Universidade Federal de Pernambuco – UFPE
Centro Acadêmico de Vitória – CAV
**Programa de Pós-Graduação em Nutrição, Atividade Física e Plasticidade Fenotípica – PPGNAFPF**

DISSERTAÇÃO DE MESTRADO

# Relação entre antropometria, composição corporal, peso ao nascer, taxa metabólica de repouso e dispêndio energético diário de crianças dos 7 aos 10 anos de idade da cidade de Vitória de Santo Antão.

***Relationship between anthropometry, body composition, birth weight, resting metabolic rate and daily energy expenditure from children aged 7-10 years old in the city of Vitória de Santo Antão.***

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Vitória de Santo Antão
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Dissertação apresentada à Universidade Federal de Pernambuco, como parte das exigências do Programa de Pós-Graduação em Nutrição, Atividade Física e Plasticidade Fenotípica, área de concentração em Fatores Ambientais moduladores da Plasticidade Fenotípica, para a obtenção do título de Mestre.

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Dissertação de Mestrado apresentada por **ISABELE GÓES NOBRE** ao Programa de Pós-Graduação em Nutrição, Atividade Física e Plasticidade Fenotípica do Centro Acadêmico de Vitória da Universidade Federal de Pernambuco, sob o título "**Relação entre antropometria, composição corporal, peso ao nascer, taxa metabólica de repouso e dispêndio energético diário de crianças dos 7 aos 10 anos da cidade de Vitória de Santo Antão**", orientada pela Prof.ª Dr.ª Carol Virgínia Góis Leandro e coorientada pelo Prof. Dr. Marcos André Moura dos Santos, aprovada no dia 23 de fevereiro de 2016 pela Banca Examinadora composta pelos seguintes professores:

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RESUMO

Os objetivos do presente estudo foram: a) analisar estudos que consideram os efeitos do baixo peso ao nascer (BPN) em crianças e sua relação com a antropometria e composição corporal durante o crescimento; b) descrever variáveis antropométricas e de composição corporal e metabolismo energético de acordo com o peso ao nascer; c) verificar a associação entre peso ao nascer, taxa metabólica de repouso (RMR) e gasto energético diário (DEE) com variáveis antropométricas e de composição corporal; d) estabelecer um modelo preditivo para RMR e DEE considerando a influência da antropometria, composição corporal e peso ao nascer em crianças de 7 a 10 anos de idade. Foram avaliadas 464 crianças (241 meninos e 223 meninas) nascidos em Vitória de Santo Antão (Nordeste do Brasil). Variáveis utilizadas: Antropometria (peso, altura, altura do assento, cintura, quadril, braço, perna e perímetro cefálico), composição corporal (dobras cutâneas, área muscular do braço e percentual de gordura corporal [% BF]), RMR e DEE. A noção de que o BPN pode promover um rearranjo no metabolismo energético é plausível. Há uma associação positiva entre o BPN e a redução do peso corporal, estatura, massa livre de gordura e um aumento da massa de gordura. Crianças de 8-10 anos com BPN apresentaram valores médios elevados para a maioria das variáveis quando comparado com crianças de 7 anos de idade, enquanto que para as com BPN, as diferenças estavam entre todas as idades analisadas. O peso ao nascer foi positivamente correlacionado com a circunferência da cabeça (8-10 anos), RMR, DEE, altura e %BF (9-10 anos). Todas as variáveis antropométricos e de composição corporal foram fortemente correlacionadas com RMR e DEE. A partir do modelo de regressão, a altura, circunferência do quadril, % BF, dobras cutâneas tricipital e subescapular foram preditores significativos para RMR e DEE, independentemente da idade. Preditores relevantes da RMR e DEE foram dobra cutânea bicipital aos 8 anos, circunferência da perna aos 9-10 anos, e prega cutânea supra-ilíaca em ambas as idades. O principal determinante da RMR e DEE foi % BF. Crianças com BPN apresentaram um déficit no ganho de medidas antropométricas e de composição corporal em todas as idades. Para o metabolismo energético, a variação na estrutura do corpo das crianças pode ser relacionada com a reestruturação do componente de gordura, uma vez que as diferenças observadas entre as idades estão ligados aos seus indicadores.



PALAVRAS-CHAVE: tamanho corporal, dobras cutâneas, metabolismo energético, crianças, baixo peso ao nascer, crescimento e desenvolvimento.

ABSTRACT

The goals of the present study were: a) To analyze studies that consider the effects of low birth weight children and the relationship with anthropometry and body composition during growth; b) To describe anthropometric and body composition variables and energy metabolism according to birth weight; c) to verify the association between birth weight, resting metabolic rate (RMR) and daily energy expenditure (DEE) with anthropometry and body composition variables; d) To stablish a predictive model for RMR and daily energy expenditure (DEE) considering the influence of anthropometry, body composition and birth weight in children at 7 to 10 years old. It was evaluated 464 children (241 boys and 223 girls) born in Vitoria de Santo Antão (Northeast of Brazil). Anthropometry (weight, height, sitting height, waist, hip, arm, leg and head circumferences), body composition (skinfold thickness, arm muscle area and body fat percentage [%BF]), RMR and DEE were evaluated. The notion that the low birth weight can promote an rearrangement in energy metabolism is plausible. There is a positive association between LBW and reduced body weight, body height, fat-free mass and an increase in fat mass. LBW children from 8 to 10y old showed high mean values for the most variables when compared to 7 y old, while for NBW children, the differences were among all ages analyzed. The birth weight was positively correlated with head circumference (8-10y old), RMR, DEE, sitting height and %BF (9-10y old). All anthropometric and body composition variables were strongly positively correlated with RMR and DEE. From the regression model, height, hip circumference, %BF, tricipital and subscapular skinfolds were significant predictors for RMR and DEE regardless age. Relevant predictors of RMR and DEE were bicipital skinfold at age 8y, leg circumference at 9-10y, and suprailiac skinfold in both ages. The major determinant of RMR and DEE was %BF. LBW children showed a deficit in gain of anthropometric and body composition measurements throughout age. For the energy metabolism, variation in body structure of children can be related to restructuring of the fat component, since the differences observed between ages are attached to their predictors.

**KEYWORDS:** Body size, skinfold thickness, energy metabolism, children, low birth weight, growth and development.

## LIST OF ABBREVIATIONS

| | |
|---|---|
| %BF | Body fat percentage |
| AC | Arm circumference |
| AGA | Adequate for gestational age |
| AMA | Arm muscle area |
| BMI | Body mass index |
| BS | Bicipital skinfold |
| CAPES | Coordination for the improvement of higher level or education personnel |
| DEE | Daily energy expenditure |
| DOHaD | Developmental origins of health and disease |
| FFM | Fat free mass |
| FM | Fat mass |
| HC | Hip circumference |
| HE | Height |
| LBM | Lean body mass |
| LBW | Low birth weight |
| LC | Leg circumference |
| LGA | Large for gestational |
| MLBW | Marginally low birth weight |
| N | Sample size |
| NBW | Normal birth weight |
| RMR | Resting metabolic rate |
| SBS | Subscapular skinfold |
| SGA | Small for gestational age |
| SPS | Suprailiac skinfold |
| TRSK | Tricipital skinfold |
| TS | Tricipital skinfold |
| W | Body mass |
| Y | Year/years |

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## 1 DELIMITATION OF THE PROBLEM

Rapid technological, socio-economic and urban changes ongoing in many developing countries have led to changes in food systems resulting in a global nutrition transition (Popkin, 1998, Kimani-Murage, 2013). The nutrition transition is often refers as the decline in the prevalence of malnutrition, accompanied by the increasing incidence of obesity (Popkin, 1998). In 1990's, Brazilian undernourished population was about 22%, decreasing to less than 5% in 2005, while the incidence of overweight and obesity is half of the adult population (Fao *et al.*, 2014, Ng *et al.*, 2014). Although Brazil have come out of hunger map, malnutrition persists in some regions and the long-term consequences are still recurring (De Menezes *et al.*, 2011, Fao *et al.*, 2014, Ng *et al.*, 2014). In Pernambuco, Brazilian state, child malnutrition decreased around 65% between 1991 and 2006, but in 2011 the incidence of malnutrition exceeded 10% of children population (De Menezes *et al.*, 2011). Thereby, two dilemmas can be observed: the short-term adjustments, experienced by the population still malnourished and long-term adaptation, experienced by people who have lived a period of malnutrition. The thematic of this study fits into the current public health problem in poor areas of the Brazilian states, as it was applied in the city of Vitória de Santo Antão, interior of Pernambuco state.

A balanced nutrition is fundamental to the growth and development of physiological systems, once nutrient deficiency can cause irreversible damage that persists into adulthood (Harding, 2001, Barker, 2007). Although the fetus has a buffering mechanism for environmental variations of the mother, studies have shown it's beneficial at short-term because ensure survival and reproduction, however at long-term, they can be associated with metabolic diseases in adult life (Barker, 1994, Barker *et al.*, 2002, Bateson *et al.*, 2004). In first 2 years of life, a nutritional insult promotes reduced height, body weight, head circumference, lean mass and an increased deposition of body fat due to the faster "*catch up*" growth pattern (Eriksson *et al.*, 1999, Ibanez *et al.*, 2008, Victora *et al.*, 2008, Martins *et al.*, 2011). Perinatal malnutrition also causes reduction of energy expenditure and physical activity levels (Varadharajan *et al.*, 2013, Wells, 2013). A recent study found that LBW promotes reduction of muscle strength, running speed and aerobic capacity in physical fitness tests of children aged 7 to 10 years of the city of Vitória de Santo Antão (Moura‐Dos‐Santos *et al.*, 2013, Moura - Dos - Santos *et al.*, 2014). The relationship between maternal environmental imbalance and the repercussions in the development has an important role in the development of phenotypic plasticity (Wells, 2003).

In this context, the phenotypic plasticity refers the ability of a single genotype enable organisms to develop functional phenotypes despite variation and environmental change (West-Eberhard, 2005). Nutrition has been identified as an important phenotypic plasticity inducer, once to the proper functioning of an organism is necessary metabolically useful energy (Wells *et al.*, 1996, Wells, 2003). The minimum levels of energy required to maintain vital body functions at rest is known as resting metabolic rate (RMR) (Rolfe e Brown, 1997). Daily energy expenditure (DEE) includes RMR, the thermic effect of food, and the energy expenditure during physical activity (Ravussin *et al.*, 1986, Rolfe e Brown, 1997). The insufficient supply of nutrients during critical period of development, can compromise the energy needed for organs growth, which may causing changes in body proportions (Harding, 2001). Changes in body structure, physiology and metabolism raise the risk to develop obesity and co-morbidities in later life including metabolic syndrome, diabetes, and cardiovascular disease (Bateson *et al.*, 2004, Barker, 2007, Martins *et al.*, 2011).

Thus, this study was guided by the following question: Could body changes caused by a low birth weight interfere or modify the RMR and DEE in children aged 7-10 years? In pursuit of understanding this issue, this study aimed to develop regression models to predict the relationship between anthropometric variables, body composition on weight at birth, RMR and DEE. This search yielded 02 scientific articles. The first article entitled "Phenotypic plasticity and the putative link between low birth weight and resting metabolic rate: a review", which will be submitted for publication as review article for the journal Early Human Development with Qualis B1 in nutrition area in the Coordination for the improvement of higher level or education personnel (CAPES). The second article entitled “Birth weight, anthropometry, resting metabolic rate and daily energy expenditure in children aged 7-10 years old” will be submitted for publication as original article for a journal with Qualis A1 or A2 in nutrition in the CAPES.

## 2 REVIEW OF THE LITERATURE

**Title**: Phenotypic plasticity and the putative link between low birth weight and resting metabolic rate: a review

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**Abstract**

Low birth weight (LBW) seems to be associated with reduction of lean mass and increase of fat accumulation during growth. The long-term effects of the LBW on the probability to develop obesity and co-morbidities are potentiated by exposure to the obesogenic environment as seen in countries undergoing nutrition transition. Phenotypic plasticity of less lean body mass (LBM) rather than fat mass by a LBW might explain this adaptative process. LBM is the main determinant of resting metabolic rate (RMR). It is plausible to understand the changes on anthropometry and body composition in response to the LBW by considering the reduced RMR with high probability to accumulate fat mass. This review aims to analyze studies that consider the effects of low birth weight children and the relationship with anthropometry and body composition during growth. The reduced LBM and fat accumulation as seen in LBW children is potentiated by a reduced RMR.

**Keywords:** Anthropometry. Body composition. Malnutrition. Energy metabolism. Birth weight. Developmental plasticity.

**Introduction**

The recognition that stimuli act during early period of development (intrauterine or early postnatal life) influence long-term health is now one of the major public health concerns. The exposure to early adverse nutritional conditions promotes physiological and morphological changes that require organic and metabolic adaptations (Wells, 2013). In animals, perinatal malnutrition induced retard development of the nervous system, somatic growth, and change of the phenotype of skeletal and cardiac muscle fibres (Barreto Medeiros *et al.*, 2002, Barreto-Medeiros *et al.*, 2004a, Barros *et al.*, 2006a, Toscano *et al.*, 2008). In humans, low birth weight (LBW) children showed a reduced height, body weight, head circumference, lean mass and increased fat mass (Biosca *et al.*, 2011, Moura - Dos - Santos *et al.*, 2013, Lindberg *et al.*, 2015). These changes seem to be beneficial at short-term because ensure survival and reproduction, however at long-term, they can be associated with metabolic diseases in adult life (Hochberg *et al.*, 2011).

The relationship between early environmental challenge and the late consequences can be understood in the context of the phenotypic plasticity. Phenotypic plasticity is defined as the ability of a single genotype enable organisms to develop functional phenotypes despite variation and environmental change (West-Eberhard, 2003). LBW and childhood malnutrition raise the risk to develop obesity and co-morbidities in later life including metabolic syndrome, diabetes, and cardiovascular disease (Huxley *et al.*, 2007, Bateson *et al.*, 2014). This scenario is potentiated by exposure to the obesogenic environment of countries undergoing rapid nutrition transition (Conde e Monteiro, 2014, Parra *et al.*, 2015). One consequence of this nutrition transition has been the decline in the prevalence of undernutrition accompanied with a rapid increase in the prevalence of obesity (Thomas *et al.*, 2012).

The minimum levels of energy required to maintain vital body functions at rest is known as resting metabolic rate (RMR) (Rolfe e Brown, 1997, Kensara, Wooton, Phillips, Patel, Hoffman, Jackson e Elia, 2006). Previous study has suggested that a nutritional insult during the critical period of development can promote an rearrangement of the energy needed for growing (Harding, 2001). In undernourished children, it has been shown a reduction in the lean mass in detriment of fat mass in order to preserve the development of the brain during growth (Wells, 2003, Yajnik, 2004). The reduced lean tissue may be implicated in the reduction of energy metabolism and promoting body fat accumulation (Kensara, Wooton, Phillips, Patel, Hoffman, Jackson, Elia, *et al.*, 2006, Müller *et al.*, 2011). Studies have linked reduced values of RMR with stunting, wasting and low birth weight (Soares-Wynter, Suzanne Y e Walker, Susan P, 1996, Wren *et al.*, 1997, Grillol *et al.*, 2005, Correia *et al.*, 2014).

This review aims to analyze studies that consider the effects of low birth weight children and the relationship with anthropometry and body composition during growth. In addition, it is suggested that reduced lean mass and fat accumulation as seen in low birth weight children is potentiated by a reduced resting metabolic rate.

**Phenotypic plasticity and low birth weight in the context of nutrition transition and "dual burden"**

The study of phenotypic plasticity encompasses aspects of behaviour, development, ecology, evolution, genetics, genomics, and multiple physiological systems at various levels of biological organization (Kelly *et al.*, 2011). Epigenetic modifications underlying the phenotypic plasticity and provide a plausible mechanism for a putative link between environmental variation and alterations in gene expression (Geng *et al.*, 2013). Accordingly, the precepts of phenotypic plasticity underlies some theoretical models such as "thrifty phenotype hypothesis" (Hales e Barker, 1992), programming (Singhal *et al.*, 2003), capacity-load model (Wells, 2003) and developmental origins of health and disease (DOHaD) (Bateson *et al.*, 2014) that report evidences resultant from the relationship between malnutrition during early life and adult outcomes. Indeed, LBW and childhood malnutrition raise the probability to develop obesity and co-morbidities in later life including hypertension, diabetes, and cardiovascular disease (Hales e Barker, 1992, Ashton, 2000, Hemachandra *et al.*, 2006). This scenario is potentiated by exposure to the obesogenic environment of countries undergoing rapid nutrition transition (Conde e Monteiro, 2014, Parra *et al.*, 2015).

The nutrition transition addresses a broad range of socioeconomic and demographic shifts that bring rapid dietary changes (Thomas *et al.*, 2012). One consequence of this nutrition transition has been the decline in the prevalence of undernutrition accompanied with a rapid increase in the prevalence of obesity (Thomas *et al.*, 2012). For example, in 1990's, Brazilian undernourished population was about 22% (Fao *et al.*, 2014, Ng *et al.*, 2014). In 2005, this prevalence was less than 5% while the incidence of overweight and obesity was more than 50% of adults (Fao *et al.*, 2014, Ng *et al.*, 2014) . The simultaneous occurrence of under and overnutrition within a population is known as the double burden of malnutrition (Shetty, 2013). The incidence of dual burden are strongly associated to the environmental stimulus, such as diet combined with reduced physical activity (Vaezghasemi *et al.*, 2014).

Epidemiological studies have shown that children and adolescents living in countries undergoing nutrition transition can be simultaneously growth retarded and higher probability to become overweight/obese (Hoffman *et al.*, 2000, Iriart *et al.*, 2013, Le Nguyen *et al.*, 2013, Shetty, 2013, Gartner *et al.*, 2014). In addition, an etiological model of stunting concomitant to overweight is highlighted around food restriction during the early stages of life, causing growth delay and predisposition to fat gain in later life (Wells, 2013). Previous studies suggested that perinatal undernutrition might induce growth retardation and impaired fat oxidation, decreased resting energy expenditure and low physical activity (Varadharajan *et al.*, 2013, Wells, 2013). The relationship between RMR and growth in children who are simultaneously stunted and overweight can be studied in the context of the phenotypic plasticity.

**Does low birth weight influence RMR in children?**

RMR refers to the energy requirements at complete rest, or the minimum levels of energy needed to maintain physiological functions (Rolfe e Brown, 1997). Daily energy expenditure (DEE) includes RMR, the thermic effect of food, and the energy expenditure during physical activity (Buchholz *et al.*, 2001, Gregory *et al.*, 2014). DEE is the increase of the energy expenditure above rest that is associated with the ingestion of food and accounts for approximated 10% of the total daily energy expenditure (Buchholz *et al.*, 2001).

A main predictor of RMR is the fat-free mass (FFM) and the main factors influencing RMR are gender, age and body composition (Cunningham, 1980, Mole, 1990). It was found that older adults had reduced RMR adjusted for FFM compared with the young men (Du *et al.*, 2014). In overweight and obese individuals, RMR may be a marker of energy intake and could represent a physiologic signal for hunger (Caudwell *et al.*, 2013). In addition, restricted energy intake is related to reduced RMR (Forsum *et al.*, 1981). Children with moderate-to-severe degrees of malnutrition have special adaptation to low energy intakes, that include impaired fat oxidation and reduced RMR (Soares-Wynter, Suzanne Y e Walker, Susan P, 1996).

Stunting and wasting are the most common state of undernutrition and are related to reduced RMR in children (Prendergast e Humphrey, 2014). In Jamaican children aged 7-8 years, it has been shown that short-stature group present a reduced RMR (RMR = 4702 ± 570 kJ/d) when compared to normal-stature group (RMR = 5802 ± 616 kJ/d) (Wren *et al.*, 1997). The ratio of low height-for-age (stunting) may be related to increased accumulation of body fat and this association also can change the RMR (Correia *et al.*, 2014). Grillol *et al.* (2005) have found lower values for RMR in stunted Brazilian girls between 7-11years and higher propensity of accumulate fat. Stunting can ocurr because of the impaired balanced nutrients avaibility during childhood, but also because of the low or excessive avaiability of nutrients during fetal and postnatal life (as indicated by birth weight) (Soares-Wynter, S. Y. e Walker, S. P., 1996, Kensara, Wooton, Phillips, Patel, Hoffman, Jackson, Elia, *et al.*, 2006).

A large number of epidemiological and experimental studies have demonstrated that there is a close relationship between unbalanced nutrient intake during perinatal life and subsequent development of adult metabolic diseases (Forsen *et al.*, 1997, Ozanne e Hales, 2004, Eriksson *et al.*, 2011). In the last 5 years, a number of studies have shown the effects of LBW on the anthropometric and body composition of children changes during growth (Table 1). In animal models, the exposure to a low-protein diet (8% casein) during gestation followed by the consumption of a normoproteic diet throughout the life-course was associated with growth restriction, slightly elevated systolic blood pressure and increased fasting plasma insulin concentration (Ozanne e Hales, 2004, De Brito Alves *et al.*, 2014). Perinatal undernutrition leads to asymmetric reduction in organ growth, such that the weight of liver and pancreas are reduced, whereas heart and brain are spared (Gluckman *et al.*, 2009). Previous studies using rats demonstrated that perinatal low-protein diet may alter brain growth spurt, feeding behavior and ontogeny of reflexes (Lopes De Souza *et al.*, 2008, Falcao-Tebas *et al.*, 2012).

Perinatal malnutrition is associated with an increase in body fat deposition resulting from a rapid growth (*catch up*) and a reduction in lean body mass during childhood (Eriksson *et al.,* 1999, Moura-Dos-Santos *et al.,* 2013). Maternal malnutrition (under and overweight) can change the size at birth and permanently alter the physiology of the offspring (Wells, 2013). In babies born at term with a low ponderal index, there is a reduction in subcutaneous adipose tissue, and an increased amount of visceral fat in post-catch-up of growth (Ibanez *et al.*, 2008, Meas, 2010). The preservation of fat at the expense of lean tissue in LBW infants is probably due the need for 'brain preservation' during development (Wells, 2003, Yajnik, 2004). However, a lower proportion of lean body mass may persist until adult life (Martins *et al.*, 2004).

A longitudinal study with chronically undernourished children showed that the increased body fat gain observed in the group of boys with stunting was associated with lower gains in LBM (Martins *et al.*, 2004). Because LBM is the main determinant of RMR, low birth weight children present a reduced RMR with high probability to accumulate fat mass (Kensara, Wooton, Phillips, Patel, Hoffman, Jackson, Elia, *et al.*, 2006, Müller *et al.*, 2011). Wren *et al.* (1997) found no differences in RMR after LBM adjustment between the stunted and age-matched control subjects. The reduced LBM in growth-retarded children, induces a higher proportional contribution of the more metabolically active organs (brain and muscle) to total body size, which may cause changes in body proportions (Harding, 2001, Said-Mohamed *et al.*, 2012) [Figure 1].

Satisfactory growth is a sensitive indicator about if the energy needed and is being avaiable (Butte *et al.*, 2000). The longitudinal measurements of children growth are a dynamic statement of the general condition and health (Rogol *et al.*, 2000). The impairment of the energy needed for growth, can lead to the growth of body parts at different rates than expected for a normal child. Indeed, the predictive effect of the birth weight on development of body structures could explain an energetic rearrangement compatible with changes in RMR. Some hypotheses address to the interaction among different tissues, with a considerable variation in the size of organ masses, and the growth of a tissue in detriment of another (Aiello e Wheeler, 1995, Navarrete *et al.*, 2011). Aiello e Wheeler (1995) suggest that the metabolic requirements of relatively large brains are offset by a corresponding reduction of the gut. Nonetheless Navarrete *et al.* (2011) attributes this increase to the reduced adipose depots. These changes in the relative size of organs contributes to the energy balance of an individual (Aiello e Wells, 2002). The different contribution of tissues to total RMR is the basis of studies that try to explain some evolutionary changes in body proportions (Aiello e Wells, 2002, Navarrete *et al.*, 2011).

## Conclusion

The notion that the low birth weight can promote an rearrangement in energy metabolism is plausible. There is a positive association between LBW and reduced body weight, body height, fat-free mass and an increase in fat mass. In addition, there is an elevated risk of being overweight if children were LBW or growth restricted as seen in countries that experienced undernutrition incidence and are living the increase in prevalence of overweight and obesity (nutrition transition). The reduction in fat-free mass and increase in fat mass can be a reflex of organs size variation. The changes in body size, proportion of body components (mainly fat-free mass) and organs size variation may be determinant factors in variation of the RMR. This issue requires further research, but it is important because represent a key challenge of reducing stunting and malnutrition in order to reduce the risks of obesity.

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Table 1 - Studies that associated undernutrition markers with anthropometric and body composition variables in humans.

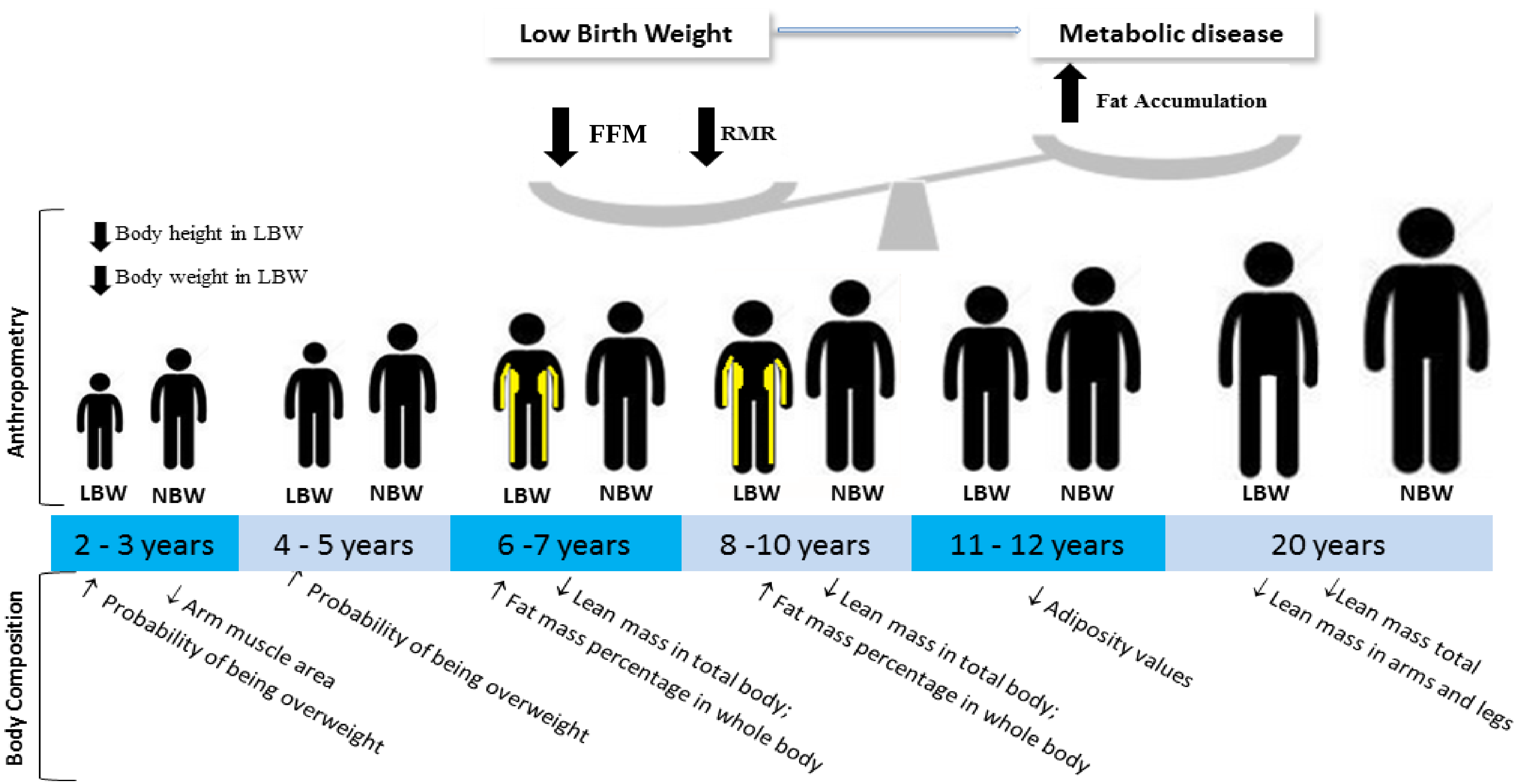
| Reference | Country | N | Nutritional condition | Objective | Age Assessment | Main Results (LBW/SGA) |
|---|---|---|---|---|---|---|
| Biosca *et al.* (2011) | South Africa | 124 | SGA <$10^{th}$ percentil<br>LGA >$90^{th}$ percentil<br>AGA =$10^{th}$-$90^{th}$ percentile | To evaluate body composition differences between children that were born small (SGA) or large for gestational age (LGA) compared with their counterparts born adequate for gestational age (AGA). | 6-10y | ↓ Body weight,<br>↓ Lean mass in all the considered body areas (left arm, left leg, trunk, abdominal regions and total body) after height adjustment the differences were not significant,<br>↑ Fat mass percentage in whole body, trunk and in abdominal regions. |
| Lima, Marilia C. *et al.* (2011) | Brazil | 213 | LBW 1500g -2499g | To assess the influence of low birth weight in full-term infants on body composition at school age. | 8y | → Triceps and subscapular skinfold,<br>→ arm circumference,<br>→ arm total area,<br>→ arm muscle area,<br>→ arm fat area,<br>→ arm fat index |
| Bove *et al.* (2012) | Uruguay | 2069 | LBW <2,500g<br>Macrosomia> 4000g<br>Stunting = Height-for-age ≤ 2 SD | The aim of this paper is to identify linkages between LBW, macrosomia, reduced head circumference, stunting, overweight and child development impairment and to examine a broad range of factors that may simultaneously contribute to these problems in children under five years old. | <5y | ↓ Head circumference<br>↑ Probability for stunting ↑ probability of being overweight |
| Thomas *et al.* (2012) | India | 117 | LBW <$10^{th}$ percentil ~ <2450g<br>NBW $70^{th}$ -$90^{th}$ percentile ~ ≥3100 and <3500 g | Study the metabolic impact of being born with LBW in a rural non-migrant Indian population. | 20y | ↓Weight,<br>↓ Height,<br>↓ Lean mass total<br>↓ Lean mass in arms and legs<br>→ Skinfold thickness<br>→ Total fat mass and percentages. |
| Harada *et al.* (2013) | Japan | 759 | BW category<br><2,500<br>2,500 ≤ < 3,000<br>3,000 ≤ < 3,500<br>3,500 ≤ | The purpose of this study was to clarify the relationship between birth weight and the waist-to-height ratio in Japanese children stratified by sex. | 7-8y | < 3,000 g group:<br>↓ Height and weight in boys and girls;<br>↑ Waist-to-height ratio in girls. |
| Datta Gupta, N. *et al.* (2013) | Denmark | 4783 | LBW <2,500g<br>NBW | Analysing the medium run effects of low birth weight on child behavioural outcomes as well as physical growth at ages 6 months, 3½, 7½ and 11 years using data from the Danish Longitudinal Survey of Children. | 6 months, 3½ y,<br>7½ y<br>11 y | ↓Weight,<br>↓ Height |

Table 1 (Cont.) - Studies that associated undernutrition markers with anthropometric and body composition variables in humans

| | | | | | | |
|---|---|---|---|---|---|---|
| Moura - Dos - Santos *et al.* (2013) | Brazil | 356 | LBW <2500g<br>NBW ≥ 3000g ≤ 3999g | Verify the influence of low birth weight (LBW) on the physical fitness of children aged 7-10 years. The comparisons were subsequently adjusted for chronological age, gender, physical activity (PA), and body composition | 7-10y | ↓Weight,<br>↓ Height<br>↓Fat-free mass<br>→Fat mass<br>→Body fat (%) |
| Kramer *et al.* (2014) | Belarusian | 17,046 | SGA <10th percentil<br>LGA >90th percentile<br>AGA =10th-90th percentile | Assessed the effects of small for gestational age (SGA) birth and weight gain in early infancy on adiposity at age 11.5 y | 11,5y | ↓Weight,<br>↓ Height,<br>↓ Percentage body fat (%)<br>↓ Fat mass index (kg/m2)<br>↓ Waist circumference,<br>↓ Hip circumference,<br>→Waist-to-hip ratio<br>↓ Triceps skinfold,<br>↓ Subscapular skinfold,<br>↑ Subscapular:triceps ratio |
| Wang *et al.* (2014) | Taiwan | 322 | VLBW = 2 SD below of the control group | Compare the growth and effect of growth on cognitive performance at 5 years of age of a group of very-low-birth-weight (VLBW) infants and a group of healthy full-term infants. | 5y | ↓Weight,<br>↓ Height,<br>↓ Head circumference |
| Machado *et al.* (2014) | Brazil | 479 | LBW<br>NBW<br>HBW | Evaluate the relationship between birth weight and body composition in preschool children with excess weight. | 2-3y | ↓ Arm muscle area<br>→ Arm fat area |
| Lindberg *et al.* (2015) | Sweden | 380 | MLBW = 2000-2500 g<br>SGA ≤ 2 SD<br>Control 2501 - 4500 g | The aim of this cohort study was to investigate the possible associations between marginally low birth weight (MLBW) and early childhood risk of overweight and obesity as well as other anthropometric signs of metabolic syndrome in a Swedish setting. | 3,5y<br>7y | LBW: ↓Weight,<br>↓ Height,<br>↓ Head circumference<br>→ Skinfold thickness<br>Only 3,5y: ↓ waist circumferences<br>Only 7y: ↓ ↓ Fat-free Mass Index<br>↓ Total body fat and lean mass, however after height adjustment the differences were not significant<br><br>SGA: ↓Weight,<br>↓ Height,<br>↓ Fat Mass Index<br>↓ Fat-free Mass Index |

SGA, small for gestational age; LGA, large for gestational; AGA, adequate for gestational age; LBW, low birth weight; NBW, normal birth weight; BW, Birth weight; VLBW, very low birth weight; HBW, high birth weight; MLBW, marginally low birth weight, N, sample size.

Figure 1 - Effect of low birth weight in body composition and anthropometric parameters.




RMR, resting metabolic rate; FFM, fat free mass, low birth weight; NBW, normal birth weight; Body fat

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# 3 HYPOTHESIS

The change in body size during childhood is associated with the RMR and DEE, and birth weight strongly influences these relations, once the birth weight may be associated to changes on anthropometry and body composition during growth and development of children.

# 4 OBJECTIVE

## 4.1 General

To evaluate the association between anthropometric and body composition variables with birth weight, RMR and DEE and stablish a predictive model for RMR and DEE considering the influence of anthropometry, body composition and birth weight in children at 7 to 10 years old.

## 4.2 Specifics

- To describe anthropometric and body composition variables and energy metabolism according to birth weight;

- To verify the association between birth weight, resting metabolic rate and daily energy expenditure with anthropometry and body composition variables;

-To develop a predictive model for the relationship between Anthropometrical variables, resting metabolic rate and body composition on weight at birth.

## 5 ORIGINAL ARTICLE

**Title:** Birth weight, anthropometry, body composition, resting metabolic rate and daily energy expenditure in children aged 7-10 years old.

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## ABSTRACT

**Objective:** This study investigated the association between anthropometry and body composition with birth weight, resting metabolic rate (RMR) rate and daily energy expenditure (DEE) of children at 7 to 10 years old. **Methods**: It was evaluated 464 children (241 boys and 223 girls) born in Vitória de Santo Antão (Northeast of Brazil). Anthropometry (weight, height, sitting height, waist, hip, arm, leg and head circumferences), body composition (skinfold thickness, arm muscle area and body fat percentage (%BF)), RMR and DEE were evaluated. **Results**: LBW children from 8 to 10y old showed high mean values for the most variables when compared to 7 y old, while for NBW children, the differences were among all ages analyzed. The birth weight was positively correlated with head circumference (8-10y old), RMR, DEE, sitting height and %BF (9-10y old). All anthropometric and body composition variables were strongly positively correlated with RMR and DEE. From the regression model, height, hip circumference, %BF, tricipital and subscapular skinfolds were significant predictors for RMR and DEE regardless age. Relevant predictors of RMR and DEE were bicipital skinfold at age 8y, leg circumference at 9-10y, and suprailiac skinfold in both ages. The major determinant of RMR and DEE was %BF. **Conclusion:** LBW children showed a deficit in gain of anthropometric and body composition measurements throughout age. For the energy metabolism, variation in body structure of children can be related to restructuring of the fat component, since the differences observed between ages are attached to their predictors.

**KEYWORDS:** Body size, skinfold thickness, energy metabolism, children, low birth weight, growth and development.

**5.1 INTRODUCTION**

Most studies associating the early period of development with later risks of disease have used birth weight as an index of fetal growth, with low birth weight (LBW) being shown to be predictive of increased subsequent impairment of health (Barker et al 2005; Kajantie et al 2005; Ortega et al 2009). In humans, cross-sectional studies have shown that LBW is associated with reduced height, body weight, head circumference, lean mass and increased fat mass (Bove *et al.*, 2012, Thomas *et al.*, 2012, Datta Gupta, Nabanita *et al.*, 2013, Harada *et al.*, 2013, Moura ‐ Dos ‐ Santos *et al.*, 2013). The ability of a single genotype enable organisms to develop functional phenotypes despite variation and environmental change, is known as phenotypic plasticity (West-Eberhard, 2005). This is the theoretical model of the relationship among malnutrition during early life, phenotypic changes during the stages of growth and development with long-term consequences in adulthood (Barker, 1991, Bateson *et al.*, 2004).

A nutritional insult during critical period of development can promote rearrangements of energy needed for growing (Harding, 2001). In undernourished children, it has been shown a reduction in the fat free mass (FFM) in order to preserve the development of the brain during growth (Wells, 2003, Yajnik, 2004). In addition, the decrease of lean mass may be implicated in the reduction of energy metabolism; consequently it can promote body fat accumulation (Kensara, Wooton, Phillips, Patel, Hoffman, Jackson, Elia, *et al.*, 2006, Müller *et al.*, 2011). FFM is the main determinant of resting metabolic rate (RMR), the minimum levels of energy needed to maintain vital body functions. Some studies have linked reduced values of RMR with stunting, wasting and low birth weight (LBW) (Soares-Wynter, Suzanne Y e Walker, Susan P, 1996, Barker, 2007).

Total energy expenditure or daily energy expenditure (DEE) includes RMR, the thermic effect of food, and the energy used during physical activity (Buchholz *et al.*, 2001, Gregory *et al.*, 2014). A cross-sectional study in healthy children shows that the DEE is related to body height, weight, BMI, fat free mass, fat mass and body fat percentage (Ball *et al.*, 2001). The level of physical activity is also an important modulator of these variables (Ball *et al.*, 2001). However, the relationship between low birth weight and energy components are mostly limited to RMR analysis and little is known about the relationship of growth pattern controlled by chronological age.

In the present study, we hypothesized that the change in body size during childhood is associated with the RMR and DEE, and birth weight strongly influences these relations, once the birth weight may be associated to changes on anthropometry and body composition during growth and development of children. Thus, the main goal of this study was to evaluate the association between anthropometric and body composition variables with birth weight, RMR and DEE and stablish a predictive model for RMR and DEE considering the influence of anthropometry, body composition and birth weight in children at 7 to 10 years old.

## 5.2 METHODS

### 5.2.1 Sample

This study was conducted in the city of Vitória de Santo Antão, located in an economically poor rural zone in the Pernambuco state, in northeast Brazil. A total of 464 children (241 males and 223 females) aged 7 to 10 years all born in Vitória of Santo Antão participated in this study. The sample was divided into two groups according to their birth weight: LBW from 1.500 g to 2.500 g (N=92) and normal birth weight (NBW) from 2.501 g to 3.999 g (N=372). All measurements were carried out during a 6-month period from March to November 2009, according to the school calendar. The birth weights were obtained from health booklets in which this information was recorded by nurses and/or pediatricians. Written informed consent was obtained from the parents or legal guardians of each child. Information on gestational age and mothers' health conditions during pregnancy was not available, and the sample included both children who were born preterm and term.

### 5.2.2 Anthropometry and body composition

The body weight of lightly dressed and barefooted children was measured to the nearest 0.1kg with a digital scale (Filizola, São Paulo, Brazil), and the stature was measured to the nearest 0.5cm using a portable stadiometer (Sanny, São Paulo, Brazil) with each child's shoes off, feet together, and head in the Frankfurt horizontal plane. To evaluate the sitting height was used a stadiometer (brand Sunny) with accuracy of 0.1 cm (Martin *et al.*, 1988). Head circumference: The tape was placed over the occipital protuberance and the arch of the eyebrows (Lohman *et al.*, 1988). Arm circumference: The midpoint between the acromion of the scapula and the olecranon of the ulna. The midpoint is obtained with arm bent at 90 degrees (Frisancho, 1974). Waist circumference: Smallest circumference between the last rib and the iliac crest (Lohman *et al.*, 1988). Hip circumference: held around the widest part of the trochanter (buttocks) (Kissebah e Krakower, 1994). Medial thigh circumference: midpoint between the inguinal line and the top edge of the patella (Lohman *et al.*, 1988). The skinfolds (mm) were measured with a Lange caliper (Lange, Santa Cruz, CA, USA) using a standard protocol. All measurements were performed in the right hemisphere of the region evaluated in the biceps, triceps, subscapularis, supra-iliac, thigh and calf and repeated twice at each location (Lohman *et al.*, 1988). The percent body fat (%BF), fat mass (FM, kg) and fat free-mass (FFM, kg) were estimated using Lohman e Going (2006). The arm muscle area, was estimated from the circumference of the arm, the equation Frisancho (1984).

### 5.2.3 Resting metabolic rate and daily energy expenditure

Metabolic requirements for maintenance of body weight, were calculated by Kleiber's equation, which relates the RMR and body weight (Kleiber, 1932, 1961).

$$RMR = 70\ W^{0.75}$$

where; W = body mass (kg) and RMR = resting metabolic rate ($kcal/d^{-1}$)

The relationship between DEE and body weight were calculated using the equation of daily energy requirements (Leonard e Robertson, 1992)

$$DEE = 86.0\ W^{0.792}.$$

where; W = body mass (Kg) and DEE = daily energy expenditure ($kcal/d^{-1}$).

The RMR and DEE results from the formulas were multiplied by 4.184 to conversion from kilocalorie (kcal) to kilojoule (kJ).

### 5.2.4 Predictive model

The predictive model was developed from the idea that linear regression is the study of linear, additive relationships between variables. A formula was suggested to express the relationship between RMR and DEE (Y) as dependent variable and anthropometric and body composition variables as independent variables (X). This formula has the property that the prediction for Y is a straight-line function of each of the X variables, holding the others fixed, and the contributions of different X variables to the predictions are additive. Then the equation for computing the predicted value of Y is:

$$Y = b_0 + b_1X_1 + b_2X_2 + ... + b_kX_k$$

### 5.2.5 Ethics statement

This study was approved by the ethics committee of the Centre of Health Science, Federal University of Pernambuco (protocol number 0175.0.172.000–09) in accordance with the ethical standards of the 1964 Helsinki Declaration. Written informed consent from parents or legal guardians was a criterion for the inclusion of each child in the study. Birthweights were obtained from health booklets in which this information was recorded by nurses and/or pediatricians.

### 5.2.6 Statistical analysis

Exploratory data analysis was used to identify potentially inaccurate information and outliers. Variables with skewed distributions were binary transformed to obtain a more symmetrical distribution. Descriptive statistics are presented as means and standard deviations, minimum and maximum values. Potential interaction factors (i.e. sex-by-RMR/DEE and age-by-RMR/DEE) were evaluated using T student and ANOVA models. As no statistically significant differences were found between 9 and 10 years old, groups were analyzed together.

After inspection of correlation results (Spearman correlations) among the studied variables, the effects of birth weight on RMR and DEE were analyzed by linear regression. The model included RMR and DEE as the dependent variable and all anthropometric and body composition components as independent variables. Some variables were excluded from the model because of the absence of significance. SPSS software version 18.0 (SPSS Inc, Chicago, IL, USA) was used for all analysis, and the significant level was set at 5%.

## 5.3 RESULTS

In table 2 are presented the descriptive statistics on anthropometric and body composition variables according to birth weight (normal and low birth weight) and age (7, 8 and 9-10 years old). There was no difference between LBW and NBW groups for all variables (P>0.05). LBW children from 8, 9 – 10 y old showed high mean values for all variables, except skinfold thickness, when compared to 7 y old. For NBW children, the differences appeared in the comparison to 7 and 8 y old, except for skinfold thickness (Table I).

Table 3 appeared the Spearman correlation (r and p values) among birth weight, RMR, DEE, current body size (height, sitting height, head, waist, hip, arm and leg circumferences) and body composition (tricipital, bicipital, subscapular, suprailiac and calf skinfolds, % body fat and arm muscle area) are showed. All anthropometric and body composition variables were strongly positively correlated with RMR and DEE. Birth weight was positively correlated with head circumference at 8 years, and with RMR, DEE, sitting height, head circumference and % body fat at 9-10 years. In addiction, table 3 shows the formulas of prediction for RMR and DEE in which height, hip circumference, leg circumference, bicipital, tricipital, subscapular and suprailiac skinfolds and % body fat contributed differently in each age studied (7, 8 and 9-10 years).

Additional analyses were performed to identify prediction models for RMR and DEE using linear regression (Table 4). The prediction models for RMR and DEE showed values for at least 97% (F=1215.04**,** p<0.001). The variables that were not significant to predict RMR and DEE were excluded from the model, including: birth weight, arm muscular area, calf skinfold, waist, arms and head circumferences. From the variables included in the model, height, hip circumference, tricipital skinfold, subscapular skinfold and % body fat were significant predictors for RMR and DEE regardless age. In addition, relevant predictors of RMR and DEE were bicipital skinfold at age 8y, leg circumference at age 9-10y, and suprailiac skinfold in both ages. No differences were found between RMR and DEE due to collinearity between these variables.

## 5.4 DISCUSSION

In present study, we evaluated the short-term influences of LBW on anthropometric and body composition variables and the association with energy metabolism during childhood. In contrast with previous studies, LBW children and NBW children did not differ in terms of anthropometry and body composition (Datta Gupta, Nabanita *et al.*, 2013, Harada *et al.*, 2013, Moura‐Dos‐Santos *et al.*, 2013). Accordingly, Lima, Marilia C *et al.* (2011) did not show differences between LBW and NBW children (N=213 children aged 8 years old) for anthropometric and body composition variables. We categorized our sample per chronological age, and intra-group differences showed that LBW and NBW children present distinguish mean values throughout age. LBW children present similar anthropometric and body composition, RMR and DEE mean values at 8, 9 – 10 years. Our findings suggest that LBW children present a deficit in the gain of body weight and height, lean mass, anthropometric and body composition measurements. In addition, the RMR and DEE did not changed with chronological age. Our result support the previous literature (Singhal *et al.*, 2003, Wells *et al.*, 2013, Bateson *et al.*, 2014)

Birth weight has been strongly correlated with growth and development during childhood (Ericson e Kallen, 1998). Previous studies have shown that both LBW and high birth weight are predictors of reduced lean mass and fat accumulation (Biosca *et al.*, 2011). In the present study, birth weight was positively correlated with head circumference at 8 and 9-10 y old. Perinatal environment may influence the morphological and physiological development of the brain. In animals, rats submitted to a low-protein diet (casein 8%) during gestation and lactation presented a low birth weight, reduced dimensions of the skull (longitudinal, latero-lateral and antero-posterior skull axis), delayed reflexes ontogeny, reduced number of neurons and neuromotor deficits (Borba *et al.*, 2000, Barreto-Medeiros *et al.*, 2004b, Barros *et al.*, 2006b). In humans, low birth weight was correlated with decrease cognitive ability, learning ability, long-term storage and retrieval, and visuo-spatial ability (Puga *et al.*, 2009, Veena *et al.*, 2010). At 9-10 y old, we observed that birth weight was positively correlated with RMR, DEE, sitting height and % body fat. Our findings are in accordance with previous studies, which showed changes in RMR due stature and body fat variations (Wren *et al.*, 1997, Grillol *et al.*, 2005, Correia *et al.*, 2014). The predictive effect of the birth weight on development of body structures could explain an energetic rearrangement compatible with different growth patterns among ages.

The impairment of the energy needed for growth, often experienced by LBW children, can led to different rates of development of body parts than those expected for a normal child (Holliday, 1971). Correlation analysis showed a strong association between RMR and DEE with anthropometric and body compositions variables. Accordingly, Goran *et al.* (1993) showed that DEE and RMR was significantly correlated with fat-free mass, body weight, body surface area, REE, height, and fat mass. Even thought LBW children can adopt an adaptive growth strategies, which integrate various components of phenotype sensitive to actual environmental stimuli (Wells, 2010), our data showed that the current variables have a greater association with energy metabolism, showing that birth weight was weakened by the current environment (Wells, 2010). Although we have no data concerning the level of physical activity, sports, eating habits and any information about the period of gestational age and lactation, our findings suggest that birth weight was not deterministic for the current anthropometry and body composition of those children, and the environment experienced has to be considered for the energy metabolism.

For further analysis, we used linear regression to identify how much a variable can interfere in RMR and DEE and from that stablish a predictive equations in each age. Our data showed that the major predictor for the RMR and DEE was the % body fat. According to Epstein *et al.* (1989) the fat component has an important role in determining the RMR, once obese children had higher RMR than lean children, and body weight accounted for 72 and 78% of the variance in RMR (Epstein *et al.*, 1989). In addition, triceps, biceps, suprailiac and subscapular skinfold presented a high degree of association with the % body fat, together they represent around 72% of body fat mass (Durnin e Rahaman, 1967, Aniteli *et al.*, 2006). Similarly to hip circumference, that also reflects to a certain extent of the body fat and leg circumference, which to represent the gluteofemoral adipose tissue contributes indirectly to more body fat (Fredriks *et al.*, 2005, Bjørndal *et al.*, 2011). However, the adiposity, defined as % fat or adipose tissue, is largely independent of height (Heymsfield *et al.*, 2007). The relationship between height, RMR and DEE was seen probable because the energy requirements are largely determined by body weight. Considering that body weight increases as a function of height, the body height is important marker of energy metabolism (Heymsfield *et al.*, 2009). The different contribution of the variables to the RMR and DEE at 7, 8 and 9-10 years old, could be explained by growth dynamics, causing changes in body proportions specific for each age, contributing differently to the energy metabolism. Thus, different equations were developed at 7, 8 and 9-10 years, in order to respect the differentiated growth in each age group. Furthermore, it was observed that the differences between ages are associated with the predictors of % body fat. Thus, the different contributions of age on energy metabolism may be linked to a "restructuring" of the fat component of the growing organism.

The limitations of the present work are the lack of information about the period of gestational age and lactation that could also influence the birthweight outcomes. Physical activity is also an important variable that could be analyzed to better understand the current effects of the environment and especially the understanding on the DEE.

## 5.5 CONCLUSION

LBW children and NBW children did not differ in terms of anthropometry and body composition; however, LBW children had a deficit in the gain of anthropometric and body composition measurements throughout age. The association between birth weight and head circumference (8-10years), RMR, DEE, sitting height and % body fat (9-10 years), also justifies the effects of birth weight. For the energy metabolism, the major predictor for RMR and DEE was % body fat, justifying some variables also correlated with RMR and DEE. To explain the dynamics of growth, we also observed that the variation in body structure of individuals can be related to the restructuring of the fat component, since the differences observed among ages are supported by their predictors.

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Table 2 - Sample descriptive characteristics (mean with SD, minimum and maximum) of anthropometry and body composition in the low birth weight (LBW) and normal birth weight (NBW) of children aged 7-10 years.

| | LBW | | | | NBW | | | |
|---|---|---|---|---|---|---|---|---|
| **Age** | **N** | **Mean (SD)** | **Min** | **Max** | **N** | **Mean (SD)** | **Min** | **Max** |
| **Weight (kg)** | | | | | | | | |
| 7 | 30 | 26.11 (6.32) | 16.9 | 42.9 | 83 | 27.39 (7.34) | 17.7 | 54.1 |
| 8 | 24 | 31.07 (8.59) | 21.4 | 55.5 | 105 | 29.18 (6.81) | 19.7 | 51.5 |
| 9-10 | 38 | 31.42 (7.44)[a] | 20.4 | 57.1 | 184 | 33.37 (8.27)[ab] | 19.9 | 72 |
| **Height (cm)** | | | | | | | | |
| 7 | 30 | 125.7 (6.71) | 110.6 | 141 | 83 | 126.1 (6.74) | 113 | 151.5 |
| 8 | 24 | 133.2 (7.45)[a] | 121.3 | 146 | 105 | 131.2 (7.16)[a] | 112.5 | 158 |
| 9-10 | 38 | 136.4 (6.95)[a] | 123.5 | 148 | 184 | 136.8 (7.25)[ab] | 119 | 155 |
| **Sitting height (cm)** | | | | | | | | |
| 7 | 30 | 63.68 (6.77) | 50 | 75 | 83 | 64.62 (5.67) | 50 | 82 |
| 8 | 24 | 68.52 (5.50)[a] | 56 | 80 | 105 | 67.41 (5.30)[a] | 51 | 78 |
| 9-10 | 38 | 69.19 (5.94)[a] | 54 | 81 | 184 | 70.85 (6.39)[ab] | 53 | 90 |
| **Waist circumference (cm)** | | | | | | | | |
| 7 | 30 | 55.65 (7.60) | 44 | 81 | 83 | 55.90 (7.70) | 43 | 80 |
| 8 | 24 | 60.08 (9.19) | 48 | 84 | 105 | 56.46 (6.11) | 47 | 76 |
| 9-10 | 38 | 58.50 (6.97) | 49 | 81 | 184 | 59.41 (8.23)[a] | 47 | 85 |
| **Hip circumference (cm)** | | | | | | | | |
| 7 | 30 | 63.62 (8.00) | 54 | 86 | 83 | 65.28 (7.83) | 54 | 87 |
| 8 | 24 | 69.68 (9.22)[a] | 57 | 89 | 105 | 66.67 (7.27) | 52 | 89 |
| 9-10 | 38 | 69.66 (8.07)[a] | 57 | 98 | 184 | 71.07 (8.57)[ab] | 51 | 109.5 |
| **Head circumference (cm)** | | | | | | | | |
| 7 | 30 | 51.43 (1.54) | 48 | 55 | 83 | 51.00 (1.65) | 47 | 55.5 |
| 8 | 24 | 51.73 (1.93) | 48 | 55 | 105 | 51.46 (1.70) | 46.5 | 55 |
| 9-10 | 38 | 51.84 (1.56) | 49 | 55 | 184 | 52.05 (1.61)[ab] | 48 | 56.5 |
| **Arm circumference (cm)** | | | | | | | | |
| 7 | 30 | 16.89 (2.14) | 13 | 21 | 83 | 17.68 (2.84) | 13 | 26.5 |
| 8 | 24 | 19.13 (3.16)[a] | 14 | 27 | 105 | 17.85 (2.54) | 14 | 26 |
| 9-10 | 38 | 18.58 (2.15)[a] | 15 | 23 | 184 | 19.04 (2.60)[ab] | 15 | 28.5 |
| **Leg circumference (cm)** | | | | | | | | |
| 7 | 30 | 24.12 (2.33) | 19.5 | 29 | 83 | 24.80 (2.94) | 20 | 34.25 |
| 8 | 24 | 26.41 (3.67) | 21.5 | 36 | 105 | 25.51 (2.85) | 20.25 | 35.5 |
| 9-10 | 38 | 27.34 (6.30)[a] | 21.5 | 61 | 184 | 26.80 (2.87)[ab] | 21 | 36 |

Table 2 (Cont.) - Sample descriptive characteristics (mean with SD, minimum and maximum) of anthropometry and body composition in the low birth weight (LBW) and normal birth weight (NBW) of children aged 7-10 years.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Triciptal skinfold (mm)** | | | | | | | | | | |
| 7 | 30 | 10.65 | (4.07) | 5 | 21 | 83 | 13.43 | (5.70) | 5 | 30 |
| 8 | 24 | 14.68 | (6.72)$^{a}$ | 5 | 30 | 105 | 12.71 | (5.16) | 4.5 | 29 |
| 9-10 | 38 | 12.34 | (4.89) | 5 | 23 | 184 | 14.02 | (5.88) | 5 | 34 |
| **Bicipital skinfold (mm)** | | | | | | | | | | |
| 7 | 30 | 6.683 | (2.77) | 3 | 15 | 83 | 7.879 | (4.09) | 3 | 22.5 |
| 8 | 24 | 8.770 | (4.80) | 3 | 19 | 105 | 7.328 | (3.61) | 3 | 22 |
| 9-10 | 38 | 7.407 | (3.63) | 3 | 16 | 184 | 7.970 | (4.12) | 3 | 20 |
| **Subscapular skinfold (mm)** | | | | | | | | | | |
| 7 | 30 | 8.933 | (6.85) | 3 | 31 | 83 | 10.30 | (7.62) | 3.5 | 33 |
| 8 | 24 | 11.87 | (9.84) | 4 | 41 | 105 | 9.433 | (6.48) | 3 | 36.5 |
| 9-10 | 38 | 10 | (6.47) | 4 | 30 | 184 | 11.49 | (8.40) | 3 | 41 |
| **Suprailiac skinfold (mm)** | | | | | | | | | | |
| 7 | 30 | 10 | (8.55) | 3 | 36 | 83 | 11.73 | (9.72) | 3 | 44 |
| 8 | 24 | 14.08 | (11.1) | 4 | 46 | 105 | 11.06 | (8.41) | 3 | 40 |
| 9-10 | 38 | 11.05 | (8.48) | 4 | 35 | 184 | 13.68 | (10.4) | 3 | 48.5 |
| **Calf skinfold (mm)** | | | | | | | | | | |
| 7 | 30 | 10.82 | (5.43) | 4 | 30 | 83 | 13.11 | (5.81) | 4 | 30.5 |
| 8 | 24 | 13.47 | (8.50) | 5 | 44 | 105 | 12.7 | (5.08) | 4 | 26 |
| 9-10 | 38 | 12.63 | (5.37) | 4 | 25 | 184 | 14.09 | (5.89) | 3.5 | 33.5 |
| **AMA** | | | | | | | | | | |
| 7 | 30 | 14.67 | (3.08) | 10.04 | 24.51 | 83 | 14.78 | (3.94) | 8.497 | 34.60 |
| 8 | 24 | 17.04 | (3.60)$^{a}$ | 10.35 | 24.60 | 105 | 15.47 | (3.10) | 9.390 | 24.31 |
| 9-10 | 38 | 17.42 | (2.89)$^{a}$ | 11.19 | 22.25 | 184 | 17.33 | (3.38)$^{ab}$ | 10.61 | 28.45 |
| **Body fat (%)** | | | | | | | | | | |
| 7 | 30 | 21.19 | (3.51) | 13.39 | 30.75 | 83 | 21.16 | (4.02) | 14.91 | 35.46 |
| 8 | 24 | 23.37 | (4.33) | 18.04 | 36.65 | 105 | 22.96 | (3.76)$^{a}$ | 15.51 | 34.53 |
| 9-10 | 38 | 24.58 | (3.79)$^{a}$ | 16.90 | 33.83 | 184 | 25.32 | (4.35)$^{ab}$ | 15.42 | 48.70 |
| **RMR ($KJ/d^{-1}$)** | | | | | | | | | | |
| 7 | 30 | 3363.0 | (602.) | 2438.8 | 4904.7 | 83 | 3482.5 | (678.0) | 2524.9 | 5836.7 |
| 8 | 24 | 3826.5 | (775.)$^{a}$ | 2911.2 | 5949.6 | 105 | 3657.1 | (627.6) | 2736.0 | 5625.0 |
| 9-10 | 38 | 3864.9 | (673.)$^{a}$ | 2808.6 | 5077.8 | 184 | 4041.0 | (735.7)$^{ab}$ | 2756.8 | 7232.2 |
| **DEE ($KJ/d^{-1}$)** | | | | | | | | | | |
| 7 | 30 | 4741.4 | (898.) | 3374.1 | 7056.3 | 83 | 4920.2 | (1016.9) | 3500.0 | 8479.4 |
| 8 | 24 | 5435.2 | (1167)$^{a}$ | 4067.8 | 8652.7 | 105 | 5179.9 | (941.8) | 3809.7 | 8155.0 |
| 9-10 | 38 | 5491.3 | (1013)$^{a}$ | 3916.5 | 8849.7 | 184 | 5756.4 | (1110.6)$^{ab}$ | 3840.3 | 10633. |

RMR, resting metabolic rate; DEE, daily energy expenditure; LBW, low birth weight; NBW, normal birth weight; AMA – Arm muscle area.
* P<0,05; ** P,0,001 – t student; $^{a}$ *vs* 7; $^{b}$ *vs* 8– ANOVA one way

Table 3 - Bivariate correlations (Spearman correlation coefficients, R) among resting metabolic rate, daily energy expenditure, birth weight, anthropometric and body composition variables.

| Variables | 7 years | | 8 years | | 9-10 years | |
|---|---|---|---|---|---|---|
| | Birth weight | RMR and DEE (KJ/d-1) | Birth weight | RMR and DEE (KJ/d-1) | Birth weight | RMR and DEE (KJ/d-1) |
| **Birth weight** | (-) | .090 | (-) | .141 | (-) | .148* |
| **Height** | 0.02 | .691** | 0.04 | .767** | 0.11 | .700** |
| **Sitting height** | 0.04 | .508** | 0.00 | .626** | .192** | .594** |
| **Waist circumference** | 0.01 | .819** | 0.12 | .872** | 0.08 | .845** |
| **Hip circumference** | 0.10 | .913** | 0.05 | .903** | 0.11 | .918** |
| **Head circumference** | -0.12 | .471** | .218* | .621** | .184** | .526** |
| **Arm circumference** | 0.08 | .866** | 0.04 | .898** | 0.08 | .859** |
| **leg circumference** | 0.10 | .887** | 0.08 | .873** | 0.11 | .897** |
| **Tricipital skinfold** | 0.07 | .702** | 0.08 | .678** | -0.02 | .643** |
| **Bicipital skinfold** | 0.15 | .718** | 0.08 | .723** | 0.04 | .715** |
| **Subscapular skinfold** | 0.07 | .685** | 0.06 | .701** | -0.03 | .777** |
| **Suprailiac skinfold** | 0.06 | .741** | 0.05 | .801** | -0.01 | .757** |
| **Calf skinfold** | 0.12 | .701** | 0.16 | .742** | 0.05 | .735** |
| **AMA** | -0.01 | .656** | -0.0 | .771** | 0.06 | .584** |
| **% Body Fat** | -0.01 | .825** | 0.14 | .900** | .211** | .825** |

* (p<0,05); ** (p<0,01); RMR, resting metabolic rate; DEE, daily energy expenditure; AMA – Arm muscle area

Table 4 - Linear regression coefficients showing estimated change in predictive variable to RMR and DEE over the years (7 to 10 years).

| | 7 Years | | 8 Years | | 9-10 years | |
|---|---|---|---|---|---|---|
| | ***RMR*** | ***DEE*** | ***RMR*** | ***DEE*** | ***RMR*** | ***DEE*** |
| **$r^2$ (SEE)** | .985 (79.5) | .987 (118.5) | .980 (95.1) | .981 (142.2) | 0.979 (108.9) | 0.979 (163.5) |
| ***F*** | 945.42** | 957.1 ** | 749.76** | 754.5** | 1201.24** | 1215.04** |
| **Residual excluded** | 1,184 | 1,949 | -5,084 | -7,384 | -2,106 | -3,047 |
| **$\beta_0$ (Constant)** | -508.15* | -1007.95* | -555.36* | -1091.3** | -996.6** | -1754.0** |
| **$\beta_1$ (Height)** | 6.2* | 9.1* | 8.68** | 12.71** | 8.81** | 12.75** |
| **$\beta_2$(Hip circumference)** | 10.5* | 15.08* | 10.3* | 15.2* | 5.94* | 8.81* |
| **$\beta_3$ (Leg circumference)** | 3.5 | 6.01 | -0.128 | -0.242 | 42.7** | 62.7** |
| **$\beta_4$ (Tricipital skinfold)** | 21** | 30.64** | 28.83** | 42.96** | 10.54* | 15.08* |
| **$\beta_5$ (Bicipital skinfold)** | -1.69 | -3.05 | -10.56* | -16.06* | 4.54 | 6.9 |
| **$\beta_6$ (Subscapular skinfold)** | 23.32** | 35.13** | 17.5** | 26.68** | 21.02** | 32.24** |
| **$\beta_7$ (Suprailiac skinfold)** | 1.5 | 3.1 | 7.89* | 12.2* | 7.1* | 10.66* |
| **$\beta_8$ (% Body Fat)** | 90.0** | 135.05** | 80.2** | 120.83** | 68.6** | 104.91** |

* (p<0,05); ** (p<0,01); RMR, resting metabolic rate; DEE, daily energy expenditure.

The linear model for *RMR* and *DEE* from 7 to 10 years old children is:

$$RMR \text{ or } DEE = \beta_0 + \beta_1 H + \beta_2 HC + \beta_3 LC + \beta_4 TS + \beta_5 BS + \beta_6 SBS + \beta_7 SPS + \beta_8 BF.$$

where *H*, height; *HC*, hip circumference; *TS*, tricipital skinfold; *BS*, bicipital skinfold; *SBS*, subscapular skinfold; *SPS*, suprailiac skinfold; *BF*, body fat, and the values for constants $\beta_0, \ldots, \beta_8$ are lie in Table 3.

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# APPENDIX

**APENDIX A –** Termo de consentimento livre e esclarecido

## TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Nome da Pesquisa: Programação Perinatal, desenvolvimento neuro-motor, aptidão física e composição corporal: estudo com crianças dos 7 aos 10 anos de idade da Zona da Mata do Estado de Pernambuco
Pesquisador responsável: Carol Virginia Góis Leandro – Marcos André Moura dos Santos
Universidade Federal de Pernambuco
Av. Porf. Moares Rego, s/n – Cidade Universitária
CEP:50670-901 – Recife /Pernambuco
Fone: (081) 2126-8588

O seu filho foi escolhido entre as crianças que nasceram no Município Vitória de Santo Antão no período de 1999 a 2003, para fazer parte de um estudo a ser realizado pelo Centro Acadêmico de Vitória- UFPE, que tem como objetivo avaliar o nível de aptidão física, o desenvolvimento neuromotor (coordenação corporal e equilíbrio), o nível de atividade física diário, bem como avaliar algumas medidas corporais. Para avaliarmos o perfil de crescimento, estado nutricional, aptidão física, a coordenação e o equilíbrio corporal do seu filho, vamos precisar medir o seu peso corporal, altura em pé e sentado, circunferência da cabeça, do braço, da cintura e do quadril e os depósitos de gordura do corpo. Realizaremos também testes de: velocidade, força, resistência, agilidade, flexibilidade e um teste de coordenação e equilíbrio corporal. Ainda será aplicado um questionário para saber sobre as atividades físicas diárias do seu filho durante uma semana. Vamos também avaliar a pressão sanguínea. Essas avaliações serão realizadas em dois momentos e as crianças serão levadas para o Centro Acadêmico de Vitória em uma condução especifica deste projeto.

## CONSENTIMENTO DO PACIENTE

Li e entendi as informações descritas neste estudo e todas as minhas dúvidas em relação à participação do meu filho ________________________________nesta pesquisa, sendo estas respondidas satisfatoriamente. Dou livremente o consentimento para participação do meu filho neste estudo até que decida pelo contrário.

Assinatura do pai ou responsável:_____________________________Data:______________
PESO DE NASCIMENTO DA CRIANÇA:_______________________________________
NOME COMPLETO DA MÃE:___________________________________________________
NASCIDO EM VITORIA ( ) SIM ( ) NÃO

**DECLARAÇÃO DO PESQUISADOR**

Declaro que obtive de forma apropriada e voluntária o consentimento livre e esclarecido deste pai ou responsável para a participação nesta pesquisa.

Assinatura do pesquisador:____________________________________Data:_________

**APPENDIX B -** Comunicado aos pais ou responsáveis sobre os procedimentos, avaliações e testes.

# C O M U N I C A D O

Prezado senhor (a) responsável pelo aluno (a)

____________________________________________

Comunicamos que estamos iniciando a **COLETA** de dados do ***PROJETO PROGRAMAÇÃO FETAL DESENVOLVIMENTO NEUROMOTOR E APTIDÃO FISICA: ESTUDO COM CRIANÇAS DE 7 A 10 ANOS DA ZONA DA MATA DO ESTADO DE PERNAMBUCO.***

Informamos que a avaliação das medidas antropométricas e testes motores será realizada nesta XXXXXXXXXXXXXXX podendo escolher entre o horário da manhã ou a tarde.

Na ocasião iremos entregar uma CAMISA do nosso projeto como forma de agradecer pela valiosa participação em nossa pesquisa. Por isso é muito IMPORTANTE que você compareça a esta avaliação.

Desde já renovamos os nossos sinceros votos de elevada estima e consideração,

Atenciosamente,

Prof$_o$ Ms. Marcos Andre Moura dos Santos

Coordenador do Projeto: Programação Fetal, desenvolvimento neuromotor e aptidão física: estudo com crianças dos 7 aos 10 anos da Zona da Mata do Estado de Pernambuco

Universidade Federal de Pernambuco-PE, Recife - Pernambuco

Em, Recife, de 2009

**APPENDIX C** – Ficha de avaliação antropométrica

FICHA DE AVALIAÇÃO ANTROPOMÉTRICA

NOME:________________________________________________IDADE:_________

NASC.______ /_____/_____ DATA ALIAÇÃO:_____/______/______

P. ARTERIAL: 1. _______/________ 2. ______/________ 3. ______/_______

Peso (Kg)..................................... [ ] Peso ao nascer (g): [ ]

Altura (cm).................................... [ ]

Altura sentado (cm)....................... [ ] **(-50cm banco)**

| **Perímetros** | DIR | ESQ. |
|---|---|---|
| Perímetro do Braço Relaxado (cm)........ | | |
| Perímetro Geminal (cm)........................ | | |
| Perímetro da Cintura (cm)................. | | |
| Perímetro do Quadril (cm)................. | | |
| Perimetro Cefálico (cm)......................... | | |

| **Gordura subcutânea** | | | |
|---|---|---|---|
| Tricipital SKF (mm).............................. | | | |
| Bíceps SKF (mm)................................. | | | |
| Suprailiaca (mm)........................... | | | |
| Subescapular SKF(mm)........................ | | | |
| Coxa medial SKF (mm)........................ | | | |
| Panturrilha media SKF (mm)................ | | | |

# ANNEXES

**ANNEX A –** Parecer do comitê de ética

ANEXO III

SERVIÇO PÚBLICO FEDERAL
UNIVERSIDADE FEDERAL DE PERNAMBUCO
Comitê de Ética em Pesquisa

Of. Nº. 231/2009 - CEP/CCS

Recife, 20 de agosto de 2009

Registro do SISNEP FR – 261629
CAAE – 0175.0.172.000-09
Registro CEP/CCS/UFPE Nº 178/09
Titulo: **"Programação perinatal e desenvolvimento neuromotor: estudo com crianças dos 7 aos 10 anos da Zona da Mata do Estado de Pernambuco".**

Pesquisadora Responsável: Carol Virginia Góis Leandro.

Senhora Pesquisadora:

Informamos que o Comitê de Ética em Pesquisa Envolvendo Seres Humanos do Centro de Ciências da Saúde da Universidade Federal de Pernambuco (CEP/CCS/UFPE) registrou e analisou, de acordo com a Resolução N.º 196/96 do Conselho Nacional de Saúde, o protocolo de pesquisa em epigrafe, aprovando-o e liberando-o para inicio da coleta de dados em 20 de agosto de 2009.

Ressaltamos que o pesquisador responsável deverá apresentar o relatório ao final da pesquisa.

Atenciosamente

Prof. Geraldo Bosco Lindoso Couto
Coordenador do CEP/ CCS / UFPE

Geraldo Bosco Lindoso Couto
Coordenador do CEP/CCS/UFPE

A
Dra. Carol Virginia Góis Leandro
Departamento de Nutrição - CCS/UFPE

Av. Prof. Moraes Rego, s/n Cid. Universitária, 50670-901, Recife - PE, Tel/fax: 81 2126 8588; cepccs@ufpe.br

**ANNEX B** – Questionário de avaliação do nível de atividade Física Habitual

**Questionário de Atividade Física Habitual**

**(Godin & Shephard, 1985)**

Nome:_______________________________________________ Sexo:_______
Data da Avaliação:___/_____ /2009
Com que você reside: ______________________________________________________

1. Considere num período de 7 dias (uma semana) quantas vezes, em média, você realiza diferentes tipos de exercícios por mais de 15 minutos durante o seu tempo livre (escreve em cada linha o número apropriado).

a) **Exercícios e**
o Coração [illegible]
corridas, futebol, basquete, judô, natação vigorosa, longos percursos vigorosos de bicicleta.

**Nº de vezes por semana**

| |
|---|
| |

b) **Exercícios moderados (não exaustivos)**: (ex.: caminhadas rápidas, voleibol, percursos lentos de bicicleta, natação não exaustiva, dança etc).

**Nº de vezes por semana**

| |
|---|
| |

c) **Exercício suave:** esforço mínimo (ex.: yoga, caminhadas lentas, pesca, etc).

**Nº de vezes por semana**

| |
|---|
| |

2. Considere num período de 7 dias (uma semana), durante o seu tempo de lazer, quantas vezes realiza uma atividade física suficientemente longa para suar (transpirar), em que o coração bate rapidamente?

______ Nunca/raramente _______ Às vezes ________ Muitas vezes