 6 skinfolds or waist circumference (independent first-level time-varying variables) on motor performance. Physical activity, SES and geographical area were also entered as independent first-level time-invariant variables because data were collected only at baseline. Each predictor variable was time centered on its mean. Physical activity and SES were treated as a continuous variable; while geographical area was handled as a dummy with urban as reference category. The minimal statistical significance for all variables was set at $p < 0.05$.

5.3 Results

Table 5.2 contains the descriptive statistics for anthropometric, motor and environmental characteristics of the sample. Participants' age is also included. The mean age is very close to the half year interval at each time of measurement and sex.

Height and body mass were within the normal ranges of international growth standards developed by the Health World Organization [WHO] (WHO, 2006) and the Centers for Disease Control and Prevention [CDC] (CDC, 2002). In 2012, the total prevalence of overweight and obese boys and girls was 4.9% and 14.7%, respectively. Physical activity, SES and geographical area data were collected only at baseline. Overall, a large percentage of boys were active (42.1%) in leisure-time, belonged to the high socioeconomic group (63.3%) and lived in urban area (45.5%). For girls, 50.4% were insufficiently active, 60.9% belonged to the high socioeconomic group, and 41.1% lived in urban area.

Tables 5.3-5.5 show the estimated parameters, standard errors and p values of the full multilevel models. Age is positively associated with catching, standing long jump, balance, and tennis ball throw for distance, i.e., age is associated to a better performance. For scramble and speed run tests, the negative β coefficient also means a higher performance since a lower time implies a better score. On average, boys perform better than girls, in scramble ($p = 0.018$), speed run ($p = 0.001$), and standing long jump ($p = 0.003$) tests. No statistical significance is found for catching, balance, and tennis ball throw for distance. The interaction between age and sex reaches statistical significance on scramble ($p = 0.031$), balance ($p = 0.021$) and tennis ball throw for distance ($p < 0.001$).

Table 5.2 Anthropometry, motor performance, and environmental characteristics of participants in the 'Madeira Child Growth Study'.

	Period of measurement					
	2012		2013		2014	
Characteristics	Boys	Girls	Boys	Girls	Boys	Girls
Chronological age (years)	3.60±0.28†	3.59±0.27	4.56±0.28	4.55±0.29	5.43±0.27	5.44±0.29
Anthropometry						
Height (cm)	102.0±4.5	101.6±4.6	107.8±5.2	107.4±5.1	113.1±5.7	113.3±5.4
Body mass (kg)	16.4±2.1	16.3±2.6	18.4±2.7	18.7±3.6	20.4±3.2	21.3±4.5
Body mass index (kg/m^2)	15.7±1.3	15.9±1.8	15.8±1.5	16.1±2.0	15.9±1.8	16.5±2.5
Weight status						
Healthy	132 (92.3)‡	109 (84.5)	112 (78.3)	93 (72.1)	90 (62.9)	71 (55.0)
Overweight	5 (3.5)	12 (9.3)	12 (8.4)	17 (13.2)	12 (8.4)	20 (15.5)
Obese	2 (1.4)	7 (5.4)	3 (2.1)	12 (9.3)	7 (4.9)	14 (10.9)
Overweight + obese	7(4.9)	19 (14.7)	15 (10.5)	29 (22.5)	19 (13.3)	34 (26.4)
Skinfolds (mm)						
Abdominal	8.1±3.0	10.2±4.0	8.9±3.2	12.9±6.7	9.2±3.8	12.9±6.7
Biceps	5.1±1.2	6.0±1.6	5.2±1.3	6.0±1.7	5.0±1.3	6.0±1.7
Calf	8.5±1.9	10.4±2.9	8.3±2.1	10.7±3.8	8.4±2.7	10.7±3.8
Subscapular	5.4±1.1	6.4±1.6	5.5±1.2	6.7±2.3	5.4±1.1	6.7±2.3
Suprailiac	4.8±1.4	6.2±2.3	4.7±1.4	6.6±3.2	4.8±1.7	7.8±4.7
Triceps	8.8±2.0	10.5±2.7	8.4±2.0	10.8±3.3	8.7±2.1	10.8±3.3
Sum of 6	39.9±7.9	47.7±10.6	39.9±8.5	50.4±14.8	39.2±8.7	50.4±14.8
Wait circumference (cm)	52.5±2.7	52.1±3.8	53.7±2.9	53.6±4.4	54.4±3.5	55.2±5.4
Motor performance						
Catching (points)	1.7±0.8	1.6±0.8	2.3±0.5	2.2±0.5	2.6±0.4	2.5±0.4
Scramble (s)	6.5±1.2	6.8±1.3	5.1±0.9	5.3±0.9	4.7±0.7	4.8±0.6
Speed run (s)	4.1±0.6	4.4±0.7	3.4±0.4	3.6±0.5	3.1±0.3	3.3±0.4
Standing long jump (cm)	50.5±19.3	44.0±17.4	77.8±15.2	68.6±16.2	95.1±13.1	87.5±13.8
Balance (s)	2.4±1.5	2.8±2.0	6.4±4.1	7.4±5.1	10.9±5.7	12.9±6.9
Tennis ball throw for distance (m)	3.2±1.1	2.6±0.8	4.7±1.5	3.7±1.0	6.8±1.8	5.2±1.4
Physical activity						
Active	59 (42.1)	33 (26.0)	-	-	-	-
Moderately active	31 (22.1)	30 (23.6)	-	-	-	-
Insufficiently active	50 (35.7)	64 (50.4)	-	-	-	-
Total weekly leisure-time (score)	20.9±16.6	15.7±14.6	-	-	-	-
Socioeconomic status						
High	88 (63.3)	78 (60.9)	-	-	-	-
Average	44 (31.7)	40 (31.3)	-	-	-	-
Low	7 (5.0)	10 (7.8)	-	-	-	-
Total (range 5-25)	12.6±3.0	12.8±3.1	-	-	-	-
Geographical area						
Urban	65 (45.5)	53 (41.1)	-	-	-	-
Semi urban	54 (37.8)	51 (39.5)	-	-	-	-
Rural	24 (16.8)	25 (19.4)	-	-	-	-

†Values are mean ± standard deviation; ‡absolute and relative frequencies.

Table 5.3 Estimated parameters and standard errors of the multilevel analyses for motor performance: catching and scramble.

	Catching			Scramble		
Fixed effect	Coefficient	S.E.	*p* value	Coefficient	S.E.	*p* value
Intercept	1.303	0.084	< 0.001	7.268	0.136	< 0.001
Age	0.460	0.036	< 0.001	-1.133	0.060	< 0.001
Sex	0.100	0.109	0.378	-0.416	0.175	0.018
Age*sex	0.005	0.050	0.928	0.183	0.085	0.031
Body mass index	0.019	0.012	0.105	0.047	0.022	0.030
Physical activity	0.001	0.002	0.475	-0.006	0.003	0.031
Socio economic status	-0.001	0.008	0.865	-0.002	0.015	0.878
Area						
Semi-urban	0.183	0.056	0.001	0.016	0.101	0.875
Rural	-0.003	0.070	0.969	0.191	0.126	0.131
Random effect						
Level-two variance						
Between subjects	0.050	0.017	0.003	0.072	0.049	0.143
Level-one variance						
Between occasions	0.183	0.016	< 0.001	0.626	0.056	< 0.001

Notes: Age is centred at 3.01 years (minimum age of the participants); sex: girls as reference category; body mass index, physical activity, and socioeconomic status are centred on their means; area: urban as base, the reference category.

The BMI is positively associated with scramble ($\beta = 0.047$; $p = 0.030$) and speed run ($\beta = 0.038$; $p < 0.001$). As a high score in the scramble and speed run scales represents the less performance, the higher the BMI is the lowest is the performance. The BMI is also negatively ($\beta = -0.009$; $p = 0.012$) associated with the standing long jump, i.e., the higher the body fat, the lower the performance. Physical activity in leisure-time is negatively ($\beta = -0.006$; $p = 0.031$) associated with scramble, i.e., the higher the physical activity is the lowest is the time to perform the scramble and the better the performance. No statistical significance is found for the association between SES and motor tests. Semi-urban children are fitter in catching than urban peers ($p = 0.003$). The trajectories of the children are not parallel for catching, speed run and balance (level-two variance).

Table 5.4 Estimated parameters and standard errors of the multilevel analyses for motor performance: speed run and standing long jump.

	Speed run			Standing long jump		
Fixed effect	Coefficient	S.E.	*p* value	Coefficient	S.E.	*p* value
Intercept	4.671	0.069	< 0.001	0.311	0.020	< 0.001
Age	-0.611	0.026	< 0.001	0.232	0.009	< 0.001
Sex	-0.300	0.088	0.001	0.074	0.025	0.003
Age*sex	0.066	0.036	0.067	0.005	0.012	0.686
Body mass index	0.038	0.010	< 0.001	-0.009	0.004	0.012
Physical activity	-0.003	0.002	0.066	0.000	0.001	0.705
Socio economic status	-0.005	0.008	0.539	0.001	0.003	0.768
Area						
Semi-urban	-0.017	0.051	0.731	0.005	0.018	0.781
Rural	-0.104	0.062	0.093	0.031	0.023	0.175
Random effect						
Level-two variance						
Between subjects	0.024	0.009	0.004	0.001	0.001	0.468
Level-one variance						
Between occasions	0.090	0.008	< 0.001	0.013	0.002	< 0.001

Notes: Age is centred at 3.01 years; sex: girls as reference category; body mass index, physical activity, and socioeconomic status are centred on their means; area: urban as base, the reference category.

Table 5.5 Estimated parameters and standard errors of the multilevel analyses for motor performance: balance and tennis ball throw for distance.

	Balance			Tennis ball throw for distance		
Fixed effect	Coefficient	S.E.	*p* value	Coefficient	S.E.	*p* value
Intercept	-0.673	0.441	0.127	1.768	0.130	< 0.001
Age	5.475	0.295	< 0.001	1.331	0.072	< 0.001
Sex	0.385	0.519	0.459	0.256	0.152	0.093
Age*sex	-0.951	0.411	0.021	0.584	0.101	< 0.001
Body mass index	-0.044	0.111	0.696	0.048	0.031	0.124
Physical activity	-0.010	0.013	0.430	0.003	0.004	0.378
Socio economic status	-0.068	0.067	0.315	0.037	0.020	0.064
Area						
Semi-urban	0.593	0.448	0.186	0.102	0.133	0.444
Rural	0.304	0.563	0.590	0.144	0.167	0.391
Random effect						
Level-two variance						
Between subjects	3.437	1.046	0.001	0.108	0.067	0.108
Level-one variance						
Between occasions	9.981	0.921	< 0.001	0.794	0.072	< 0.001

Notes: Age is centred at 3.01 years; sex: girls as reference category; body mass index, physical activity, and socioeconomic status are centred on their means; area: urban as base, the reference category.

5.4 Discussion

Motor performance was investigated in 3- to 5-year-old children. Boys and girls improved their performance with age. Boys performed better than girls in scramble, speed run, and standing long jump. BMI was negatively associated with standing long jump. High levels of physical activity were associated with a better score in scramble. SES was not associated with motor performance and semi-urban children were fitter than urban peers in catching. Results from our study also revealed that pre-schoolers showed different trajectories across time in catching, speed run and balance tests.

The normal course of motor performance during early childhood has been reported by Morris et al. (1982). Generically, older children perform more proficiently than younger children. The age-related increase is more pronounced in catching, scramble, speed run, standing long jump, and tennis ball throw for distance. Boys outperform girls in speed run, standing long jump and tennis ball throw for distance. Girls perform somewhat better in balance and no sex-related differences are found for catching test. As a whole and aside from the large temporal gap between the two studies (~30 years), our age- and sex-related changes are similar to the cross-sectional data of Morris et al. (1982). Notwithstanding, no statistically significance was observed between boys and girls in tennis ball throw for distance. It was also observed that the interaction between age and sex reached statistical significance on scramble, balance, and tennis ball throw for distance, implying that the effect of sex on these motor tasks varies as a function of age. In the absence of another outcome-based longitudinal study, the interpretation of our results is limited. It can be plausible that the type of activities, role of the models and societal expectations are becoming similar, and girls are closer to boys in tasks that require power and speed (see also Malina et al., 2004).

BMI was a significant predictor of scramble, speed run and standing long jump tests. This is acceptable since body fatness is often inversely associated with running or jumping in pre- and school-children (Chivers et al., 2013; Krombholz, 2013; Niederer et al., 2012; Sacchetti et al., 2012). In general, body fatness acts as an inert load that must be supported or moved against gravity (Gentier et al., 2013 and Morano et al., 2011). It is interesting to question if BMI should be used as an indicator of fatness in this age group. Trying to address to this question, the sum of 6 skinfolds or waist circumference was entered in the multilevel regression models instead of BMI (not reported). Surprisingly, similar results were obtained for sum of 6 skinfolds or waist circumference. Only one exception was found when exploring the association of waist circumference with standing long jump where the p-value was not statistically significant. Therefore, BMI, sum of 6 skinfolds and waist circumference seem to be representative of body fatness in this sample of preschool children.

There have been few longitudinal studies that have investigated the association of physical activity with motor performance in preschool children. Furthermore, most of them used a process-oriented rather than a product-oriented assessment of motor performance/fundamental motor skills and each type of assessment produces scores that may lead to different understandings of performance (Williams et al., 2013 and Logan et al., 2014). Results from the MCGS indicated that the higher the physical activity is the lowest is the time to perform the scramble, but no statistical significance was found in the remaining associations. This trend parallels previous studies (Iivonen et al., 2013 and Fisher et al., 2005) which reported a weak and non-significant relationship between physical activity and fundamental motor skills in preschoolers. However, our findings are not consistent with earlier studies (Morrison et al., 2012; Tanaka et al., 2012; Bürgi et al., 2011; Cliff et al., 2009; Williams et al., 2008; Wrotniak et al., 2006) which have indicated that physical activity was positive and significantly related to motor performance/fundamental motor skills in children. Recently, Holfelder and Schott (2014) suggested that a cause-effect relationship between fundamental motor skills and physical activity is suspected but has not been demonstrated yet. The reasons for the inconsistent results reflected the differences in motor tests, study design, sampling procedures, age, methods for assessing physical activity, and analytical strategies.

In this current study, motor performance did not differ among socioeconomic groups. This result is not consistent with Krombholz (2006; 1997) who found that school-age children (3 to 7 years old) from higher socioeconomic backgrounds surpassed children from lower SES in most motor skills. However, our findings are supported by Okely and Booth (2004), who reported no consistent association between prevalence of skill mastery and socio-economic status, with only the kick and vertical jump for boys and catch, dodge, and vertical jump for girls differing across SES tertiles. Similarly, Largo et al. (2001) did not find any significant correlation between SES and timed motor performances in children between 5 and 18 years of age. Our results are also in line with a study by Freitas et al. (2007) who reported no significant differences among SES in shuttle run, standing long jump and balance in children 7 to 9 years.

Opposite results were found by Mészáros et al. (2008) who observed that low socioeconomic girls performed worse in speed (30m dash), explosive strength (standing long jump) and speed endurance (400m run) than average and high SES (control group). The nonexistence of a clear trend in the literature may be explained by different indicators and scales of SES used in the analyses, as well as differences in assessment methods, i.e. process and outcome scores.

To our knowledge, the relationship between geographical area and motor performance has not been addressed in preschool children, so that results of the multilevel analyses are novel. Only for catching, semi urban children were fitter than urban-based peers. Although not directly comparable, Sheykhi et al. (2013) reported that rural children, 7-10 years old, performed better in some motor-perceptual abilities than urban peers; however, no statistical significance were found for static and motor coordination. The link relating geographical area to physical fitness has been studied in previous studies, but results are also unclear. For example, Özdirenç et al. (2005) did not find differences between rural and urban children in cardiopulmonar (20m shuttle run) and balance, but flexibility (sit and reach) and muscle endurance (bent arm hang and sit ups) were significantly higher in the rural children. In a Spanish sample, Chillón et al. (2011) reported that rural adolescents had a healthier profile than their urban peers in terms of cardiorespiratory fitness, and upper- and lower-limb muscular fitness, while they performed worse in speed-agility and flexibility. A great variability of results was also observed in children from Portugal (Machado-Rodrigues et al., 2011), Croatia (Dario et al., 2010), Mexico (Pena Reyes et al., 2003), and Australia (Dollman et al., 2002). A heterogeneity of factors, including distance from home to school, availability of physical activity facilities, perception of the area of residence, attitudes towards physical activity and aerobic fitness, social inequalities, and cultural differences may influence the relationship between geographic area and motor performance and have to be considered in future analyses (Machado-Rodrigues et al., 2011; Malina et al., 2004).

Despite being the first longitudinal study of motor performance in Portuguese preschool children, it has some methodological limitations. The first is the use of a questionnaire asking parents/legal guardians to self-report the physical activity levels of their children. Although the questionnaire was administered through a face-to-face interview by the lead author, data were self-reported, and therefore theoretically open to bias. Nonetheless, the 'Godin leisure-time exercise questionnaire' provides reliable and valid information in the light of the accumulating evidence (Godin, 2011 and American College of Sports Medicine, 1997). Another drawback related to physical activity is that data were collected at baseline, and, consequently, no longitudinal or time-variant records are available. The strengths of the MCGS include the longitudinal nature of the motor and growth characteristics, a relatively large sample size, the low dropout rate (12.8%), and a multidimensional approach to motor performance of children, aged 3- to 5 years.

In conclusion, motor performance increased with age in all motor tests and boys excel girls in scramble, speed run and tennis ball for distance. BMI and physical activity were negatively associated with standing long jump or scramble suggesting that higher BMI or low levels of physical activity were associated with a poor performance. SES and geographic area were not associated with motor performance. Overall, results support the hypotheses that physical activity, SES and geographical area have a negligible influence on motor performance among children. In this context, neuromuscular maturation and specific instruction and practice, apart from other environmental characteristics, may be primary factors influencing motor performance (Malina, 2012). Future research should investigate these issues and incorporate direct measures of physical activity in order to generalise our findings.

5.5 References

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Chapter 6

Skeletal maturation, fundamental motor skills and motor coordination in children 7-10 years

Duarte L. Freitas, Berthold Lausen, José A. Maia,

Johan A. Lefevre, Élvio R. Gouveia, Martine A. Thomis,

António M. Antunes, Albrecht L. Claessens, Gaston Beunen, Robert M. Malina

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Abstract

Relationships between skeletal maturation and fundamental motor skills and gross motor coordination were evaluated in 429 children (213 boys, 216 girls) 7-10 years. Skeletal age was assessed (Tanner-Whitehouse 2 method), and stature, body mass, motor coordination (Körperkoordinations Test für Kinder, KTK) and fundamental motor skills (Test of Gross Motor Development, TGMD-2) were measured. Relationships among chronological age, skeletal age (expressed as the standardized residual of skeletal age on chronological age) and body size and fundamental motor skills and motor coordination were analysed with hierarchical multiple regression. Standardized residual of skeletal age on chronological age interacting with stature and/or body mass explained a maximum of 7.0% of the variance in fundamental motor skills and motor coordination over that attributed to body size per se. Standardized residual of skeletal age on chronological age alone accounted for a maximum of 9.0% of variance in fundamental motor skills and motor coordination over that attributed to body size per se and interactions between standardized residual of skeletal age on chronological age and body size. In conclusion, skeletal age alone or interacting with body size has a negligible influence on fundamental motor skills and motor coordination in children 7-10 years.

6.1 Introduction

Interrelationships among growth, biological maturation and motor performance among children and adolescents are of interest to the physical activity and sport sciences. Two indicators of biological maturation have been traditionally used in studies of motor performance: skeletal age and stage of puberty. The former can be used from childhood through adolescence, while the latter is limited to the pubertal years (Malina, Bouchard & Bar-Or, 2004). Early studies of skeletal age and motor performance were correlational (Clarke, 1971; Espenschade, 1940; Rajic et al., 1979; Rarick & Oyster, 1964; Seils, 1951), whereas more recent analyses have incorporated interactions among skeletal age, chronological age and body size (Beunen, Ostyn, Simons, Renson & van Gerven, 1981; Beunen et al., 1997; Katzmarzyk, Beunen & Malina, 1997). Motor items were limited to dashes (speed), vertical and standing long jumps and ball throws (power), and several fitness tests. Skeletal age influenced performance mainly through interactions with stature and body mass, although explained variances ranged from low to moderate.

The development of fundamental motor skills and motor coordination have received less attention in the context of growth and maturation. Correlations between skeletal age and outcome-based tests of striking, catching and balance were low to moderate in primary grade children (Seils, 1951), while a serial tapping task (motor control) was not related to skeletal age in children 5-9 years (Kerr, 1975). More specific measures of motor coordination and fundamental motor skills have not, to our knowledge, been considered relative to skeletal age. In this context, two questions were addressed in Portuguese children 7-10 years of age: (1) Controlling for potential effects of body size per se, what is the contribution of the interaction of skeletal age and body size to the variance in fundamental motor skills and motor coordination? (2) Controlling for the potential effects of body size per se and interactions with skeletal age, what is the contribution of skeletal age to the variance in fundamental motor skills and motor coordination? It was hypothesized that interactions of skeletal age and body size would contribute negligibly to the variation in fundamental motor skills and motor coordination over and above body size per se (H_1), and that skeletal age alone would contribute negligibly to the variation in fundamental motor skills and motor coordination over and above body size and interactions of skeletal age with body size (H_2).

6.2 Methods

6.2.1 Sample.

The cross-sectional sample of 213 boys and 216 girls (n = 429) 7-10 years was part of the Healthy Growth of Madeira Study. The study was approved by the Scientific Committee of the University of Madeira and Ethics Committee of the Hospital of Funchal. Parents/legal guardians provided informed consent and participation was voluntary.

Proportional stratified random sampling was used. The number of the participants was proportional to the number of school children by age and sex in 40 schools randomly selected from the 11 districts of Madeira and Porto Santo. Children at each school were selected randomly until the required number of boys and girls was obtained (about 50 boys and 50 girls at each age from 7-10 years). Children with known disabilities were excluded.

6.2.1.1 Anthropometry

Stature (nearest mm) was measured with a portable stadiometer (Siber-Hegner, GPM). Body mass (100 g) was measured with a balance-beam scale (Seca Optima 760, Germany). Children wore swimming attire (two-piece for females) without shoes.

6.2.1.2 Skeletal maturation

Radiographs of the left hand and wrist were taken with a portable X-ray apparatus (Top 25, For you, Belgian) using Kodak films (OMAT MA, Ready Pack). Skeletal age was assessed with the Tanner-Whitehouse (TW2) 20 bone method (Tanner et al., 1983). The radius, ulna, seven carpals (excluding the pisiform) and metacarpals and phalanges of the 1st, 3rd and 5th rays were compared to written criteria for each bone; maturity scores were summed and converted to skeletal age. The TW2, 20-bone method was selected because maturation of both the carpals and radius-ulna-short bones characterizes childhood and the transition into adolescence. During puberty and the growth spurt, on the other hand, carpals approach the mature state while changes in long bones leading to epiphyseal union are dominant (Malina et al., 2004). A 20 bone maturity score/skeletal age was not available in the TW3 revision (Tanner, Healy, Goldstein, & Cameron, 2001).

6.2.1.3 Fundamental Motor Skills

The Test of Gross Motor Development (TGMD-2, Ulrich, 2000) included six locomotor skills (run, gallop, hop, leap, jump horizontally and slide from side to side) and six object control skills (strike a stationary ball with a bat held by both hands, dribble a basketball while standing stationary, catch a plastic ball that was tossed underhand, kick a stationary ball with the preferred foot, throw a ball overhand and roll a ball underhand using the preferred hand). Performance criteria were described for each fundamental motor skill (3, 4 or 5 criteria depending on the task, Ulrich, 2000). A score of 1 was assigned if the child’s performance met the respective criteria for each skill; otherwise 0 was assigned. Each skill was performed twice; the sum of individual scores for the two trials represented the score. Raw scores were summed to provide overall scores for locomotor and object control skills, respectively (Ulrich, 2000). The maximum score for each subset was 48.

6.2.1.4 Motor Coordination

The “Körperkoordinations Test für Kinder” (KTK) (Kiphard & Schilling, 1974; Schilling & Kiphard, 1976) included four specific tasks: balance while moving backwards on balance beams - number of successful steps; (2) hopping on one leg over an obstacle - sum of successful attempts at each height (three points for the first, two points for the second and one point for the third attempt); (3) jumping laterally as rapidly as possible from side to side over a small beam - number of correct jumps in 15 seconds; (4) shifting platforms - with the child standing with both feet on one platform and holding a second identical platform, he/she was required to place the second platform alongside the first and to step on to it; the first platform was then lifted and placed alongside the second and the child stepped on to it and so on – number of successful transfers (two points per transfer) in 20 seconds. Raw scores for each test were retained for analysis to reflect variation and specific components of motor coordination.

6.2.2 Field procedures

Data were collected between February and July 2006 by a team of six physical education teachers who completed a 3-month theoretical and practical training program on anthropometry and motor assessment. Equipment, measurement procedures, performance criteria, administration and scoring were studied in detail using demonstration, discussion, DVDs and videos. The lead author and teachers also scored sample motor performances. A pilot study was then conducted with 46 school children, 3-10 years (30, 6-10 years for motor coordination) who were measured and completed the test batteries twice within an 8-day period. Absolute and relative intra-observer technical errors of measurement were, respectively, 0.31 cm and 0.26% for stature, and 0.66 kg and 2.56% for mass. Test-retest reliability via ANOVA-based intraclass correlations ranged from 0.98 to 0.99 for stature and body mass, and 0.56 to 0.85 for the KTK. Mean test-retest reliability coefficients for TGMD-2 ratings were 0.90 (locomotor) and 0.85 (object control).

Field staff worked in pairs. Testing was done in the morning. Children started at different stations and did not follow the same sequence. Stature and body mass were measured in the gymnasium or unused classroom. Motor tests were conducted outdoors (school playground). Children were given a verbal description followed by a visual demonstration of each skill/test. About 20 children completed the anthropometry and motor assessments in the same day. Children appeared highly motivated and did not show overt signs of fatigue.

Hand-wrist radiographs were also taken at each school by a local hospital technician with the assistance of a field team member. Skeletal age ratings were done by the lead author. Inter-observer agreement between the author and an experienced assessor was 85.3%; intra-observer agreement was 91.8% (Freitas et al., 2004).

6.2.3 Analysis.

Data were initially screened for entry errors and checked for outliers. Descriptive statistics were calculated for sex-specific single year age groups. Two way ANOVAs were used to simultaneously test the effects of sex and age group on each variable and to verify interaction effects.

Hierarchical multiple regression analyses were used to estimate the contribution of skeletal age alone or interacting with stature and/or mass to the unique variance in fundamental motor skills and motor coordination over and above that explained by covariates. An advantage of hierarchical analysis is that once the order of the independent variables is specified, a unique partition of the total variance of the dependent variable accounted for by the independent variables may be made (Cohen, Cohen, West & Aiken, 2003). Hierarchical analysis is also suitable when models include interactions terms and when independent variables are correlated with each other (Aiken & West, 1991; Pedhazur, 1997).

Given the lack of normality in distributions, body mass and locomotor subtest scores were either log-transformed or squared. Skeletal age was regressed on chronological age within each sex and age group; the standardized residuals were retained for analysis (Katzmarzyk et al., 1997). In order to reduce collinearity, stature and mass were z-standardized within each sex and age group prior to entry into the models. First- and second-order interactions (standardized residuals × stature, standardized residuals × mass, stature × mass, and standardized residuals × stature × mass) were computed from the standardized values. In almost all models, correlations (Pearson *r*) between independent variables and dependent variables were less than 0.30. Correlations among independent variables ranged from -0.21 to 0.80. In 14 of 78 regression models, correlations between some independent variables were >0.80 and were thus removed (Cohen et al., 2003). Variance inflation factors ranged from 1.29 to 3.75 (<10); variables with high variance inflation factors were control variables or interactions terms. Assumptions of linearity and homoscedasticity were also met.

Locomotor and object control fundamental motor skills subscale scores and the four motor coordination tests were entered separately as dependent variables. Stature and mass were entered as covariates in the first block. First- and second-order interactions between standardized residuals of skeletal age and body size were entered as variables of interest in the second block, while standardized residuals of skeletal age alone was entered in the third block. Accordingly, the effects of stature, mass and/or interactions of skeletal age with body size would be taken into account before the variable of interest, standardized residuals of skeletal age, was explored. Changes in explained variance (R^2 change) across blocks were estimated using F-tests. Allowing for sample sizes, hierarchical analyses were performed for two-year age groups by sex: 7-8 and 9-10 years. All analyses were completed with STATA, version 11 (StataCorp, 2009) and SPSS, version 19.0. Significance was set at $p < 0.05$.

6.3 Results

Descriptive characteristics are presented by sex and age group in Table 6.1. Older youth were taller [F (3, 421 = 148.33, $p < 0.001$)] and heavier [F (3, 421 = 51.99, $p < 0.001$)] than younger children. Scores on the locomotor [F (3, 420 = 19.01, $p < 0.001$)] and object control [F (3, 420 = 37.39, $p < 0.001$] subscales improved with age. Boys performed better than girls on the object control subscale [F (1, 420 = 89.12, $p < 0.001$)]. Significant interactions between sex and age group were not evident for fundamental motor skills subtests.

A significant main effect of age was noted for each motor coordination test: balancing backwards [F (3, 421 = 11.78, $p < 0.001$)], hopping on one leg [F (3, 421 = 24.09, $p < 0.001$)], jumping side-to-side [F (3, 421 = 35.80, $p < 0.001$)] and shifting platforms [F (3, 421 = 42.64, $p < 0.001$)]. Girls scored significantly better than boys on jumping side-to-side [F (1, 421 = 5.40, $p < 0.001$)] and boys scored significantly better than girls on shifting platforms [F (1, 421 = 4.85, $p < 0.001$)].

Results of hierarchical multiple regression analyses of fundamental motor skills are summarized in Table 6.2. Standardized residuals of skeletal age × stature, standardized residuals of skeletal age × mass, and standardized residuals of skeletal age × stature × mass interactions explained 0.0% to 3.0% of the total variance in the locomotor subscale over and above stature, mass, and stature × mass interaction (change in R^2 [ΔR^2] from step 1 to 2). Standardized residuals of skeletal age alone contributed 0.0% to 2.0% to the total variance over and above body size (block 1) and interactions of standardized residuals of skeletal age with body size (block 2) in step 3. Interactions terms for standardized residuals of skeletal age and body size, and standardized residuals of skeletal age alone did not reach significance. Standardized beta coefficients (β) for standardized residuals of skeletal age × stature, standardized residuals of skeletal age × mass, standardized residuals of skeletal age × stature × mass interactions and standardized residuals of skeletal age alone were negative in some models.

Table 6.1 Descriptive statistics (mean, Sd) for all variables by age group and sex.

	Age intervals (years)			
	7	8	9	10
Variables	x̅±Sd	x̅±Sd	x̅±Sd	x̅±Sd
Boys	(n = 48)	(n = 51)	(n = 45)	(n = 69)
Chronological age (years)	7.5±0.3	8.5±0.3	9.5±0.3	10.6 ±0.3
Skeletal age (years)	7.6±0.9	8.3±1.0	9.2±1.0	10.5±1.4
Anthropometry				
Stature (cm)	126.8±5.5	131.6±6.3	135.7±5.8	143.4±6.6
Body mass (kg)	27.1±4.7	30.9±6.6	32.4±7.1	40.6±10.0
Fundamental motor skills				
Locomotor, total score	34.7± 5.1	37.5±3.8	39.2±5.6	39.3±4.7
Run	7.0±1.6	7.3±1.1	7.3±1.3	7.3±1.2
Gallop	6.0±2.3	7.0±1.8	7.6±1.4	7.4±1.3
Hop	6.7±1.4	7.1±1.6	7.7±2.0	8.0±1.7
Leap	2.2±1.3	2.4±1.0	2.6±1.4	3.1±1.7
Horizontal jump	5.4±2.3	5.7±1.8	6.2±1.5	5.6±1.6
Slide	7.5±1.2	8.0±0.1	7.8±0.8	7.9±0.5
Object control, total score	31.7±5.8	35.9±4.1	37.0±5.8	39.9±4.6
Striking a stationary ball	6.1±1.7	7.1±1.6	7.2±2.7	7.7±1.9
Stationary dribble	6.0±2.2	7.2±1.4	7.4±1.2	7.4±1.1
Catch	4.3±1.4	4.6±1.3	5.2±0.9	5.5±0.9
Kick	4.5±1.6	5.1±1.1	5.2±1.6	6.2±1.8
Overhand throw	4.9±2.1	5.7±1.5	5.9±1.5	6.2±1.3
Underhand roll	6.0±1.5	6.3±1.3	6.0±1.9	6.9±1.4
Motor coordination†				
Balancing backwards	42.0±11.0	48.4±11.7	53.2±11.4	50.4±11.8
Hopping on one leg	26.7±12.2	35.3±9.1	37.9±11.2	42.7±16.6
Jumping side-to-side	33.6±9.2	44.1±9.9	47.1±11.4	50.5±14.1
Shifting platforms	33.1±5.0	37.2±4.9	40.1±6.5	42.4±6.3
Girls	(n = 45)	(n = 41)	(n = 52)	(n = 78)
Chronological age (years)	7.5±0.3	8.5±0.3	9.4±0.3	10.6±0.3
Skeletal age (years)	7.3±1.0	8.6±1.1	9.5±1.1	11.0±1.4
Anthropometry				
Stature (cm)	125.7±5.2	131.6±5.7	136.4±6.2	141.9±6.9
Body mass (kg)	26.4±5.9	29.7±6.6	34.5±8.6	36.6±7.8
Fundamental motor skills				
Locomotor, total score	36.0±4.1	37.8±4.0	38.2±3.9	40.0±4.1
Run	7.0±1.1	7.0±1.2	6.9±1.4	7.4±1.2
Gallop	6.4±2.4	7.2±1.6	7.4±1.6	7.6±1.0
Hop	6.9±2.0	7.3±1.6	7.4±1.5	8.4±1.5
Leap	2.4±1.3	2.9±1.4	2.7±1.2	2.8±1.7
Horizontal jump	5.4±1.7	5.4±1.9	5.9±1.6	5.9±1.7
Slide	7.9±0.7	8.0±0.2	7.9±0.6	7.9±0.5
Object control, total score	28.6±6.2	29.0±5.3	32.3±4.7	34.7±5.8
Striking a stationary ball	5.4±2.2	5.3±1.6	5.9±1.8	6.2±2.4
Stationary dribble	5.6±2.2	6.1±2.1	7.0±1.4	7.1±1.3
Catch	4.1±1.4	4.3±1.2	4.9±1.1	5.6±0.8
Kick	3.8±1.6	3.9±1.3	4.4±1.0	4.9±2.1
Overhand throw	4.1±2.0	4.0±2.4	4.2±1.8	4.9±1.9
Underhand roll	5.6±1.8	5.4±1.6	6.0±1.7	6.1±1.8
Motor coordination†				
Balancing backwards	43.6±11.6	47.9±14.2	50.7±11.0	50.9±11.1
Hopping on one leg	28.9±10.9	32.7±13.1	35.7±11.9	41.4±13.9
Jumping side-to-side	38.3±13.7	45.4±12.0	48.2±9.5	54.6±14.5
Shifting platforms	32.8±4.9	35.7±5.4	38.5±5.2	40.7±7.6

†Raw scores. Units for each motor test: balancing backwards - number of successful steps; hopping on one leg over an obstacle - sum of successful attempts at each height (three points for the first, two points for the second and one point for the third attempt); jumping side-to-side - number of correct jumps in 15 seconds; shifting platforms - number of successful transfers (two points per transfer) in 20 seconds.

Table 6.2 Results of hierarchical multiple regression analyses of body size and skeletal maturation on locomotor and object control fundamental motor skills (TGMD-2).

	Locomotor subtest†									Object control subtest								
	Step 1			Step 2			Step 3			Step 1			Step 2			Step 3		
Variables	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Boys, 7-8 years																		
Stature	118.44	48.69	.36*	136.07	53.73	.41*	140.96	53.41	.43*	0.82	0.87	.15	1.38	0.93	.26	1.59	0.95	.30
Body mass‡	-136.48	51.59	-.40*	-135.40	53.16	-.39*	-130.62	52.84	-.38*	-0.72	0.89	-.13	-0.85	0.94	-.16	-0.86	0.94	-.16
Stature × body mass	-16.57	33.26	-.05	-5.04	37.38	-.02	-8.93	37.18	-.03	-0.46	0.51	-.10	-0.12	0.63	-.03	-0.21	0.63	-.05
SAsr x ST				-17.96	50.61	-.05	-14.43	50.27	-.04				-1.47	0.93	-.23	-1.55	0.93	-.29
SAsr × BM				-12.33	59.87	-.03	-22.97	59.80	-.06				1.08	0.93	.22	0.99	0.93	.20
SAsr × ST × BM				-28.41	37.75	-.10	5.42	43.33	.02				-0.44	0.44	-.15	-0.16	0.52	-.06
SAsr							-69.01	44.44	-.21							-0.81	0.79	-.15
R^2		.08*			.09			.11			0.2			.05			.06	
ΔR^2					.01			.02						.03			.01	
Boys, 9-10 years																		
Stature	81.09	54.46	.22	75.22	54.77	.21	72.65	55.02	.20	1.24	0.81	.23	1.23	0.83	.23	1.06	0.80	.20
Body mass	-129.93	52.25	-.38*	-140.80	54.74	-.41*	-135.32	55.42	-.39*	-1.15	0.79	-.22	-1.20	0.83	-.23	-0.87	0.81	-.17
Stature × body mass	-33.72	32.55	-.10	-8.16	36.85	-.02	-9.17	36.96	-.03	-0.89	0.51	-.17	-0.82	0.57	-.16	-0.98	0.55	-.19
SAsr × ST				(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)				-0.30	0.67	-.05	-0.20	0.65	-.03
SAsr × BM				-68.74	40.58	-.20	-67.22	40.73	-.19				(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
SAsr × ST × BM				32.80	31.79	.13	45.48	36.59	.18				0.13	0.52	.03	1.01	0.58	.25
SAsr							-30.72	43.58	-.09							-1.92	0.65	-.36**
R^2		.08*			.11*			.11			.07			.07			.14*	
ΔR^2					.03			.00						.00			.07**	
Girls, 7-8 years																		
Stature	66.20	42.19	.22	50.87	48.21	.17	49.21	49.67	.16	-0.49	0.86	-.08	-0.15	0.99	-.03	0.20	1.02	.03
Body mass	-85.77	45.07	-.27	-88.14	48.34	-.28	-87.80	48.69	-.28	-0.38	0.85	-.07	-0.82	1.00	-.14	-0.92	0.99	-.16
Stature × body mass	-127.08	33.69	-.40***	-171.92	48.07	-.54**	-171.43	48.48	-.54**	-0.67	0.59	-.12	-1.37	0.94	-.25	-1.55	0.94	-.29
SAsr × ST				45.72	47.22	.19	46.42	47.73	.19				-0.55	0.87	-.12	-0.56	0.87	-.12
SAsr × BM				3.08	50.05	.01	2.51	50.50	.01				1.31	0.96	.27	1.30	0.95	.27
SAsr × ST × BM				4.87	25.01	.03	2.25	30.28	.01				0.07	0.48	.03	0.49	0.56	.17
SAsr							7.22	46.38	.02							-1.31	0.94	-.23
R^2		.16**			.18*			.18*			.04			.06			.09	
ΔR^2					.02			.00						.02			.02	
Girls, 9-10 years																		
Stature	89.32	38.21	.28*	93.50	46.83	.29*	96.41	46.64	.30*	1.03	0.67	.19	2.05	0.81	.38*	2.13	0.80	.40**
Body mass	-128.33	38.44	-.40**	-124.58	42.89	-.39**	-104.16	44.79	-.33*	-0.95	0.68	-.18	-0.81	0.74	-.15	-0.32	0.76	-.06
Stature × body mass	-7.87	26.06	-.03	-5.30	42.69	-.02	-9.04	42.54	-.03	0.53	0.46	.10	0.75	0.73	.15	0.67	0.72	.13
SAsr × ST				2.19	40.55	.01	15.01	41.23	.05				-0.68	0.69	-.14	-0.38	0.70	-.08
SAsr × BM				-5.69	40.74	-.02	-17.94	41.35	-.06				0.67	0.70	.13	0.37	0.70	.07
SAsr × ST × BM				-5.33	24.91	-.03	7.34	26.18	.04				-0.83	0.43	-.27	-0.53	0.44	-.17
SAsr							-58.08	38.66	-.18							-1.40	0.66	-.26*
R^2		.09**			.09			.10			.03			.06			.10	
ΔR^2					.00			.02						.04			.03*	

Note. †Square-transformed; ‡log-transformed; B, unstandardized coefficients; SE B, standard error of B; β, standardized coefficients; ΔR2, R^2 change; stature and body mass are standardized estimates; SAsr, standardized residuals of skeletal age on chronological age; SAsr × ST, interaction of SAsr with stature; SAsr × BM, interaction of SAsr with body mass; (a) excluded from the model due to a strong linear relationship with other predictor(s); *p < .05; **p < .01; ***p < .001. N = 97 for locomotor subtest, boys, 7-8 years; N = 111 for locomotor subtest, boys, 9-10 years; N = 97 for object control subtest, boys, 7-8 years; N = 110 for object control subtest, boys, 9-10 years; N = 85 for locomotor subtest, girls, 7-8 years; N = 130 for locomotor subtest, girls, 9-10 years; N = 86 for object control subtest, girls, 7-8 years; N = 129 for object control subtest, girls, 9-10 years.

Adding the interactions of standardized residuals of skeletal age with body size to the first block of variables explained a maximum of 4.0% of total variance in object control tasks (ΔR^2 ranged from 0.0% to 4.0%), and did not lead to a significant improvement. Standardized residuals of skeletal age alone accounted for an additional 7.0% of the variance in boys 9-10 years [F change (1, 103) = 8.78, $p < 0.01$] and an additional 3% in girls 9-10 years [F change (1, 121) = 8.78, $p < 0.05$] over and above body size and interactions of standardized residuals of skeletal age with body size (ΔR^2 ranged from 1.0% to 7.0%). Again, β coefficients for standardized residuals of skeletal age × body size interactions and standardized residuals of skeletal age alone were negative in some regression models.

Corresponding analyses of motor coordination are summarized in Tables 6.3 (balance and hopping) and 6.4 (jumping and shifting platforms). For balancing backwards, step 2 accounted for an additional 1.0% to 7.0% of the total variance over and above block 1, and was significant in girls 9-10 years [F change (3, 123) = 8.78, $p < 0.05$]. Standardized residuals of skeletal age entered in step 3 resulting in ΔR^2 from 0.0% to 1.0%, and did not contribute to predicting balancing backwards over and above steps 1 and 2. The interaction between standardized residuals of skeletal age and stature reached significance for girls 7-8 years (β = -.40, $p < .05$) and 9-10 years (β = .38, $p < .01$).

For hopping on one leg, the explained variance of standardized residuals of skeletal age × stature, standardized residuals of skeletal age × mass, and standardized residuals of skeletal age × stature × mass interactions ranged from 1.0% to 6.0% over and above the variance accounted for by stature, mass, and stature × mass interaction. When standardized residuals of skeletal age alone entered the model, R^2 changed from 0.0% to 9.0% and was significant in boys 7-8 years [F change (1, 90) = 12.29, $p < 0.01$]. In the final models, β coefficients for standardized residuals of skeletal age (boys 7-8 years, β = -.41) and standardized residuals of skeletal age × stature (boys 7-8 years, β = -.30; girls 9-10 years, β = .31) reached significance.

For the jumping side-to-side task, interactions between standardized residuals of skeletal age and body size did not explain a large percentage of total variance after controlling for body size (ΔR^2 ranged from 1.0% to 5.0%) and did not result in a significant increase in explained variance. In the final models, standardized residuals of skeletal age contributed a maximum of 2.0% to the explained variance (ΔR^2 ranged from 0.0% to 2.0%) after controlling for body size and interactions between standardized residuals of skeletal age and body size. β coefficients for the interactions of standardized residuals of skeletal age with body size and standardized residuals of skeletal age alone were negative is some models.

Table 6.3 Results of hierarchical multiple regression analyses of body size and skeletal maturation on motor coordination (KTK): balance and hopping.

	Balancing backwards									Hopping on one leg								
	Step 1			Step 2			Step 3			Step 1			Step 2			Step 3		
Variables	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Boys, 7-8 years																		
Stature	.80	1.82	.07	1.18	2.02	.10	1.22	2.02	.10	6.45	1.59	.58***	7.51	1.63	.68***	8.19	1.55	.74***
Body mass†	-2.52	1.97	-.20	-2.38	2.01	-.19	-2.12	2.02	-.17	-7.59	1.64	-.69***	-7.51	1.67	-.68***	-7.22	1.58	-.65***
Stature × body	1.70	1.40	.13	1.66	1.57	.13	1.29	1.60	.10	0.82	0.94	.09	2.29	1.14	.24*	1.82	1.08	.19
SAsr × ST				0.49	1.90	.04	0.61	1.90	.05				-3.36	1.58	-.32*	-3.15	1.49	-.30*
SAsr × BM				0.55	2.28	.03	0.16	2.30	.01				1.43	1.61	.14	0.44	1.55	.04
SAsr × ST × BM				-1.02	1.69	-.08	0.21	2.02	.02				-1.21	.80	-.20	0.40	0.89	.07
SAsr							-1.93	1.75	-.16							-4.52	1.29	-.41**
R^2		.03			.04			.05			.19***			.25***			.34***	
ΔR^2					.01			.01						.06			.09*	
Boys, 9-10 years																		
Stature	1.98	1.50	.18	2.05	1.53	.19	2.02	1.53	.18	11.47	1.91	.76***	11.73	1.94	.78***	11.66	1.93	.77***
Body mass	-6.26	1.48	-.58***	-6.30	1.57	-.59***	-6.21	1.59	-.58***	-12.97	1.90	-.86***	-12.57	2.01	-.84***	-12.31	2.01	-.82***
Stature × body	0.08	0.93	.01	0.53	1.06	.05	0.50	1.07	.05	-2.14	1.15	-.15	-2.37	1.31	-.16	-2.44	1.31	-.17
SAsr × ST				-1.10	1.26	-.09	-1.03	1.27	-.09				(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
SAsr × BM				(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)				1.11	1.53	.07	1.27	1.53	.08
SAsr × ST × BM				0.08	0.92	.01	0.30	1.05	.04				-1.09	1.17	-.10	-0.25	1.33	-.02
SAsr							-0.56	1.28	-.05							-2.09	1.59	-.14
R^2		.21***			.22***			.22***			.36***			.36***			.37***	
ΔR^2					.01			.00						.01			.01	
Girls, 7-8 years																		
Stature	2.88	1.83	.22	4.92	2.07	.38*	4.74	2.14	.36*	8.54	1.35	.73***	8.10	1.55	.69***	8.53	1.60	.73***
Body mass	-5.36	1.81	-.41**	-6.57	2.07	-.51**	-6.52	2.09	-.50**	-10.15	1.33	-.87***	-10.04	1.55	-.86***	-10.16	1.56	-.87***
Stature × body	-2.41	1.26	-.20	-1.89	1.96	-.16	-1.80	1.99	-.15	-0.93	0.92	-.09	-2.41	1.47	-.22	-2.63	1.48	-.24
SAsr × ST				-4.10	1.82	-.40*	-4.10	1.83	-.40*				1.46	1.36	.16	1.47	1.36	.16
SAsr × BM				3.27	2.00	.31	3.28	2.01	.31				0.43	1.50	.05	0.42	1.49	.04
SAsr × ST × BM				-0.25	1.00	-.04	-0.47	1.19	-.07				0.05	0.75	.01	0.54	.88	.10
SAsr							0.68	1.98	.05							-1.58	1.48	-.14
R^2		.14**			.19**			.20*			.43***			.45***			.46***	
ΔR^2					.06			.00						.02			.01	
Girls, 9-10 years																		
Stature	2.66	1.31	.24*	2.09	1.54	.19	2.05	1.55	.19	6.28	1.74	.44***	5.88	1.84	.42**	5.93	1.85	.42**
Body mass	-4.88	1.31	-.44***	-3.16	1.41	-.29*	-3.45	1.49	-.31*	-7.34	1.59	-.56***	-7.01	1.73	-.54***	-6.81	1.80	-.52***
Stature × body	1.54	0.89	.15	-0.39	1.40	-.04	-0.34	1.41	-.03	1.36	1.15	.10	-0.89	1.69	-.07	-0.91	1.70	-.07
SAsr × ST				3.96	1.33	.40**	3.78	1.37	.38**				4.33	2.04	.29*	4.55	2.11	.31*
SAsr × BM				-1.79	1.34	-.17	-1.62	1.37	-.15				-0.70	1.74	-.05	-0.90	1.81	-.07
SAsr × ST × BM				-0.84	0.82	-.13	-1.02	0.87	-.16				0.46	1.12	.05	0.65	1.20	.08
SAsr							0.81	1.28	.07							-0.67	1.55	-.05
R^2		.11***			.18***			.18**			.15***			.18***			.19***	
ΔR^2					.07*			.00						.04			.00	

Note. †log-transformed; B, unstandardized coefficients; SE B, standard error of B; β, standardized coefficients; ΔR2, R^2 change; stature and body mass are standardized estimates; SAsr, standardized residuals of skeletal age on chronological age; SAsr × ST, interaction of SAsr with stature; SAsr × BM, interaction of SAsr with body mass; (a) excluded from the model due to a strong linear relationship with other predictor(s); $p < .05$; $^{**}p < .01$; $^{***}p < .001$.
N = 95 for balancing backwards, boys, 7-8 years; N = 111 for balancing backwards, boys, 9-10 years; N = 98 for hopping on one leg, boys, 7-8 years; N = 110 for hopping on one leg, boys, 9-10 years; N = 86 for balancing backwards, girls, 7-8 years; N = 130 for balancing backwards, girls, 9-10 years; N = 85 for hopping on one leg, girls, 7-8 years; N = 127 for hopping on one leg, girls, 9-10 years.

Table 6.4 Results of hierarchical multiple regression analyses of body size and skeletal maturation on motor coordination (KTK): jumping and shifting platform.

	Jumping side-to-side									Shifting platforms								
	Step 1			Step 2			Step 3			Step 1			Step 2			Step 3		
Variables	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*B*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Boys, 7-8 years																		
Stature	3.24	1.75	.28	4.20	1.82	.37*	4.64	1.83	.41*	2.34	0.77	.46**	2.61	0.79	.52**	2.69	0.79	.53**
Body mass†	-3.84	1.88	-.32*	-1.96	2.06	-.16	-1.49	2.07	-.12	-1.93	0.80	-.38*	-1.42	0.81	-.28	-1.38	0.81	.27
Stature × body mass	1.19	1.14	.11	3.42	1.78	.31	3.74	1.78	.34*	0.09	0.46	.02	0.80	0.55	.19	0.74	0.56	.17
SAsr × ST				0.08	1.69	.01	0.25	1.69	.02				0.21	0.76	.04	0.24	0.76	.05
SAsr × BM				-1.63	2.19	-.14	-2.69	2.29	-.22				-0.80	0.78	-.18	-0.93	0.79	-.20
SAsr × ST × BM				-2.45	1.11	-.35*	-1.94	1.16	-.28				-0.75	0.39	-.27	-0.55	0.45	-.20
SAsr							-2.22	1.49	-.20							-0.57	0.66	-.11
R^2		.05			.10			.12			.09*			.16*			.17*	
ΔR^2					.05			.02						.07			.01	
Boys, 9-10 years																		
Stature	5.65	2.02	.41**	5.93	2.06	.43**	5.84	2.06	.43**	2.69	0.83	.47**	2.71	0.85	.48**	2.73	0.85	.48**
Body mass	-6.15	2.00	-.46**	-5.54	2.12	-.41*	-5.30	2.14	-.39	-3.01	0.84	-.53**	-3.01	0.85	-.53**	-2.85	0.88	-.50**
Stature × body mass	-0.38	1.24	-.03	-0.23	1.41	-.02	-0.26	1.41	-.02	-0.59	0.37	-.15	-0.53	0.58	-.14	-0.54	0.58	-.14
SAsr × ST				(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)				(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
SAsr × BM				0.19	1.58	.01	0.25	1.58	.02				-0.08	0.55	-.02	0.02	0.57	.01
SAsr × ST × BM				-1.12	1.24	-.11	-0.50	1.43	-.05				(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
SAsr							-1.49	1.71	-.11							-0.43	0.63	-.08
R^2		.09*			.10*			.11			.15**			.15**			.15**	
ΔR^2					.01			.01						.00			.00	
Girls, 7-8 years																		
Stature	4.36	1.91	.33*	6.23	2.18	.47**	6.07	2.26	.46**	2.51	0.64	.52***	3.06	0.73	.64***	3.24	0.75	.67***
Body mass	-5.64	1.89	-.42**	-5.68	2.19	-.43*	-5.63	2.20	-.42*	-2.97	0.63	-.62***	-3.33	0.73	-.69***	-3.38	0.73	-.70***
Stature × body mass	-0.90	1.31	-.07	1.00	2.07	.08	1.08	2.10	.09	-1.04	0.44	-.23*	-0.82	0.69	-.18	-0.92	0.69	-.21
SAsr × ST				-3.05	1.91	-.29	-3.05	1.93	-.29				-1.21	0.64	-.32	-1.21	0.64	-.32
SAsr × BM				1.13	2.10	.10	1.13	2.12	.10				0.85	0.70	.21	0.84	0.70	.21
SAsr × ST × BM				-0.96	1.05	-.15	-1.16	1.25	-.18				-0.03	0.35	-.01	0.19	0.41	.08
SAsr							0.60	2.08	.05							-0.67	0.69	-.14
R^2		.10*			.15*			.15			.26***			.29**			.30**	
ΔR^2					.04			.00						.03			.01	
Girls, 9-10 years																		
Stature	4.36	1.48	.36**	5.56	1.77	.45**	5.61	1.77	.46**	2.48	0.65	.45***	2.63	0.78	.47**	2.62	0.79	.47**
Body mass	-4.62	1.49	-.38**	-3.69	1.62	-.30*	-3.36	1.70	-.27	-3.11	0.65	-.56***	-3.22	0.71	-.58***	-3.27	0.75	-.59***
Stature × body mass	0.08	1.01	.01	-2.49	1.61	-.22	-2.55	1.62	-.22	-0.14	0.44	-.03	-0.79	0.71	-.15	-0.78	0.71	-.15
SAsr × ST				1.18	1.53	.11	1.38	1.57	.13				-0.16	0.67	-.03	-0.19	0.69	-.04
SAsr × BM				2.82	1.54	.23	2.63	1.57	.22				1.22	0.68	.22	1.25	0.69	.23
SAsr × ST × BM				-1.70	0.94	-.24	-1.50	1.00	-.21				-0.10	0.42	-.03	-0.13	0.44	-.04
SAsr							-0.94	1.47	-.08							0.15	0.65	.03
R^2		.08*			.13**			.14*			.17***			.19***			.19**	
ΔR^2					.05			.00						.02			.00	

Note. †log-transformed; B, unstandardized coefficients; SE B, standard error of B; β, standardized coefficients; ΔR2, R^2 change; stature and body mass are standardized estimates; SAsr, standardized residuals of skeletal age on chronological age; SAsr × ST, interaction of SAsr with stature; SAsr × BM, interaction of SAsr with body mass; (a) excluded from the model due to a strong linear relationship with other predictor(s); *p < .05; **p < .01; ***p < .001. N = 95 for jumping side-to-side, boys, 7-8 years; N = 113 for jumping side-to-side, boys, 9-10 years; N = 98 for shifting platforms, boys, 7-8 years; N = 112 for shifting platforms, boys, 9-10 years; N = 86 for jumping side-to-side, girls, 7-8 years; N = 129 for jumping side-to-side, girls, 9-10 years; N = 84 for shifting platforms, girls, 7-8 years; N = 127 for shifting platforms, girls, 9-10 years.

For shifting platforms, addition of standardized residuals of skeletal age × stature, standardized residuals of skeletal age × mass, and standardized residuals of skeletal age × stature × mass interactions to the hierarchical process (step 2) contributed an additional 0.0% to 7.0% of the total variance over and above body size. When standardized residuals of skeletal age were entered in step 3, the model explained an additional 0.0% to 1.0% of the total variance over and above body size and interactions between standardized residuals of skeletal age and body size. β coefficients for the interactions of standardized residuals of skeletal age and body size, and standardized residuals of skeletal age alone were negative is some models.

6.4 Discussion

Relationships between skeletal maturation and fundamental motor skills and motor coordination were considered in Portuguese children 7-10 years. Overall, a relatively limited amount of the variance in fundamental motor skills and motor coordination was explained by the interactions of standardized residuals of skeletal age × stature, and of skeletal age × mass over and above body size per se, or by standardized residuals of skeletal age alone (Tables 6.2-6.4). Although not directly comparable, correlation studies of skeletal age and outcome-based skills indicated somewhat stronger though variable relationships in children of approximately the same age. Zero order correlations between skeletal age and two locomotor skills ranged from 0.32 to 0.51 for dashes (speed) and 0.25 to 0.56 for the standing long jump (power) in primary grade boys and girls (Rarick & Oyster, 1964; Seils, 1951). Controlling for chronological age, stature and body mass did not markedly alter correlations in boys, 0.30 (dash) and 0.20 (jump) (Rarick & Oyster, 1964).

Corresponding analyses among adolescents ~13-16 years indicated moderate correlations between skeletal age and performances in boys (dash 0.37, standing long jump 0.25 to 0.56, vertical jump 0.48), and negligible correlations in girls (dash -0.02, standing long jump -0.11, vertical jump 0.14) in girls (Clarke, 1971; Espenschade, 1940). When chronological age was controlled, correlations were lower in boys, 0.10, 0.25 and 0.25, respectively, but largely unchanged in girls, -0.02, -0.00 and 0.10, respectively (Espenschade, 1940).

For object control skills, zero-order correlations between skeletal age and distance thrown ranged from 0.38 to 0.48 in primary grade boys and girls (Seils, 1951), while the third order partial correlation (controlling for chronological age, stature, mass) between skeletal age and throwing velocity was 0.27 in boys (Rarick & Oyster, 1964). Correlations between skeletal age and striking a softball with a baseball bat were low (0.26 boys, 0.02 girls), while those between skeletal age and catching a tossed tennis ball were moderate (0.45 boys, 0.49 girls); partial correlations controlling for chronological age and size were not reported (Seils, 1951). Among adolescents ~13-16 years, the zero order correlation between skeletal age and distance thrown differed in boys (0.51) and girls (-0.19); relationships changed slightly after controlling for chronological age, 0.40 in boys and -0.26 in girls (Espenschade, 1940).

Results of regression analyses provide more variable results. Stepwise multiple regressions of chronological age, weight, height and skeletal age resulted in coefficients of determination approximating zero for the dash, jump and agility shuttle run in children 7-11 years (Rajic et al., 1979). In contrast, standardized residuals of skeletal age independently or in interaction with stature and mass was a significant predictor of the dash, standing long jump and distance throw in children 7-12 years (Katzmarzyk et al., 1997); variance explained in the three skills varied by age group and test among boys (4%-30%) and girls (7%-27%). Using a different regression protocol, skeletal age separately or in combination with chronological age, stature or mass were not significant predictors of the standing long and vertical jumps and shuttle run among girls 6-16 years (Beunen et al., 1997), but accounted for 6% to 13% of the variance in the vertical jump in boys 13-17 years and for only 1% to 3% of the variance in a shuttle run in boys 12-16 years (Beunen et al., 1981).

With several exceptions, the explained variances for the different outcome-based measures overlapped the variances in fundamental motor skills observed with hierarchical analyses (Table 6.2). Variation in results reflected, in part, the tests, sampling, age, method of skeletal age assessment and analytical strategies. Moreover, skeletal age per se or interacting with body size is probably more relevant in outcome-based tests requiring a maximal effort as in dashes, jumps and distance throws. The TGMD-2 tests of locomotor and object control skills, in contrast, emphasize specific components of movement patterns rather than outcomes.

Interactions between standardized residuals of skeletal age and body size accounted for a maximum of 7.0% of variance in the four KTK tests over and above body size alone, while standardized residuals of skeletal age alone explained a maximum of 9% of the variance over and above the influence body size and standardized residuals of skeletal age × size interactions (Tables 6.3 and 6.4). Many of the β coefficients were negative, suggesting that later maturation was associated with better performances on the motor coordination tests. Several studies have considered different balance tests. Skeletal age was not correlated with standing on a stick lengthwise) in primary grade children (Seils, 1951), while skeletal age alone or in combination with chronological age, stature and/or mass was not a significant predictor of the flamingo stand among girls 6-16 years (Beunen et al., 1997) and a stick balance test among adolescent boys (Beunen et al., 1981). Among adolescents ~13-16 years, correlations between skeletal age and the Brace test (composite score based on a series of stunts requiring coordination and balance) were low but positive in boys (0.22) and negative in girls (-0.26), and were reduced with chronological age constant, 0.08 and -0.34, respectively (Espenschade, 1940).

Allowing for the relatively small increments in the total explained variance in fundamental motor skills and motor coordination (7% to 9%) one can inquire about their relevance. This can be addressed through the effect size statistic (Cohen, 1988). In hierarchical multiple regression, effect size is defined as: $f^2 = (R^2_{AB} – R^2_A)/(1- R^2_{AB})$, where R^2_A is the variance accounted for a block of independent variables A and R^2_{AB} is the combined variance accounted for the block of independent variables A and another block of independent variables B. Effect sizes of increments from steps 1 to 2 and from steps 2 to 3 were small in both fundamental motor skills (f^2 0.00 to 0.03) and KTK (f^2 0.00 to 0.09). In light of the small effect sizes, it may be postulated that skeletal maturation alone or interacting with body size has a relatively small influence on the development of fundamental motor skills and motor coordination in this sample of children 7-10 years. Fundamental motor skills and motor coordination are probably more dependent upon neuromuscular maturation independent of body size and skeletal maturity status. It is also likely that a certain level of motor coordination is a component of fundamental motor skills, so that children deficient in motor coordination may not perform well in fundamental motor skills. It would seemingly make sense to control for motor coordination while evaluating the relationship between skeletal age and fundamental motor skills, and vice versa. There is also a need to expand the skills assessed in each domain and view their interrelationships.

The interaction between standardized residuals of skeletal age and stature reached statistical significance for balancing backwards and hopping on one leg (Table 6.3) implying that skeletal age affects these tests through stature. Following suggestions of Dawson (2014), two-way interaction effects for standardized variables were thus plotted and visually inspected by calculating predicted values of the balancing tests under different conditions (high and low values of standard residuals of skeletal age and high and low values of stature). For balancing backwards, taller 7-8 year old girls scored better than shorter peers at low values of standards residuals of skeletal age; however, at high values of the residuals the short and tall groups had similar scores. Taller 9-10 year old girls also scored better than shorter girls at high values of standards residuals of skeletal age. Scores on balancing backwards overlapped considerably for the two stature groups relative to low standards residuals of skeletal age.

The relationship between standards residuals of skeletal age and hopping on one leg (boys, 7-8 years) was consistently negative for tall and short children. The high stature group scored better than the low stature group at high and low values of standard residuals of skeletal age. For boys 9-10 years, differences were noted at high values of standard residuals of skeletal age; taller boys had better scores. Although limited, the relationship between standardized residuals of skeletal age and motor coordination may differ as a function of stature among children 7-10 years. Given the potential role of stature, it may be worthwhile to consider percentage of predicted mature height attained at the time of study as a maturity indicator (Malina, 2014). For example, a negative relationship between percentage of predicted mature height and activity level was noted in children 5-9 years of age (Eaton & Yu, 1989); other applications of the method have been largely limited to adolescents and youth athletes (Malina, 2014).

Although fundamental motor skills and motor coordination were largely independent of skeletal age in Portuguese children 7-10 years, the results were generally consistent with previous studies, allowing for different analytical approaches. Future research with more children within single year age groups would provide a more robust analysis and more specific insights. A longitudinal design would better capture changes over time and allow for inter-individual variation in rates of growth and maturation. There is also a need to extend the research to children age below 7 and above 10 years.

The results imply a limited role for skeletal maturation per se or interacting with body size in the development of fundamental motor skills and motor coordination among children 7-10 years of age. It is possible that skeletal age is not a sufficiently sensitive indicator of maturity status at these ages as also suggested in the correlation and regression analyses of outcome-based motor tests requiring an all-out effort and skeletal age assessed with different methods. Tests of fundamental motor skills and motor coordination may be more reflective of neuromuscular maturation per se which may be not strongly related with skeletal maturation and body size. Indeed, development of fundamental movement skills is often described in terms of stages leading to mature movement patterns (Haubenstricker & Seefeldt, 1986).

The results have several implications for those working with children. The negligible contribution of skeletal age per se and interacting with body size to variance in fundamental motor skills and motor coordination implies an important role for other factors affecting movement proficiency. These likely involve neuromuscular maturation per se, differential growth in body composition and proportions, environmental conditions related to home, school and neighbourhood, habits of outdoor play and physical activity, and/or specific instruction and practice as in physical education and sport (Malina, 2012).

In summary, skeletal maturation expressed as the standardized residual of the regression of skeletal age on chronological age was not strongly associated with fundamental motor skills and motor coordination. Standardized residuals of skeletal age interacting with stature and/or body mass, or of skeletal age by itself explained only 0.0% to 9.0% of total variance in fundamental motor skills and motor coordination. Many of the β coefficients were negative, suggesting that later maturation was associated with better performances on fundamental motor skills and motor coordination. The results support the hypotheses that skeletal age per se or interacting with body size has a negligible influence on tests of fundamental motor skills and motor coordination in children. By inference, individual differences in neuromuscular maturation interacting with environmental conditions, habits of play and physical activity, and/or specific instruction and practice may be primary factors influencing fundamental motor skills and motor coordination among children.

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Chapter 7

Summary and future prospects

7.1 Summary

Age- and sex-specific analyses of FMS and MC in early, middle and late childhood are central issues in Motor Development. FMS are the ABCs of movement (Goodway and Robinson, 2006) or the building blocks of the more specifics skills, i.e., those required in sport-specific activities (Lubans et al., 2010; Clark and Metalfe, 2002; Seefeldt, 1980).

In recent times, there is evidence for a link between FMS, physical activity and health-related physical fitness; that is, good development of FMS seems to be associated with high levels of physical activity (Cliff et al., 2009; Hume et al., 2008; Williams et al., 2008), better proficiency on physical fitness tests (Stodden et al., 2009 and Barnett et al., 2008) and a decrease of body fatness (Foley et al., 2008; Hume et al., 2008; Okely et al., 2004). In this way, interrelationships among FMS, MC, human physical growth, biologic maturation, physical fitness, and environmental characteristics (physical activity, SES and geographical area) are of interest to the Physical Education and Sport Sciences. The current study was an attempt to gain more insight about MC growth curves, to investigate change, stability and prediction of MC, to examine the relationship between motor performance and weight status, and to explore the potential effects of body size and skeletal maturation in FMS and MC.

Four original papers addressed these concerns. The first one (chapter 3), provided age- and gender-specific percentiles for gross MC tests based on 1276 children, aged 6-14 years. This study showed that scores on walking backwards and moving sideways improved with age and boys performed better than girls on moving sideways. After adjustment for age, physical activity and SES, normal-weight children outperformed their obese peers in almost all gross MC tests. Overweight boys displayed better scores than obese counterparts in walking backwards (6-8 years), hopping on one leg (12-14 years) and moving sideways (12-14 years). Additionally, overweight girls surpassed obese colleagues in walking backwards (9-11; 12-14 years), hopping on one leg (all age groups) and jumping sideways (12-14 years). It was concluded that: (1) Portuguese children improved their scores on gross MC with age and demonstrated a large interindividual variation; (2) gender differences vary over age and gross MC test; and (3) normal-weight children outperformed obese peers on gross MC even controlling for age, physical activity and SES. The distinctive and innovative features of this study were the novel fitting approach to derive the gross MC curves, the setting of the study, the homogeneity of the sample, the number of health characteristics available and the small prevalence of overweight and obese children when deriving the gross MC curves.

The second study (chapter 4) considered change, stability, and prediction of MC in a longitudinal sample of Portuguese children, from Madeira and Porto Santo Islands; i.e., the extent to which MC is stable over time and predictors of MC. A total of 158 children, aged 6, 7 and 8 years, were evaluated in 2006 and reevaluated in 2012 at 12, 13 and 14 years of age. A mixed between-within subjects analysis of variance was conducted to assess the effect of age, sex and its interaction on each MC test, across two time periods, and predictors of MC were identified via stepwise multiple linear regression. The results revealed that boys performed better than girls in walking backwards, hopping for height and moving sideways. Group 1 (6-12 years) performed less proficiently than group 2 (7-13 years) and/or group 3 (8-14 years) in all MC tests. Inter-age correlations between the 1st and 2nd measurements for MC tests were between 0.15 and 0.60. Correlations above 0.60 were found for walking backwards hopping for height and jumping sideways. Childhood predictors of MC at early adolescence were MC tests, human physical growth characteristics, physical fitness, FMS and SES. The total variance explained by the models was between 17% and 79%. Physical activity and biological maturation in childhood did not contribute to MC prediction in early adolescence. It was concluded that MC tracks at low-to-moderate levels during childhood and early adolescence, and childhood predictors of MC at early adolescence were MC, human physical growth characteristics, physical fitness, FMS and SES. This studied was built on previous research by including FMS and biological maturation as predictors of MC, in addition to human physical growth, physical fitness, physical activity and SES. Other strengths lied in the stratified sampling procedure, a large sample size, and the high quality control of the data.

The third study (chapter 5) investigated the relationship between motor performance and body fatness in 3- to 5-year-old children. Two hundred seventy-two healthy children, aged 3-yr-old, were followed over 2 years: 2012 to 2013 and 2013 to 2014. A two-level regression models with repeated measurements (level one) nested within individuals (level two) was used to estimate the longitudinal effect of age and body fatness on motor performance, controlling for physical activity, SES and geographical area at baseline. Age was associated to a better performance in catching, scramble, speed run, standing long jump, balance, and tennis ball throw for distance. Boys outperformed girls in scramble, speed run, and standing long jump.

The body mass index was positively associated with scramble and speed run, and negatively related to the standing long jump. Physical activity in leisure-time was negatively associated with scramble. No statistical significance was found for the association between SES and motor tests. Semi-urban children were fitter in catching than urban peers. We concluded that: (1) body fatness was associated to a poor performance in scramble, speed run and standing long jump, and (2) physical activity, SES and geographical area had a negligible influence on motor tests in this sample of preschool children. This current study is the first longitudinal study of motor performance in Portuguese preschool children. Other strengths included a relatively large sample size, the low dropout rate (12.8%), and a multidimensional approach to motor performance of children, aged 3- to 5 years.

The last study (chapter 6) evaluated the relationships between skeletal maturation and FMS and gross MC in 429 children, aged 7-10 years. Hierarchical multiple regression analyses were used to estimate the contribution of skeletal age alone or interacting with stature and/or mass to the unique variance in FMS and MC over and above that explained by covariates. Skeletal age was regressed on chronological age within each sex and age group; the standardized residuals were retained for analysis. Stature and mass were entered as covariates in the first block. First- and second-order interactions between standardized residuals of skeletal age and body size were entered as variables of interest in the second block, while standardized residuals of skeletal age alone was entered in the third block. The results showed that standardized residual of skeletal age on chronological age interacting with stature and/or body mass explained a maximum of 7.0% of the variance in FMS and MC over that attributed to body size per se. Standardized residual of skeletal age on chronological age alone accounted for a maximum of 9.0% of variance in FMS and MC over that attributed to body size per se and interactions between standardized residual of skeletal age on chronological age and body size. It was concluded that skeletal age alone or interacting with body size has a negligible influence on FMS and MC in children 7-10 years. To our knowledge, the potential influence of individual differences in skeletal maturation on the development of FMS and MC has not been addressed so that results are novel.

7.2 Future prospects

Data from this thesis are very useful to Physical Education teachers and Health and Sport Professionals for several reasons. First, MC curves can be used as reference data for Portuguese children. According to Branta et al. (1984), research that describes change serves as standard against which individuals of certain ages, grades, programs and populations can be compared, and the knowledge about a general pattern of change can stimulate attempts at explanation, intervention, and prediction. Since MC, together with FMS, are determinants of the children's general development (Haga, 2008; Henderson and Sugden, 1992) and are associated with health-related parameters (Stodden et al., 2008) it is crucial to promote MC during childhood and adolescence. In fact, our study highlights the importance of normal-weight status in MC. Second, the extent to which MC is stable over time is of interest because of its significance in the prediction of human performance, identification of clumsy and motor-impaired children, and application of preventive measures (Ahnert et al., 2009). Third, given that FMS and physical fitness in childhood are predictors of MC in early adolescence it is crucial to enhance them to promote coordination. Fourth, since environmental variables were not statistically associated with motor performance in early childhood, instruction and practice should be main focus of interventions in children. Finally, the limited role for skeletal maturation per se or interacting with body size in the development of FMS and MC among children implies an important role for other factors affecting movement proficiency. These likely involve neuromuscular maturation per se, differential growth in body composition and proportions, environmental conditions related to home, school and neighbourhood, habits of outdoor play and physical activity, and/or specific instruction and practice as in physical education and sport. By inference, individual differences in neuromuscular maturation interacting with environmental conditions, habits of play and physical activity, and/or specific instruction and practice may be primary factors influencing FMS and MC among children (Malina, 2012).

Overall, others studies should be developed to generalize the present findings. Given that we identified some shortcomings in the current research, future studies should use direct measures of physical activity, to strengthen the longitudinal component in order to capture real developmental changes across time, to cover the entire growth period, to increase the sample size for ensuring a more robust analysis, and to use video assessments taken with several cameras and in different positions, together with direct observation, for minimizing the error through the visualization of the motor skills. A heterogeneity of factors, including distance from home to school, availability of physical activity facilities, perception of the area of residence, attitudes towards physical activity and aerobic fitness, social inequalities, and cultural differences may influence previous relationships and have to be considered in future analyses (Machado-Rodrigues et al., 2011 and Malina et al., 2004).

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Chapter 8

Appendices

Appendix A

CRES (1st phase): Fundamental Motor Skills (TGMD-2)

Crescer com Saúde na RAM

Nome ____________________ IDNR ☐☐☐☐☐

Morada ____________________ Idade ______

Concelho ____________ Telefone ____________ Data Nascimento IND - INM - INY

Escola Infantário Os Louros Sexo Fem ☐ 0 Mas ☐ 1 Data Avaliação IND - INM - INY

CEE 3 1 0 3 0 0 4 Turma ____ Ano Esc. ☐ P3 ☐ P5 ☐ 2 ☐ 4 ☐ 6 ☐ 8 ☐ P4 ☐ 1 ☐ 3 ☐ 5 ☐ 7 ☐ 9

Skills e Padrões Motores Fundamentais - 3 aos 10 anos T G M D 2

Pé Dominante ☐ Dir ☐ Esq

Mão Dominante ☐ Dir ☐ Esq

AVALIAÇÃO LOCOMOTORA

Corrida (RUN)

	Tent. 1	Tent. 2	Corrida Total
1. Braços movem-se em sentido contrário às pernas, com os cotovelos flectidos.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
2. Breve período aéreo em que ambos os pés não estão em contacto com o solo.	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Reduzir a superfície de apoio (apoiar 1º o calcanhar e despois a zona dos dedos).	☐ 0 ☐ 1	☐ 0 ☐ 1	
4. Perna livre (contrária à perna de apoio) realiza ângulo de apox. 90º.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Galope (GAAL)

	Tent. 1	Tent. 2	Galope Total
1. Braços flectidos e elevados ao nível da cintura no inicio do movimento.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
2. Realiza um passo à frente com o pé mais avançado, arrasta o outro pé para uma posição adjacente ou ligeiramente atrás do pé mais avançado.	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Breve período em que ambos os pés não estão em contacto com o solo (fase aérea).	☐ 0 ☐ 1	☐ 0 ☐ 1	
4. Mantém um padrão rítmico para quatro galopes sucessivos.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Salto a Pé Coxinho (HOP)

	Tent. 1	Tent. 2	Pé Coxinho Total
1. A perna que não serve de apoio serve de pêndulo para produzir força.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
2. A perna que não serve de apoio está flectida e atrás do corpo.	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Os braços estão flectidos e balançam para a frente para produzir força.	☐ 0 ☐ 1	☐ 0 ☐ 1	
4. É capaz de realizar três saltos a pé coxinho sobre o pé não predilecto.	☐ 0 ☐ 1	☐ 0 ☐ 1	
5. É capaz de realizar três saltos a pé coxinho sobre o pé predilecto.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Pulo/Salto (LEAP)

	Tent. 1	Tent. 2	PuloSalto Total
1. Salta com um pé (impulsão) e faz a recepção com o outro.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
2. Momento aéreo em que ambos os pés estão fora do chão e bastante afastados entre si, mais do que na fase aérea da corrida.	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Braço contrário a perna de ataque alcança ou aproxima-se do pé da perna de ataque.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Salto na Horizontal Parado (SLJ)

	Tent. 1	Tent. 2	Salto Horiz Parado Total
1. Os movimentos preparatórios incluem a flexão de ambos os joelhos com os braços esticados atrás do corpo.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
2. Projecção dos braços esticados à frente e para cima, alcançando a extensão total acima da cabeça.	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Salta e faz a recepção no solo com os dois pés em simultâneo.	☐ 0 ☐ 1	☐ 0 ☐ 1	
4. Os braços estão dirigidos para o solo.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Deslocamento Lateral (SLID)

	Tent. 1	Tent. 2	Desloc Lateral Total
1. Corpo na lateral e ombros alinhados com o solo (linha).	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
2. Realiza um passo para o lado seguido de um deslocamento (arrastamento) do outro pé para um ponto próximo do pé de apoio.	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Realiza um mínimo de quatro ciclos contínuos (deslocamentos) para o lado direito.	☐ 0 ☐ 1	☐ 0 ☐ 1	
4. Realiza um mínimo de quatro ciclos contínuos (deslocamentos) para o lado esquerdo.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Total Avaliação Locomotora ☐

AVALIAÇÃO DE CONTROLO DE OBJECTOS

Batimento numba Bola Estática (STRB)

	Tent. 1	Tent. 2	Bat Bola Estática Total
1. Segura o taco com ambas as mãos e coloca a mão dominante à frente da outra mão.	☐ 0 ☐ 1	☐ 0 ☐ 1	
2. O lado não dominante do corpo está mais próximo da bola com os pés paralelos (posição lateral com os pés ligeiramente afastados).	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Rotação do ombro e da anca durante a fase de batimento (balanço).	☐ 0 ☐ 1	☐ 0 ☐ 1	
4. Transfere o peso do corpo para a perna da frente.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
5. O taco bate na bola e não no suporte.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Drible (SDRI)

	Tent. 1	Tent. 2	Drible Total
1. Contacta a bola com a mão a altura da cintura.	☐ 0 ☐ 1	☐ 0 ☐ 1	
2. Empurra a bola com os dedos (não efectua o batimento).	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. A bola deverá contactar com o solo à frente ou ao lado do pé da mão que contacta com a bola.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
4. Dribla a bola quatro vezes consecutivas sem mexer os pés.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Agarrar (CATC)

	Tent. 1	Tent. 2	Agarrar Total
1. Na fase preparatória as mãos estão colocadas à frente do corpo e os braços flectidos pelo cotovelo.	☐ 0 ☐ 1	☐ 0 ☐ 1	
2. Os braços estão em extensão e preparados para o contacto com a bola.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
3. A bola deverá ser apanhada e controlada somente pelas mãos.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Pontapear (KICK)

	Tent. 1	Tent. 2	Pontapear Total
1. Aproximação rápida e continua à bola.	☐ 0 ☐ 1	☐ 0 ☐ 1	
2. Passo mais largo ou pequeno salto antes do contacto com a bola.	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. O pé de apoio está colocado à frente e ligeiramente atrás da bola.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
4. Pontapear a bola com o pé preferido (contacta bola com a ponta do pé ou com o peito do pé).	☐ 0 ☐ 1	☐ 0 ☐ 1	

Lançamento de Ombro (OVTH)

	Tent. 1	Tent. 2	Lanç Ombro Total
1. Indicar o lançamento com o movimento descente da mão/braço oposto.	☐ 0 ☐ 1	☐ 0 ☐ 1	
2. Rodar a anca e os ombros e forma a ficarem paralelos à parede de lançamento.	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Transferir o peso do corpo para o pé de apoio contrário à mão do lançamento.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
4. Lançar a bola diagonalmente ao longo do corpo em direcção do braço que irá lançar (o braço de lançamento dirige-se em direcção ao não dominante).	☐ 0 ☐ 1	☐ 0 ☐ 1	

Lançamento da Bola por Baixo (UNDR)

	Tent. 1	Tent. 2	Lanç Bola por Baixo Total
1. Mão preferida vai atrás e para baixo colocando-se junto às costas, enquanto o tronco está paralelo ao solo.	☐ 0 ☐ 1	☐ 0 ☐ 1	
2. Passos grandes à frente com o pé oposto à mão de lançamento à frente (mais próximo dos cones).	☐ 0 ☐ 1	☐ 0 ☐ 1	
3. Pernas flectidas pelos joelhos.	☐ 0 ☐ 1	☐ 0 ☐ 1	☐
4. Larga a bola junto ao solo, evitando que saltite mais do que 1,22cm do solo.	☐ 0 ☐ 1	☐ 0 ☐ 1	

Total Avaliação Controlo Objectos ☐

Appendix B

CRES (1st phase): Human Physical Growth and Physical Fitness

UNIVERSIDADE da MADEIRA

Nome ______ ID sujeito ______

Morada ______ Idade ______

Concelho ______ Telefone ______ Data Nascimento ______ (Dia - Mês - Ano)

Escola ______ Turma ______ Data Avaliação ______

C E E ______ Sexo: Fem ☐ 0 Mas ☐ 1 Ano Esc. ☐ P3 ☐ P5 ☐ 2 ☐ 4 ☐ 6 ☐ 8 ☐ P4 ☐ 1 ☐ 3 ☐ 5 ☐ 7 ☐ 9

ANTROPOMETRIA

Massa Corporal Tamanho Esquelético Diâmetros

Peso				Kg
Altura				5 mm
Altura Sentado				5 mm
Diâmetro Biacromial				5 mm
Diâmetro Bicristal				3 mm
Diâmetro Umeral				1 mm
Diâmetro Femural				1 mm

Perímetros

Perímetro Geminal				2 mm
Perímetro Crural				4 mm
Perímetro Braquial Relaxado				2 mm
Perímetro Antebraço				2 mm
Perímetro Braquial Tenso				5 mm
Perímetro Cintura				5 mm
Perímetro Cintura				5 mm
Perímetro Anca				5 mm

Gordura Subcutânea

Prega Tricipital				10%
Prega Bicipital				10%
Prega Subescapular				10%
Prega Suprailíaca				10%
Prega Geminal				10%
Prega Crural				10%
Prega Abdominal				10%

FITNESSGRAM

Corrida Vai Vem ______

Flexibilidade Dir ______ cm Trunk lift 1 ______ cm Push up ______

Flexibilidade Esq ______ cm Trunk lift 2 ______ cm Curl up ______

EUROFIT

Corrida andar 12min ______ m

Batimento em placas 1 ______ seg Shuttle run ______ seg Salto comp s cor prep ______ cm

Batimento em placas 2 ______ seg Susp na barra ______ seg Sit e reach ______ cm

Dinamometria ______ Kg Equilibrio flamingo ______ Sit ups 30s ______

Appendix C

CRES (1st phase): Gross Motor Coordination (KTK)

Crescer com Saúde na RAM

Nome ________ Idade ____ IDNR

Morada ________ Data Nascimento IND - INM - INY

Concelho ________ Telefone ________

Escola ________ Sexo Fem ☐ 0 Mas ☐ 1 Data Avaliação IND - INM - INY

C E E ________ Turma ____ Ano Esc. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Coordenação Corporal - 6 aos 14 anos

Bateria KTK

Equilíbrio em Marcha à Retaguarda (ER)

	1ª tentativa	2ª tentativa	3ª tentativa
Trave de 6 cm			
Trave de 4,5 cm			
Trave de 3 cm			

Saltos laterais (SL)

1ª tentativa	2ª tentativa

Transposição lateral (TL)

1ª tentativa	2ª tentativa

Saltos Monopedais (SM)

Direito					Esquerdo			
5 cm	☐ 0	☐ 1	☐ 2	☐ 3	5 cm	☐ 0 ☐ 1	☐ 2	☐ 3
10 cm		☐ 1	☐ 2	☐ 3	10 cm	☐ 1	☐ 2	☐ 3
15 cm		☐ 1	☐ 2	☐ 3	15 cm	☐ 1	☐ 2	☐ 3
20 cm		☐ 1	☐ 2	☐ 3	20 cm	☐ 1	☐ 2	☐ 3
25 cm		☐ 1	☐ 2	☐ 3	25 cm	☐ 1	☐ 2	☐ 3
30 cm		☐ 1	☐ 2	☐ 3	30 cm	☐ 1	☐ 2	☐ 3
35 cm		☐ 1	☐ 2	☐ 3	35 cm	☐ 1	☐ 2	☐ 3
40 cm		☐ 1	☐ 2	☐ 3	40 cm	☐ 1	☐ 2	☐ 3
45 cm		☐ 1	☐ 2	☐ 3	45 cm	☐ 1	☐ 2	☐ 3
50 cm		☐ 1	☐ 2	☐ 3	50 cm	☐ 1	☐ 2	☐ 3
55 cm		☐ 1	☐ 2	☐ 3	55 cm	☐ 1	☐ 2	☐ 3
60 cm		☐ 1	☐ 2	☐ 3	60 cm	☐ 1	☐ 2	☐ 3

0 - Não realização
1 - Realização à 1ª tentativa
2 - Realização à 2ª tentativa
3 - Realização à 3ª tentativa

Appendix D

CRES (1st phase): Physical Activity Questionnaire (Baecke et al., 1982)

Crescer com Saúde na RAM

Nome ______________________ IDNR

Morada ______________________ Idade ______

Concelho ____________ Telefone ____________ Data Nascimento IND - INM - INY

Escola ____________ Sexo Fem ☐ 0 Mas ☐ 1 Data Avaliação IND - INM - INY

CEE 3 1 0 3 0 0 4 Turma ____ Ano Esc. ☐ P3 ☐ P4 ☐ P5 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Questionário de Actividade Física (Baecke et al., 1982)

NOTA: As perguntas de 1 a 8, que constituem o questionário de Baecke, repercutem-se à ocupação profissinal dos inquiridos. Assim sendo, uma vez estarmos a avaliar a actividade física em crianças até aos 14 anos de idade, não possuindo uma profissão, retiraram-se do presente questionário.

I 9. Pratica algum desporto? Sim ☐ 1 Não ☐ 0

Se respondeu sim:

9.1. • Qual o desporto que pratica com mais frequência? ______________________

9.2. • Quantas horas por semana? ☐ < 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ > 4

9.3. • Quantos meses por ano? ☐ < 1 ☐ 1-3 ☐ 4-6 ☐ 7-9 ☐ > 9

9.4. Se pratica um segundo desporto:

• Qual é o desporto? ______________________

9.5. • Quantas horas por semana? ☐ < 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ > 4

9.6. • Quantos meses no ano? ☐ < 1 ☐ 1-3 ☐ 4-6 ☐ 7-9 ☐ > 9

I 10. Em comparação com os outros colegas da minha idade penso que a minha actividade física durante o tempo de lazer é?

☐ Muito maior ☐ Maior ☐ A mesma ☐ Menor ☐ Muito menor

I 11. Durante o tempo de lazer transpiro

☐ Muito frequentemente ☐ Frequentemente ☐ Algumas vezes ☐ Raramente ☐ Nunca

I 12. Durante o tempo de lazer pratico desporto

☐ Nunca ☐ Raramente ☐ Algumas vezes ☐ Frequentemente ☐ Muito

I 13. Durante o tempo de lazer vejo televisão

☐ Nunca ☐ Raramente ☐ Algumas vezes ☐ Frequentemente ☐ Muito

I 14. Durante o tempo de lazer ando a pé

☐ Nunca ☐ Raramente ☐ Algumas vezes ☐ Frequentemente ☐ Muito

I 15. Durante o tempo de lazer ando de bicicleta

☐ Nunca ☐ Raramente ☐ Algumas vezes ☐ Frequentemente ☐ Muito

I 16. Quantos minutos anda a pé por dia e/ou de bicicleta para se dirigir à escola, local de treino e às compras?

☐ < 5 ☐ 5-15 ☐ 15-30 ☐ 30-45 ☐ > 45

Appendix E

CRES (1st phase): Socioeconomic Status Questionnaire

Crescer com Saúde na RAM

Nome ____________________ IDNR

Morada ____________________ Idade ______

Concelho ______________ Telefone ______________ Data Nascimento (IND - INM - INY)

Escola ____________________ Sexo Fem ☐ 0 Mas ☐ 1 Data Avaliação (IND - INM - INY)

CEE 3 1 0 3 0 0 4 Turma ____ Ano Esc. ☐ P3 ☐ P4 ☐ P5 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Questionário: ESTATUTO SÓCIO-ECONÓMICO

		CNP	Graffar
Profissão pai (FP)	____________________		☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Profissão mãe (MP)	____________________		☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Habilitações Académicas

Pai (FAQ)		Mãe (MAQ)
☐ 1	Ensino Universitário ou equivalente (curso superior)	☐ 1
☐ 2	Curso Técnico ou Profissional	☐ 2
☐ 3	3º Ciclo, Ensino Secundário	☐ 3
☐ 4	Ensino Primário ou Ciclo Preparatório (Ensino Básico)	☐ 4
☐ 5	Ensino primário incompleto ou nulo	☐ 5

(PMV) Fontes de rendimento familiares

- ☐ 1 Vive de rendimentos
- ☐ 2 Vencimento mensal fixo
- ☐ 3 Vencimento mensal de familiares, não tem rendimentos próprios
- ☐ 4 Remunarações por semana, à hora ou à tarefa
- ☐ 5 Benificiência pública ou privada

(HC) Conforto do alojamento

- ☐ 1 Casas ou andares luxuosos e muito grandes
- ☐ 2 Casas ou andares espaçosos e confortáveis
- ☐ 3 Casas ou andares modestos (ex. bairro camarário)
- ☐ 4 Casa bem conservada, mas sem casa de banho dentro de casa ou construção clandestina
- ☐ 5 Barracas

(NA) Aspecto do bairro onde habita

- ☐ 1 Bairro residêncial elegante, preços dos terrenos elevados
- ☐ 2 Bairro residêncial bom, ruas largas e casas confortáveis e bem conservadas
- ☐ 3 Ruas comerciais ou estreitas e antigas, com casas menos confortável, ou bairro de construção económica
- ☐ 4 Construção razoável mas sem água, luz ou saneamento
- ☐ 5 Zona degradada

Appendix F

CRES (1st phase): Authorization Letter Emitted by the Regional Secretary of Education

S. R.

REGIÃO AUTÓNOMA DA MADEIRA

GOVERNO REGIONAL

SECRETARIA REGIONAL DE EDUCAÇÃO

DIRECÇÃO REGIONAL DE EDUCAÇÃO

EXMO. SENHOR
DUARTE FREITAS
DEPARTAMENTO DE EDUCAÇÃO
FÍSICA E DESPORTO
CAMPUS UNIVERSITÁRIO DA PENTEADA
9000 FUNCHAL

Sua referência	Sua comunicação de	Nossa referência	Data
		/5 Proc. IND.	31 .. 2005

ASSUNTO: **Projecto "Crescer com Saúde na Região Autónoma da Madeira" – Um Estudo em Crianças e Jovens dos 3 aos 14 Anos de Idade"**

Em referência ao v/requerimento de 30/11/05, a solicitar autorização para contactar vários Estabelecimentos de Ensino, somos a informar V. Exa. que a Direcção Regional de Educação, autoriza que a equipa de campo do referido projecto se desloque às Escolas pretendidas devendo no entanto contactar as respectivas Direcções para o efeito.

Com os melhores cumprimentos,

O DIRECTOR REGIONAL

(Rui Anacleto Mendes Alves)

RA/MCP

Direcção Regional de Educação - Ed. D. João - Rua Cidade do Cabo, nº 38 - 9050-047 Funchal
✆ 291708420 Fax 291708437

Appendix G

CRES (1st phase): Letter of support from the Ethics Committee for Health

REGIÃO AUTÓNOMA DA MADEIRA
SERVIÇO REGIONAL DE SAÚDE, E.P.E.

Exm.º Senhor
Prof.º Duarte Luís de Freitas
Universidade da Madeira – Departamento de Educação Física e Desporto
Caminho da Penteada
9000 – 390 FUNCHAL

Serviço Regional de Saúde, E.P.E
SAÍDA
S.0601949 / 5 2006/02/15

Sua referência	Sua comunicação	N/Ofício	Data

Assunto: PEDIDO DE AUTORIZAÇÃO PARA APLICAÇÃO DO PROJECTO DE INVESTIGAÇÃO "CRESCER COM SAÚDE NA REGIÃO AUTÓNOMA DA MADEIRA".

Relativamente ao pedido formulado por V. Exª., subordinado ao assunto acima mencionado, informo que o mesmo foi autorizado nos termos do Parecer nº 11/06, da Comissão de Ética para a Saúde, que abaixo se transcreve:

"A CES/SRS,EPE, organizada e a funcionar de acordo com os requisitos das Normas da Boa Prática Clínica (ICHGCP Guidelines) e da legislação nacional em vigor (Dec. Lei nº 97/95, de 10 de Maio), composta por Dr. Edward Richard Maul, Médico e Presidente, Dr. Ricardo Jorge Santos, Médico, Dr. Carlos Miguel Pestana, Médico, Dr. José Manuel Freitas, Teólogo, Dr. Sílvio Sousa, Juiz, e Drª. Inês Ribeiro, Farmacêutica, na sua reunião de 01 de Fevereiro de 2006, decidiu por unanimidade dar parecer favorável ao pedido acima identificado por não levantar qualquer problema de ordem ética."

Com os melhores cumprimentos.

O Presidente do Conselho de Administração

Filomeno Paulo Gomes

CF

Rua João Gago, 2A – 9000-071 Funchal ☎291 213 284 291 213 281 email:cadmin@srs.pt

Appendix H

CRES (1st phase): Participant Consent Form

UNIVERSIDADE da MADEIRA

Crescer com Saúde na RAM

DEPARTAMENTO DE EDUCAÇÃO FÍSICA E DESPORTO

Campus Universitário da Penteada

9000-390 Funchal

PROJECTO DE INVESTIGAÇÃO

'CRESCER COM SAÚDE NA REGIÃO AUTÓNOMA DA MADEIRA'

O (A) seu (sua) filho (a) foi convidado (a) a participar no projecto de investigação 'Crescer com Saúde na Região Autónoma da Madeira' desenvolvido pela Universidade da Madeira e a Universidade do Porto, em parceria com o Instituto Politécnico de Bragança, Secretaria Regional de Educação e Secretaria Regional dos Assuntos Sociais.

O objectivo principal desta pesquisa consiste em recolher informação sobre a actividade física, aptidão física, coordenação motora, crescimento físico humano, estatuto sócio-económico, factores de risco de doenças degenerativas comuns, habilidades motoras, maturação biológica, padrões alimentares e 'skills' motores fundamentais. São, pois, preocupações centrais o excesso de peso e obesidade, actividade física *versus* inactividade, factores de risco de doenças degenerativas comuns e desenvolvimento motor das crianças e jovens madeirenses dos 3 aos 14 anos de idade.

A pesquisa será conduzida pelos Professores Doutores Duarte Freitas (Universidade da Madeira) e José Maia (Universidade do Porto), e terá como investigadores a Professora Doutora Maria João Almeida (Universidade da Madeira), o Professor Doutor Vítor Lopes (Instituto Politécnico de Bragança), a Mestre Carmo Faria (Direcção Regional de Planeamento e Saúde Pública), o Mestre Celso Silva (Médico no Hospital Central do Funchal) e o Dr. António Rodrigues (Médico Radiologista no Núcleo de Imagem Diagnostica).

A participação neste estudo envolve uma manhã e uma tarde do (a) seu (sua) filho (a) na realização das seguintes tarefas: testes motores, medição de características somáticas, avaliação da maturação esquelética (raio-x à mão e ao punho), medição da tensão arterial e recolha de sangue por punção venosa pediátrica [análise do colesterol (total, HDL e LDL), triglicérideos e glicemia]. A isto, acresce o uso de um sensor de movimento e de um instrumento para registo da frequência cardíaca (equipamento com cerca de 100 gramas) ao longo de uma semana. Será, também, promovida na escola uma reunião com o pai e/ou mãe para preenchimento dos questionários de actividade física, padrões alimentares e condições sociais.

Não há riscos associados à participação do (a) seu (sua) filho (a) nesta investigação. Os benefícios incluem a análise de parâmetros motores e clínicos. Em simultâneo, os dados ajudar-nos-ão a (1) precisar o excesso de peso e obesidade; (2) caracterizar as crianças obesas em termos de crescimento somático, maturação biológica, 'skills' motores, habilidades motoras, coordenação motora e performance desportivo-motora; (3) conhecer a variação e co-variação nos ‘skills’ motores, habilidades motoras, coordenação motora, e força e performance motora, associada ao tamanho corporal, físico, composição corporal, maturação biológica e actividade física; (4) identificar o perfil de risco de doenças degenerativas comuns; (5) definir o padrão de actividade física e (6) aferir a percentagem de crianças aptas e não aptas nos testes de aptidão física.

A confidencialidade dos registos do (a) seu (sua) filho (a) será mantida através do uso de um número de identificação. A equipa de investigação compromete-se, no entanto, a informar os pais acerca de qualquer característica ou comportamento que se afaste da normalidade. A participação é voluntária e o (a) seu (sua) filho (a) poderá recusar a avaliação numa ou noutra variável de estudo. É, também, possível abandonar a investigação a qualquer momento. A presente pesquisa não irá afectar o rendimento escolar do (a) seu (sua) filho (a).

Os critérios de exclusão incluem a presença de alguma restrição ou limitação médica na prática de actividades desportivas, uma história familiar ou antecedentes clínicos graves ou qualquer condição anormal que limite a função. Se há qualquer aspecto acerca do estudo ou participação do (a) seu (sua) filho (a) que não seja claro ou que não entenda; se tem questões ou se quer falar de problemas relacionados com a investigação, contacte o investigador responsável (Duarte Freitas, tel: 291 705332, dfreitas@uma.pt, Departamento de Educação Física e Desporto, Campus Universitário da Penteada, 9000 Funchal) ou um dos elementos da equipa de campo [Dr.ª Ana Costa Neves (TM 96 5270062), Dr.ª Ana Rodrigues (TM 96 9402391), Dr. Carlos Esteves (TM 93 6267703) e Dr. Gil Afonso (TM 91 7619898)].

PERMISSÃO DE PARTICIPAÇÃO

Li, compreendo e aceito, os termos e as condições acima referidos, autorizando a participação do (a) meu (minha) filho (a) no projecto de investigação ‘Crescer com Saúde na Região Autónoma da Madeira[1].

Nome do (a) seu (sua) filho (a)																																				

(Assinatura do pai)

(Assinatura da mãe)

Data			

[1]Para efeito de arquivo irá receber uma cópia deste consentimento.

UNIVERSIDADE da MADEIRA

Crescer com Saúde na RAM

DEPARTAMENTO DE EDUCAÇÃO FÍSICA E DESPORTO
Campus Universitário da Penteada
9000-390 Funchal

DADOS BIOGRÁFICOS, ENDEREÇO E CONTACTOS [Filho(a)]

Data de Nascimento .... Sexo Masculino ☐ Feminino ☐

Dia Mês Ano

Morada ....

Código postal .... - ....

Concelho ....

Telefone fixo (casa) .... Telemóvel ....

Correio electrónico ....

Escola ....

Ano .... Turma ....

O investigador responsável

____

(Professor Doutor Duarte Luís de Freitas)

Appendix I

CRES (2nd phase): Human Physical Growth and Gross Motor Coordination (KTK)

UNIVERSIDADE da MADEIRA
2ª Fase
Crescer com Saúde na RAM

Nome: ____________________ IDNR

Morada: ____________________ Data Nascimento

IND INM INY

Concelho: ____________________ Data Avaliação

Escola: ____________________ Ano: ______ Sexo F M Cont. Telefónico

ANTROPOMETRIA

Peso	(WT)	Kg
Altura	(HT)	5 mm
Perímetro da Cintura	(WACI)	5 mm

PRESSÃO ARTERIAL

Pressão Arterial Sistólica	(SBP)
Pressão Arterial Diastólica	(DBP)
Pulsação	(P)

COORDENAÇÃO CORPORAL (KTK)

Equilíbrio em Marcha à Retaguarda (EMR)

	1ª T	2ª T	3ª T
Trave de 6 cm			
Trave de 4,5 cm			
Trave de 3 cm			

	1ª Ten.	2ª Ten.
Saltos Laterais (SL)		
Transposição Lateral (TL)		

Saltos Monopedais (SM)

Direito

5 cm	0	1	2	3
10 cm	0	1	2	3
15 cm	0	1	2	3
20 cm	0	1	2	3
25 cm	0	1	2	3
30 cm	0	1	2	3
35 cm	0	1	2	3
40 cm		1	2	3
45 cm		1	2	3
50 cm		1	2	3
55 cm		1	2	3
60 cm		1	2	3
65 cm		1	2	3

Esquerdo

5 cm	0	1	2	3
10 cm	0	1	2	3
15 cm	0	1	2	3
20 cm	0	1	2	3
25 cm	0	1	2	3
30 cm	0	1	2	3
35 cm	0	1	2	3
40 cm		1	2	3
45 cm		1	2	3
50 cm		1	2	3
55 cm		1	2	3
60 cm		1	2	3
65 cm		1	2	3

Legenda:

0= Não realiza

1= Realiza à 1ª tentativa

2= Realiza à 2ª tentativa

3= Realiza à 3ª tentativa

Appendix J

CRES (2^{nd} phase): Physical Fitness and Socioeconomic Status Questionnaire

UNIVERSIDADE da MADEIRA
2ª Fase
Crescer com Saúde na RAM

Nome: ____________________ IDNR [| | | |]

EUROFIT

Sit ups (SUP) [| |] n/30seg. **Equilíbrio flam.** (FLB) [|] n/1min.

Sit and reach (SAR) [| |] **Salto comp. s/ cor. Prep.** (SLJ) [| |]

Corrida/andar 12 min. (END) [| | |] m [|] n-v + [| |] m 1 Volta = ________ m

Questionário do Estatuto Socioeconómico

		CNP	Graffar
Profissão do pai (FP)	______________________	[ ]	[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5
Profissão da mãe (MP)	______________________	[ ]	[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5

(FAQ) Pai	Habilitações Académicas	(MAQ) Mãe	(PMV)	Fontes de rendimento familiares
[ ] 1	Ensino Universitário ou equivalente (curso superior)	[ ] 1	[ ] 1	Vive de rendimentos
[ ] 2	Curso Técnico ou Profissional	[ ] 2	[ ] 2	Vencimento mensal fixo
[ ] 3	3º Ciclo, Ensino Secundário	[ ] 3	[ ] 3	Vencimento mensal de familiares, não tem rendimentos próprios
[ ] 4	Ensino Primário ou Ciclo Preparatório (Ensino Básico)	[ ] 4	[ ] 4	Remunarações por semana, à hora ou à tarefa
[ ] 5	Ensino primário incompleto ou nulo	[ ] 5	[ ] 5	Beneficiência pública ou privada

Conforto do alojamento

(HC)

- [ ] 1 Casas ou andares luxuosos e muito grandes
- [ ] 2 Casas ou andares espaçosos e confortáveis
- [ ] 3 Casas ou andares modestos (ex. bairro camarário)
- [ ] 4 Casa bem conservada, mas sem casa de banho dentro de casa ou construção clandestina
- [ ] 5 Barracas

Aspecto do bairro onde habita

(HC)

- [ ] 1 Bairro residêncial elegante, preços dos terrenos elevados
- [ ] 2 Bairro residêncial bom, ruas largas e casas confortáveis e bem conservadas
- [ ] 3 Ruas comerciais ou estreitas e antigas, com casas menos confortável, ou bairro de construção económica
- [ ] 4 Construção razoável mas sem água, luz ou saneamento
- [ ] 5 Zona degradada

Appendix K

CRES (2nd phase): Physical Activity Questionnaire (Baecke et al., 1982)

UNIVERSIDADE da MADEIRA
2ª Fase
Crescer com Saúde na RAM

Nome: ____________________ IDNR

Morada: ____________________ Data Nascimento (IND INM INY)

Concelho: ____________________ Data Avaliação

Escola: ____________________ Ano: ______ Sexo F M Cont. Telefónico

ACTIVIDADE FÍSICA

1 Qual a sua principal ocupação: ____________________ 1 3 5

2 No trabalho, costuma sentar-se?

Nunca	Raramente	Algumas vezes	Frequentemente	Muito frequentemente
1	2	3	4	5

3 No trabalho, mantém-se de pé?

Nunca	Raramente	Algumas vezes	Frequentemente	Muito frequentemente
1	2	3	4	5

4 Anda a pé no trabalho?

Nunca	Raramente	Algumas vezes	Frequentemente	Muito frequentemente
1	2	3	4	5

5 No trabalho, pega em cargas pesadas?

Nunca	Raramente	Algumas vezes	Frequentemente	Muito frequentemente
1	2	3	4	5

6 Depois do trabalho sente-se cansado?

Muito frequentemente	Frequentemente	Algumas vezes	Raramente	Nunca
5	4	3	2	1

7 Durante o trabalho transpira?

Muito frequentemente	Frequentemente	Algumas vezes	Raramente	Nunca
5	4	3	2	1

8 Em comparação com os outros colegas da sua idade, pensa que o seu trabalho é fisicamente ...

Mais pesado	Pesado	Tão pesado	Leve	Mais leve
5	4	3	2	1

9 Pratica algum desporto? Sim Não

Se respondeu afirmativamente:

-Qual o desporto que pratica frequentemente: ____________________

-Quantas horas por semana?

< 1	1-2	2-3	3-4	> 4
0,5	1,5	2,5	3,5	4,5

-Quantos meses por ano?

< 1	1-3	4-6	7-9	> 9
0,04	0,17	0,42	0,67	0,92

Se pratica um segundo desporto:

-Qual é o desporto? ____________________

-Quantas horas por semana?

< 1	1-2	2-3	3-4	> 4
0,5	1,5	2,5	3,5	4,5

-Quantos meses por ano?

< 1	1-3	4-6	7-9	> 9
0,04	0,17	0,42	0,67	0,92

UNIVERSIDADE da MADEIRA
2ª Fase
Crescer com Saúde na RAM

Nome: ______________________________ IDNR

10 Em comparação com os outros colegas da sua idade pensa que a sua actividade física, durante os tempos livres, é

Muito maior	Maior	Igual	Menor	Muito menor
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

11 Durante os tempos livres transpira?

Muito frequentemente	Frequentemente	Algumas vezes	Raramente	Nunca
☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

12 Durante os tempos livres pratica desporto?

Nunca	Raramente	Algumas vezes	Frequentemente	Muito frequentemente
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

13 Durante os tempos livres vê televisão?

Nunca	Raramente	Algumas vezes	Frequentemente	Muito frequentemente
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

14 Durante os tempos livres anda a pé?

Nunca	Raramente	Algumas vezes	Frequentemente	Muito frequentemente
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

15 Durante os tempos livres anda de bicicleta?

Nunca	Raramente	Algumas vezes	Frequentemente	Muito frequentemente
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

16 Quantos minutos anda a pé por dia para se dirigir ao trabalho, local de treino ou às compras?

< 5	5-15	15-30	30-45	> 45
☐	☐	☐	☐	☐

Questionário adaptado de Baecke et al. (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. AM J Clin Nutr 36: 396-972

Appendix L

CRES (2nd phase): Authorization Letter Emitted by the Regional Secretary of Education and Culture

S. R.

REGIÃO AUTÓNOMA DA MADEIRA

GOVERNO REGIONAL

SECRETARIA REGIONAL DE EDUCAÇÃO E CULTURA

DIREÇÃO REGIONAL DE EDUCAÇÃO

EXMO. SENHOR

C/C EB23 e Sec.

DR. ANTÓNIO MANUEL MARQUES ANTUNES

005071 /5

Sua referência	Sua comunicação de	Nossa referência	Data
	07/10/11	Proc. 5.72/11	12.OUT 2011

ASSUNTO: **Autorização – Estudo "Crescer com Saúde na Região Autónoma da Madeira, 2ª Fase"**

Em referência à v/carta, informo que autorizo o Estudo sobre o tema em epígrafe, nas Escolas Básicas com os 2º e 3º ciclos e Secundário, conforme mapa em anexo, com a condição do pedido ser operacionalizado junto das Direções das referidas Escolas.

Com os melhores cumprimentos,

O DIRETOR REGIONAL

(Rui Anacleto Mendes Alves)

MCP

Direção Regional de Educação - Ed. D. João - Rua Cidade do Cabo, nº 38 - 9050-047 Funchal
✆ 291708420 - Fax 291708437

Appendix M

CRES (2^{nd} phase): Participant Consent Form

UNIVERSIDADE da MADEIRA
DEPARTAMENTO DE EDUCAÇÃO FÍSICA E DESPORTO
Campus Universitário da Penteada
9000-390 Funchal

2ª Fase
Crescer com Saúde na RAM

PROJECTO DE INVESTIGAÇÃO

'CRESCER COM SAÚDE NA REGIÃO AUTÓNOMA DA MADEIRA - 2ª Fase'

O seu educando foi convidado (a) a participar na segunda fase do projecto de investigação 'Crescer com Saúde na Região Autónoma da Madeira' desenvolvido pela Universidade da Madeira e a Universidade do Porto, Secretaria Regional de Educação e Secretaria Regional dos Assuntos Sociais.

O objectivo principal desta pesquisa consiste em recolher informação sobre a actividade física, aptidão física, coordenação motora, crescimento físico humano, estatuto socioeconómico, factores de risco de doenças degenerativas comuns e maturação biológica. São, pois, preocupações centrais o excesso de peso e obesidade, actividade física *versus* inactividade, factores de risco de doenças degenerativas comuns e desenvolvimento motor das crianças e jovens madeirenses.

A pesquisa será conduzida pelos Professores Doutores Duarte Freitas (Universidade da Madeira) e José Maia (Universidade do Porto), e terá como investigador o Mestre António Antunes (Universidade da Madeira).

A participação neste estudo envolve uma manhã e uma tarde do (a) seu (sua) filho (a) na realização das seguintes tarefas: testes motores, medição de características somáticas, avaliação da maturação esquelética (raio-x à mão e ao punho), medição da tensão arterial e recolha de sangue por punção venosa pediátrica [análise do colesterol (total, HDL e LDL), triglicérideos e glicemia]. Será, também, promovida no final do dia uma sessão para o preenchimento dos questionários de actividade física e condições sociais.

Não há riscos associados à participação do educando nesta investigação. Os benefícios incluem a análise longitudinal de parâmetros motores e clínicos. Em simultâneo, os dados ajudar-nos-ão a (1) precisar o excesso de peso e obesidade; (2) caracterizar as crianças obesas em termos de crescimento somático, maturação biológica, coordenação motora e desempenho motor; (3) conhecer a variação e co-variação no desempenho motor e coordenação motora, associada ao tamanho corporal, maturação biológica e actividade física; (4) identificar o perfil de risco de doenças degenerativas comuns; (5) definir o padrão de actividade física e (6) aferir a percentagem de crianças aptas e não aptas nos testes de aptidão física, e; (6) perceber o comportamento de todas as variáveis envolvidas ao longo dos últimos seis anos.

A confidencialidade dos registos do (a) seu (sua) filho (a) será mantida através do uso de um número de identificação. A equipa de investigação compromete-se, no entanto, a informar os pais acerca de qualquer característica ou comportamento que se afaste da normalidade. A participação é voluntária e o (a) seu (sua) filho (a) poderá recusar a avaliação numa ou noutra variável de estudo. É, também, possível abandonar a investigação a qualquer momento. A presente pesquisa não irá afectar o rendimento escolar do (a) seu (sua) filho (a).

Os critérios de exclusão incluem a presença de alguma restrição ou limitação médica na prática de actividades desportivas, uma história familiar ou antecedentes clínicos graves ou qualquer condição anormal que limite a função. Se há qualquer aspecto acerca do estudo ou participação do seu educando que não seja claro ou que não entenda; se tem questões ou se quer falar de problemas relacionados com a investigação, contacte o orientador responsável (Duarte Freitas, tel: 291 705332, dfreitas@uma.pt, Depart. de Educação Física e Desporto, Campus Universitário da Penteada, 9000 Funchal) ou o investigador de campo [António Antunes (TM 92 5959168)].

PERMISSÃO DE PARTICIPAÇÃO

Li, compreendo e aceito, os termos e as condições acima referidos, autorizando a participação do meu educando na segunda fase do projecto de investigação 'Crescer com Saúde na Região Autónoma da Madeira'.

Nome do (a) seu (sua) filho (a)

____

(Assinatura do encarregado de educação)

Data: ____ | ____ | ____

RASTREIO DE DOENÇAS

1. O participante possui alguma restrição ou limitação médica na prática de actividades desportivas?
Sim [ ] Não [ ] Se sim, quais? ______________________________

2. O participante sofre dos seguintes problemas:

Sim [ ] Não [ ] cardíacos;
Sim [ ] Não [ ] dificuldades respiratórias (ex: asma);
Sim [ ] Não [ ] musculares, ósseos ou articulares;
Sim [ ] Não [ ] pressão arterial;
Sim [ ] Não [ ] diabetes;
Sim [ ] Não [ ] tiróide;
Sim [ ] Não [ ] epilepsia;
Sim [ ] Não [ ] desmaios ou tonturas regulares e/ou esporádicos;
Sim [ ] Não [ ] fibrose, anorexia/bulimia, rins ou fígado;
Sim [ ] Não [ ] outros. Quais? ______________________________

3. O participante realiza ou realizou recentemente, algum tratamento médico?
Sim [ ] Não [ ] Se sim, quais? ______________________________

4. O participante toma medicação regularmente?
Sim [ ] Não [ ] Se sim, qual? ______________________________

5. Os familiares em 1º grau do participante sofrem ou sofreram recentemente, de problemas cardíacos, respiratórios e/ou sanguíneos?
Sim [ ] Não [ ] Se sim, quais? ______________________________

(Assinatura do Encarregado de Educação)

O investigador

____

(António Manuel Antunes)

Appendix N

MCGS: Human Physical Growth and Motor Performance

UNIVERSIDADE da MADEIRA
2ª Fase
Crescer com Saúde na RAM

Nome: ______________________ IDNR

Morada: ______________________ Data Nascimento (IND / INM / INY)

Concelho: ______________________ Data Avaliação

Escola: ______________ Ano: ______ Sexo F / M   Cont. Telefónico

ANTROPOMETRIA

Peso	(WT)						Kg
Altura	(HT)						5 mm
Perímetro da Cintura	(WACI)						5 mm

PRESSÃO ARTERIAL

Pressão Arterial Sistólica	(SBP)						
Pressão Arterial Diastólica	(DBP)						
Pulsação	(P)						

APTIDÃO FÍSICA 3-6 Anos (PTB)

Data Avaliação (IND / INM / INY)

Catching (CATC)

1	0	1	2	3	6	0	1	2	3
2	0	1	2	3	7	0	1	2	3
3	0	1	2	3	8	0	1	2	3
4	0	1	2	3	9	0	1	2	3
5	0	1	2	3	10	0	1	2	3

Standing Long Jump (SLJ)

1
2
3
4
5

Scramble (SRAM)

1
2
3
4

Speed Run (SPEE)

Observação1	Observação2
1	1
2	2
3	3

Balance (BALA)

	Dir	Esq
1		
2		
3		
4		
5		
6		
7		

Tennis Ball Throw for Distance (TBTD)

	Dir	Esq		Dir	Esq
1			5		
2			6		
3			7		
4					

Appendix O

MCGS: Physical Activity Questionnaire (Godin and Shephard, 1985)
and Socioeconomic Status Questionnaire

Crescer com Saúde na RAM — 2ª Fase — UNIVERSIDADE da MADEIRA

Nome: ______________________ IDNR [ ][ ][ ][ ][ ]

Morada: ______________________ Data Nascimento [ ][ ][ ][ ][ ][ ] (IND, INM, INY)

Concelho: ______________________ Data Avaliação [ ][ ][ ][ ][ ][ ]

Escola: ______________________ Ano: ______ Sexo F [ ] M [ ] Cont. Telefónico [ ]

Questionário: ACTIVIDADE FÍSICA (Godin e Shephard, 1985)

1- Considera um período de 7 dias (uma semana), quantas vezes, em média, realizas diferentes exercícios por mais de 15 minutos durante o teu tempo livre (escreve em cada linha o número apropriado).

Número de vezes por semana

a) Exercício Extenuante (O coração bate rapidamente) [ ]

(Ex. corridas, hoquei, futebol, squash, basquetebol, judo, karaté, patins em linha, natação vigorosa, longos percursos vigorosos de bicicleta).

b) Exercício Moderado (Não exaustivo) [ ]

(Ex. caminhadas rápidas, basebol, ténis, percursos lentos de bicicleta, voleibol, badminton, natação não exaustiva, folclore e danças populares).

c) Exercício Suave (Esforço Mínimo) [ ]

(Ex. yoga, tiro com arco, pesca, bowling, golf, caminhadas lentas).

2- Considera um período de 7 dias (uma semana), durante o teu tempo de lazer quantas vezes realizas uma actividade regular suficientemente longa para suares (o coração bate rapidamente)?

[ ]1 Nunca / raramente [ ]2 Às vezes [ ]3 Muitas vezes

Questionário: ESTATUTO SÓCIO-ECONÓMICO

			CNP	**Graffar**
Profissão do pai	(FP)	______________________	[ ]	[ ]1 [ ]2 [ ]3 [ ]4 [ ]5
Profissão da mãe	(MP)	______________________	[ ]	[ ]1 [ ]2 [ ]3 [ ]4 [ ]5

(FAQ) Pai	**Habilitações Académicas**	**(MAQ) Mãe**	**(PMV)**	**Fontes de rendimento familiares**
[ ]1	Ensino Universitário ou equivalente (curso superior)	[ ]1	[ ]1	Vive de rendimentos
[ ]2	Curso Técnico ou Profissional	[ ]2	[ ]2	Vencimento mensal fixo
[ ]3	3º Ciclo, Ensino Secundário	[ ]3	[ ]3	Vencimento mensal de familiares, não tem rendimentos próprios
[ ]4	Ensino Primário ou Ciclo Preparatório (Ensino Básico)	[ ]4	[ ]4	Remunarações por semana, à hora ou à tarefa
[ ]5	Ensino primário incompleto ou nulo	[ ]5	[ ]5	Beneficiência pública ou privada

Conforto do alojamento

(HC)

[ ]1 Casas ou andares luxuosos e muito grandes

[ ]2 Casas ou andares espaçosos e confortáveis

[ ]3 Casas ou andares modestos (ex. bairro camarário)

[ ]4 Casa bem conservada, mas sem casa de banho dentro de casa ou construção clandestina

[ ]5 Barracas

Aspecto do bairro onde habita

(HC)

[ ]1 Bairro residêncial elegante, preços dos terrenos elevados

[ ]2 Bairro residêncial bom, ruas largas e casas confortáveis e bem conservadas

[ ]3 Ruas comerciais ou estreitas e antigas, com casas menos confortável, ou bairro de construção económica

[ ]4 Construção razoável mas sem água, luz ou saneamento

[ ]5 Zona degradada

Appendix P

MCGS: Letter Emitted by the Regional Secretary of Education
Validating the Training of the On-site Team

S. R.

REGIÃO AUTÓNOMA DA MADEIRA
GOVERNO REGIONAL
SECRETARIA REGIONAL DE EDUCAÇÃO E CULTURA
DIREÇÃO REGIONAL DE EDUCAÇÃO

Exmo(a). Senhor(a) Diretor de Serviços
Gabinete Coordenador do Desporto Escolar
Rua do Seminário, n.º 7, 3.º andar
9050-022 - Funchal

Ofício Nº 005397 /5

Sua referência	Sua comunicação	Nossa referência	DATA
		Proc. 5.6/11	31. OUT 2011

Assunto: ***Validação de Formação não Creditada***

Relativamente ao vosso requerimento, de 26/10/2011, atualizado a 31/10/2011, subordinado ao assunto em epígrafe, somos a informar que o (a) Curso de Formação **"Avaliação do desempenho motor em crianças do pré-escolar do ensino básico: uma ferramenta essencial para os profissionais de Educação Física"** foi validado(a) por esta Direção Regional, com 32 horas, para efeitos de progressão na carreira dos ***Professores dos grupos de recrutamento 110 e 160***, nos termos do Despacho n.º 106/2005, de 21 de setembro.

Solicitamos que, após a conclusão da atividade formativa, nos seja remetido o Anexo II, a que se refere a alínea b) do n.º 2 do Despacho n.º 106/2005, de 21 de setembro.

Com os melhores cumprimentos,

O SUBDIRETOR REGIONAL

Manuel Nunes André

Direção Regional de Educação - Ed. D. João - Rua Cidade do Cabo, nº 38 - 9050 - 047
☏ 291708420 Fax 291708437

Appendix Q

MCGS: Authorization Letter Emitted by the Regional Secretary of Education and Human Resources

S. R.
REGIÃO AUTÓNOMA DA MADEIRA
GOVERNO REGIONAL
SECRETARIA REGIONAL DA EDUCAÇÃO E RECURSOS HUMANOS
DIREÇÃO REGIONAL DE EDUCAÇÃO

Direção Regional de Educação
GGAD

SAÍDA	PROCESSO(s)	DATA
Of: 1.846	5.68.0.0	01-08-2014

Exmo. Senhor
Professor António Antunes
Rua V Centenário, Edifício Vale da Ribeira do Sol
Bloco B2, Apartamento AE
9360-500 Ponta do Sol

ASSUNTO: **2.ª via de autorização do projeto "Motor performance, fundamental motor skils and motor coordination. THE CHILD GROWS STUDY."**

Na sequência da vossa solicitação, de 04-07-2014, informa-se Vossa Excelência de que por despacho do Diretor Regional de Educação, de 01-08-2014, foi deferido o pedido para 2.ª via de autorização para a implementação e operacionalização do projeto nos termos abaixo indicados:

"No âmbito do doutoramento do professor António Manuel Marques Antunes, o estudo "Motor performance, fundamental motor skills and motor coordination. THE CHILD GROWTH STUDY" (TCGS), inicialmente definido por "Crescer com Saúde na Região Autónoma da Madeira (CRES), 2ª Fase" constituiu uma mais-valia na recolha de informação no âmbito das Ciências do Desporto em crianças da Região Autónoma da Madeira dos 3 aos 14 anos.

TCGS teve como objetivo central avaliar a mudança e estabilidade de vários fenótipos em crianças e adolescentes da Região Autónoma da Madeira, mais precisamente, atividade física, aptidão física, coordenação motora, crescimento físico humano, desempenho motor, estatuto socioeconómico e habilidades motoras.

Por um lado, o trabalho foi o prolongamento do projeto CRES desenvolvido em 2005/2006, isto é, as mesmas crianças foram reavaliadas passados 5/6 anos com o objetivo de estudar a estabilidade nas variáveis descritas anteriormente (2º e 3º Ciclos do Ensino Básico e Secundário). Por outro, foi definida uma outra amostra de crianças de 3 anos, que foi avaliada e acompanhada até aos 5 anos de idade, ou seja, num espaço temporal de 3 anos contínuos (Pré-escolar).

Devido à importância do mapear as características fisiológicas, motoras e coordenativas destas crianças, com especial objetivo de, no futuro, construirmos diretrizes pedagógicas de qualidade para o processo ensino-aprendizagem, consideramos que a sua implementação foi de máximo relevo na Região Autónoma da Madeira. Como tal, os estabelecimentos de ensino e respetivos

Na resposta indicar a «Nossa referência». Em cada ofício tratar só de um assunto.

docentes de Expressão e Educação Físico-Motora foram convidados a colaborarem ativamente no projeto em causa."

Com os melhores cumprimentos,

O Diretor de Serviços,

Bernardo Valério

(Bernardo Valério)

Appendix R

MCGS: Participant Consent Form

UNIVERSIDADE da MADEIRA
DEPARTAMENTO DE EDUCAÇÃO FÍSICA E DESPORTO
Campus Universitário da Penteada
9000-390 Funchal

2ª Fase
Crescer com Saúde na RAM

PROJECTO DE INVESTIGAÇÃO

'CRESCER COM SAÚDE NA REGIÃO AUTÓNOMA DA MADEIRA - 2ª Fase'

O seu educando foi convidado (a) a participar na segunda fase do projecto de investigação 'Crescer com Saúde na Região Autónoma da Madeira' desenvolvido pela Universidade da Madeira e a Universidade do Porto, Secretaria Regional de Educação e Secretaria Regional dos Assuntos Sociais.

O objectivo principal desta pesquisa consiste em recolher informação sobre a actividade física, desempenho motor, crescimento físico humano, estatuto socioeconómico e maturação biológica. São, pois, preocupações centrais o excesso de peso e obesidade, actividade física *versus* inactividade, factores de risco de doenças degenerativas comuns e desenvolvimento motor das crianças e jovens madeirenses.

A pesquisa será conduzida pelos Professores Doutores Duarte Freitas (Universidade da Madeira) e José Maia (Universidade do Porto), e terá como investigador o Mestre António Antunes (Universidade da Madeira).

A participação neste estudo envolve uma manhã e uma tarde do (a) seu (sua) filho (a) na realização das seguintes tarefas: testes motores, medição de características somáticas, avaliação da maturação esquelética (raio-x à mão e ao punho), medição da tensão arterial. Será, também, promovida no final do dia uma reunião com os encarregados de educação para o preenchimento dos questionários de actividade física e condições sociais.

Não há riscos associados à participação do educando nesta investigação. Os benefícios incluem a análise longitudinal de parâmetros motores e clínicos. Em simultâneo, os dados ajudar-nos-ão a (1) precisar o excesso de peso e obesidade; (2) caracterizar as crianças obesas em termos de crescimento somático, maturação biológica e desempenho motor; (3) conhecer a variação e co-variação no desempenho motor associado ao tamanho corporal, maturação biológica e actividade física; (4) identificar o perfil de risco de doenças degenerativas comuns; (5) definir o padrão de actividade física e (6) aferir a percentagem de crianças aptas e não aptas nos testes motores, e; (6) perceber o comportamento de todas as variáveis envolvidas ao longo dos três anos consecutivos.

A confidencialidade dos registos do (a) seu (sua) filho (a) será mantida através do uso de um número de identificação. A equipa de investigação compromete-se, no entanto, a informar os pais acerca de qualquer característica ou comportamento que se afaste da normalidade. A participação é voluntária e o (a) seu (sua) filho (a) poderá recusar a avaliação numa ou noutra variável de estudo. É, também, possível abandonar a investigação a qualquer momento. A presente pesquisa não irá afectar o rendimento escolar do (a) seu (sua) filho (a).

Os critérios de exclusão incluem a presença de alguma restrição ou limitação médica na prática de actividades desportivas, uma história familiar ou antecedentes clínicos graves ou qualquer condição anormal que limite a função. Se há qualquer aspecto acerca do estudo ou participação do seu educando que não seja claro ou que não entenda; se tem questões ou se quer falar de problemas relacionados com a investigação, contacte o orientador responsável (Duarte Freitas, tel: 291 705332, dfreitas@uma.pt, Departamento de Educação Física e Desporto, Campus Universitário da Penteada, 9000 Funchal) ou o investigador [António Antunes (TM 92 5959168)].

PERMISSÃO DE PARTICIPAÇÃO

Li, compreendo e aceito, os termos e as condições acima referidos, autorizando a participação do meu educando na segunda fase do projecto de investigação 'Crescer com Saúde na Região Autónoma da Madeira'.

Nome Completo do (a) seu (sua) filho (a)

____
(Assinatura do encarregado de educação)

Data: ____|____|____

RASTREIO DE DOENÇAS

1. O participante possui alguma restrição ou limitação médica na prática de actividades desportivas?
Sim ☐ Não ☐ Se sim, quais? ______________________

2. O participante sofre dos seguintes problemas:

Sim ☐ Não ☐ cardíacos;
Sim ☐ Não ☐ dificuldades respiratórias (ex: asma);
Sim ☐ Não ☐ musculares, ósseos ou articulares;
Sim ☐ Não ☐ pressão arterial;
Sim ☐ Não ☐ diabetes;
Sim ☐ Não ☐ tiróide;
Sim ☐ Não ☐ epilepsia;
Sim ☐ Não ☐ desmaios ou tonturas regulares e/ou esporádicos;
Sim ☐ Não ☐ fibrose, anorexia/bulimia, rins ou fígado;
Sim ☐ Não ☐ outros. Quais? ______________________

3. O participante realiza ou realizou recentemente, algum tratamento médico?
Sim ☐ Não ☐ Se sim, quais? ______________________

4. O participante toma medicação regularmente?
Sim ☐ Não ☐ Se sim, qual? ______________________

5. Os familiares em 1º grau do participante sofrem ou sofreram recentemente, de problemas cardíacos, respiratórios e/ou sanguíneos?
Sim ☐ Não ☐ Se sim, quais? ______________________

(Assinatura do Encarregado de Educação)

O investigador

____
(António Manuel Antunes)

A Nossa
Universidade

Colégio dos Jesuítas
Rua dos Ferreiros - 9000-082, Funchal

Tel: +351 291 209400
Fax: +351 291 209410
Email: gabinetedareitoria@uma.pt

A Nossa Universidade

Colégio dos Jesuítas
Rua dos Ferreiros - 9000-082, Funchal

Tel: +351 291 209400
Fax: +351 291 209410
Email: gabinetedareitoria@uma.pt