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Original article

Metabolic characteristics of Appalachian children☆

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SUMMARY

Purpose: The purpose of this investigation is to assess the physiological characteristics and the resting metabolic rates of a representative population of children in Buchanan County in order to identify those factors that may be contributing to the predisposition for being overweight or obese and provide nutritional and physical activity guidance for prevention.
Methods: Twenty-three volunteers from grades 5, 6 and 7 from Buchannan County, VA underwent parametric and metabolic testing over three consecutive years in order to determine their height, weight, BMI, percent body fat, resting oxygen consumption (VO_2), resting energy expenditure (REE), respiratory exchange ratio (RER) and daily energy expenditure (DEE) and consumption.
Results: Over the 3 year study period, subjects' BMI increased significantly over time ($p = 0.001$) while there were no changes in their, REE, RER, VO_2, percent fat and DEE. However, there was a moderate negative correlation between VO_2 and BMI in grade 5 ($r = -0.578$, $p = 0.002$), grade 6 ($r = -0.477$, $p = 0.015$) and grade 7 ($r = -0.438$, $p = 0.023$). Gender specific differences in percent body fat were evident among subjects during the last two measurement cycles and were strongly correlated with BMI ($r = 0.907$, $r = 0.959$, $p = 0.000$).
Conclusions: The use of resting VO_2, REE, and RER values as a screening tool for identifying those children or adolescents at risk for becoming overweight or obese is most likely cost and time prohibitive due to the need for several repeated measures to ensure accurate results. However increased VO_2 is correlated with decreased BMI.

1. Introduction

The prevalence of obesity in the adult population of the United States continues to climb and is currently a staggering 37.7% (CDC/NCHS, 2015) [1,2], Geographically, the states with counties in the top quintiles in both obesity and diabetes prevalence were concentrated in the South and Appalachian region [3]. Specifically, Virginia has a an obesity rate of 28.5%, while the surrounding states are even worse with rates of 31.6% for KY, 29.7% for NC, 31.2% for TN and 35.7% for WV [1]. Furthermore, the latest National Health and Nutrition Examination Survey (NHANES) indicates that the prevalence of obesity among children and adolescents (youths) aged 2–19 years is a dismal 17.2% [1]. The NHANES has tracked the trends in obesity among youths over the past 38 years as displayed in Table 1. It appears that obesity among the youths increased until 2003–04 then plateaued through 2013–14.

2. Background

The weight status of children is defined on the basis of the sex-specific smoothed percentile curves for BMI-for-age in the 2000 CDC growth Charts. Extreme obesity is defined as a BMI at or above the 120% of the 95th percentile for children of the same age and sex. Childhood obesity is categorized by body mass index (BMI) specific to the child's age and sex. A BMI between the 85th and 95th percentiles is considered overweight (usually 25–29.9), while a BMI at or above the 95th percentile (>30–35) is considered obese [7,8]. Extreme obesity is defined as a BMI at or above the 120% of the 95th percentile for children of the same age and sex [9].

Childhood obesity may lead to a daunting number of health related problems including: diabetes when the BMI > 30 with a

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Table 1
Trend in obesity among children and adolescents aged 2–19 [4–6].

Obesity prevalence among children and adolescents in the US						
Age	Survey time periods					
	NHANES II 1976–1980	NHANES III 1988–1994	NHANES 1999–2002	NHANES 2003–2006	NHANES 2011–2012	NHANES 2013–2014
2–5	5%	7.2%	10.3%	12.4%	8.4%	8.9%
6–11	6.5%	11.3%	15.8%	17.0%	17.7%	17.5%
12–19	5%	10.5%	16.1%	17.6%	20.5%	20.5%

prevalence of 4.1/1000, metabolic syndrome in 30–50% of overweight children and 4% in adolescents, hyperandrogenism, menstrual disorders and early onset of polycystic ovarian syndrome (PCOS), hyperinsulinemia, heart disease, development of early aortic and coronary arterial fatty streaks and fibrous plaques in children as young as 3–8 yrs old, hypertension, respiratory problems (recoil & lung volume), sleep disorders, obstructive sleep apnea, nonalcoholic fatty liver disease, gallbladder disease, growth plate injury, slipped capital femoral epiphysis, genu valga, tibia vara, knee pain, flat feet, scoliosis, osteoarthritis, acanthosis nigricans, skin tags, keratosis pilaris, pseudotumor cerebri, GERD, constipation, elevated cholesterol and triglycerides [10–12]. It follows that the presence of adolescent obesity increases the risk of remaining obese as an adult [12–14]. Steinberger J. et al. [15] found that the correlation between BMI at age 13 and age 22 was 0.75, $p = 0.0001$ and Franks PW et al. [16] found that children in the highest BMI quartile had more than double the endogenous death rate when adults, as children in the lowest BMI quartile. Furthermore, the National Cholesterol Education Program (NCEP) highlighted the findings that children and adolescents with elevated cholesterol are more prone to have high levels as adults [17]. Adults have a choice regarding whether they become or remain obese but, the World Health Organization (WHO) states that government and society have a moral responsibility to act on behalf of the child to reduce the risk of obesity [18].

The pathophysiology underlying obesity relates to the flow of energy in living systems obeying the 1st law of thermodynamics which states that energy can be transformed, but it cannot be created or destroyed [19]. This translates into if kcals in are greater than kcals out, you will gain weight! Unfortunately, people continually try to rationalize weight gain by blaming genetic or environmental or metabolic deficiencies but, the bottom line is if you have any predisposition for weight gain then you must either reduce your caloric intake or increase your caloric output in order to further compensate for the potential energy excess.

So, how do we find a balance between intake and output? Most of us simply step on the bathroom scale and if we have gained some weight it means we are either eating too much or exercising too little. Our basal metabolic rate dictates how much energy (kcals) we need in order to maintain basal body functions without a net weight gain or loss. The body utilizes the breakdown of Adenosine Triphosphate (ATP) as its energy source. The regeneration of this ATP is generally an oxidative process breaking down consumed carbohydrates, proteins and fats which ultimately utilizes the electron transport chain located in the mitochondria and requires oxygen. Therefore the amount of oxygen consumed reflects the amount of ATP regenerated. Conversely, the amount of energy utilized by the body in the form of ATP is reflected in the amount of oxygen consumed. By measuring the amount of oxygen taken in at rest we can calculate the number of calories generated by the body's resting metabolism or Resting Energy Expenditure (REE) [20]. When CHO, proteins or fats are metabolized, oxygen (O_2) is used and carbon dioxide (CO_2) is produced. We can measure O_2 uptake and CO_2 production by the mitochondria indirectly by measuring the gas exchange occurring at the mouth during each breath. By examining the ratio of O_2 consumed versus CO_2 produced, termed the Respiratory Exchange Ratio (RER) [20], we can determine what type of food stuff is being metabolized. For example if one molecule of glucose is metabolized using the formula:

$$6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 38ATP$$

$$RER = VCO_2/VO_2 = 6CO_2/6O_2 = 1.0$$

And for fat:

$$23O_2 + C_{16}H_{32}O_2 \rightarrow 16CO_2 + 16H_2O + 129ATP$$

$$RER = VCO_2/VO_2 = 16CO_2/23O_2 = 0.7$$

We can extrapolate these relationships for a normal diet with normal amounts of carbohydrate, protein and fat to produce an average R value of 0.825 which is equivalent to 4.825 kcal/L of oxygen consumed [20]. If we measure resting oxygen consumption we can then calculate an individual's basal daily energy expenditure or basal metabolic rate fairly accurately. This value represents how many kcals a person at rest needs to take in each day in order to maintain body weight. If daily energy expenditure exceeds this basal amount, the individual will lose weight or if caloric intake exceeds expenditure, the person will gain weight. With knowledge of one's true daily caloric needs then decisions regarding lifestyle changes affecting caloric intake or exercise prescription can be made to improve that individual's health and/or wellness.

2.1. Purpose

The purpose of this investigation is to assess the physiological characteristics and the resting metabolic rates of a representative population of children in Buchanan County in order to: 1) Identify those children with low basal caloric needs that predisposes them to being overweight or obese. 2) Identify those children with high R values representing disproportionate CHO intake or reliance on CHO metabolism. 3) Compare daily caloric intake versus output in order for individuals and families living in Rural Appalachia to better understand their present metabolic state and associated need for either decreased/increased caloric intake or increased/decreased exercise or a combination of both. 4) Provide education and strategies for all students regarding healthy nutritional practices and exercise programs. 5) Collect individual parametric and metabolic data annually for three years in order to track any trend towards becoming overweight or obese and/or track progress of any interventions. 6) Provide healthcare related professionals with information that can help them better understand current local trends in children being overweight or obese. This information