The Role of Fetuin-A in Disease Processes Prevalent in Postmenopausal Women

El papel de la fetuina A en los procesos de enfermedad prevalentes en mujeres posmenopáusicas

Annie A. Bane & Peter W. Grandjean
Baylor University, USA

Abstract. The purpose of this review is to summarize the role of fetuin-A in disease processes prevalent in postmenopausal women and synthesize effective interventions in obtaining healthy fetuin-A levels. A review of databases for articles related to fetuin-A and diseases associated with postmenopausal women was conducted. Articles were limited to full-text access, published in English since 1944. High fetuin-A levels are closely associated with decreased bone mineral density, increased cardiovascular disease risks, impairment of insulin signaling and disruption of adipocyte functioning. Postmenopausal women have increased risk of osteoporosis, cardiovascular disease, insulin-resistance, intra-abdominal fat accumulation and vascular calcification. Low-levels of fetuin-A have been shown to be protective against the latter. The role of fetuin-A is multi-factorial and the mechanisms in which it is involved in each of these processes are vast. The present body of literature is inconsistent in defining high versus low levels of fetuin-A and their association with healthy-matched controls. The diseases associated with high levels of fetuin-A mimic diseases most prevalent in postmenopausal women. In addition, there is no research, to date, exploring fetuin-A levels in postmenopausal women and the associations it may or may not have in related diseases.

Key words: fetuin-A, Alpha2-Heremans-Schmid glycoprotein, cardiovascular disease; and elderly, insulin-resistance, intra-abdominal fat, metabolic syndrome, exercise, weight-loss, calorie restriction and postmenopausal.

Resumen. El propósito de esta revisión es sintetizar el papel de la fetuina A en los procesos de enfermedad prevalentes en mujeres posmenopáusicas y resumir las intervenciones efectivas que permiten obtener niveles saludables de fetuina A. Para ello, se revisaron bases de datos con artículos relacionados con fetuina A y las enfermedades asociadas con mujeres posmenopáusicas. Se buscó a artículos de la sección de texto completo publicados en el idioma inglés desde el año 1944. Se encontró que altos niveles de fetuina A están íntimamente relacionados con una reducción de la densidad mineral ósea, un aumento en el riesgo de enfermedad cardiovascular, deterioro de la señalización de la insulina y la alteración del funcionamiento de los adipocitos. Las mujeres posmenopáusicas tienen un mayor riesgo de osteoporosis, enfermedad cardiovascular, resistencia a la insulina, acumulación de grasa intra abdominal y calcificación vascular. Se ha demostrado que niveles bajos de fetuina A son protectores contra esta última condición. El papel de fetuina A es multifactorial y los mecanismos en los que está involucrado en cada uno de estos procesos son muy amplios. El estado actual de la literatura no es consistente en la definición de niveles de fetuina A altos versus bajos y su asociación con controles sanos. Las enfermedades asociadas con altos niveles de fetuina A asumen las enfermedades más prevalentes en mujeres posmenopáusicas. Además, no existen investigaciones, hasta la fecha, en las que se exploren los niveles de fetuin-A en mujeres posmenopáusicas y las asociaciones que puede o no puede tener en las enfermedades relacionadas.

Palabras claves: fetuina A, glicoproteína Alpha2-Heremans-Schmid, enfermedad cardiovascular, adulto mayor, resistencia a la insulina, grasa intra abdominal, síndrome metabólico, ejercicio, pérdida de peso, restricción calórica, posmenopausia.

Introduction

Fetuin-A is a circulating glycoprotein that plays a critical role in bone homeostasis (Price, Toroian, & Lim, 2009), prevention of vascular calcification (Schäfer et al., 2003), impairment of insulin signaling (Goustin & Abou-Samra, 2011) and disruption of adipocyte functioning (Rasul, Wagner, & Kautzky-Willer, 2012). Arguably, the role this liver-phosphorylated glycoprotein plays in the prevention and/or amplification of these disease processes seems to be concentration dependent. High levels of fetuin-A have been associated with diseases such as type-2 diabetes mellitus (T2DM), obesity (Schultes, Frick, Ernst, Stefan, & Frische, 2010) and metabolic syndrome (Ix et al., 2006). An increase in myocardial infarction and stroke are also positively correlated with increased fetuin-A blood concentrations (Ix, Wasse & Kanaya et al., 2008). Low levels, however, have been linked to both detrimental and beneficial health effects (Mehrotra, 2007; Price et al., 2009). Higher mortality rates in patients with chronic kidney disease (CKD) have been closely linked to low circulating fetuin-A (Mehrotra, 2007). Conversely, low levels have a potentially protective effect on arterial calcification in non-CKD patients (Schäfer et al., 2003).

High-levels of fetuin-A seem to be of utmost concern in populations at higher risk of diabetes and cardiovascular disease (CVD). In addition to being at higher risk than pre-menopausal women and age-matched men for diabetes and CVD, postmenopausal women have decreased bone mineral density and increased abdominal fat (Tchernof, Toth, & Poehlman, 1999). The negative health impact that occurs in these women can adversely affect quality and quantity of life. In fact, the risk of CVD, insulin resistance and metabolic syndrome have been shown to rise substantially in postmenopausal women compared to age-matched premenopausal women (Janssen, Powell, Crawford, Lasley, & Sutton-Tyrrell, 2008; Lemieux, Prud’homme, Bouchard, Tremblay, & Després, 1993; Sutton-Tyrrell et al., 2005). A decrease in ovarian production of estrogen and progesterone has been linked to an increase in insulin resistance (Sathya Bhaum, Bali, & Seethalakshmi, 2012), intra-abdominal fat (Tchernof, Calles-Escandon, Sites, & Poehlman, 1998) and increased inflammatory markers (Hennig et al., 2008), all of which are associated with metabolic syndrome and cardiovascular disease. Studies determining fetuin-A levels in postmenopausal women are non-existent. High levels have been reported in women with T2DM (Ley et al., 2014), polycystic ovary syndrome (Enli, Fenkci, Fenkci, & Oztekin, 2013), morbid obesity (Brix et al., 2010) and obesity (Schultes et al., 2010). Postmenopausal women, particularly, have the highest prevalence of these diseases combined.

The purpose of this review is to summarize the role of fetuin-A in disease processes prevalent in postmenopausal women and synthesize effective interventions in obtaining healthy fetuin-A levels. The role that fetuin-A plays in adipocyte functioning, insulin resistance, inflammation and CVD will be explained. In addition, the physiological alteration that postmenopausal women demonstrate in all of these areas will also be addressed. The importance of this literature review is to initiate a discussion in the importance of fetuin-A’s role in menopause-related diseases and to find interventions that make this population less susceptible to these health complications.

This review of literature included searches of the databases PubMed, Medline, EBSCOhost, Google Scholar and Academic Search Complete for related articles published in English since 1944. Search terms included: fetuin-A or Alpha2-Heremans-Schmid glycoprotein in combination with: cardiovascular disease and elderly, insulin-resistance, intra-abdominal fat, metabolic syndrome, exercise, weight-loss, calorie restriction and postmenopausal. There are currently no papers (reviews or original research) that look specifically at postmenopausal women and levels of fetuin-A. Due to the lack of research done in the area, a subsequent search was done to provide a review on fetuin-A-related diseases and postmenopausal women. Search terms included: postmenopausal and premenopausal in combination with insulin resistance, cardiovascular...
disease, intra-abdominal fat and calcification. Papers were included that pertained to diseases and/or conditions in which postmenopausal women are most susceptible to. Eighty-nine articles were included in this review; of which, 38 were original research about fetuin-A, 3 were a review of fetuin-A in cardiovascular disease, 1 was a review of modifications of fetuin-A ELISA kits, 22 included a review on the menopausal prevalence of disease and/or hormonal changes, 14 were original research with menopause and insulin resistance or metabolic syndrome, 3 were longitudinal studies with menopause and heart disease and 8 were pertaining to menopause and central-fatness and/or intra-abdominal fat.

The lack of research regarding fetuin-A and postmenopausal women was very limiting in compiling this review. The lack of research in homogenous populations made it difficult to compare interventions and their effectiveness in lowering fetuin-A. Moreover, the inconsistency of categorized concentrations of low versus high fetuin-A levels made studies hard to compare. In addition, linking diseases associated with menopause and mechanisms of fetuin-A has not been done. The assortment of literature for menopause and related diseases are vast, yet fetuin-A and menopause is non-existent in current literature.

Physiological Function of Fetuin-A

Fetuin was first isolated from bovine serum in 1944 (Pedersen, Kai O, 1944). The human form of fetuin is known as Alpha2-Heremans-Schmid glycoprotein (AHSG). Structurally, this glycoprotein has binding sites for hydroxyapatite (Heiss et al., 2003) and transforming growth factor-Beta (TGF-Beta) (Demetriou, Binkert, Sukhu, Tenenbaum, & Dennis, 1996), which help to partially explain fetuin-A’s role in bone homeostasis. Hydroxyapatite is a major component and essential ingredient for normal bone and teeth development and maintenance. The TGF-Betas are plasminogen activators, which are implicated in a wide variety of cell functions, critically regulating inflammation, extracellular matrix deposition, cell proliferation, differentiation and growth (Dobuzinskis, Chen, & Frangogiannis, 2011). Fetuin-A is rapidly downregulated under acute inflammation and, thus, classified as a negative acute-phase protein (Gangneux et al., 2003). Acute inflammation occurs minutes following injury of tissues when blood flow, permeability and migration of neutrophils are increased (Kumar, Abbas, Fausto, & Mitchell, 2012). Acute injury can occur after infections, thermal injury (sunburn), and splinters and gastric ulcers. Interestingly, in diseases where chronic inflammation is a notable characteristic, as in obesity, CVD or T2DM, fetuin-A is upregulated (Choi et al., 2013; Rasal et al., 2012).

The multi-factorial function of fetuin-A might be further explained by the phosphorylated form of the glycoprotein. Fetuin-A present in blood exists in both active (phosphorylated) and inactive (dephosphorylated) forms. Apart from its role in bone regulation, fetuin-A must be phosphorylated to be physiologically active in mammals (dephosphorylated) forms. Apart from its role in bone regulation, fetuin-A is related to N-linked and O-linked glycosylation (Gejyo et al., 1983). This very modification of fetuin-A may help to explain the plasma-concentration discrepancies in visceral fat content and fetuin-A in elderly subjects (73±3) (Ix et al., 2009). Fetuin-A levels in individuals with morbid obesity (877±318µg/mL), coronary artery disease (640±13µg/mL) (Ix et al., 2006), obesity (440µg/ mL) (Schultes et al., 2010) and peripheral artery disease and T2DM (411.19±163µg/mL) (Lorant et al., 2011) were well above the normal concentrations. Interestingly, all studies included in Table 1 described fetuin-A levels as high, yet the remaining fell below the normal range reported in adults. The lowest fetuin-A level reported in a clustered cohort (230.2±135.9µg/mL) was in a cross-sectional study evaluating arterial stiffness in women (41±10 years of age) (Yang et al., 2011). Other sub-300µg/mL levels included studies evaluating myocardial infarction and ischemic stroke (Weikert et al., 2008), hyperinsulinemia (Stefan et al., 2006) and T2DM with and without atherosclerosis (Emoto et al., 2010).

Very few studies examined fetuin-A levels in diseases versus non-diseased states. In fact, only studies examining myocardial infarction and ischemic stroke (Weikert et al., 2008), morbid obesity (Brix et al., 2010) and peripheral artery disease in T2DM (Lorant et al., 2011) were matched with a healthy-controlled counterpart. Interestingly, high levels of fetuin-A were used to describe all diseased conditions displayed in Table 1. All reported significant differences in concentrations of disease in comparison to healthy-controls. Perhaps a more definitive concentration of what is considered healthy-normal and observed normal levels of fetuin-A would be better understood. This would help to strengthen the definition of high and low fetuin-A levels in studies without healthy, non-diseased counterparts.

Endocinjal Changes in Menopause

The endocinjal changes that occur in postmenopausal women have a steep decline in hormone levels and have been associated with adverse health issues. Particularly, the decrease in ovarian production of estrogen and progesterone has been linked to an increase in insulin resistance (Simpson, Merrill, Hollub, Graham-Lorenze, & Mendelson, 1989), hyperinsulinemia (Tchernof et al., 1998), intra-abdominal fat (Sathya, 2010) and peripheral artery disease in T2DM (Emoto et al., 2006) and T2DM with and without atherosclerosis (Lorant et al., 2011).

Table 1. Fetuin-A levels reported in various diseases and conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Ages</th>
<th>Fetuin-A Levels</th>
<th>Referece</th>
</tr>
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<tbody>
<tr>
<td>Visceral adiposity in Elderly</td>
<td>73±3</td>
<td>30±9 g/mL</td>
<td></td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>67±10</td>
<td>64±13 µg/mL</td>
<td></td>
</tr>
<tr>
<td>Obesity</td>
<td>43±13</td>
<td>46±6 µg/mL</td>
<td></td>
</tr>
<tr>
<td>Myocardial Infarction</td>
<td>54±8</td>
<td>253±83 µg/mL</td>
<td></td>
</tr>
<tr>
<td>Ischemic Stroke</td>
<td>59±8</td>
<td>248±78 µg/mL</td>
<td></td>
</tr>
<tr>
<td>NAFLD</td>
<td>56±6</td>
<td>420±10 µg/mL</td>
<td></td>
</tr>
<tr>
<td>T2DM &amp; Atherosclerosis</td>
<td>65±8</td>
<td>262±85 µg/mL</td>
<td></td>
</tr>
<tr>
<td>T2DM</td>
<td>60±11</td>
<td>281±84 µg/mL</td>
<td></td>
</tr>
<tr>
<td>Mortal Obesity</td>
<td>43±10</td>
<td>872±138 µg/mL</td>
<td></td>
</tr>
<tr>
<td>Arterial Stiffness</td>
<td>45±13</td>
<td>230±13 µg/mL</td>
<td></td>
</tr>
<tr>
<td>Periferal Artery Disease + T2DM</td>
<td>62±6</td>
<td>41.1±16 ±µg/mL</td>
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</table>
In past studies, estrogen therapy has been shown to decrease coronary heart disease (Williams, Adams, & Klopfenstein, 1990). Recent studies, however, show that hormone replacement treatment has been shown to be ineffective in preventing cardiovascular disease events and may, in fact, increase the risk of stroke and venous thromboembolic events (Main et al., 2013). Hormone replacement therapy is a combination of estrogen and progesterone, however, and not estrogen alone. Fertile women are most protected from cardiovascular disease among adults (Vaccarino et al., 2011). The protective mechanisms that estrogen may have on cardiovascular disease has been shown to attenuate cardiovascular oxidative stress two-fold: first, by preventing generation of reactive oxygen species and second, by scavenging reactive oxygen species in the myocardium and in the vasculature (Arias-Loza, Muehlfelder, & Pelzer, 2013).

There are no studies, to the authors knowledge, that exist that show correlation between estrogen reduction and changes in fetuin-A levels. An indirect relationship between fetuin-A and estrogen can be inferred due to the increased prevalence of disease in women who experience rapid declines in estrogen due to menopause.

**Factors Influencing Fetuin-A**

There are a range of factors influencing fetuin-A and the roles this glycoprotein may play in various diseases and/or conditions. Fetuin-A has shown to be protective against atherosclerosis at low levels (Schäfer et al., 2003). High levels have been shown to increase various CVD risk factors (Weikert et al., 2008). In addition, insulin resistance (Catalano et al., 2008) and increased intra-abdominal fat (Hennige et al., 2006) have been associated with high levels. In this section, a summary of fetuin-A’s role in numerous diseases and/or conditions and their parallel prevalence in postmenopausal women are addressed.

**Cardiovascular Disease**

The roles of fetuin-A in cardiovascular disease seem to be contrasting in various pathogenetic mechanisms such as calcification, inflammation and insulin resistance (Weikert et al., 2008). Although low levels of fetuin-A have been shown to have a protective effect against calcification (Schäfer et al., 2003), high levels have been associated with increased risk of cardiovascular disease (Choi et al., 2013). High fetuin-A levels had an approximate 4-fold increase in the risk for myocardial infarction and stroke compared to patients presenting low fetuin-A levels in a 8-year follow-up case-cohort study of over 27,000 individuals who averaged 54 years of age (Weikert et al., 2008).

Arterial stiffness has also been associated with high levels of fetuin-A. An association between increased fetuin-A and metabolic syndrome phenotypes and atherogenic lipid profile in 711 non-diabetics with metabolic syndrome (Catalano et al., 2008). The association between high levels of fetuin-A and increased hypertension, body mass index, inflammatory markers, low-density lipoproteins, triglyceride concentrations and lower high-density lipoproteins. While low fetuin-A levels in younger men have been shown to be associated with decreased cardiovascular markers such as high blood pressure and cholesterol (Hennige et al., 2008) a case cohort study showed that in subjects with low-cholesterol, fetuin-A may be more closely associated with cardiovascular disease. Low levels have also been associated with peripheral artery disease in T2DM (Eraso et al., 2010). The link between fetuin-A and inflammation has also been shown in individuals with carotid arterial stiffness (Mori et al., 2007).

CVD increases substantially after the transition of menopause. Premenopausal women appear to be protected from cardiovascular disease compared with men of the same age, a finding that is similar to insulin resistance in young age-matched males and females (Lejsková, Alášik, Suchánek, Zecová, & Pítha, 2011). In a nine-year follow-up study, cardiovascular metabolic risk in postmenopausal women was found independent of other cardiovascular disease risk factors (Ramezani Tehrani, Behboudi-Gandevani, Ghanbarian, & Azizi, 2014). Primary findings of this study revealed women who had experienced menopause compared to those who had not, showed increased serum concentrations of low-density lipoproteins and total cholesterol. It is well-established that the risk of CVD increases as age increases. The occurrence of cardiovascular disease, however, is different in men versus women. In fact, the average onset of cardiovascular disease is delayed ten years in women compared to age and health-risk matched men (Kim & Reaven, 2013). Statistics from industrialized nations from 2007 show that more women than men die of cardiovascular disease (Rosemondi et al., 2007). The acceleration of the development of CVD in women has largely been attributed to adverse health complications due to menopause.

**Calcification**

The beneficial effects of low levels of fetuin-A have been shown to inhibit spontaneous calcium phosphate precipitation, acting as a protective mechanism for atherosclerosis and peripheral artery disease (Schäfer et al., 2003). It has been proposed this is due to fetuin-A’s involvement in bone homeostasis (Heiss et al., 2003). In a homeostatic bone, less calcium phosphate precipitation means that less calcium is being pulled from the bone, decreasing the calcification of blood vessels. An inverse association with the presence of atherosclerotic calcified plaques and fetuin-A plasma levels in humans has been presented (Emoto et al., 2010). Animal studies have also shown low levels of fetuin-A to be an inhibitor of vascular calcification (Schinke et al., 1996). In patients with End Stage Renal Disease (ESRD) low levels of fetuin-A were associated with increased cardiovascular and all-cause mortality. The increased vascular calcification in patients with renal disease with low fetuin-A levels is likely to be the mechanism for increased mortality in ESRD patients (Mehtrotra, 2007). Hemodialysis has been shown to independently decrease fetuin-A levels (Stout, 1990), possibly decreasing them past the threshold of optimal levels for calcification protection. Individuals with mitral and aortic calcification and stenosis have shown an inverse relationship with fetuin-A (Ix et al., 2007). In this study, levels of fetuin-A were not labeled as «high» or «low». In fact, fetuin-A levels ranged from 590-700 g/mL. As seen in Table 1, these levels would be considered high in many cases. These findings may shed light on the importance of fetuin-A in bone homeostasis to prevent calcification of arteries, especially in diseased states. The level in which bone-homeostasis is optimal has not been studied. In the absence of CKD fetuin-A is associated with plaque stability (Beckman, Ganz, Creager, Ganz, & Kinlay, 2001; Huang et al., 2001). High levels have been associated with coronary artery calcification in patients with T2DM (Mehtrotra et al., 2005). Primary findings were that serum fetuin-A showed significant positive correlations with arterial stiffness measured by brachial-ankle pulse wave velocity, systolic blood pressure, total cholesterol and inflammatory markers. More research is warranted in this area to determine the protective effects in specific populations.

The role that fetuin-A plays in cardiovascular diseases is debated in the literature. Though few reviews exist, a thorough examination of the multiple functionality of fetuin-A in the exacerbating and protective factors in the cardiovascular system is examined (Mori, Emoto, & Inaba, 2012). The conclusion was that fetuin-A had an exacerbating effect on insulin-resistance at high-levels in the blood and a protective effect by inhibiting calcification at low levels. Specific levels, however, were not examined. Limitations, however, are shown to be in the fetuin-A assay reliability, which may explain the contradictory findings in the literature (Smith et al., 2010).

**Insulin Resistance**

The health impact of insulin resistance are vast and include complications from diseases such as breast cancer, cardiovascular disease and metabolic syndrome (Catalano et al., 2008). The association between Fetuin-A and insulin resistance has been shown in human and animal models (Mathews et al., 2002). Fetuin-A has been found to inhibit insulin receptor tyrosine kinase activity (TKA) in mice (Mathews et al., 2002) and humans (Srivas et al., 1996). TKA plays an essential role in the activation of the insulin receptor and the insulin receptor substrate (IRS).
role in insulin signaling and may help to explain why fetuin-A knockout mice show enhanced glucose sensitivity and clearance, resistance to weight gain (on a high fat diet), decreased serum free-fatty acid levels and decreased body fat compared to controlled mice (on the same high fat diet) (Mathews et al., 2002). Due to this finding, it has been suggested that fetuin-A might be a novel therapeutic target for the treatment of T2DM, obesity and other insulin-resistant conditions.

In humans, high fetuin-A levels were associated with insulin resistance and fat accumulation in the liver in 106 Caucasian subjects without T2DM (Stefan et al., 2006). Individuals with high fetuin-A levels showed impaired glucose tolerance compared to subjects with normal glucose tolerance after adjusting for age, sex and body fat percentage. After 7-days of aerobic exercise (60-min/day at ~85% maximum heart rate), fetuin-A levels decreased substantially (11%, P<0.05) and insulin sensitivity was significantly increased (29%, P<0.05) in obese men with non-alcoholic fatty liver disease (NAFLD) (Malin et al., 2013). Similarly, high levels of fetuin-A predict risks of developing T2DM (Rasul et al., 2012) independent of diabetes or glucose levels. A strong association and/or relationship is, therefore, reasonably drawn between fetuin-A and insulin resistance.

The steep decline in estrogen in this population has been closely linked with an increase in insulin resistance. In fact, previously untreated postmenopausal women given oral estrogen therapy improved insulin sensitivity and pancreatic insulin responses to glucose 18-months after treatment (Sutton-Tyrrell et al., 2005). Animal studies have also demonstrated the correlation between insulin resistance and estrogen levels in females. A cessation of female hormone production in mice and rats post an ovarietomy is associated with reduction in insulin sensitivity (Meeter & Gamer, 1997; Prush & Bailey, 1985; Rincon et al., 1996). In a large 9-year follow-up study, glucose-impaired older women (~71 years of age) displayed higher fetuin-A levels compared to age matched-women with normal-glucose tolerance (Ramezani Tehrani et al., 2014). In addition, older glucose-impaired men’s fetuin-A levels did not differ from their matched normal glucose-tolerant counterparts. Therefore, fetuin-A may be a greater influence in the development and/or predictor of T2DM in older women, but not men.

It has been shown that fertile women display the highest insulin sensitivity among adults (Manco et al., 2006). In an age-grouped comparison, non-obese women with a mean age of 67 ± 6 years were significantly less insulin sensitive in comparison to non-obese women in other age-grouped cohorts (28-53 years of age) (DeNino et al., 2001). A longitudinal comparison (6 years) of metabolic changes in women who experienced menopause with age-matched women who did not concluded that natural menopause was associated with a worsening metabolic profile (Poehlman, Toth, & Gardner, 1995). In comparison to the women who did not experience menopause, the postmenopausal group had reduced energy expenditure (postmenopausal: -103 ± 55 kcal/d and premenopausal: -8 ± 17 kcal/d, P<0.01), accelerated loss of fat-free mass (postmenopausal: -3.0 ± 1.1 kg and postmenopausal: -0.5 ± 0.5 kg) and elevated fasting insulin levels (postmenopausal: -11 ± 5 pmol/L and postmenopausal: -2 ± 5 pmol/L, P<0.01) (Poehlman et al., 1995). Fetuin-A levels were not measured in this study.

It is therefore apparent that fetuin-A and its role in insulin resistance could serve as an important biomarker in postmenopausal women. The increased incidence of insulin sensitivity in this population is prominent. More research is needed to understand the mechanisms behind the relationship between fetuin-A and insulin resistance.

Hyperinsulinemia is associated with hypertension, obesity, dyslipidemia and glucose intolerance (Modan et al., 1985). In addition, hyperinsulinemia may increase cardiovascular disease risk (Reaven, 1997; Stout, 1990). Postmenopausal women, in particular, have increased development of hyperinsulinemia compared to premenopausal women (Gupta et al., 2008). The hormonal changes associated with menopause decrease progesterone levels markedly (Tchernof et al., 1998) and common treatments for menopause include progesterone (Spark & Willis, 2012). Progesterone has been shown to independently cause hyperinsulinemia and insulin resistance (Beck, 1969; Kalkhoff, Jacobson, & Lemper, 1970). The mechanisms underlying the association between insulin resistance and hyperinsulinemia and cardiovascular disease are still debated. It has been speculated that hyperinsulinemia may require the presence of insulin resistance to increase the risk of cardiovascular disease or may act independently on atherosclerosis (Modan et al., 1985). In a retrospective analysis of the European Group for the Study of Insulin Resistance database, hyperinsulinemia was the best predictor of cardiovascular disease risk score (Manco et al., 2006). In this study, whole-fat accumulation, insulin concentration, body composition, blood pressure and blood lipid levels were measured in 523 normal and overweight patients. After adjustments for fat free mass, it was determined that insulin levels rather than insulin resistance may be a better predictor of CVD risks.

The link between CVD risks, hyperinsulinemia and insulin resistance in postmenopausal women is apparent. The relationship that hyperinsulinemia and insulin resistance have in atherosclerosis needs further investigation. In addition, measuring levels of fetuin-A and their role in these processes could help shed light on the understanding of this glycoprotein and its protective and/or detrimental mechanisms.

**Intra-Abdominal Fat**

Fetuin-A, metabolic syndrome and hyperaiproteinemia are all strongly associated with low-grade chronic inflammation and increased intra-abdominal fat (Golden et al., 2007; Matsu et al. 2013; Stefan et al., 2006). Moreover, subclinical inflammation has been shown to be a critical factor in development of atherosclerosis, cardiovascular disease and metabolic syndrome. Metabolic syndrome (Berg et al., 2004; McKinlay, Bremhalla, & Posner, 1992) and abdominal adiposity (DeNino et al., 2001) in women is accelerated during the menopausal transition. Fetuin-A induces inflammatory cytokines related to these conditions by repressing adiponectin production in animals (Hennige et al., 2008). Adiponectin is an anti-inflammatory agent that is produced by fat and is important for the metabolism of glucose and fatty acids (Sathyam Bhanma et al., 2012). Adiponectin plays an important role in the increased sensitivity of the muscle and liver to insulin. In fact, low-serum adiponectin levels cause intra-abdominal weight gain and thus, are indirectly associated with insulin resistance and metabolic syndrome (Williams et al., 1996).

There are multiple mechanisms behind this association and are only briefly summarized here. The presence of abdominal fat is highly lipolytic, releasing high levels of fatty acids in circulation (Mauriege, Prud’homme, Lemieux, Tremblay, & Després, 1995). In turn, high levels of free fatty acids in the portal vein, specifically, can increase the secretion of triglyceride-rich lipoproteins and apolipoprotein (apo-B) by the liver (Björntorp, 1990). High levels of free fatty acids are not only associated with increased abdominal fat and hyperinsulinemia, they are also a result of insulin resistance. This in turn affects apo-B and reduces the plasmatic activity of lipoprotein lipase. This can lead to high triglycerides and low density lipoprotein cholesterol dyslipidemia and the promotion of small, dense LDLs (Lemieux & Després, 1994). The association with this metabolic profile is closely associated with an array of cardiovascular diseases.

In a study with human monocytes and mice, fetuin-A exerted strong pro-inflammatory effects as well as provoked cytokine expression (Hennige et al., 2008). In this study, mice treated with fetuin-A increased adipose tissue inflammatory markers significantly. This increase showed plasma fetuin-A levels and metabolic syndrome may be the result of fetuin-A induced suppression of adiponectin production. This mechanism may help to explain high levels of fetuin-A in older individuals with increased visceral fat content (Ix et al., 2009). This study was comprised of a majority of female participants (74%) who were 73±3 years of age. Although controls were not used, a strong correlation was demonstrated between abdominal fat and fetuin-A levels of 9000 ig/mL, a level 3-times higher than what is considered to be normal. A worsening metabolic profile was found in women who experienced menopause in comparison to age-matched counterparts who had not
It is crucial to examine these interventions and their association with resistance, increased glucose tolerance and markers of cardiovascular (Choi et al., 2013) and/or exercise (Jenkins, McKenzie, Hagberg, & Kalkhoff, 1991). These changes may help mitigate the worsening cardiovascular and metabolic risk profile associated with menopause.

The accentuated storage of excess fat in the abdominal area may augment the development of hepatic insulin resistance (Williams et al., 1996). Adverse health concerns associated with central obesity in a correlational study of 455 normoglycemic normotensive postmenopausal women included a positive correlation with age, BMI, fasting plasma glucose, triglycerides, insulin, blood pressure, homeostatic model assessment of insulin resistance (HOMA-IR), aortic and peripheral pulse wave velocity (Park et al., 2010). In these same women, a negative correlation with central obesity and high-density lipoprotein levels and adiponectin was shown (Park et al., 2010).

In two studies investigating the endocrine characteristics (Després & Marette, 1994) and metabolic complications (Lord & Wilkin, 2002) in polycystic ovary syndrome phenotypes, central distribution and accumulation of adipose tissue and insulin resistance was shown to be important components in metabolic abnormalities associated with coronary heart disease. When comparing two patterns of fat-distribution in the abdominal region versus the gluteo-femoral region, abdominal region was only associated with dyslipidemia and insulin resistance (Després & Marette, 1994). The alteration of hormonal balance contributes to an increased visceral fat deposition (Kalish, Barrett-Conner, Laughlin, & Gulanski, 2003) which in turn is associated with insulin resistance and increased cardiovascular disease in postmenopausal women (Kahn et al., 2001). Deposition of intra-abdominal fat through the menopausal transition has also been associated with alterations of the lipoprotein profile and carbohydrate metabolism (Costrini & Kalkhoff, 1971; Schäfer et al., 2003).

Through the menopausal transition, androgenic status increases in conjunction with abdominal fat deposition (Mesch et al., 2008). This study demonstrated this effect by the significant negative correlation found between waist circumference and sex hormone binging globulin (SHBG) and a positive correlation between waist circumference and the free androgen index. In addition, metabolic syndrome, which is highly correlated with cardiovascular disease, has shown a strong correlation between abdominal obesity and accelerated incidence of metabolic syndrome (Janssen et al., 2008).

It can be speculated that increased CVR risk is due to a rise in androgenic effects associated with adipose tissue redistribution in postmenopausal women. Fetuin-A and its role in suppressing adiponectin has been demonstrated. Adiponectin has been directly linked to increased intra-abdominal fat. The link between fetuin-A levels, suppression of adiponectin and accumulation of central-adiposity through the menopausal transition has yet to be studied.

Interventions Affecting Fetuin-A Levels

Although studies are limited in their direct effect on altering fetuin-A levels, few interventions have been shown to be effective. Decreasing fetuin-A levels through weight loss (Brix et al., 2010), dietary intervention (Choi et al., 2013) and/or exercise (Jenkins, McKenzie, Hagberg, & Witkowsk, 2011) has been positively correlated with decreased insulin resistance, increased glucose tolerance and markers of cardiovascular disease risks. In high-risk populations, such as postmenopausal women, it is crucial to examine these interventions and their association with decreased risk of susceptible diseases.

Weight Loss

Significant weight loss has been shown to affect fetuin-A levels. Six-months post-gastric bypass surgery and dramatic weight loss, significant drops in fetuin-A levels were demonstrated in 75 morbidly obese patients (n=65 women) (Lorant et al., 2011). All patients were free of cardiovascular disease, but not insulin resistance. Before gastric bypass surgery intervention, fetuin-A concentrations were elevated in patients that were morbidly obese compared with non-obese controls. The fetuin-A levels in the morbidly obese patients were comparable with the accumulation of visceral adipose tissue in older persons (Ix et al., 2009) (900µg/ml) indicating a possible upper limit for fetuin-A levels and the association with disease.

The link with obesity and diabetes is known. Bariatric surgery has been shown to induce resolution of T2DM in 70-80% of those undergoing the surgery (Buchwald et al., 2009; Koppy et al., 2003). The association between insulin resistance and fetuin-A has been made clear. In fact, subjects with high fetuin-A levels have an increased risk of incident diabetes (Stefan et al., 2008). Increased age increases the incidence of diabetes in individuals with high fetuin-A plasma levels (Ix et al., 2009).

Limited studies in this area show that morbidly obese individuals have increased fetuin-A levels compared to normal-weight controls and levels mimic older individuals that are not-obese (Brix et al., 2010). It is commonly known that obesity is highly associated with low-grade chronic inflammation (Gangneux et al., 2003). The mechanisms behind the decrease in weight and the association with fetuin-A and inflammation are unknown, but can be speculated. Further research is needed to investigate this relationship.

Dietary Interventions

Calorie restriction over 12-weeks in overweight sedentary women with T2DM significantly decreased fetuin-A levels (-133.3±g/mL, p=0.038) (Choi et al., 2013). Primary findings also indicated a decrease in apo-B (-0.08g/L, p=0.007) and low-density lipoproteins (-0.3mM, p=0.47) demonstrating a decrease in cardiovascular disease risks. Concerning postmenopausal women, a decrease in apo-B may help to lessen the degree of intra-abdominal fat accumulation and low-grade inflammation. Also in relation to favorable decreases in abdominal fat, adiponectin was increased 2.96% (p<0.021). A 9-month longitudinal study showed that by reducing total dietary fat and intake of saturated fat, subsequent decreases in mean liver fat and fetuin-A plasma levels were demonstrated in healthy Caucasian individuals without diabetes (Stefan et al., 2006). This result was independent of significant decreases in body fat. A correlational analysis of the data collected also showed a strong association between fat on the liver and increases in fetuin-A release.

The role that calorie restriction plays in decreasing fetuin-A may be independent of weight loss. Many postmenopausal women are not obese, yet have increased intra-abdominal fat (DeNino et al., 2001), insulin resistance and CVD (Mancio et al., 2006) compared to their premenopausal years. It is important for future research studies to observe fetuin-A changes due to dietary intervention in obese and non-obese women. Perhaps the link between inflammation and fetuin-A could be better understood in this differentiation.

Exercise

Several exercise-centered studies have shown promising improvements in fetuin-A plasma content. Overall, fetuin-A is higher in sedentary individuals, absent of disease, in comparison to those who were highly active (Jenkins et al., 2011). Another primary finding in this study was fetuin-A was 20% higher in low-active men compared to age-matched high-active men and inversely related to VO2 maximum oxygen uptake.

In middle aged men with non-alcoholic fatty liver disease (NAFLD), 7-days of aerobic exercise at 85% maximum heart rate for 60 minutes dramatically decreased fetuin-A levels, insulin resistance (29%) and...
glucose tolerance (13%) (Malin et al., 2013). These results were independent of weight loss. Moreover, fourteen nondiabetic, obese women did not show changes in fetuin-A levels after 6-weeks of self-regulated aerobic exercise performed 3-days per week despite a decrease in body fat content and waist circumference (Schultes et al., 2010). While weight loss studies may show the relationship between fetuin-A and inflammation, the improvement with exercise may show the role that fetuin-A plays in skeletal muscle insulin-resistance.

In a three-month combined aerobic and resistance training program, individuals did not alter their levels of fetuin-A (Yang et al., 2011). The exercise protocol consisted of 45-minutes of aerobic exercise at 60-75% of age-predicted maximum heart rate and 20-minutes of resistance training five-days per week. Arterial stiffness was improved, but fetuin-A was unchanged. This may indicate that an alteration in fetuin-A levels with an exercise intervention maybe dose and intensity-responsive rather than weight-loss dependent. More research is needed in this area.

Exercise and healthy dieting has been proven to be beneficial in preventing or attenuating all of the previously mentioned diseases. Weight loss has often been a determinant for exercise and diet effectiveness in healthy and diseased-individuals. The focus solely on weight loss might have more negative impact than was once thought. In fact, fragility, after the age of 65 leads to increased mortality in comparison to obesity (Cao, Moineddin, Urquía, Razak, & Ray, 2014). It is therefore apparent that other biomarkers in preventing and treating postmenopausal conditions need to be established. The impact of formulating a nutrition and or exercise intervention that decreases fetuin-A levels has important implications in individuals more susceptible to these diseases and or conditions, such as postmenopausal women.

Future Studies

Future studies are needed to determine the levels and types of populations in which fetuin-A crosses the threshold from being protective against calcification to being a precursor to increased insulin resistance, inflammation and cardiovascular events. A standardization of fetuin-A assays is needed in order to validate findings. This would help further explain differentiating concentrations of fetuin-A and help to confirm if low levels are indeed protective and high levels are detrimental. In addition, establishing normal, low and high levels of fetuin-A is warranted to justify claims of high and low levels in the literature.

Second, fetuin-A levels before and after menopause need to be determined to further explain the increased risk of disease in postmenopausal women. Postmenopausal women are a very vulnerable population to CVD, T2DM and metabolic syndrome. Understanding the levels of fetuin-A in this population and drawing links between the possible association with disease would be pivotal for research in this area and possible interventions to achieve optimal levels. Once optimal levels are established in various populations and diseases, fetuin-A could be a target blood marker in clinical settings.

Last, randomized controlled-trials in exercise and nutrition interventions need to be studied to infer causal relationships with fetuin-A and previously mentioned disease-processes. Most interventional studies pertaining to exercise and fetuin-A are cross-sectional. More controlled studies with interventions varying in exercise duration and intensity would help to clear up any discrepancies with exercise and the possible beneficial effects on fetuin-A levels. In addition, frequency and intensity-specific exercise protocol need to be compared in their alterations of fetuin-A in diseased and healthy populations. Studies of this nature would also help to establish better or more precise normative, healthy levels of plasma fetuin-A concentrations.

Conclusions

It is apparent that postmenopausal women are at increased risk for insulin resistance, hyperinsulinemia, metabolic syndrome and CVD. The potential role that fetuin-A plays in intra-abdominal redistribution, insulin resistance, inflammatory markers and CVD is vast and not fully understood. The positive correlation with age and negative correlation with physical activity that has been displayed with levels of fetuin-A makes it a novel plasma target for disease prevention and or treatment. In postmenopausal women who are susceptible to insulin resistance, metabolic syndrome and CVD, this biomarker may shed light on effective interventions. It is apparent that more research is needed in order to standardize target fetuin-A levels in postmenopausal women.

The protective and exacerbating effects of fetuin-A seem to be dose-responsive and further research is needed to fully understand this mechanism. Due to the strong association with increased fetuin-A in older women, inactive individuals, obese patients and individuals with insulin resistance, NAFLD and T2DM, it is apparent that further investigation would help explain the mechanisms behind the role of fetuin-A. In addition, establishing parameters of low and high fetuin-A levels may help to make this glycoprotein applicable in the clinical setting.

Exercise and dietary interventions have been shown to lower fetuin-A levels. Some of the same interventions are currently used to decrease cardiometabolic risks and improve health in men and women. The role that fetuin-A plays in ameliorating risks and or improving health has yet to be fully elucidated. This is particularly true in postmenopausal women.

References

Acute effects of whole body vibration on functional capabilities of skeletal muscle
Los efectos agudos de la vibración corporal total sobre las capacidades funcionales del músculo esquelético

James D. Burns, Paul C. Miller, and Eric E. Hall
Elon University, Elon, NC, USA

Abstract. The focus of this research was to evaluate the effect whole body vibration (WBV) on measures of muscular contractile function. In addition, this research was conducted to compare the effects of WBV on athletes versus non-athletes. Nineteen male, non-athlete college students, as well as eighteen male Division I collegiate athletes participated in this research. All participants completed 2 conditions, vibration and no vibration, in a randomized order. Participants were exposed to either a 2-minute bout of vibration or a 2-minute no vibration condition. Immediately following both conditions, participants were tested for peak vertical jump height, isokinetic peak torque and average power of knee extensors and flexors, and anaerobic power during a 30-second maximal effort cycle task. Results showed a significant improvement in knee flexion peak torque at 6.28 rad·sec⁻¹ in the athlete group following the vibration condition. Results also showed a trend toward a significant improvement in knee extensor and knee flexor average power at 6.28 rad·sec⁻¹ in the athlete group following the vibration condition. There were no significant changes in any isokinetic measure for the non-athlete group. There were no significant changes in vertical jump or anaerobic power for either group. This may be due in part to the complexity of the dose-response relationship, which is largely dictated by the parameters of vibration frequency, amplitude, and duration. However, previous studies have found positive results using similar protocols as the present study. Practically speaking, the use of WBV prior to exercise may result in facilitated contractile and athletic performance. Consequently, this study sought to describe the impact of using WBV prior to exercise on muscle function.

Key Words. Performance enhancement; Athletes; Power; Muscle Performance

Resumen. El objetivo de esta investigación fue evaluar el efecto de la vibración de cuerpo entero (WBV) sobre parámetros de la función contráctil muscular. Además, esta investigación se realizó para comparar los efectos de la WBV en atletas en comparación con no atletas. Diecinueve hombres, estudiantes universitarios no deportistas, así como 18 hombres, atletas de División I universitaria participaron en esta investigación. Todos los participantes completaron dos condiciones en orden aleatorio: la vibración y la ausencia de vibración. Los participantes fueron expuestos a 2 min de vibración o 2 min de condición control. Inmediatamente después de ambas condiciones, a los participantes se les midió la altura pico de salto vertical, el torque pico isocinético, la potencia media de extensores y flexores de la rodilla y la potencia anaeróbica durante una tarea de ciclo de esfuerzo máximo 30 s. Los resultados muestran una mejoría significativa en el torque pico de la rodilla a 6.28 rad·sec⁻¹ en el grupo de deportistas luego de la condición de vibración. Los resultados también muestran una tendencia hacia un aumento significativo en la potencia promedio de los flexores y extensores de la rodilla a 6.28 rad·sec⁻¹ en el grupo de deportistas luego de la condición de vibración. No hubo cambios significativos en las variables isocinéticas en el grupo de no atletas. Tampoco hubo cambios significativos en el salto vertical ni en la potencia anaeróbica en ambos grupos. Esto puede explicarse en parte a la complejidad de la relación de dosis-respuesta, la cual está ampliamente determinada por los parámetros de frecuencia, amplitud y duración de la vibración. Sin embargo, estudios previos han encontrado resultados positivos utilizando protocolos similares a los del presente estudio. En términos prácticos, el uso de WBV antes del ejercicio puede resultar en una mejor contractilidad y rendimiento deportivo. En consecuencia, este estudio trató de describir el impacto del uso de WBV antes del ejercicio en la función muscular.

Palabras claves. mejora del rendimiento, atletas, potencia, rendimiento muscular

Introduction

In athletics, the area of performance enhancement is ever expanding. One category in particular that receives a great deal of interest in the literature is ergogenic aids. Ergogenic aids are external influences that are used in an attempt to improve performance. These include mechanical, pharmacological, psychological, physiological, and nutritional aids. Whole body vibration (WBV) is a technology that has recently been investigated as a mechanical ergogenic device. WBV has been studied in both chronic and acute settings, with acute applications being more geared toward the enhancement of muscular performance. While the focus of the current study is on the acute effects of WBV, it should also be noted that there has been significant research investigating prolonged WBV use. These studies have examined various age groups and have found WBV to have positive effects on muscle strengthening, balance, and bone density (Bogaerts et al., 2007; Jordan et al., 2010, Verschueren et al., 2006).

Acute applications of WBV have been shown to be successful in improving muscular performance (Bosco et al., 2000; Cochrane & Stannard, 2005; Cochrane et al., 2008; Cormie et al., 2006; Gerodimas et al., 2010; McBride et al., 2010). Studies have shown that acute use of WBV can have a positive effect on vertical jump, isometric squat peak force, muscle twitch torque, maximal voluntary contraction, peak isometric torque, neuronal excitability, neuromuscular response, and hormone release. The acute hormonal changes seen following WBV may serve to facilitate training-related fitness gains.

In a study of elite female field hockey players, Cochrane and Stannard (2005) examined the acute effects of WBV on arm countermovement vertical jump (ACMVJ), flexibility, and grip strength. This study compared the effects of a WBV to that of stationary cycling and a non-vibrating control condition. A positive condition*time interaction was found for ACMVJ as well as flexibility with the WBV condition eliciting a superior response for ACMVJ and flexibility. Given these improvements in ACMVJ and flexibility, the researchers suggest that WBV may be an effective means of warming up. In a similar study of potential warm up modalities, Cochrane et al. (2008) compared the effects of WBV to stationary cycling and a hot water bath passive warm-up. All three interventions showed a significant increase in CMVJ peak power and height, but WBV increased temperature of the leg muscles more rapidly than the cycling or hot water bath. Because of this, the researchers again noted the potential for WBV to be used as a warm up prior to athletic competition. Much like the results of Cochrane and Stannard (2005) and Cochrane et al. (2008), Cormie et al. (2006) also found WBV to improve CMVJ in moderately resistance trained males.

Concomitant with the importance of performance enhancement is the necessity to understand the neuromuscular effects of WBV. In order to shed light on this area, Bosco et al. (2000) measured average velocity, acceleration, average force, and power during a leg press exercise. The researchers posited that neuromuscular activation caused by WBV might lead to improved neuromuscular function. The results showed a significant increase in power output of the leg extensor muscles, as well as a significant increase in ACMVJ following WBV. The researchers attributed these results to a potential increase in neuromuscular efficiency due to the WBV. In a related study, McBride et al. (2010) also investigated the neuromuscular response following a bout of WBV. The researchers found that the WBV group significantly increased peak force during maximal voluntary contraction of knee extensors by 9.4% immediately after
post and 10.4% eight minutes post vibration. The findings of these studies support the hypothesis that WBV positively impacts neuromuscular function of the lower limb.

Because it is a new ergogenic modality, there is a need to explore and further clarify the appropriate dosing for WBV. To elucidate the relationship between WBV duration and effect, Stewart et al. (2009) investigated the impact of vibration duration on the effectiveness of WBV. Participants were pre-tested for peak and mean torque of the knee extensor muscles. All subjects then completed three sessions lasting 2.4, and 6 minutes, which were administered in a balanced, randomized order. Peak and mean torque were recorded during three maximal 2-second contractions. The data showed that only the 2-minute vibration protocol led to significant improvement in peak and mean torque. Both the 4-minute and 6-minute protocols had a significant, negative effect on torque output. Given these results it is evident that contractile function can be improved by WBV, but optimal WBV duration has yet to be established.

Despite the prevalence of positive results, the findings in regard to the acute effect of WBV on muscular performance have been inconsistent. Studies have found that exposure to WBV does not necessarily improve muscular performance, and in some cases can even produce a significant decrease in knee extensor and knee flexor MVC (de Ruiter et al., 2003; Enser et al., 2007; Jordan et al., 2010). Studies using similar measures have shown very different outcomes, and it is not presently apparent why this is. It is clear that this is an area that warrants continued investigation given the number of studies that have found positive results. Therefore, the purpose of this investigation was to describe the effects of WBV on muscle performance among collegiate athletes and non-athletes.

**Methods**

**Experimental Approach to the Problem**

This study was a repeated measures design, with the condition being administered in a randomized and counterbalanced fashion. The study protocol required participants to complete two sessions, one for each condition. The two conditions were vibration and control. The protocol was identical for both conditions with the only difference being whether or not vibration was administered. The order of the performance tests was identical for all participants and sessions. The test order was designed to minimize the impact one test might have on another.

**Subjects**

Nineteen, non-athlete college men, as well as, 18 Division I collegiate athlete men agreed to participate in this study. See Table 1 for descriptive information concerning the sample. The non-athlete participants were recreationally active, but were not participating in any competitive sports. Before testing, all participants signed an informed consent form that was approved by the University’s Institutional Review Board prior to participation in the study. Participants also received a twenty-dollar gift card as compensation for their participation.

| Table 1. Participant Characteristics (Means ± Standard Deviation) |
|---|---|---|
| Athlete (n = 18) | Non-athlete (n = 19) |
| Age (years) | 19.8 ± 2.8 | 21.2 ± 1.9 |
| Height (cm) | 186.4 ± 8.4 | 178.7 ± 9.2 |
| Weight (kg) | 97.7 ± 21.1 | 80.2 ± 14.1 |
| Percent body fat | 16.8 ± 6.5 | 13.2 ± 6.0 |
| BMI (kg/m²) | 28.0 ± 5.4 | 24.8 ± 2.7 |

**Measures**

A vertical jump test was used as a functional measure of anaerobic power. Data was collected using a Just Jump vertical jump testing mat (Probotics, Inc. Huntsville, Alabama). Participants stepped onto the mat and were instructed to jump as high as they could whenever ready. Three measurements of maximal jump height were recorded. The control module for the mat records contact time between liftoff and landing, and uses this time in air to calculate height jumped. Leard et al. (2007) found the Just Jump timing system to be a valid measure of vertical jump when compared with a three-camera system ($r = 0.967, p < 0.001$).

The Bodex™ System 2 Isokinetic Dynamometer was used to measure peak torque and average power, which are measures of skeletal muscle contractile function. In an isokinetic assessment the participant gives maximal force against a device that limits the speed at which a movement can be performed. The six speeds used in this testing were 1.05, 2.09, 3.14, 4.19, 5.24, and 6.28 radians · sec^{-1}. Three repetitions were performed at each speed.

The Wingate anaerobic cycle test was also used to measure anaerobic power as well as anaerobic capacity. This test required the participant to pedal a stationary bike for thirty seconds at maximal effort against a resistance defined as 7.5% of the participant’s bodyweight. This test measured peak power and power drop.

**Apparatus**

The vibration platform used in this study was a NitroFit Deluxe™ model (Medvibe LLC, Scottsdale, Arizona). This device vibrates in a sinusoidal manner, with the axis of rotation between the feet. For this research, the platform generated vibrations at a 13 mm peak-to-peak amplitude. Frequency was set at a 30 Hz level, which was found by Cardinale, & Lim (2003) to be the frequency of vibration that elicited the greatest EMG activation of the vastus lateralis muscle when in a half squat position.

**Procedure**

Upon arriving at the laboratory for their first session, participants were instructed to be seated. Participants also completed a physical activity questionnaire, which asked them to report about their current, regular physical activity habits (e.g. running, bicycling, weight training etc.). Anthropometric measures of height, weight, body mass index (BMI), and percent body fat were then recorded. Percent body fat was measured using an Omron Body HBF-306C Body Fat Analyzer (Omron, Kyoto, Japan). Participants were then subjected to either the vibration or no vibration condition, with order dictated by random assignment.

The Vibration treatment protocol required participants to stand on a vibration platform (with their shoes off) at 120° of knee flexion while holding on to handles affixed to the vibration apparatus. After two minutes of vibration, participants were instructed to put their shoes back on and complete three vertical jumps for maximal height on the Just Jump vertical jump testing mat (Probotics, Inc. Huntsville, Alabama). Contractile function of the knee extensors and flexors was then measured on a Bodex System 2 isokinetic dynamometer. Participants were asked to perform repetitions of maximal effort knee extension and flexion at six speeds: 1.05, 2.09, 3.14, 4.19, 5.24, and 6.28 radians · sec^{-1}. Order of speeds was randomly assigned for each participant in order to eliminate any potential ordering effect. For each trial, participants were told to put their arms across their chest as to not brace against the machine and to begin with their leg in a flexed position. They were then instructed to begin when given a verbal signal of “3, 2, 1, Go” from the tester and to stop when given a verbal signal of “Relax”. One minute of rest was given between each one of the six trials.

After completing measures on the Bodex, participants were then asked to complete a 30-second Wingate anaerobic cycle test. Participants then returned to the lab no less than 48 hours later to complete the other protocol (vibration or no treatment). Sessions were scheduled such that each one took place at a similar time of day to account for diurnal variations.

**Statistical Analyses**

Comparisons between the vibration and no vibration condition were made using a Repeated Measures General Linear Model (RM GLM). A significance level of $p < 0.05$ was selected a priori.
Results

Vertical Jump
Results from the RM GLM did not reveal a significant condition or group*condition interaction for either maximal vertical jump or average vertical jump (all p’s > .05).

Isokinetic Peak Torque
Results from the RM GLM did not reveal a significant condition or group*condition interaction for isokinetic peak torque of knee extensors at 1.05, 2.09, 3.14, 4.19, 5.24, or 6.28 radians · sec⁻¹ (all p’s > .05). However, at 6.28 radians · sec⁻¹ a significant condition*group interaction was found (p = .003). See Figure 2 for results.

Isokinetic Average Power
Results from the RM GLM did not reveal a significant condition or group*condition interaction for isokinetic average power for knee extensors at 1.05, 2.09, 3.14, 4.19, 5.24, or 6.28 radians · sec⁻¹ (all p’s > .05). However, at 6.28 radians · sec⁻¹ a trend for significance was found for the group*condition interaction (p = .059). See Figure 3 for results.

Wingate
Results from the RM GLM did not reveal a significant condition or group*condition interaction for peak power for the Wingate test (all p’s > .05).

Discussion
This research sought to describe the acute effects of WBV on measures of muscular performance. While research comparing the effects of WBV on athletes and non-athletes is limited, there have been a number of studies showing WBV to be successful in improving muscular performance (Bosco et al., 2000; Cochrane & Stannard, 2005; Cormie et al., 2006; Gerodimas et al., 2010; McBride et al., 2010). It was hypothesized that the athletes would have a more pronounced positive response to the WBV than the non-athletes due to the differences in training history. Athletes often perform high-speed training in order to simulate the speeds at which they move during competition. This type of training would cause the athletes to have different contractile characteristics than those in the non-athlete group, which might affect the response to WBV.

This study found no changes in peak vertical jump height or average vertical jump height associated with acute WBV use. These results support the findings of Gerodimos et al. (2010), who looked at a range of vibration frequencies and amplitudes and found no improvement in vertical jump. However, this is in contrast to previous studies, which have found WBV to increase vertical jump (Bosco et al., 2000; Cochrane et al., 2008; Cormie et al., 2006). The present study also found no changes in Wingate test performance. These results support the findings of Cochrane et al. (2008) who found no significant differences in peak power for the five-second maximal cycle test following WBV. The researchers hypothesized that the warming produced by WBV may not have been enough to produce positive changes in a maximal cycling effort. If temperature increase is the primary mechanism by which maximal cycling would be affected, then this current research may not have elicited enough of a temperature increase to see improvement in the Wingate test.
Another possible explanation as to why no effect was seen in vertical jump and Wingate tests may be due to inadequate stimulation of post activation potentiation. As stated by Bazett-Jones, Finch, and Dugan (2008), for post activation potentiation to occur following contractile activity there must be a net balance in favor of actions that cause potentiation rather than those that cause fatigue. It may be the case that a small adjustment to vibration parameters can lead to entirely different results. There have not yet been enough studies conducted to fully understand the relationships of these parameters.

The present study found a significant group*condition effect for knee flexion peak torque at 6.28 radians/sec\(^{-1}\). This supports the results of McBride et al. (2010), who found that WBV significantly increased peak force during MVC of the triceps surae muscle complex. While not the same muscle group, these results show that WBV can acutely enhance contractile function of leg muscles during maximal efforts. At 6.28 radians/sec\(^{-1}\), athletes in the present study performed better in measures of knee flexion peak torque following acute WBV. At this speed, it is not surprising that the athletes responded better than the non-athletes. The training programs of athletes often require high-speed movements and rapid muscle contractions. This may prime the neural connections to respond more positively to the high-speed contractions induced by WBV. It has been hypothesized that the rapid muscle contractions induced by WBV may affect the interneurons within the spinal cord, leading to reciprocal inhibition (Norlund & Thorstensson, 2007). This inhibition of antagonistic muscles may allow for greater maximal contraction at higher speeds. However, it is not currently known if past training history affects this mechanism. It is possible that training may have a significant impact in this area.

The present study also found a trend toward a significant group*condition interaction for knee extension average power at 6.28 radians/sec\(^{-1}\). This result supports the findings of Bosco et al. (2000) whose results showed a significant increase in power output of the leg extensor muscles during maximal dynamic leg presses. The vibration parameters in that study were set to 26 Hz frequency and 8 mm peak-to-peak amplitude, which were similar to the parameters of the present study. However, Bosco et al. (2000) utilized a 10-minute non-continuous total vibration duration, while the present study used a 2-minute continuous total duration. Although both studies showed improvement in power output of the leg extensors after acute WBV, the results of the present study suggest that benefits may be had at much shorter durations relative to the findings of previous research.

Two key limitations should be taken into account when interpreting the results of the present study. Firstly, many of the athletes that participated in this research were freshman football players. This is somewhat problematic because they potentially came from very different high school training programs. It would have been beneficial to have a majority of upperclassmen participants, as it would ensure that all the subjects had participated in the same training program prior to this research. Secondly, our athlete group was also disproportionately made up of football players. It is possible that athletes of other sports may have responded differently to the vibration. Having a fairly homogenous athlete group makes it difficult to generalize these results to other sports, and also calls for further research to be conducted on athletes of various sports.

Currently, there are a number of unanswered questions surrounding the use of WBV as a mechanical ergogenic. To better understand WBV and its potential for performance enhancement, future research should continue to shed light on the effects of protocol variation. The effects of frequency, duration and amplitude need to be exhaustively researched in order to have a more comprehensive understanding of the possible impact of WBV as a mechanical ergogenic. There are numerous combinations of these parameters, and the potential for significantly different effects. If it can be determined which parameters are most efficient at eliciting beneficial muscle activation, it would make the reproducibility of results much easier. At this stage of the research it is difficult to make definitive conclusions about the effectiveness of WBV given how much has yet to be explored.

The findings of this study may have important implications in regard to preparation for athletic events. In athletic competition, anaerobic power and high-speed movements, such as sprinting, are often of utmost importance. Nesser, Latin, Berg, and Prentice (1996) found knee flexion peak torque at 7.85 radians/sec\(^{-1}\) to be a significant predictor of 40-meter sprint time. It was also noted that hamstring strength is particularly important in the acceleration phase of sprint performance. This finding lends support to the idea that improving high-speed force output of the hamstring muscles could also lead to improved sprint performance. Newman, Tarpenning, and Marino (2004) also found that single-sprint performance to be correlated with both knee flexor and extensor peak torque at 1.05, 2.62, and 4.19 radians/sec\(^{-1}\). Because hamstring strength is integral to sprint performance, it would not be surprising to see WBV mediated improvements in hamstring force output lead to improved sprint speed. In addition to use as a pre-competition aid, WBV could potentially be used as a pre-training aid in order to accrue long-term benefits due to acute enhancements that improve individual training sessions.

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A meta-analysis on the effects of exercise training on the VO$_2$max in children and adolescents

Meta análisis de los efectos del entrenamiento en el VO$_2$ máx en niños y adolescentes

Pedro Carazo-Vargas & José Moncada-Jiménez
University of Costa Rica

Abstract. The chronic adaptations of the cardiovascular system to exercise training in children and adolescents yield inconclusive results, in spite of previous meta-analytic evidence. The aim of this meta-analysis was to determine the effectiveness of exercise training on the VO$_2$max of children and adolescents. The studies meta-analyzed met the following inclusion criteria: a) healthy individuals, b) participants between 10 and 18 years old, c) being trained in some type of supervised exercise program, d) VO$_2$max reported in ml·kg$^{-1}$·min$^{-1}$, e) the study reported before and after mean and standard deviation, f) pre-test post-test research designs, and g) the study was published in a peer-reviewed journal up to February, 2013. Thirty-four studies and 96 effect sizes (ES) were obtained. Compared to controls, experimental groups showed a significant improvement in VO$_2$max (p < 0.01) following exercise training. The increase in VO$_2$max was maintained regardless of the sample size characteristics and the exercise protocol. Based on the findings of this study, in order for children and adolescents to improve their VO$_2$max, exercise training should include at least two sessions per week of > 20 minutes duration per session, performed at a moderate intensity. In summary, planned exercise training improves VO$_2$max in children and adolescents.

Key words. VO$_2$ max, aerobic power, training, children, adolescents, meta-analysis.

Resumen. Las adaptaciones crónicas del sistema cardiovascular al entrenamiento físico en niños y adolescentes arrojan resultados inconclusivos, a pesar de previa evidencia meta analítica. El objetivo de este meta-análisis fue determinar la efectividad de la práctica de ejercicio en el VO$_2$ máx de los niños y adolescentes. Los estudios meta analizados cumplieron los siguientes criterios de inclusión: a) individuos sanos, b) participantes entre 10 y 18 años de edad, c) entrenados en algún tipo de programa de ejercicio supervisado, d) VO$_2$ máx reportado en ml·kg$^{-1}$·min$^{-1}$, e) se contara con desviación estándar antes y después del experimento, f) diseños de investigación con pre-test y post-test, y g) estudio publicado en una revista revisada por pares hasta febrero de 2013. Se obtuvieron treinta y cuatro estudios y 96 tamaños del efecto (ES). En comparación con los controles, los grupos experimentales mostraron una mejora significativa en el VO$_2$ máx (p < 0.01) después del entrenamiento de ejercicio físico. El aumento en el VO$_2$ máx se mantuvo independientemente de las características de tamaño de la muestra y el protocolo de ejercicio. Con base en los hallazgos de este estudio, a fin de que los niños y adolescentes puedan mejorar su VO$_2$ máx, el entrenamiento debe incluir por lo menos dos sesiones por semana > 20 min de duración por sesión, realizados a una intensidad moderada. En resumen, el entrenamiento planificado mejora VO$_2$ máx en niños y adolescentes.

Palabras claves. VO$_2$ máx, potencia aeróbica, entrenamiento, niños, adolescentes, meta-análisis.

Introduction

Training programs designed to improve the cardiovascular system in children and adolescents date from the 70’s and 80’s (Kobayashi et al., 1978; Mirwald, Bailey, Cameron, & Rasmussen, 1981). Equivocal findings were found, with most of the studies concluding that exercise training did not produce significant changes in VO$_2$max before the age of 12. These conclusions were subsequently supported by two narrative reviews of literature (Bar-Or, 1989; Borns, 1986).

However, these previous findings have been challenged by recent studies (Breil, Weber, Koller, Hoppeler, & Vogt, 2010; McMillan, Helgerud, Macdonald, & Hoff, 2005; Perini et al., 2006), where significant improvements in VO$_2$max have been found in these age groups following physical training. In general, it is concluded that a sufficient training stimulus must be provided for a significant enhancement of the VO$_2$max in children and adolescents to occur. In practical terms, new directions regarding the frequency, intensity and duration of the exercise programs are needed.

Meta-analytic research on the subject was published in the 90’s (LeMura et al., 1999; Payne & Morrow, 1993), allowing for a better understanding of the state of the knowledge at that time. The first meta-analysis published on the subject (Payne & Morrow, 1993) included 28 studies, and 70 effect sizes (ES) were computed from a pooled sample of 420 participants. The mean VO$_2$max before starting an exercise program was 46.22 ml·kg$^{-1}$·min$^{-1}$ and 48.39 ml·kg$^{-1}$·min$^{-1}$ after the training period. The researchers concluded that exercise training improved aerobic power in children by nearly 5%, with cross-sectional studies producing larger ES than studies using pre-test post-test research designs. No significant gender differences were found, even though the mean ES for girls was more than twice (ES = 0.78 ± 0.53) that of boys (ES = 0.32 ± 0.91), suggestive of a greater benefit of exercise training for girls. In this meta-analysis no significant differences were found in exercise programs. These programs were categorized only as «adequate» or «inadequate» due to a lack of information regarding the training protocol details. Furthermore, testing protocol did not moderate the effects of training on VO$_2$max.

Another meta-analysis published in the late 90’s (LeMura et al., 1999) supported the findings previously mentioned. In general, the meta-analysis showed higher VO$_2$max in children following exercise training. The authors included 20 studies, allowing for an estimation of 32 ES from 562 participants and found that in children, the VO$_2$max increased from 47.2 ± 4.3 ml·kg$^{-1}$·min$^{-1}$ to 50.1 ± 4.6 ml·kg$^{-1}$·min$^{-1}$ following an exercise training program (increase ~5.8%). Studies where a control group was used showed significantly larger ES than studies using repeated measures designs (i.e., the participant as its own control) (ES = 1.1 ± 0.1 vs. ES = 0.32 ± 0.2, respectively). Also, children between the ages of 11 and 13 reported significantly larger improvements in VO$_2$max (ES = 1.1 ± 0.7) than children between 8 and 10 years old (ES = 0.47 ± 0.4). No significant differences were found between males (ES = 0.64 ± 0.6) and females (ES = 1.0 ± 0.6), or between treadmill (ES = 0.75 ± 0.7) and cycle ergometer (ES = 0.94 ± 0.7) testing modalities.

The authors were unable to extract information from the articles to fully characterize the exercise protocol (LeMura et al., 1999). Exercise programs were categorized as having «adequate» (i.e., a minimum of three sessions per week for six weeks at an intensity equal to or greater 70% maximal heart rate) or «inadequate» training based on recommendations from professional organizations (American College of Sports Medicine, 1995). Statistical analysis showed that an appropriate training (ES = 1.2 ± 0.5) improved VO$_2$max more than an inadequate training (ES = 0.3 ± 0.2).

The meta-analytic evidence suggests a direct association between children’s age and VO$_2$max resulting from exercise training. It also shows that male and females benefit similarly from their participation in exercise training programs, with a trend towards larger improvements in females compared to males. However, this finding must be cautiously interpreted since only few studies with female groups were analyzed and greater benefits are expected due to their initial lower fitness level. A proper exercise prescription is critical to enhance VO$_2$max, since insufficient

Reference:
stimuli generated much smaller ES; however, the limited description of the training programs reported in the studies included in these meta-analyses precludes from drawing definite conclusions.

Although the meta-analytical evidence (LeMura et al., 1999; Payne & Morrow, 1993) support the fact that children and adolescents benefit from properly designed exercise training programs, the magnitude of this response must be evaluated in terms of the variables that might be moderating the effect. Therefore, the purpose of the study was to determine the effect of exercise training on the VO2max of children and adolescents and to detect relevant moderator variables.

**Methods**

**Search Strategy**

A systematic search was conducted of Academic Search Complete, Educational Resource Information Center (ERIC), MEDLINE, SPORTDiscus, Arts and Humanities Citation Index, Physical Education Index, Science Citation Index Expanded, Social Sciences Citation Index, and the Spanish database Dialnet for the period October, 2012 until February, 2013. The search strategy included a mix of subject headings and free text terms for the key words aerobic, endurance, exercise, training, children, teenagers, adolescents, VO2, VO2max, aerobic power, and their combination. Reference lists of articles found were scrutinized for new references. No language limits were imposed.

**Inclusion Criteria**

The inclusion criteria for this meta-analysis were as follows: a) healthy individuals, b) participants between 10 and 18 years old, c) being trained in some type of supervised exercise program, d) VO2max reported in ml·kg⁻¹·min⁻¹, e) the study reported before and after mean and standard deviation, f) pre-test post-test research designs, and g) the study was published in a peer-reviewed journal up to February, 2013. Any studies not meeting these criteria were excluded.

**Variable Coding**

Moderator variables that might influence the effect of exercise training on VO2max in children and adolescents were divided into four categories: a) general characteristics of the study, b) general information about participants, c) exercise program characteristics, and d) testing modalities (Table 1).

**Statistical Analysis**

All meta-analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 20.0. The outcome measure was VO2max. Descriptive data are reported as the mean ± SD unless otherwise noted. Effect sizes (ES) for each study group were calculated by subtracting the pre-test value from the post-test value for both, the VO2max. Descriptive data are reported as the mean ± SD unless otherwise noted. ES magnitude was considered small (ES < 0.40), moderate (ES 0.41 to 0.70), and large (ES > 0.71) based on previous literature (Thomas, Salazar, & Landers, 1991).

The ES was estimated for each moderator variable, and the standard error and the meta-analytic z-test was calculated for each category on a Microsoft Excel spreadsheet (Thomas & French, 1986). Statistical heterogeneity among the studies was assessed using Cochran’s Q test. Differences between categories were determined by on-way analysis of variance (ANOVA), followed by Tukey’s post hoc comparisons. Pearson product-moment correlations were used to test associations between continuous variables. In this study, ES magnitude was considered small (ES < 0.40), moderate (ES 0.41 to 0.70), and large (ES > 0.71) based on previous literature (Thomas, Salazar, & Landers, 1991). Thirty-four studies were included in the meta-analysis, and 96 ES were computed from 2113 participants. Cochran’s Q showed heterogeneity among ES (Q = 149.17, p < 0.01); therefore, the moderator variables were scrutinized. One-way ANOVA showed no significant differences between true, quasi-, and pre-experimental research designs on the mean VO2max ES (F = 1.016, p = 0.369). Since ES were similar between research designs (Table 2), we pooled the ES from all the studies for further analysis.

Subjects participating in exercise training programs significantly improved their VO2max ES (M = 0.47 ± 0.56, z = 2.89, p < 0.05) compared to their control counterparts (ES = 0.05 ± 0.31, z = 0.25, p > 0.05). One-way ANOVA for exercise training characteristics as a moderator variable showed significant differences between the types of activities (F = 5.956, p < 0.0001). Tukey’s post hoc analysis revealed differences (p < 0.05) between control groups and running and other aerobic activities (e.g., dancing, climbing stairs, practicing taekwondo or combined aerobic and resistance exercise) (Figure 1).

**Results**

**Table 2.** Effect size according to the research design

<table>
<thead>
<tr>
<th>Research design</th>
<th>ES</th>
<th>SD</th>
<th>t</th>
<th>p</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>True experimental</td>
<td>0.48</td>
<td>0.51</td>
<td>16</td>
<td>0.05</td>
<td>0.70</td>
</tr>
<tr>
<td>Quasi-experimental</td>
<td>0.58</td>
<td>0.50</td>
<td>16</td>
<td>0.05</td>
<td>0.70</td>
</tr>
<tr>
<td>Pre-experimental</td>
<td>0.71</td>
<td>0.42</td>
<td>5</td>
<td>0.25</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**Table 3.** Characteristics of the sample

<table>
<thead>
<tr>
<th>Variable</th>
<th>ES</th>
<th>SD</th>
<th>t</th>
<th>p</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>0.54</td>
<td>0.63</td>
<td>26</td>
<td>0.05</td>
<td>0.77</td>
</tr>
<tr>
<td>Female</td>
<td>0.40</td>
<td>0.51</td>
<td>18</td>
<td>0.05</td>
<td>0.70</td>
</tr>
<tr>
<td>Mixed</td>
<td>0.53</td>
<td>0.51</td>
<td>17</td>
<td>0.05</td>
<td>0.70</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.45</td>
<td>0.55</td>
<td>58</td>
<td>0.14</td>
<td>0.52</td>
</tr>
<tr>
<td>Type of participant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athlete</td>
<td>0.60</td>
<td>0.42</td>
<td>13</td>
<td>0.05</td>
<td>0.44</td>
</tr>
<tr>
<td>Non-athlete</td>
<td>0.44</td>
<td>0.34</td>
<td>21</td>
<td>0.05</td>
<td>0.34</td>
</tr>
</tbody>
</table>

**Table 4.** Characteristics of the exercise training interventions

<table>
<thead>
<tr>
<th>Variable</th>
<th>ES</th>
<th>SD</th>
<th>t</th>
<th>p</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>0.37</td>
<td>0.36</td>
<td>12</td>
<td>0.05</td>
<td>0.52</td>
</tr>
<tr>
<td>High</td>
<td>0.30</td>
<td>0.14</td>
<td>2</td>
<td>0.26</td>
<td>0.40</td>
</tr>
<tr>
<td>Not reported</td>
<td>0.51</td>
<td>0.27</td>
<td>2</td>
<td>0.05</td>
<td>0.47</td>
</tr>
<tr>
<td>Frequency (sessions/week)</td>
<td>0.64</td>
<td>0.56</td>
<td>54</td>
<td>0.12</td>
<td>0.40</td>
</tr>
<tr>
<td>Session duration (min)</td>
<td>0.48</td>
<td>0.51</td>
<td>40</td>
<td>0.11</td>
<td>0.49</td>
</tr>
<tr>
<td>Program length (weeks)</td>
<td>0.40</td>
<td>0.55</td>
<td>60</td>
<td>0.10</td>
<td>0.44</td>
</tr>
</tbody>
</table>

**Table 1.** Moderator variables included in the study

<table>
<thead>
<tr>
<th>Characteristics of the study</th>
<th>Research design</th>
<th>True experimental</th>
<th>Quasi-experimental</th>
<th>Pre-experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Mixed</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Type of activity</td>
<td></td>
<td>Football</td>
<td>Running</td>
<td>Soccer</td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td></td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Session duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test characteristics</td>
<td></td>
<td>M (mode)</td>
<td>M (mode)</td>
<td>M (mode)</td>
</tr>
</tbody>
</table>

**Figure 1.** Effect size (ES) magnitude of the training interventions on the VO2max in children and adolescents.

a < b, p < 0.05
One-way ANOVA for the sample characteristics as a moderator variable showed no significant differences for gender ($F = 0.732, p = 0.486$), age ($r = 0.14, p = 0.152$) and type of participant ($F = 0.448, p = 0.508$). In general, all participants improved their VO2max when participating in an exercise training program (Table 3).

One-way ANOVA for the characteristics of the exercise training interventions as a moderator variable showed no significant differences for exercise intensity ($F = 0.216, p = 0.885$), weekly frequency ($r = 0.12, p = 0.409$), session duration ($r = 0.11, p = 0.496$), and program length ($r = -0.10, p = 0.442$) (Table 4).

One-way ANOVA for VO2max testing characteristics as a moderator variable showed significant differences between cycle ergometer ($ES = 0.50 \pm 0.57, z = 5.82, p < 0.05$) and treadmill ($ES = 0.49 \pm 0.63, z = 4.70, p < 0.05$) compared to 20-m interval running ($ES = 0.25 \pm 0.12, p > 0.05$).

**Discussion**

The aim of the study was to determine the effect of exercise training on the VO2max of children and adolescents and to detect relevant moderator variables. The main finding of this study was a confirmation of the human body's ability to chronically adapt to exercise training, leading to an improvement in the aerobic power (i.e., VO2max) from childhood to adolescence. A moderate ES was found for VO2max regardless of the sample and training program characteristics. The increase in 6.53% in VO2max resulting from exercise training found in the present study is at the higher range of the 5% to 6.14% reported in previous meta-analyses (LeMura et al., 1999; Payne & Morrow, 1993) (Figure 2).

![Figure 2. Change in VO2max (ml kg^-1 min^-1) in children and adolescents following exercise training.](image)

No significant gender differences in VO2max following training were found in this study. Others (LeMura et al., 1999; Payne & Morrow, 1993) suggested that females might benefit more than males from an exercise program. However, with the similar number of ES computed in the present study that trend is no longer supported.

We found improvements in VO2max in children and adolescents from 10 to 18 years by increasing the age range. Others (LeMura et al., 1999; Payne & Morrow, 1993) reported ES differences by age group; however, these authors only included participants with a limited age range (i.e., 8 to 10 and 11 to 13 yrs.). In agreement with previous reports (Baquet, van Praagh, & Berthoin, 2003), no significant ES differences in the VO2max were found between athletes and non-athletes.

In this study, similar ES were found for moderator variables exercise frequency, duration and the training program length. In opposition, others (Armstrong, Barrett, & Welsman, 2007), suggested a minimum of three to four sessions per week, for 40-60 min/session, for at least 12 weeks to obtain aerobic power benefits. Our evidence suggests that an exercise program characteristic is not a strong moderator for the effects on VO2max. We found that at least two exercise sessions/week of a minimum of 20 min/session, executed at a moderate intensity for at least 11 days, provide significant benefits to children and adolescents.

Exercise intensity is a key element in a training program. This feature is difficult to meta-analyze since some authors do not report the training intensity used in their studies. Another limitation is that for those authors reporting exercise intensities, maximal heart rate (HRmax) and VO2max percentage were used interchangeably. In the present study we categorized the high intensity exercise as 80-100%, moderate intensity as 60-79%, and low intensity as > 59%.

We found that a moderate exercise intensity of (e.g., ~60% of an individual's HRmax) provided enough stimuli for a VO2max improvement. This contrasts previous findings (Armstrong et al., 2007; Baquet et al., 2003), suggesting a higher exercise intensity (e.g., > 80% HRmax) necessary to achieve aerobic power benefits.

There were changes in the initial characteristics of the exercise protocol in several studies. This is an expected finding that follows the principle of exercise progression, which states the need of adjusting the work load for optimal results; however, modifying the original protocol (and not reporting it) precludes from studying a cause-effect association and potential physiological mechanisms responsible for the observed outcomes. A methodologically sound suggestion for future studies would be to test participants in all dependent variables any time a change in the program work load is done.

In this study, 20-m interval running tests did not result in ES statistically different from zero. Although this test is easier to administrate and is inexpensive compared to laboratory equipment such as cycle ergometers, metabolic carts and treadmills, the validity and reliability of data derived from this field test is not always reported or known. Therefore, in order to obtain valid and reliable VO2max estimates, direct measurement of aerobic power must be used when studying the effects of exercise interventions in children and adolescents.

We agreed with others (Payne & Morrow, 1993), who found similar ES when participants were tested in treadmill and cycle ergometers. Undoubtedly, the children and adolescent's ability to improve their aerobic capacity by exercise training is demonstrated. Empirical evidence suggests similar benefits regardless of the characteristics of exercise program; however, further experimental research is needed that address proper and quantifiable exercise frequency, intensity and duration.

In conclusion, in order for children and adolescents to improve their VO2max, exercise training should include at least two sessions per week, for > 20 minutes duration per session, performed at a moderate intensity.

**References**


**Studies meta-analysed**


Income and Expenditure Patterns in Recreation and Leisure in Costa Rica

Yamileth Chacón-Araya* & Brian Crow**

*University of Costa Rica, **Slippery Rock University, USA

Abstract. The purpose of the study was to analyze the income and expenditure patterns in recreation and leisure in Costa Rican households. The original sample consisted of 5,220 randomly selected households; and complete information was obtained from 4,231 homes. Variables of per capita income and expenditure patterns were analyzed. Hypotheses testing based on the 95% confidence intervals indicated that at the national level 13.70% of the people in the lowest quintile spent more money on recreation and leisure than the money they earned. Lower expenses were reported as the number of family members living in the house increased, yet higher expenses were reported as the level of education of the home owner increased. In conclusion, the expenses in aspects related to recreation and leisure in Costa Rica has modestly increased for people in the lowest and higher income quintiles since 1988.

Keywords: recreation, culture, expenses, income, leisure, national survey, Costa Rica.

Introduction

Recreation and leisure are directly related to the development of a nation by promoting positive health habits, which in turn causes a direct impact in the economic development by improving labor performance and reducing the economic impact of sick-leave (Kool, de Bie, Oesch, Knisel, Brandt, & Bachmann, 2004; Moncada-Jiménez, 2005). According to the United Nations Inter-Agency Task Force on Sport for Development and Peace (2005), in the United Kingdom, expenses for activities related to sport reached approximately 1.7% of the gross national product (GNP), a figure comparable to expenses in the automobile, goods and services, and food industries. Globally, it is estimated that the sport industry produces $36 billion annually and the annual growth tendencies are of the order of the 3-5% (World Bank, 1999).

Although Costa Rica does not have a systematic methodology to determine expenditure patterns in recreation and leisure, it has been reported that ticket sales generated approximately US $1 930 744 for the Major League of Soccer Tournament 2003-2004, (Moncada-Jiménez, 2005). In Costa Rica the total investment for education and health for 2003 was of 5.53% and 5.73% of the GNP respectively (Observatory of the Development, University of Costa Rica, 2005), these ticket sales reported by the soccer teams contribute to less than $505, $279 and $190 for active, passive relaxation, and social entertainment. Respectively. However, the greater expenses were in the social category after correcting for family income. Therefore, the homes whose mean annual income was highest spent more money in passive activities, whereas when the mean annual income was in the medium range, the expenses were greater in active relaxation, and when income was lowest, the expenses were greater in social entertainment. Also a correlation between educational level and expenses in recreational activities was found. In households where the head of the home (i.e., female head) had a greater degree of education (i.e., beyond high-school diploma), the household spent more money in active relaxation, followed by passive relaxation and social entertainment (Dardis et al., 1994).

Expenditure surveys in Canada from 1982 and 1999 included 11,000 and 16,000 households, respectively. Recreation and leisure expenses broadly included tickets for shows and theater, recreation services, materials and devices for home entertainment, sporting goods, computers, vehicles, camping supplies, cable T.V., and tourism. When comparing these surveys, researchers found a 39% increase in expenses from 1982 to 1999 (Kremarik, 2002). Interestingly, the increase in expenditures in sporting goods and recreation services reached 8%, whereas an exaggerated increment in computers (515%) and cable T.V. (253%) was observed.

A mode to use the information provided by these types of surveys is given by Dardis, Soberon-Ferrer and Patro (1994). These authors created categories based on the items people tend to use to satisfy their needs: a) active relaxation; b) passive relaxation; and c) social entertainment. The investigators defined active relaxation like those activities that required some physical effort, for example jogging, running or riding a bicycle. Passive relaxation was understood as those activities that did not require physical effort, such as watching T.V., computer use, or listening to a radio. Finally, social entertainment consisted of activities like attending sport events, the cinema, theater and other forms of home entertainment.

Based on the previous definitions, Dardis et al. (1994), analyzed data from the 1988 and 1989 income and expenses survey made on 2,088 U.S. homes and found a mean household monthly expenditure of $505, $279 and $190 for active, passive relaxation, and social entertainment, respectively. However, the greater expenses were in the passive relaxation category after correcting for family income. Therefore, the homes whose mean annual income was highest spent more money in passive activities, whereas when the mean annual income was in the medium range, the expenses were greater in active relaxation, and when income was lowest, the expenses were greater in social entertainment. Also a correlation between educational level and expenses in recreational activities was found. In households where the head of the home (i.e., male or female head) had a greater degree of education (i.e., beyond high-school diploma), the household spent more money in active relaxation, followed by passive relaxation and social entertainment (Dardis et al., 1994).
Information from these kinds of surveys also allows consumers and researchers to understand participation trends in different recreation and leisure activities. For instance, in the US, from 1995 to 1996 there was an increase in participation in sports like soccer (15.6%), and basketball (10.6%) compared to a reduction in golf (-8.8%) participation (Mullin, Hardy, and Sutton, 2000). These trends are related to changes in expenditure patterns of the population, which allowed for an increase of the 3.7% in the sales related to soccer and basketball. These data are supported by reports of the National Sporting Goods Association of the USA, which reported sales increases in sporting goods (National Sporting Goods Association, 2006).

This finding directly relates to the results of a study by Weagley and Huh (2004b), where these authors indicate that the leisure time of the American workers aged 18 to 64 has increased from 35 hours per week in 1965 to 40 hours per week in 1985. Therefore, workers had more time to spend their money in activities related to the recreation and leisure. This might explain why the percentage of expenses in home entertainment increased from 3.3% to 5.0% from 1960 to 1996.

The availability of such data is very limited in Costa Rica, and other Central American countries. In Costa Rica the last survey of «Income and Expenditure» (also called «Family Budget Survey») was conducted in 1988 (ENIG-1988). However, in 2005, The National Institute of Statistics and Census (INEC), with support from the Central Bank of Costa Rica, created the 5th National Survey of Home Income and Expenses from 2004 and 2005 (ENIG-2004). Thus, the purpose of the study was to describe expenditure patterns in recreation and leisure in diverse segments of the Costa Rican population.

Method

Participants

The ENIG-2004 was based on a complex probabilistic sample, which was constituted by 5220 urban and rural households in all of Costa Rica. The probabilistic sampling method was used to take into account different geographic areas (i.e., urban, rural), economic sector (i.e., high, medium, low-income), and phases. These phases consisted of two time-points when data was going to be collected, second semester of 2004 and first semester of 2005 (INEC, 2006).

Procedures

Several trained groups interviewed the selected households during 2004 and 2005. Later, the information was coded and tabulated by members of INEC. Data was converted to SPSS® (Statistical Package for Social Sciences®) for further analyses.

For this study, variables related to income and expenses were selected and described as follows.

Variables related to the house and economic sector. Geographic area was defined as either urban or rural. It was hypothesized that people from urban areas would spend a higher percentage of their income in recreation and leisure than their rural area counterparts. The variable «house ownership» was defined as 8 categories: 1) own house, paid in-full; 2) own, yet still being paid; 3) own, given as a gift or donated; 4) rented; 5) loaned or provided by a company; 6) loaned or provided by a relative, friend or others; 7) shelter (precarious); and 8) other. It was hypothesized that home owners would spend more money in recreation and leisure that those families who did not own a house. The variable «number of members living in the house» was selected, with the purpose to determine whether significant relationship existed, if any, between recreation and leisure expenses and the number of people within the family nucleus. Accordingly, it was hypothesized that large families would spend less money in recreation and leisure than small families. Finally, the variable «level of education» of the family head was analyzed to determine whether some relationship in recreation and leisure expenses and levels of education existed. The level of education was defined as the last approved degree of the formal education. It was hypothesized that education would have a positive impact in recreation and leisure expenditure.

Income. Total household income was defined as all the income earned by the different family members over a period of time. These wages included paid labor and/or wired money coming from renting properties, and bank transfers among others.

For the analysis and comparison with the data of the ENIG-1988, the variables related to the gross income of the household per capita were selected. The current income of the household refers to all periodic and regular income such as wages, rent, interest from bank accounts, and dividends from trust funds whose final destiny is expenditure. On the other hand, the household per capita income is defined as the total household income divided by the number of members of the household.

Consumption expenses. These expenses were defined as those related directly to the goods and services used for need satisfaction. These expenses found in ENIG-2004 were categorized according to the Classification of Personal Expenses (CPE), which is an internationally recognized measure. In table 1 are described some of the more than 700 types of consumption expenses taken into consideration for the present analysis.

Statistical analysis

The Statistical Package for Social Sciences (SPSS®), version 20.0 for Windows® was used to conduct all the statistical analyses. Descriptive statistics and the standard error of the estimation were obtained. Based on this information, logical groups of analysis based on income were formed; for which the corresponding quintiles were obtained. In the present study, the quintile 1 (Q1) represents the 20% of the poorest (lowest income) households, and the quintile 5 (Q5) the 20% of the richest (highest income) households (INEC, 2006).

Hypotheses testing were conducted based on the 95% confidence intervals. This interval includes the average of the estimations of all the possible samples with a probability of 95%. This interval has a longer lower limit, within which the population value is expected to fall with a 95% confidence level.

Table 1.

Table of expenses in recreation and leisure (INEC, 2006)

<table>
<thead>
<tr>
<th>Type of Expense</th>
<th>Example of goods and services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audiovisual, photographic equipment and of processing of information</td>
<td>Video and photography materials, tripods, developing services. Musical instruments like guitars, piano, drums, harmonica and other instruments, including loudspeakers and microphones fortunariae. Repair of photographic and cinematographic equipment. Repair and tuning of musical instruments.</td>
</tr>
<tr>
<td>Food for domestic animals, hygiene, food and for swimming. Other glass-orienting pools, surfboards, diving gear, clubs for soccer, balls and other sporting goods, billiard tables, tennis. Medications for domestic animals, lodging for domestic animals. Crossman trees, “pitalas”, trees (natural and felled), turf for parks, forests, meadows, grass, lines, trees, bicyles, cardboard, golf, tennis, soccer, baseball, volleyball, bowling, basketball, amusement park, home, boats or ships. Membership fees in fitness centers, personal trainer, gymnasiums, parks, beaches, rivers, sports goods and equipment.</td>
<td></td>
</tr>
<tr>
<td>Recreation and cultural services</td>
<td>Home games for sports and recreation (e.g., skids, shoes or go k). rent of times for VIP and INO, stunt, tennis, fitness centers, night games, swimming pools, private clubs, dance, theater, sports house, cinema, art galleries, circus, ballet, amusement park, home, boats or ships. Membership fees in fitness centers, personal trainer, gymnasiums, parks, beaches, rivers, sports goods and equipment.</td>
</tr>
<tr>
<td>Newspapers, books and paper and office supplies</td>
<td>Home games for sports and recreation (e.g., skids, shoes or go k). rent of times for VIP and INO, stunt, tennis, fitness centers, night games, swimming pools, private clubs, dance, theater, sports house, cinema, art galleries, circus, ballet, amusement park, home, boats or ships. Membership fees in fitness centers, personal trainer, gymnasiums, parks, beaches, rivers, sports goods and equipment.</td>
</tr>
<tr>
<td>Tourist services</td>
<td>Service of lodging in hotels, bed and breakfast, schools, motels, universities or other training centers, service of lodging for camping, town payment of quota of clubs for trips overseas.</td>
</tr>
</tbody>
</table>

Results

In the survey, only single-family households were considered sampling units; therefore, collective houses (i.e., nursing homes, jail) were excluded from the analyses. The response rate was 85%. Thus, information from 4,231 homes was obtained, from which 2,530 (59.8%) were of urban and 1,701 (40.2%) from rural geographic areas.

For a better understanding of the results in a global scope, figures of Costa Rican currency (Colón, ¢) were converted to United States dollars (USD) using an exchange ratio of US $ 0.001931 for each Costa Rican colón (CRC¢). Thus, for the population, the total expenses were approximately $541,350,450.55, from which 7.87%, or approximately $42,183,152.41 was spent in recreation and leisure. This amount locates the 20% of the poorest (lowest income) households, and the quintile 5 (Q5) the 20% of the richest (highest income) households (INEC, 2006).

- 189 -
As far as the specific expenses of the factors composing the area of recreation and leisure, it was observed that people, independently of the per capita income quintile, spent more than 20% in audio-visual and photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electronic devices like radios, DVD players, and television sets, but also photographic equipment. This area includes not only the acquisition of electron...
Urban and rural recreation and leisure expenses was ranked in 6th place of other basic needs; for instance, groceries, housing and clothing. In the habits of physical activity based on the previous research that showed people in urban areas spend more money than they earned.

Another factor that could influence spending on recreation and leisure can be the family size. Therefore, we determined whether a significant relationship between expenditure and number of members of the household existed. This hypothesis was based on the assumption that a larger number of family members would require satisfying basic needs instead of «secondary» needs (i.e., sporting goods) and therefore would spend more money in groceries, tuition, housing, and clothing. The results obtained in the present study agree with those by Dardis et al. (1994), who indicated indeed that households with a larger number of children spent less money in recreation and leisure. In the Canadian surveys described previously (Kremarik, 2002), it was found that recreation expenses from 1982 to 1999 increased significantly regardless of the family composition. Thus, four-member families increased their expenses in recreation by 50%, families with only one parent present increased their expenses by 57%, couples with no children increased spending by 36%, and singles increased spending by 17% (Kremarik, 2002). Therefore, small-size families also spend less money than large-size families.

In the ENIG-2004, a national trend on expenditure in recreation and leisure was found as it increased with the level of instruction or education of the household head. This trend is also true for urban and rural homes. In the US, Daly, Janini, Keil, Paskevicz, Paulin, and Tseng (2003), found that the people with lower education (60.5%) spent more money on entertainment than people with a complete university education (39.5%). In spite of the agreement between these two surveys, in another study made in 1986 and 1987, it was found that the entertainment, recreation and sports expenses could be predicted by age and not necessarily explained by the degree of education or occupation (Cage, 1989).

Data by Jacobs and Shipp (1990) from surveys carried out in the US in which recreation, reading and entertainment are taken into account, it is reported that these represented 4.9% of household expenses between 1960 and 1961. That percentage increased between 1972-1973 and 1966-1967 by 5.5% and 6.0%, respectively. Recent data presented by Toossi (2002), indicate a percentage change in the consumption of goods and services in recreation, entertainment and sports of +6.2% in the decade from 1980 to 1990; then it declines to 4.6% in the decade from 1990 to the 2000; and a projection was estimated of an increase of 6.0% for the years 2000 to 2010.

When the change in the pattern of per capita consumption of the year 1988 and 2004 by per capita income quintile in Costa Rica is analyzed, it was found that expenditures were lower in 1988 in comparison to 2004 based on the data shown by quintiles 1 (2.3% vs. 5.95%) and 5 (5.0% vs. 12.4%). Thus, in general, the net change in recreation and leisure was 3.65% from 1988 to 2004 for people located in the lowest income (i.e., poorest) quintile, and 7.4% from 1988 to 2004 for people of the highest income (i.e., richest) quintile.

The annual growth in expenses for people in the quintile 1 was 0.23%, whereas for the people in the quintile 5 was 0.46%. In a similar period of time in Canada, the growth was approximately 40%, in other words, a mean annual growth of 2.35% (Kremarik, 2002).

In the USA and Canada, and probably in Costa Rica, this trend in expenses as it relates to income might be a reflection of an increase in leisure time and family income. This could allow families to have more time to travel, to play or to participate in different sports, to go to the movies, to concerts, the theater and sport events, among other recreation and leisure activities. Nevertheless, another tangible aspect that can influence this expenditure pattern is the aging of the population. It has been shown in the US, elderly citizens spent approximately 8.3% difference in the monthly expenditure in recreation and leisure based on house ownership. Indeed, we hypothesized that families who totally had paid their own house could spend more money in recreation and leisure. However, the statistical analyses showed otherwise, since people who had their own house, yet were still paying on it, spent more in recreation and leisure that people who totally had paid their own house. As expected, people who live in precarious shelters are those who spent the smallest amount of money in recreation and leisure.

In a large-scale survey made in Finland by the National Institute of Public Health, information of 9,324 men and 10,658 women was collected to determine the relationship between income and health habits. The Finnish investigators found that there were no significant differences in the habits of physical activity based on the per capita income quintiles and by home. In other words, the degree of physical activity was equal independently of the economic income. This finding suggests that in the Finnish culture it really does not matter economic income since physical activity and recreation are already an integral part of their culture (Kremarik, 2002).

One of the reasons by which people would not spend their money in recreation and leisure might be that they prefer to use it to cover other basic needs; for instance, groceries, housing and clothing. In the ENIG-2004, recreation and leisure expenses was ranked in 6th place of importance, below groceries and beverages, transportation, housing, furniture and home accessories, and going out for dining. However, recreation and leisure ranked above goods and other services, clothing and shoes, health, communications, and education.

With the data of the ENIG-2004, we also found a significant income quintile spent more money than they earned.

These results agree, at least for the highest income quintile, with previous research that showed people in urban areas spend more money than people in rural areas (Dardis et al., 1994; Wilcox, Castro, King, Housemann, & Brownson, 2000).

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of their income in recreation and leisure activities in 1995 (Weagley & Huh, 2004a).
In Costa Rica, on the other hand, and based on data from INEC and the Central American Center of Population Studies of the University of Costa Rica, it is estimated that there will be 2.5 million elderly people (i.e., > 60 years age) by year 2050, which could suppose a change in the pattern of expenses in issues related to recreation, sports, physical activity and culture similar to countries like Japan (Manzenreiter & Horne, 2006; Varela, 2006). Aside from this, it has been estimated that by the year 2050 there will be relatively young people (50-60 years) enjoying from their retirement due to a National ordering in the retirement regime. In this retirement plan, citizens are forced by the Government to save part of their income in state owned banks. By doing so, there will be enough budget to cover their retirement at the age of 50 or 60.
In Costa Rica, it is possible that the small proportional and gradual increase in expenses in recreation and leisure activities from 1988 to 2004 has not had positive impact in the health of the Costa Ricans; at least not as seen by the increased number of overweight, obese and sedentary children and adolescents aged 8 to 17 years. In these groups we found a prevalence of overweight of Costa Rican students in the range of 15% to 23% and of obesity from 2.2% to 9.8% (Fernandez, Pearson, Moncada, Salas, & Gonzalez, 1998; Fernandez, Gonzalez, Moncada, Pearson, Picado, & Salas, 2001; Fernandez-Ramirez & Moncada-Jimenez, 2003). These figures are alarming since long term health care costs (e.g., medication, surgery, rehabilitation), for these groups will increase (Moncada-Jimenez, 2005).
Recent data by Johnson and Lino (2000) indicate that adolescents (i.e., 14 to 17 years) also comprise an important consumer group of goods and services. Based on data from the Survey of Consumer Expenses of 1997-1998, researchers found that working adolescents spent 6.2% of their total expenses in entertainment, recreation and sports. However, the most relevant expenses for this age-group were housing (33.8%), transportation (24%), and foods (13.6%).
Future studies in Costa Rica would need to be conducted to determine how the consumer spend money and to compare it to international surveys. For instance, it has been determined that Dutch citizens spend more money in subscriptions to Spas and fitness centers than British consumers (Jones, 1990). Other surveys indicate that females spend less money in recreation and leisure than males, and that the elderly spend less money than younger consumers (Dardis et al., 1994).
Also, it is necessary to analyze how these types of surveys change over time as far as income and expenses matter in order to determine consumer price index. In USA, for example, it was found a variation of 126% in the pattern of expenses in entertainment, recreation, sports and culture over a 10 year period (1972-1973 to 1982-1983) (Gieseman and Rogers, 1986).
In summary, in Costa Rica is necessary to design specific surveys about the patterns of income and expenditure in aspects related to sports recreation and leisure. These analyses will allow more accurately considering the relationship between physical activities with other key elements of human development, for example, physical health, satisfaction, self-esteem, body image and general well-being. From the economic point of view, this information will be useful to establish or to regulate prices of goods and services for the consumers and will serve to establish public policies for health promotion based on scientific, valid, and reliable data.

Acknowledgements
This study was supported by the personnel of the National Institute of Statistic and Census, the Central Bank of Costa Rica, and the Program State of the Nation, the Central American Center of Population Studies and the Research Institute of Economic Sciences of the University of Costa Rica.

References

Quality of Life, Depression and Involvement in Physical Activity of Parents with Disabled Children in Greece

Emmanouil K Skordilis
National and Kapodistrian University of Athens, Greece

Abstract. The study examined the quality of life (QoL) of parents with disabled children in Greece. Further, the relationship between QoL with depressive symptoms and involvement in physical activity were reported as well. The total sample constituted from 73 parents (Mean age = 42.87 years, SD = 7.58), classified in 42 parents of children with disabilities and 31 parents of children without disabilities (control group). The participants responded to the Beck Depression Inventory II (BDI-II) (Beck, Steer & Garbin, 1996), the QoL SF36v2 scale (Ware et al., 2007), and the Self Administered Physical Activity Checklist (SAPAC) (Sallis, Strikmiller, Harsha, & Feldman, 1996). The multivariate (lambda = .99, F = .35, p = .70, eta2 = .01) and univariate comparisons between the two parental groups did not reveal significant differences in the physical (PCS) and mental (MCS) components of the SF36v2. The QoL was significantly related to the depressive symptoms, while the involvement in physical activity was not related to QoL. On the other hand, parents of children with disabilities had less sedentary behaviors compared to the control group. The overall findings are discussed in line with relevant studies examining the QoL of families with disabled children.

Keywords. Quality of Life, depression, physical activity, parents, disability

Resumen. Este estudio examinó la calidad de vida (QoL) de los padres de niños discapacitados en Grecia. Además, se reporta la relación entre la calidad de vida y los síntomas depresivos y la participación en actividades físicas. El total de la muestra estuvo constituida por 73 padres (edad promedio = 42.87 años, DE = 7.58), clasificados en 42 padres de niños con discapacidad y 31 padres de niños sin discapacidad (grupo control). Los participantes respondieron el Inventario de Depresión de Beck II (BDI-II) (Beck, Steer & Garbin, 1996), la escala QoL SF36 v2 (Ware et al., 2007), y el Self Administered Physical Activity Checklist (SAPAC) (Sallis, Strikmiller, Harsha, & Feldman, 1996). Las comparaciones multivariadas (lambda = .99, F = .35, p = .70, eta2 = .01) y univariadas entre los dos grupos de padres no mostró diferencias significativas en los componentes físicos (PCS) y mentales (MCS) de la escala SF36. La QoL se relacionó significativamente con síntomas depresivos, mientras que la participación en actividades físicas no estuvo relacionada con la QoL. Por otra parte, los padres de los niños con discapacidad tuvieron menos comportamientos sedentarios comparados con los padres del grupo control. Los resultados generales se discuten en línea con los estudios pertinentes que examinan la calidad de vida de las familias con niños discapacitados.

Palabras claves. Calidad de vida, depresión, actividad Física, padres, discapacidad

Introduction

Quality of Life (QoL) may be perceived as a subjective sense of well-being and incorporates elements such as the physical and mental health, access to leisure time, education, sense of social belongingness, etc. (Kane, 2002). The term ‘quality of life’ may have a different meaning to different individuals (Kane, 2002), while for certain researchers it means almost everything beyond information about longevity death rates. According to the Encyclopedia of Public Health (2002), the QoL is an umbrella concept and includes the physical health, psychological and social well-being, socio economic status, relationships with family and friends, access to occupation, leisure, physical activity, etc. (Ware et al, 2007).

Researchers have examined the QoL of individuals with disabilities (Fellinger et al. 2005; Levasseur, Desrosiers & Noreau, 2005; Schatz et al. 2005; Lavoie et al. 2005). Fellinger et al. (2005) examined the QoL and mental stress of 236 individuals with deafness. The researchers found that their sample had lower QoL compared to the ‘general’ population and concluded that health services may provide an effective mean of communication in order to increase the QoL of deaf individuals (Fellinger et al. 2005). Levasseur et al. (2005) examined older adults with physical disabilities (60 to 90 years old) and found that they exhibited a positive, although weak, association between social interaction and QoL (Levasseur et al. 2005). Schatz et al. (2005) studied asthma patients, 18 to 56 years old, and reported that their subjective perception of daily burden interfered with daily activities and overall QoL. Finally, Lavoie et al. (2005) examined the relationship among psychiatric status, levels of asthma control, and QoL in 406 adult asthma patients. The researchers suggested that the QoL was associated with several psychiatric disorders of asthmatic patients (Lavoie et al. 2005).

Recently, researchers have examined the QoL of parents and siblings of individuals with disabilities (Salah Frih, Boudoukhane, Jellad, Salah, & Rejeb, 2010; Davis & Gavidia-Payne, 2009; Hatzmann et al., 2009; Lee et al., 2009; Davidson, 2001). Salah Frih et al. (2010) examined parents living with their children (N = 53) with cerebral palsy (CP) and reported that both mothers (24.5%) and fathers (11.6%) exhibited high depressive scores. The researchers concluded that the psychological status of parents is negatively influenced from the presence of a child with CP at home (Salah Frih et al., 2010). Hatzmann et al., (2009) examined the QoL of parents with children experiencing metabolic diseases. The researchers found that the QoL was predicted from certain psychological variables to a wider extent compared to medical and socio-demographic variables (Hatzmann et al., 2009). Lee et al., (2009) compared the QoL of 89 parents with autism and 46 parents without disabilities. The researchers found lower QoL for the group of parents with autistic children, compared to the controls. Davis and Gavidia-Payne (2009) examined the predictors of family QoL, in a group of families with children with disabilities. The researchers found that the parental perceptions and experiences of professional support were the predictors of QoL. Further, perceived intensity of problems and support from other family members were significant predictors of QoL as well (Davis & Gavidia-Payne, 2009).

Further, certain factors associated with the QoL of parents living with children with disabilities have been reported as well. The most commonly reported are the socioeconomic status (Olsson & Hwang, 2008), depression (Baily, Golden, Roberts & Ford, 2007), family hardship (Failla & Corson Jones, 1991), psychological well-being (Eisenhower, Baker & Blacher, 2005; Van Riper, Ryft & Pridham, 1992), parental stress (Khamis, 2006), sleep quality (Chu & Richdale, 2009), etc. Olsson and Hwang (2008) studied families of children with intellectual disabilities (ID) and stated that the presence of a child with intellectual disability (ID) does not predict poor maternal QoL. Instead, economic hardship and health were significant predictors of QoL (Olsson & Hwang, 2008). Baily et al. (2007) found, in a systematic review that maternal stress and support were associated with the depressive...
symptoms experienced from mothers of children with developmental disabilities. Chu and Richdale (2009) examined 46 mothers and 50 children with developmental disabilities and found significant association between children’s behavior problems and mother’s sleep disturbances and depression. Eisenhour et al. (2005) examined the association between disability, behavior and well-being of mothers with autistic children. The researchers found that mothers reported higher parenting stress compared to controls, while severity of child syndrome contributed to maternal stress even after accounting for differences in behavior problems and cognitive level. Van Riper et al. (1992) examined the well-being of 34 families of children with Down syndrome and 41 controls. The researchers found no differences between the two groups and concluded that parenting a child with Down syndrome may be associated with adaptive functioning and resilience (Van Riper et al., 1992).

The acceptance of loss theory (Keany & Glueckauf, 1999) and the cognitive adaptation theory of Taylor (1983) and Taylor, Lichtman and Wood (1984) guided the present study. According to Keany and Glueckauf (1999), the response to disability varies from complete denial to exaggeration and depends upon several environmental, biological, social and psychological factors. Keany and Glueckauf (1999) stated that four major changes must occur in order to successfully cope with the existing disability. These changes include: a) enlargement of values, b) subordination of physique relative to other values, c) containment of disability effects, and d) transformation of comparative to intrinsic values. On the other hand, the cognitive adaptation theory describes the general adjustment process of threatening events. Taylor and colleagues reported that this process incorporates three major cognitive steps: a) an attempt to give a meaning to a threatening event, b) an attempt to gain control over the threatening event, and c) an attempt to increase self-esteem. Marsh and Johnson (1999) stated that disability may be perceived as a catastrophic event, and reported the burden of disability to the family members. Marsh and Johnson (1999) described several burdens, classified either as subjective (e.g. lack of sleep, anxiety, guilt, disbelief, anger, despair, shame) and/or objective (e.g. daily restrictions), along with the distress of family members due to the type and severity of the experienced disability (e.g. disturbances of mood, depression, self-destructive behavior, maladjusted behavior, poor daily living skills, etc).

Based on the above, the present study was designed to shed more light in the topic and examine the QoL of parents living with their children with disability in Greece. More specifically, the association among the health related QoL, with depression and involvement in physical activity were examined. Further, differences between parents of children with disabilities and controls were examined also. The independent variables were the parental status (parents with and without disabled children) and gender (male and female parents). The dependent variables were the health related QoL (physical and mental component), depressive symptoms and involvement in physical activity. Based on the daily burdens reported in the literature it was hypothesized that the Greek parents of disabled children would exhibit lower health related QoL, higher depressive symptoms and lower involvement in physical activity, compared to parents in the control group. Finally, a significant association among QoL, depressive symptoms and physical activity was anticipated for the group of parents with disabled children.

**Method**

**Participants**

The total sample incorporated seventy-three parents, divided to: a) forty-two parents having children with disabilities and b) thirty-one parents with non-disabled children (comparison group). A purposeful sampling selection was used (Thomas & Nelson, 1996) to recruit the parents in the first group from rehabilitation centers and special education settings in Athens, Greece. The parents in the control group were recruited from the same geographic areas in Athens.

**Measuring Instruments**

**SF-36v2 (Quality of Life)**

The SF-36v2 (Ware et al., 2007) is consisted from 36 items classified under the following eight dimensions: physical functioning, role limitation due to physical health problems, bodily pain, general health, vitality, social functioning, role limitation due to emotional health problems, and mental health. Scores range between 0 and 100, with a higher score indicating higher-related quality of life. Further, the SF-36v2 incorporates the following scales: a) the Physical Component Scale-PCS (physical functioning, physical role, bodily pain, and general health) and b) the Mental Component Scale-MCS (vitality, social functioning, emotional role, and mental health). The PCS and MCS were used for the purposes of the present study. The validity and reliability of the SF-36v2 in Greece has been reported by Pappa, Kontodimopoulos and Niakas (2005) and Anagnostopoulou, Niakas and Pappa (2005).

**Beck Depression Inventory II (BDI-II)**

The BDI-II was used to assess the depressive symptoms (Beck, Steer & Garbin, 1996). It incorporates 21 items, reflecting the cognitive and affective - somatic elements of depression. Items are rated on a 4-point Likert scale (0 to 3). Higher total scores are associated with more depressive symptoms. The BDI-II has been validated in Greece by Oikonomou and Psychountaki (2005), with a reported .92 Cronbach alpha coefficient.

**Self-Administered Physical Activity Checklist (SAPAC)**

Physical activity was measured with a checklist (SAPAC) (Sallis, Strikmler, Harsh, & Feldman, 1996), in daily minutes. The participants recalled time spent in 22 common daily physical activities and time spent in sedentary activities, such as playing video games, watching television, etc. The SAPAC examined the involvement in physical activity of both groups of parents (parents with disabled children and controls).

**Procedure**

The parents were contacted and a meeting was arranged for data collection. Before the assessment, the purpose of the study was explained and an informed consent was obtained. Parents responded to the three measuring instruments (SF 36v2, BDI-II, SAPAC) and a demographic questionnaire.

**Statistical Analysis**

The SPSS was used to analyze data (Norusis, 1993). The demographics were analyzed with frequencies, means and standard deviations. The Pearson coefficients examined the association among the dependent variables. Multivariate analysis (MANOVA) and post hoc independent t-test examined the differences between the parental groups. Univariate ANOVA was used when the multivariate findings exceeded significance (p < .05).

**Results**

The participants were mainly females (N = 53), with a monthly income of 1001-2000 euros (45.2%), while 46.6% were senior high school graduates and 53.4% had an undergraduate University degree. With respect to the 42 parents with disabled children, 31 of their children were females and 10 males (Mean age = 11.86 years, SD = 6.72), with different disabilities such as intellectual disability, autism, visual impairment, cerebral palsy, cancer, etc. Mean age of this group was 42.87 years old (SD = 7.58), with a range from 24 to 70 years old. Accordingly, the health related QoL, depressive symptoms and physical activity were assessed. With respect to the SF36v2 scores, both groups of parents exhibited higher PCS and lower MCS means compared to the Greek norms (Ware et al., 2007; Anagnostopoulous, Niakas and Pappa, 2005). With respect to the BDI-II (Beck, Steer & Brown, 1996), 2 parents exhibited severe depressive symptoms (2.7%).
3 parents experienced moderate (4.1%), 13 parents experienced mild (18.8%), while 54 parents experienced no depressive symptoms (74%). The descriptive statistics are presented in tables 1 and 2.

Table 1. Descriptive Statistics: Parents with disabled children.

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
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<tbody>
<tr>
<td>SF36v2</td>
<td>51.88</td>
<td>8.44</td>
<td>44</td>
</tr>
<tr>
<td>PCS</td>
<td>44.92</td>
<td>10.71</td>
<td>44</td>
</tr>
<tr>
<td>SAPAC</td>
<td>51.28</td>
<td>8.44</td>
<td>44</td>
</tr>
<tr>
<td>Daily min. of Physical Activity</td>
<td>150.75</td>
<td>135.66</td>
<td>44</td>
</tr>
<tr>
<td>Total BDI-II</td>
<td>7.00</td>
<td>3.62</td>
<td>44</td>
</tr>
<tr>
<td>Cognitive Factor</td>
<td>3.03</td>
<td>3.35</td>
<td>44</td>
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<tr>
<td>Total Act. Min</td>
<td>10.03</td>
<td>7.33</td>
<td>44</td>
</tr>
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</table>

Table 2. Descriptive Statistics: Control parents.

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>N</th>
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<tbody>
<tr>
<td>SF36v2</td>
<td>51.88</td>
<td>8.44</td>
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<tr>
<td>PCS</td>
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<td>10.03</td>
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The intercorrelations among health related QoL, depression and physical activity were recorded afterwards. The intercorrelation matrix, for the total sample of 73 parents is presented in table 3.

Accordingly, the differences between parents with and without children with disabilities, with respect to their self-reported health related QoL (MCS and PCS), depressive symptoms and physical activity were examined. With respect to MCS and PCS elements of the SF36v2, no significant multivariate differences were found (lambda = .99, F = .35, p = .70, eta² = .01) (Figure 1).

Figure 1. The PCS and MCS (SF36v2) of the two parental groups.

With respect to the BDI-II scores (cognitive and somatic factors), no significant multivariate differences were found between the two groups (lambda = .99, F = .39, p = .68, eta² = .01). The independent groups t-test, examining group differences in the total BDI-II score, was not significant too (t = -.85, p = .44). The overall findings are presented in figure 2.

Finally, we examined the differences between the two parental groups in the physical activity involvement. The multivariate results were not significant (lambda = .92, F = 1.89, p = .14, eta² = .08), but the univariate post hoc comparisons were significant for the minutes involved with sedentary activities (F = 5.15, p = .03, eta² = .07). Examination of the mean scores revealed that the parents with disabled children were involved less in daily sedentary activities (M = 150.75 min, SD = 135.66) compared to the control group of parents (M = 241.13 min, SD = 199.40). The overall findings are presented in figure 3.

Discussion

The study investigated the quality of life, depressive symptoms and involvement in physical activity, of Greek parents with and without disabled children.

Quality of Life

In the present study, the QoL did not differentiate parents with disabled children and controls. This finding is in line with Olsson and Hwang (2008) who reported that the presence of a child with intellectual disability did not predict poor maternal quality of life and general well-being (Olsson & Hwang, 2008). This finding may be explained through the cognitive adaptation theory. Specifically, a person facing a threatening event usually: a) searches for a meaning and b) attempts to gain mastery and control the threatening situation (Singer et al., 1999). On the other hand, certain studies suggest that the QoL of parents who raise disabled children are lower compared to controls (Salah et al., 2010; Lee et al., 2009; Chu & Richdale, 2009; Eisenhower et al., 2005). It seems therefore that this area remains open for future researchers in the field.

Quality of Life and Depression

No differences were evident between the parental groups with respect to depressive symptoms. Similarly, Van Riper, Ryff and Priddham (1992) did not report differences regarding several variables, such as depression, autonomy, purpose in life, positive relations, environmental mastery, self-acceptance and personal growth of parents who have
disability, further, only 2.7% of the parents exhibited severe depressive symptoms. This finding is in line with Salas et al. (2010) who reported that 25% of mothers and 11% of fathers exhibited high depressive risk, related to their social and financial embarrassment. On the other hand, other researchers have reported increased anxiety, depressive symptoms and lower maternal QoL due to the presence of disabled children (Bumin, Günel & Tükel, 2008; Altimdag et al., 2007). The only differences in the present study were found in the total BDII score. The intercorrelations however revealed that the MCS of QoL was negatively associated with the BDII subscales, suggesting that the higher quality of life is associated with lower depressive symptoms. **Involvement in Physical Activity**

No differences were evident between the two groups of parents (those with and without children with disabilities). Interestingly, significant differences were evident with respect to sedentary behavior. Parents with disabled children were less sedentary and more energetic compared to their counterparts. An explanation may be that they have less time to invest to sedentary activities due to the daily responsibilities they face to raise their children. Further, the major part of the sample was recruited from rehabilitation centers in Athens and probably they were already aware for the detrimental effects of sedentary behavior and the importance of daily physical activity. The present hypothesis, with respect to the association between QoL and involvement to physical activity was not confirmed. It will be useful to reexamine this finding, possibly with a wider sample, since others studies have reported significant association between habitual physical activity with mental health, QoL and low depressive symptoms (Salmon, 2001; De Moor, Beem, Stubbe, Boomsma & De Geus, 2006).

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Behavioral interventions to benefit cognition

Intervenciones cognitivas para beneficiar la cognición

Jennifer L. Etnier, Chia-Hao Shih & Aaron Piepmeier
University of North Carolina at Greensboro, USA

Abstract. With the growing population of older adults, the identification of treatment strategies to prevent or ameliorate age-related cognitive decline has been an important topic in recent years. After reviewing cross-sectional, longitudinal, and experimentally designed studies, as well as evidence from narrative and meta-analytic reviews, the authors concluded that behavioral approaches such as physical activity, cognitive training, and dietary interventions show promising results. In addition, given the likelihood that multiple underlying mechanisms support cognitive function, research is currently focusing on how to combine lifestyle factors into multi-component interventions to generate greater and more meaningful effects. Though evidence for these enhanced benefits exists from animal studies, few multi-component studies have been performed with humans. However, the findings from these studies are promising and a continued pursuit of multi-component behavioral interventions to benefit cognitive performance is warranted.

Introduction

Age-related cognitive decline is a public health concern because of its association with clinical cognitive impairment (Flicker, Ferris, & Reisberg, 1991; Larson & Lang, 2008; Myers, Kluger, Golomb, Gluck, & Ferris, 2008) and because its prevalence is expected to surge with the growing population of older adults (Hebert, Scherr, Bienias, Bennett, & Evans, 2003). Thus, it is important to identify treatments that maintain cognitive performance with advancing age. Several promising behavioural approaches have been identified with recent studies focusing on the potential benefits of physical activity, cognitive training, and dietary interventions.

Physical activity

Numerous studies have explored the relationship between chronic physical activity and cognitive performance through the use of cross-sectional, prospective, and experimental designs. This literature has been reviewed meta-analytically on several occasions with results generally supporting a positive relationship between physical activity and cognitive performance. Etnier et al. (1997) conducted the first comprehensive meta-analytic review of studies on physical activity and cognition, which included 134 cross-sectional, correlational, and experimental studies. They concluded that physical activity had a small but significant positive effect on cognitive function, with an overall mean effect size of 0.25. An important finding from this review was that experimental design was a significant moderator of the effect of physical activity on cognition, with less rigorous studies being associated with larger effects. This finding highlighted the need for more rigorous studies to be performed in order to elucidate the effect.

Prospective epidemiological studies examine the effects of baseline physical activity on subsequent cognitive performance and provide a stronger level of evidence than cross-sectional and correlational studies. In general, studies using this design report that higher levels of physical activity at baseline protect against subsequent cognitive decline. This relationship is seen whether cognitive function is assessed using standardized cognitive tests (Lytle, Vander Bilt, Pandav, Dodge, & Ganguli, 2004; van Gelder et al., 2004; Weuve et al., 2004; Yaffe, Barnes, Nevitt, Lui, & Covinsky, 2001) or clinical measures of cognitive impairment (Abbott et al., 2004; Larson et al., 2006; Podewils et al., 2005; Rovio et al., 2005). When explored meta-analytically (Sofi et al., 2011), prospective studies that investigated the association between physical activity and risk of cognitive decline in non-demented people, showed that physical activity had a protective effect against cognitive decline. This protective effect was similar for those who performed high levels compared to low-to-moderate levels of physical activity.

Randomized control trial studies provide an even higher level of evidence for the effects of physical activity on cognitive performance because they allow for the establishment of causation. Colcombe and Kramer (2003) performed a meta-analysis to explore the effect of chronic aerobic exercise training on cognitive performance by older adults specifically limiting their review to randomized control studies. Findings from their review revealed that aerobic exercise training produced a moderate overall positive effect on cognitive performance (g=0.48). Importantly, although effects were largest for executive function tasks (g=0.68), beneficial effects were observed across a variety of cognitive domains, suggesting global benefits of exercise on cognitive performance. The results from this review provided strong evidence for a beneficial effect of aerobic exercise training on cognitive performance by older adults.

Heyn, Abreu, and Ottenbacher (2004) specifically focused their review on whether physical activity was beneficial for older adults with dementia and related cognitive impairments. As with the study conducted by Colcombe and Kramer (2003), this meta-analysis only included studies that used randomized control trials. Results showed that the overall mean effect size between exercise and non-exercise groups for cognitive performance was 0.57. Therefore, they concluded that exercise training increases cognitive function in older adults with dementia and related cognitive impairments. Findings from this study are important...
because they suggest that the mechanisms responsible for the beneficial effect of exercise on cognitive performance are still functional in individuals with cognitive impairment and degenerative brain disease. These findings are support for a continued effort to explore the use of exercise to benefit those with, or at risk for, dementia.

Much of the early research in this area was conducted using the cardiovascular fitness hypothesis as a foundation. The cardiovascular fitness hypothesis asserts that cardiovascular (or aerobic) fitness is a causal factor that explains the relationship between physical activity and cognitive performance. However, Etnier and colleagues used meta-regression techniques to specifically test the cardiovascular fitness hypothesis of cognitive performance (Etnier, Nowell, Landers, & Sibley, 2006) and concluded that there was no support for this hypothesis. Specifically, analyses showed that there was no relationship between changes in aerobic fitness and changes in cognitive performance for studies with cross-sectional designs or when making comparisons of data at post-test. Surprisingly, changes in aerobic fitness from pre-test to post-test were found to be negatively related to changes in cognitive performance from pre-test to post-test indicating that increases in aerobic fitness actually predicted decreases in cognitive performance. Given that the cardiovascular fitness hypothesis was not supported, the authors suggested that other causal mechanisms for the relationship between physical activity and cognitive performance should be explored.

More recently, Angevaren, Auffdemkampe, Verhaar, Aleman, and Vanhees (2008) conducted a Cochrane systematic review of 11 studies to assess the effects of chronic aerobic exercise programs on cognitive function with nonclinical older adults. They found that the largest effects were on motor function, auditory attention, and delayed memory. However, the authors suggest that care be taken in interpreting the effect on delayed memory as it was obtained from a single study. In addition, they observed moderate positive effects on cognitive speed and visual attention. Similar beneficial effects of exercise on cognitive function were also observed for cognitively impaired older adults.

In sum, when reviewed meta-analytically, results from studies testing the effects of chronic exercise on cognitive performance consistently support that there are benefits. These results are evident in older adults and in older adults who are already experiencing cognitive decline. Further, these results are evident when using laboratory-based measures of cognitive performance and when using clinical measures of cognitive performance.

Cognitive training

Cognitive training is another behavioral intervention that has been examined for its effect on cognitive performance in clinical and non-clinical populations. Systematic and meta-analytic reviews consistently show that cognitive training has positive effects on cognitive performance. In a meta-analytic review of published studies with randomized control trial designs, Zehnder, Martin, Altgassen, and Clare (2009) revealed significant training effects for paired associate learning and immediate and delayed recall in healthy older adults and significant training effects for immediate recall in adults with mild cognitive impairment (MCI). Other reviews support cognitive training benefits for memory (Gates, Sachdev, Piatnarong Singh, & Valenzuela, 2011; Teychen et al., 2012), learning (Simon, Yokomizo, & Bottino, 2012), and various aspects of cognitive function, including objective and subjective measures of cognitive functioning, memory performance, executive functioning, processing speed, attention, and fluid intelligence (Rejinders, van Heugten, & van Bostel, 2013). Results have also shown that the effects of computer-based cognitive interventions are comparable to or better than the effects of traditional, paper-and-pencil cognitive training approaches (Kueider, Parisi, Gross, & Rebok, 2012). Recently, Jak, Seelye, and Jurick (2013) conducted a systematic review of electronic cognitive training programs (e.g., computer and video game based) and found that most studies showed significant improvements in trained cognitive tasks, specifically processing speed. Thus, there is substantial evidence supporting the use of cognitive training to improve cognitive performance.

Despite the evident benefits of cognitive training, Jak et al. point out that there is a short-coming in this scientific literature because the benefits of cognitive training programs are typically only observed in the specific tasks that have been trained. Hence, more work is needed to determine the potential benefits of cognitive training programs on more general outcomes such as age-related cognitive decline. One intriguing direction for future research is to combine cognitive training with physical activity with the hopes of producing larger effects on a broad array of cognitive tasks.

Dietary intervention

Another promising approach to protect or improve cognitive performance is through dietary interventions. The focus of this research thus far has largely been on understanding how diet can be used to reduce oxidative stress by enhancing the antioxidant-prooxidant balance through an increase in antioxidants. The reduction of oxidative stress is important because when the production of reactive oxygen species (or free radicals) exceeds the capacity of the antioxidant defense system, oxidative stress markers are elevated in the systemic circulation and result in the activation of the inflammatory process (Giunta, 2008). According to the free-radical theory of aging (Harman, 1994), as the human body ages there is an increase in the production of free radicals and/or a decrease in the quantity or quality of antioxidants resulting in an overall increase in oxidative stress and inflammation. The brain is particularly vulnerable to oxidative insults, so this theory posits that the damage caused by increased oxidative stress plays a role in age-related cognitive decline and the risk of Alzheimer’s disease (Berr, 2000; Clausen, Docrow, & Baudry, 2010; Hasnis & Reznick, 2003).

Research has shown that low plasma levels of molecular antioxidants such as plasma α-tocopherol, vitamin C, vitamin E, carotenoids, and selenium, are linked to detrimental in cognitive performance (Berr, Richard, Roussel, & Bonithon-Kopp, 1998; Gale, Martyn, & Cooper, 1996; Goodwin, Goodwin, & Garry, 1983; Jama et al., 1996; Perkins et al., 1999; Perrig-Chiello, Perrig, Ehrams, Stachelin, & Krings, 1998; Schmidt et al., 1998; Tucker et al., 1990) as well as a greater risk of cognitive decline or impairment (Berr, 2000; Engellart et al., 2005; La Rue et al., 1997; Perrig, Perrig, & Stachelin, 1997). Conversely, correlational studies have shown that people whose diets are high in antioxidants have lower levels of oxidative stress (Covas et al., 2006; Kang, Ascherio, & Grodstein, 2005; Rondanelli, Tronti, Opizzi, & Solerte, 2007; Senthilmohan, Zhang, & Stanley, 2003), perform better on cognitive tests (Kang et al., 2005; Rondanelli et al., 2007), and experience less cognitive decline over time (Wengreen et al., 2007). Interventions with older non-human animals report that those on a high antioxidant diet experienced reductions in oxidative stress and improvements in cognitive performance (Cantford, Gerrama, & Bickford, 2002; Joseph et al., 1999; Milgram et al., 2002; Rennie et al., 2008). Findings from intervention studies with humans in which dietary supplements have been used are more equivocal (Grodstein, Kang, Glynn, Cook, & Gaziano, 2007; Petersen et al., 2005). However, it has been suggested that this may be due to the variability in the antioxidant potency of various supplements, individual differences in the metabolism of supplements, and/or adherence issues. With regards to the effects of dietary interventions on cognitive performance, several researchers have shown benefits in cognitive functioning or reduced risk of Alzheimer’s disease with increased intake of vegetables (Kang et al., 2005), fruit and vegetable juices (Dai, Borenstein, Wu, Jackson, & Larson, 2006), and fruit and vegetable extracts in rats (Joseph et al., 1999) and canines (Milgram et al., 2002). More comprehensive dietary changes like those associated with the Mediterranean diet have also been shown to reduce cognitive decline in humans (Scarmeas, Stern, Tang, Mayeux, & Luchsinger, 2006; Weih, Wittfang, & Kornhuber, 2007).

In sum, the free-radical theory of aging implicates the antioxidant/prooxidant balance as being a critical determinant of age-related cognitive decline. Correlative evidence with humans and experimental evidence with non-human animals support the potential role of diet in mitigating age-related cognitive decline. Intervention studies with humans provide
some promising findings, but future studies are necessary to better understand how diet can be reliably manipulated to positively impact cognitive performance.

Multi-component interventions

Based on the abovementioned evidence, there is support for the efficacy of individual behavioral interventions to benefit cognitive performance. However, a limitation of all of these interventions is that their effects tend to be relatively modest in size and the cognitive training interventions are particularly limited in that their benefits do not transfer across cognitive domains. Given these limitations and that multiple mechanisms likely contribute to cognitive function (Emter, 2008), it has been suggested that «a cocktail of multiple interventions» may be necessary to attain larger, more generalizable effects (Droge & Schipper, 2007). In fact, recent calls for proposals from the United States National Institutes of Health (RFA-AG-09-009 and RFA-AG-14-016) focus explicitly on this expectation that combined interventions may be necessary to elicit larger, meaningful effects. The rationale behind a multi-component intervention is that the various components of the intervention might impact multiple mechanisms or might have a larger combined (i.e., synergistic) effect on a single mechanism (Rebok, Carlson, & Langbaum, 2007). Although there are several studies which have assessed the effects of multi-component interventions on non-human animals, there are only a few studies with humans which have used this approach (Benloucif et al., 2004; Masley, Weaver, Peri, & Phillips, 2008; Small et al., 2006; van Uffelen, Chinapaw, van Mechelen, & Hopman-Rock, 2008).

Non-human animal studies have shown that rodents exposed to cognitively engaging exercise demonstrate beneficial adaptations in cerebral structure (which are sometimes shown to be concomitant with improvements in behavioral measures of cognition) compared to animals that receive exercise alone (Black, Isaacs, Anderson, Alcantara, & Greenough, 1990; Klein, Lussign, Schwartz, Comery, & Greenough, 1996; Klein et al., 1998; Klein, Vrij, Ballard, & Greenough, 1997; Klintsova, Dickson, Yoshida, & Greenough, 2004). In these studies, «cognitively engaging exercise» is typically defined as physical activity in stimulating environments in which the objects/toys in an animal’s cage are changed on a regular basis to encourage exploratory physical activity while «exercise alone» is defined as access to a running wheel. In light of these positive findings, it has been proposed that more cognitively engaging forms of physical activity might result in larger cognitive gains for older adults (Colcombe, Kramer, McAuley, Erickson, & Scalf, 2004; Fabre, Chamari, Mucci, Masse-Biron, & Prefaut, 2002). However, few human studies report on the cognitive effects of interventions that include physical activity and cognitive training components in combination.

Fabre et al. (2002) tested the effects of a 2-month combined intervention on cognitive performance. Sedentary older adults were randomly assigned to one of four groups: an exercise group (two sessions per week of walking or running for 45 min), a mental training group (one 90-min session per week of performing mentally challenging tasks), a combined group that performed both the exercise sessions and the mental training session each week, or a leisure activity group. Participants in the combined group showed a significantly larger gain in memory quotient (Cohen’s d=5.22) than participants in any other group (exercise: Cohen’s d=1.64; mental training Cohen’s d=3.15; control Cohen’s d=0.20). However, there were no significant benefits for any of the training groups on 5 of the 8 cognitive measures and improvements were comparable for all three training groups on the other 2 cognitive measures. Although the multi-component program resulted in a larger improvement in cognitive performance on 1 of the 8 cognitive measures, the general lack of a difference between the combined group and the single intervention groups might indicate that combining this type of cognitive training with physical activity in this specific fashion does not result in a broad synergistic effect on cognitive performance.

Benloucif et al. (2004) used a repeated measures cross-over design to compare the effects of two (morning vs evening) 2-week daily activity interventions on the cognitive performance and sleep quality of older adults. The intervention consisted of physical activity and social cognitive activities performed in small groups for 90 min. Specifically, participants performed 30 min of stretching and low to moderate intensity physical activity, 30 min of social game playing, and another 30 min of low to moderate intensity physical activity. Results showed that participants in both the morning and evening interventions experienced significant improvements in cognitive performance as compared to their own performance during baseline. Significant benefits ranged in effect size from 0.598 to 1.235 and were evident for tasks assessing mathematical processing, memory, logical reasoning, and working memory / information processing. These effects are promising and certainly suggest that this combined intervention benefits cognitive performance, however the failure to use a randomized control trial limits the conclusions that can be drawn from this study.

Given that one of the mechanisms by which chronic physical activity may improve cognitive performance is through effects on antioxidants, it is logical to also consider combining exercise and dietary interventions that focus on reducing oxidative stress. Non-human animal studies show that chronic exercise training reduces oxidative stress. This evidence comes from studies showing that exercise reduces free radical production at rest, increases antioxidant defenses (Aksu, Topcu, Camsari, & Acikgoz, 2009; Harris, Mitchell, Sood, Webb, & Venema, 2008; Leeuwenburgh, Feibel, Chandwany, & Ji, 1994; Leeuwenburgh et al., 1997; Powers et al., 1994; Powers et al., 1993; Radak et al., 2001; Radak, Savvari, Nyakas, Taylor, et al., 2000; Venditti, Masullo, & Di Meo, 1999), and enhances the repair and elimination of oxidized molecules (Radak et al., 1999; Radak et al., 2002; Radak, Savvari, Nyakas, Pascok, et al., 2000). Although research with humans is more limited, there is evidence that chronic exercise improves antioxidant defenses in younger men and women (Evelo, Palmen, Artur, & Janssen, 1992; Sato, Nanni, Ohta, Kasi, & Ibeda, 2003) and in older men (Fatuouros et al., 2004).

Based upon this evidence and the aforementioned evidence supporting that dietary changes can influence cognitive performance and Alzheimer’s disease risk, one might expect that combining exercise with an antioxidant diet would result in maximal reductions in oxidative stress and, concomitantly, larger cognitive benefits. Researchers have tested the effect of multi-component interventions (described as behavioral enrichment that includes physical activity, opportunity for exploratory behavior, and social interactions through group housing) and an antioxidant diet on the cognitive performance of canines (Milgram et al., 2005; Nippak, Mendelsson, Mugenburg, & Milgram, 2007) with results supporting cognitive benefits. There are two studies with humans in which the effects of interventions combining physical activity with diet on cognitive performance have been examined.

Masley et al. (2008) randomly assigned fifty-six older adults to either a no-treatment control or a multi-component intervention for 10 weeks. The multi-component intervention consisted of meal plans and recipes to increase dietary fiber and decrease saturated fat and encouragement to increase physical activity that was prescriptive in weekly meetings. Participants in the intervention improved on 3 of 4 tests of cognitive performance (ES = 0.26 – 0.41). These effects are similar to what has been observed with physical activity alone and the modest effects may be due to the limitations of only recommending behavioral change, the relative brevity of the intervention, and the lack of a focus on a high antioxidant diet.

van Uffelen et al. (2008) performed a randomized placebo-controlled trial to explore the effects of 12 months of aerobic activity combined with the supplementation of folic acid and other B vitamins in older adults with MCI. The results showed that those in the aerobic activity group experienced improvements in cognitive function that positively correlated with higher levels of adherence to the exercise program. These findings suggest that those who walked more gained the biggest cognitive benefits. However, interpretation of the combined effects of aerobic activity and supplementation use is limited since the authors only presented results for the main effects of supplementation and physical activity.
To our knowledge, there is only one study which has tested the combined effects of physical activity, cognitive stimulation, and diet on cognitive performance. Small et al. (2006) examined the effects of a 14-day combined program on cognitive performance by older adults with mild age-related memory complaints. Participants were randomly assigned to a control condition or to the combined program. The combined program consisted of aerobic exercise, relaxation training, cognitive training to teach memory techniques and to give exposure to mental puzzles, and suggested meal plans that included an emphasis on fruits and vegetables high in antioxidants. They found that participants in the intervention program improved significantly on a measure of verbal fluency compared to participants in the control group.

Clearly, research on the efficacy of multi-component interventions is still in its infancy. Support for the «cocktail» hypothesis from non-human animal studies is promising and demonstrates benefits both behaviorally and mechanistically that exceed benefits from physical activity in isolation. However, research exploring multi-component interventions for humans is extremely limited. Further, human studies exploring physical activity and cognitive stimulation have not mimicked the animal research because the animal studies have typically simultaneously combined physical activity and cognitive stimulation while, by contrast, the human studies have presented these intervention components asynchronously. This may be an important distinction because the asynchronous presentation may not result in the same synergistic impact on mechanisms as might be observed with a synchronous presentation. Further, as described above, we are aware of only one short-term intervention which has tested the combined effects of physical activity, cognitive stimulation, and diet on cognitive performance. This is an important direction for future research because interventions that encompass many lifestyle factors may affect multiple mechanisms, which may in turn lead to an exponential increase in the magnitude of beneficial effects on cognitive performance. Considering additional mechanisms that explain the benefits of physical activity on cognitive performance is a logical place to begin when designing multi-component interventions that include physical activity and are hypothesized to achieve larger benefits.

Mechanisms

There is evidence supporting that chronic physical activity has beneficial effects on cerebral structure, cerebral function, and neurotrophic factors which may explain the benefits for cognitive performance. With magnetic resonance imaging techniques, Colcombe et al. (2003) observed age-related decreases in brain volume, in both white and grey matter of the frontal, parietal, and temporal cortices, in older adults. More importantly, they revealed that losses in these areas were smaller in older adults with higher levels of cardiovascular fitness. Relatedly, Colcombe et al. (2004) found that elderly individuals with higher levels of fitness showed different activation patterns in the middle frontal gyrus, superior frontal gyrus, anterior cingulate cortex, and superior parietal cortex relative to lower fit individuals. Other researchers have also provided evidence that aerobic fitness is positively associated with hippocampal volume (Bugg & Head, 2011; Erickson et al., 2009; Szabo et al., 2011).Prospective evidence is limited, but one study has shown that baseline physical activity is predictive of hippocampal volume nine years later (Erickson et al., 2010). To further understand whether aerobic fitness training can increase brain volume in regions associated with age-related decline in both brain structure and cognition, Colcombe et al. (2006) randomly assigned older adults to either an aerobic training group or a toning and stretching control group. After the 6-month intervention, individuals in the aerobic fitness training group showed significant increases in brain volume in both gray and white matter regions that were not observed in control group participants. Similarly, Erickson et al. (2011) found that participation in a 1-year exercise intervention resulted in an increased hippocampal volume in older adults. These results provide strong support for a causal effect of aerobic exercise on measures of cerebral structure and function that are indicative of central nervous system health in older adults, and extend the findings from Colcombe et al. (2004) by showing that aerobic exercise may not only ameliorate age-related declines in brain volume, but actually increase brain volumes in older adults who begin long-term aerobic exercise.

In non-human animal studies, exercise has also been shown to increase levels of brain-derived neurotrophic factor (BDNF) and other growth factors, stimulate neurogenesis, increase resistance to brain insult and improve performance on cognitive tasks including learning (Cotman & Berchtold, 2002). Gomez-Pinilla, Ying, Roy, Molteni, and Edgerton (2002) demonstrated that exercise could promote changes in neuronal plasticity via BDNF and Neeper, Gomez-Pinilla, Choi, and Cotman (1996) showed that BDNF concentration in the hippocampus was elevated after exercise. Importantly, Vaynman, Ying, and Gomez-Pinilla (2003) showed that BDNF actually acts as a mediator of the effects of exercise on hippocampal synaptic-plasticity. Even though there is strong evidence in the non-human animal literature that BDNF is a causal mechanism in the physical activity/cognitive performance relationship, this hypothesis has not been empirically tested in humans.

That being said, research with humans has shown a positive relationship between physical activity and basal BDNF concentrations, as well as an increased BDNF response to maximal exercise following five weeks of aerobic training (Zoladz et al., 2006). However, a study that assessed the relationship between a 6-month aerobic activity program, cognitive performance, and BDNF in older adults with MCI has shown that while there seems to be no effect of physical activity on cognitive performance or BDNF concentrations in men, for women there is a positive effect on cognitive performance and a decrease in BDNF concentration compared to controls (Baker et al., 2010). More research is needed to elucidate the potential causal relationship between physical activity, BDNF concentrations, and cognitive performance.

Conclusions

Research has established simple relationships between various lifestyle factors (e.g., physical activity, diet) and cognitive performance and there is evidence supporting that these relationships are causal. Research has also begun to establish mechanisms that explain the benefits of physical activity and specific dietary interventions for cognitive performance. The focus of current studies is on furthering our understanding of how to best combine lifestyle factors to achieve larger, more robust effects on cognitive performance. In so doing, the elucidation of mechanisms is an important emphasis for future research because of the potential to use this information to help identify the most promising combined interventions. Additionally, understanding mechanisms is likely to contribute to our ability to prescribe physical activity in a specific dose (intensity, duration, mode) to maximally benefit cognitive performance. Lastly, understanding mechanisms may bring to light ways to combine pharmacological or nutritional interventions (e.g., BDNF supplementation, antioxidant supplements) with behavioral interventions to, again, produce stronger cognitive benefits. With regards to the design of multi-component interventions, it is our contention that it is most efficacious to base their design on existing empirical evidence, theory, and the understanding of mechanisms. Specifically, multi-component interventions combining physical activity and cognitive training would likely benefit from more closely mimicking the extant literature with non-human animals; i.e., the combination of physical activity and cognitive training should be a synchronous experience rather than an asynchronous experience. Similarly, given the shared mechanism of antioxidants, interventions combining diet and physical activity should focus on an antioxidant diet as a way to maximize effects. Given the projected increase in the population of older adults and the anticipated coincident increase in the prevalence of age-related cognitive decline and dementia, the identification of interventions to benefit cognitive performance is a public health imperative.

References


Retos, número 27, 2015 (1º semestre)


Aerobic Power in Prepubescent Children with Different Levels of Physical Activity

Potencia Aeróbica en Niños Prepubescentes con Diferentes Niveles de Actividad Física


*Universidade Estadual do Centro-Oeste, Brasil, **Universidade do Contestado, Brasil, ***Faculdade de Educação Física e Fisioterapia de Jacarezinho, Brasil, ****Universidade de Costa Rica, Costa Rica, *****Universidade Federal do Paraná, Brasil

Abstract. The purpose of the study was to compare the aerobic power of prepubescent children (Tanner 1 stage). Participants were 95 children between 7 and 9 years old, divided into 4 physical activity level groups: a) Trained (n = 24), b) Sport beginners (n = 23), c) Active (n = 24), and d) Sedentary (n = 24). Physical activity level was determined by a three-day physical activity diary. Subjects performed a treadmill Balke protocol to obtain their peak oxygen uptake. Comparisons were made using ANOVA two-way and post hoc Tukey followed-up the significant differences for p < 0.05. Trained, sport beginners and active children presented similar amount of physical activity level, but they significantly differ from the sedentary children (p < 0.05). Overall boys (50.67 ± 8.52 ml/kg/min) had higher relative peak oxygen uptake than girls (48.90 ± 6.44 ml/kg/min). The gender by group interaction showed that this difference is explained by the superior values of the trained boys (58.80 ± 8.98 ml/kg/min) when compared to trained girls (47.51 ± 5.68 ml/kg/min), even though they presented the same amount of physical activity level. The trained group (53.16 ± 9.34 ml/kg/min) showed higher relative peak oxygen uptake compared to sport beginners (48.90 ± 6.54 ml/kg/min), active children (45.46 ± 7.50 ml/kg/min) and sedentary children (44.63 ± 9.52 ml/kg/min). The results suggest that prepubescent children that participate in systematized trained programs have better physiological indicators for aerobic fitness.

Key words. aerobic power, physical activity, children

Introduction

In general, children are considered as being a very physically-active group in the population. However, the association between daily physical activity and aerobic fitness of prepubescent children is difficult to understand because of their increased amount of daily physical activity. Is the high exercise volume and intensity naturally-performed by children good enough to guarantee the appropriate development of aerobic fitness? Aerobic power is a component of physical fitness, and the quantity of exercise needed to improve it is well-known for adults (Garber et al., 2011). However, it is less known the quantity of exercise needed to induce physiological changes leading to aerobic and strength improvements in children (Faigenbaum, Lloyd, & Myer, 2013; Pieles, Horn, Williams, & Stuart, 2014; Twisk, 2001).

There are studies suggesting that participation in sport activities during childhood and youth ages may be predictive of physical activity in the future (Malina, 1996; McMurray, Harrell, Bangdiwala, & Hui, 2003). The reduction in energy expenditure caused by low levels of physical activity has been recognized as an influential factor to increase unhealthy behaviors (Johnson et al., 2000). On the other hand, increased energy expenditure by practicing exercise has contributed to a better and efficient function of various organ systems, weight maintenance, and in the general improvement of quality of life (Malina, 1996).

Aerobic capacity is an important variable reported in the studies tracking physical activity from childhood to adulthood with the goal to demonstrate that it is a more consistent component compared to the amount of physical activity. This brings the idea that during childhood aerobic power can be a more satisfactory health parameter than a higher level of physical activity (Johnson et al., 2000; Malina, 1996; McMurray et al., 2003).

Studies on prepubescent children showed a positively association between physical activity levels and physical fitness (Eliakim, Scheet, Allmendinger, Brasel, & Cooper, 2001; Rowlands, Eston, & Inglelow, 1999). Although the majority of the studies used samples of sedentary and active children, it is difficult to understand the influence of physical activity levels and aerobic power in children’s health. Thus, one question remains unclear: is the aerobic power of a regular sport training children superior when compared to children not engaged in systematic training programs? Therefore, the aim of this study was to compare the aerobic power in different groups of male and female prepubescent children; those engaged in competitive sports training, sport training beginners, active children who do not participate in regular sports training and sedentary children.

Methods

Participants

The sample consisted of 95 children (age = 8.5 ± 0.6 yr.) divided in 4 groups: a) Trained, 12 boys and 12 girls participating in long distance running programs three times per week for more than six months; b) Sport Beginners, 11 boys and 12 girls registered in karate classes twice per week for less than two months (emphasis was learning the sport); c) Active, 12 boys and 12 girls classified as active according to the Bouchard’s three-day diary (Bouchard et al., 1983); and d) Sedentary, 12 boys and 12 girls classified as sedentary by the same three-day diary. The trained, sport beginners and active children had the same daily physical activity levels. All children were considered healthy and free-of-medication. Written informed consent was obtained from parents and the protocol was approved by the Federal University of Paraná Human Research Ethics Committee.
Measurements and Procedures

Body composition. Body mass (kg) and height (cm) were measured according to standard procedures (American College of Sports Medicine, 2010). Then, the body mass index (BMI = mass/height\(^2\)) was calculated. Children were measured barefoot and wore comfortable clothes. Body fat was estimated according to the Slaughter equation (Slaughter et al., 1988), as described and cross-validated in previous studies (Filaire & Lac, 2002; Guedes & Guedes, 2000; Rowland, Hoff, Martel, & Ferrone, 2000; Weinmann, 2002).

Physical activity. Physical activity level was determined by using a three-day diary (Bouchard et al., 1983). The instrument requires to record activities during two days of the week (Monday and Tuesday) and one day of the weekend (Saturday). The activities were recorded according to a scale from 1 to 9, calculating each activity energy expenditure in METS or kcal/kg\(^1\)min\(^{-1}\). Children recorded the activity they performed in 15 min blocks to the assistant researcher who registered the appropriated scale classification. The full-day was divided into 96 periods of 15 min. Habitual physical activity was determined as the mean value of the three days.

Peak oxygen uptake. Aerobic power (VO\(_2\)) was measured on a treadmill with the Balke protocol, using the Parvomedics metabolic system (MMS – 2400). The system was calibrated before each test according to the manufacturer’s specifications. The main advantage for choosing the Balke protocol was the constant speed (3.3 mph or ~5.3 km/h), which enabled children to adapt to the treadmill exercise. During each stage of the protocol, only the incline grade changed. Expired gases were collected every 15-s. The test ended when maximal effort was obtained, the heart rate reached values above 185 bpm (Hebestreit, Staschen, & Hebestreit, 2000), or when the participant showed physiological signs of exhaustion (i.e., hyperpnea, facial flushing, unsteady gait, sweating or dizziness) (American College of Sports Medicine, 2014).

Sexual maturation. To guarantee that all children in this sample were prepubescent, a self-assessment of pubic hair was used according to Tanner stages. This procedure is simple and it is considered to be accurate to determine sexual maturation (Bojikian et al., 2002; Hergenroeder, Hill, Wong, Sangi-Haghpeykar, & Taylor, 1999). First, the researcher explained to each child how to proceed. Then, the subject alone wrote in an image form the number (1 to 5) which corresponded to his or her sexual maturation.

The tests were conducted only in the morning. Parents were informed that children had to sleep at least 8 h, had to have a light breakfast and should not take part in any type of intensive exercise the day before the tests.

Design and statistical analyses

The study used an ex post facto design. The independent variables were physical activity levels and gender, and the dependent measures were body fat %, BMI and aerobic power. Group comparisons were made using two-way ANOVAs. Tukey’s post hoc followed-up the significant differences, with alpha level of 0.05.

Results

The age, anthropometric measurements, body mass index and body fat, and physical activity level (PAL) of the participants are reported by gender and group in Table 1.

Neither the groups nor the gender differed in BMI. Therefore, the growth of the sample was considered homogeneous. The values for BMI were similar to other studies conducted with children of similar ages (Guerra, Ribeiro, Costa, Duarte, & Mota, 2002; McMurray et al., 2003). These results were expected because there are no significant differences between boys and girls during the prepubescent years (Guedes & Guedes, 1995; Silvestri, 1999). Nevertheless, there were gender differences in the body fat content (p < 0.05). Girls had higher body fat values compared to boys. Other studies also reported high fat content for girls than boys even in the prepubescent years (Ball et al., 2001; McMurray et al., 2003; Sleap & Tolfrey, 2001). The active group showed higher values of body fat compared to the sport beginners and trained groups.

As depicted in table 1, there were not significant differences between boys and girls in physical activity performed during the day (PAL). As expected, the sedentary group was less active than the other groups. No sex analysis showed no significant differences between active, sport beginners and trained groups.

The ANOVA results revealed significant main effects for gender and groups and for relative and absolute VO\(_2\). In Table 2 are presented means and standard deviations for aerobic power, in absolute (L/min\(^{-1}\)) and relative values (ml/kg\(^{-1}\)min\(^{-1}\)).

These results showed that trained boys had higher values for absolute and relative VO\(_2\) than girls (Table 2). The gender by group interaction showed that this difference is better explained by the higher values of the trained boys when compared to trained girls, even though they showed the same amount of daily physical activity levels. The trained group had higher relative VO\(_2\) compared to sport beginners, active and sedentary children. These results suggest that prepubescent children that participate in systematized trained programs show better physiological indicators for aerobic fitness. Figures 1 and 2 present the differences in the body fat content (p < 0.05). Girls had higher body fat %, there were no differences in the quantity of physical activity performed during the day (PAL).

The similarity of the results between boys and girls in physical activity level were also shown in recent studies (Ball et al., 2001; Sleap & Tolfrey, 2001; Trost et al., 2002). Other research shows that girls are less active than boys of the same age level (Boreham, Twisk, Savage, Cran, & Strain, 1997; Eliakim et al., 2001; Epstein et al., 2001; Gavarry, Giaconomi, Bernard, Seymat, & Falgarette, 2003; Guerra et al., 2002; Janz et al., 2002; McMurray et al., 2003; Riddoch et al., 2004). In this study, half of the sample was comprised by children who are engaged in regular physical activity which could explain the lack of gender difference for physical activity level (Mascarenhas et al., 2005).

Table 1. Anthropometric and characteristics

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>BMI (kg/m(^2))</th>
<th>Body Fat (%)</th>
<th>PAL (METs/min)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>8.75 ± 0.40</td>
<td>18.06 ± 0.84</td>
<td>18.10 ± 1.00</td>
<td>46.76 ± 3.36</td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>8.75 ± 0.40</td>
<td>18.06 ± 0.84</td>
<td>18.10 ± 1.00</td>
<td>46.76 ± 3.36</td>
<td></td>
</tr>
</tbody>
</table>

Note: **significantly different from the same group, *significantly different from Sport Beginners and Trained groups, **significantly different from the other groups.

Table 2. Comparison of VO\(_2\)max according to the groups and gender

<table>
<thead>
<tr>
<th>Group</th>
<th>VO(_2)max (L/min)</th>
<th>VO(_2)max (kcal/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>14.0 ± 2.0</td>
<td>16.0 ± 2.0</td>
</tr>
<tr>
<td>Active</td>
<td>14.0 ± 2.0</td>
<td>16.0 ± 2.0</td>
</tr>
</tbody>
</table>

Note: **significantly different from the same group, *significantly different from Sedentary and Active groups.

Discussion

The sample analyzed was homogeneous in growth and the children BMI values were considered normal according to previous research (Cole, Bellizzi, Flegal, & Dietz, 2000). The body fat percentages were also in the levels expected for prepubescent children (Heyward & Wagner, 2004), however, girls showed higher fat content than boys. Similar results were found in others studies (Ball et al., 2001; McMurray et al., 2003; Rowland et al., 2000; Sleap & Tolfrey, 2001). Although girls had higher body fat %, there were no significant differences in the quantity of physical activity performed during the day (PAL).

The similarity of the results between boys and girls in physical activity level were also shown in recent studies (Ball et al., 2001; Sleap & Tolfrey, 2001; Trost et al., 2002). Other research shows that girls are less active than boys of the same age level (Boreham, Twisk, Savage, Cran, & Strain, 1997; Eliakim et al., 2001; Epstein et al., 2001; Gavarry, Giaconomi, Bernard, Seymat, & Falgarette, 2003; Guerra et al., 2002; Janz et al., 2002; McMurray et al., 2003; Riddoch et al., 2004). In this study, half of the sample was comprised by children who are engaged in regular physical activity which could explain the lack of gender difference for physical activity level (Mascarenhas et al., 2005).
The Sedentary group performed less physical activity compared to the other groups (p < 0.05). There were no differences among the other groups (i.e., Trained, Sport Beginners and Active). The lack of differences between the groups engaged in sports (i.e., Trained and Sport Beginners) and the Active group reflect the routine daily performed by active children is composed by enough amounts of physical activity tasks that guarantee a similar total PAL; however, the sport practices are not a significant item in the PAL.

In spite of PAL results, there were differences in overall VO2 between the groups. Such differences cannot be attributed to a failure of the test because a maximal effort was reached at completion. The ANOVA showed that there were no significant differences in RER following exercise between groups (p = 0.25) or between genders (p = 0.21).

Overall, the results obtained by the male subjects were 50.68 ± 9.81 and for girls 45.43 ± 9.1 ml·kg⁻¹·min⁻¹. These values are similar to those reported in previous studies on subjects with the same characteristics. For example, McMurray et al. (McMurray et al., 2003), reported VO2 = 46.5 ± 8.9 ml·kg⁻¹·min⁻¹ for boys and 41.3 ± 9.1 ml·kg⁻¹·min⁻¹ for girls. Others (Rowland et al., 2000), also reported similar mean values (47.2 ± 6.1 ml·kg⁻¹·min⁻¹ for boys and 40.4 ± 5.8 for girls ml·kg⁻¹·min⁻¹). The slightly higher values found in this study can be result of the samples’ attributes. When analyzing only the Sedentary and Active groups the mean VO2 were slightly lower to the reported earlier on children of the same age (Beunen et al., 2002; Rowland et al., 2000).

In conclusion, boys showed higher aerobic power values than girls. There were no significant between-gender differences in PAL. According to the literature, even at prepubescent age, boys have significant higher aerobic power compared to girls (Docherty, 1996; Guerra et al., 2002). Therefore, it is important to reinforce that physical activity is a significant item for both genders during childhood. However, the difference in aerobic power values is more pronounced in boys than in girls. The reason for this difference is related to the differences in body composition, muscle mass, and cardiovascular function between males and females, which are influenced by genetic and hormonal factors.

References


Exercise Intensity and Postprandial Lipemia

Lauren A. Littlefield and Peter W. Grandjean
Baylor University, USA

Abstract. Exaggerated postprandial lipemia has been observed in metabolic and cardiovascular diseases and is associated with increased risk for cardiovascular disease (CVD). Prior aerobic exercise reduces the triglyceride response to a high-fat meal. The purpose of this review is to examine the factors contributing to metabolic dyslipidemia and to review available evidence supporting the role of aerobic exercise in reducing postprandial lipemia.

The contribution of exercise intensity and excess-post exercise oxygen consumption (EPOC) to changes in postprandial lipemia is examined.

Introduction

The combination of increased dietary intake, sub-optimal physical activity, and increased overweight and obesity has placed Americans at an elevated risk for the development of metabolic diseases. In 2008, CVD accounted for 33% of deaths in America, and remained the leading cause of mortality among men and women (Rogers et al., 2011). Approximately 27% of the population met the criteria for Metabolic Syndrome (MetS) in 2000, this percentage significantly increased from 23% in 1994 (Ford, Giles, & Mokdad, 2004). Those with MetS possess elevated risk for the development of CVD, Type 2 Diabetes and Stroke (Kolovou et al., 2005; Wannamethee, Shaper, Lennon, & Morris, 2005).

Despite multiple available definitions, abdominal obesity and insulin resistance are key features thought to underlie MetS, and subsequently CVD risk (Kassi, Pervanidou, Kaltas, & Chrousos, 2011; Reaven, 1995).

In middle-aged overweight adults, following adjustment for traditional risk factors, non-fasting triglycerides remain a significant predictor of CVD, while fasting triglycerides do not (Bansal et al., 2007; Patsch et al., 1992). Exposure of the vascular endothelium to triglyceride-rich lipoprotein (TRL) particles and their remnants promotes atherosclerosis and is fundamental in the etiology of CVD (Hodis & Mack, 1998). Exposure of TRLs to the postprandial state and their remnants promotes increased exposure of the vascular endothelium to triglyceride particles (Kolovou et al., 2005; Kolovou et al., 2003; Kunnar, Madhu, Singh, & Gambhir, 2010). While multiple factors contribute to the development of postprandial lipemia, insulin resistance, associated with metabolic conditions such as MetS and CVD, has been shown to contribute to hypertriglyceridemia (Gimsberg, Zhang, & Hernandez-Ono, 2005).

A recent expert panel statement indicated that a desirable postprandial triglyceride response to a high-fat meal is no higher than 220 mg/dl (Kolovou et al., 2011). Based on these guidelines, even otherwise healthy overweight control subjects (Salazar et al., 2011). The purpose of this review is to examine the factors contributing to metabolic dyslipidemia and to review available evidence supporting the role of aerobic exercise in reducing postprandial lipemia.

The contribution of exercise intensity and excess-post exercise oxygen consumption (EPOC) to changes in postprandial lipemia is examined.

Palabras claves. Lipemia, Síndrome Metabólico, ejercicio, EPOC

Dyslipidemia

Dyslipidemia is a common feature of atherosclerotic diseases including MetS and can be characterized by elevated triglycerides, an increased number of small, dense LDL particles, and low HDL cholesterol (Kathiresan et al., 2006; Park, Kim, Lee, & Park, 2011). Elevations in triglycerides observed with insulin resistance and MetS are associated with increases in VLDL particle size and number (Adiels, Olofsson, Taskinen, & Boren, 2008; Kissebah, Alfarsi, Adams, & Wynn, 1976; Lucero et al., 2012; Tan et al., 1995). The large, triglyceride-rich VLDL produced under conditions of insulin resistance serve as precursors to atherogenic small, dense LDL particles that are slowly degraded (Dernast & Packard, 1998). The combined effects of elevated plasma triglycerides in conjunction with increased activities of hepatic triglyceride lipase (HTGL) and cholesterol ester transfer protein (CETP) result in small, dense HDL particles that are rapidly cleared from the circulation, and atherogenic small, dense LDL (Demant & Packard, 1998; Morton, 1999; Sandhofer et al., 2006; Xiao et al., 2008).

A large body of evidence confirms that elevated triglycerides and reduced HDL are significantly associated with CVD risk (Austen, Hokanson, & Edwaards, 1998; Gordon et al., 1989; National Cholesterol Education Program Expert Panel on Detection & Treatment of High Blood Cholesterol in, 2002). Meta-analysis has shown that, in men, the relative risk (RR) for CVD associated with a 1 mmol/l increase in triglycerides is significant at 32% (Austen et al., 1998). Upon accounting for HDLC and other CVD risk factors, the RR was reduced to 14%, yet triglycerides is significant at 32% (Austin et al., 1998). Upon accounting for HDLC and other CVD risk factors, the RR was reduced to 14%, yet remained statistically significant (Austen et al., 1998). The anti-atherogenic properties of HDLC have primarily been associated with reverse cholesterol transport, and antioxidant and anti-inflammatory functions (Kontush & Chapman, 2006). In men, the CHD risk reduction associated with a 1 mg/dl increase in HDLC is approximately 2% (Gordon et al., 1989).

It has been proposed that the independent effect of elevated triglycerides in promoting CVD may be attributable to the presence of triglyceride-rich lipoprotein remnants (TRL) (Zilversmit, 1979, 1995). Lipoprotein remnants of VLDL and chylomicrons are formed as a
result of the activity of LPL and increased triglyceride levels (Morton, 1999; Zilversmit, 1979). These remnants are rich in cholesterol ester and can be deposited in the arterial wall. Triglyceride level and remnant lipoproteins are strongly and significantly associated, and are predictive of future CVD development (Inkne et al., 2005). Remnant-like cholesterol is strongly and significantly associated with carotid intima-media thickness in healthy middle-aged men, this independent of triglyceride level (Karpe et al., 2001).

Postprandial Lipemia

A recent panel statement clarified the usefulness of non-fasting triglycerides in the prediction of CVD by reviewing large-scale trials that included postprandial measurements (Kolovou et al., 2011). The results from this review indicate that the peak triglyceride response can be observed 4 hours postprandially and that this response should be less than 220 mg/dl (Kolovou et al., 2011). TRL, including chylomicrons and VLDL, are increased acutely following a meal (Cohn, McNamara, Cohn, Or dovas, & Schaefer, 1988). Chylomicrons contain predominantly apo B 48, and are secreted from the intestine postprandially, while apo B 100 containing VLDL particles are hepcidically derived (Kindel, Lee, & Tso, 2010).

In those with normotriglyceridemia and hypertriglyceridemia (e.g., mean triglyceride values of 93 and 244 mg/dl, respectively) the postprandial increase in both chylomicrons and large VLDL is statistically significant (Wojcynski et al., 2011). In the same groups, chylomicrons were increased significantly following a high-fat meal, and to a significantly greater extent in those with elevated fasting triglycerides (Wojcynski et al., 2011). In healthy controls and in CAD patients with normal and elevated fasting triglycerides, there is a statistically significant increase in large chylomicrons and VLDL 3 hours following a high-fat meal (Karpe, Steiner, Olivercona, Carlson, & Hamsten, 1993). When compared to a control group, CAD patients with hypertriglyceridemia have significantly increased large chylomicrons and VLDL at 3 and 6 hours postprandially (Karpe et al., 1993). Sedentary middle-aged men with a mean BMI of 25.7 kg/m², and with fasting triglycerides below 221 mg/dl, display a significantly higher triglyceride AUC, when compared to younger sedentary men with a mean BMI of 23 kg/m² (Jackson et al., 2003). In apparently healthy control subjects with a BMI above 25.0, postprandial lipid excursions have been shown to exceed the recommended cut-point of 220 mg/dl (Patsch et al., 1992). Patsch et al., (Patsch et al., 1992) have shown that healthy control participants with normal fasting triglycerides have elevated postprandial triglyceride responses of 263 and 225 mg/dl, respectively, at 4 and 6 hours. Although these values were significantly lower than a group with CVD, they are above the recommended cut-point suggested in the latest panel statement. It can be concluded that significant postprandial increases in lipoproteins are observed even in healthy weight subjects with normal triglycerides, and these increases are more pronounced in the middle aged, and in those with hypertriglyceridemia and heart disease.

Factors Influencing Metabolic Dyslipidemia

Altered activities cholesterol ester transfer protein (CETP), hepatic triglyceride lipase (HTGL), and LPL may contribute to secondary dyslipidemia by altering the composition of lipoproteins and/or affecting their clearance rate (Morton, 1999; Xiao et al., 2008). In obese subjects and in men with Met S, the mass of CETP is increased above healthy controls, and CETP activity has been shown to be increased following a meal (Arai et al., 1994; Sandhofer et al., 2006; Tall, Sammnett, & Granot, 1986). In men, BMI is strongly and significantly associated with increased HTGL activity, and LPL activity is significantly reduced in obese subjects (Nie et al., 1998).

Cholesterol Ester Transfer Protein

CETP is responsible for the transfer of cholesterol ester and triglyceride between HDLC and lipids containing apoprotein B (apoB) particles including VLDL, LDL, chylomicrons, and intermediate density lipoprotein (IDL) (Morton, 1999; Sandhofer et al., 2006). The results of increased CETP activity and hypertriglyceridemia are HDLC enriched with triglyceride and apo B particles that are enriched with cholesterol ester (Lassell, Guerin, Aubirotun, Chapman, & Guy-Grand, 1998). Among Apo B containing particles, LDL is responsible for accepting the preponderance of cholesterol ester (Lassell et al., 1998). Due, in part, to the action of CETP, the resulting triglyceride rich HDLC are cleared more rapidly from the circulation, resulting in low HDLC levels (Gazi et al., 2006; Rashid et al., 2002; Sandhofer et al., 2006; Xiao et al., 2008). Among remnant lipoproteins, VLDL particles appear to accept a greater amount of cholesterol ester than do chylomicron remnants, which may lead to an abundance of VLDL saturated with cholesterol ester (Kissebah et al., 1976; Lassell et al., 1998).

Small, Dense LDL C

HTGL plays a role in the conversion of VLDL to small, dense LDL particles and its activity is significantly and negatively associated with LDL C size and buoyancy (Zambon, Austin, Brown, Hokanson, & Brunzell, 1993). Small, dense LDL has been shown to have a lower affinity for the LDL C receptor due to conformational changes in apo B 100, and therefore may be present in circulation for an extended period of time (Galeano et al., 1994). The atherogenicity of small, dense LDL particles arises from their increased susceptibility to oxidation when compared to larger LDL particles (Liu et al., 2002).

Oxidized LDL particles contribute to atherosclerosis and inflammation in multiple ways, being recognized most commonly for their ability to be taken up by macrophages through scavenger receptors, leading to the development of foam cells (M. S. Brown, Basu, Falk, Ho, & Goldstein, 1980; Itabe, Ohama, & Kato, 2011). In patients with CVD, the number of small, dense LDL particles is significantly increased when compared to healthy controls, despite similar LDL C levels (Koba et al., 2006). Gazi et al, have shown that small, dense LDL particles are increased in MetS when compared to healthy controls, and that triglyceride concentration is a significant predictor of particle number (Gazi et al., 2006). Additionally, these authors showed that, in a small sub-set of patients with MetS who had triglyceride values below 150 mg/dl, no difference was evident in mean LDL C particle size compared to healthy controls (Gazi et al., 2006). These results confirm the close association between serum triglyceride concentration and increased small, dense LDL C (Gazi et al., 2006; Kathiresan et al., 2006).

Lipoprotein Lipase

LPL is responsible for the hydrolysis of triglyceride contained in LDL C, VLDL, and chylomicrons and its activity is partially modulated by insulin (Maheux, Azhar, Kern, Chen, & Reuven, 1997; Nilsson-Ehle, Garfinkel, & Schotz, 1980). In adipose tissue, LPL activity is greater with increased insulin concentration, while in skeletal muscle, the activity of LPL is reduced under similar conditions (Kiens, Litthell, Mikines, & Richter, 1989; Kobayashi, Tashiro, Murano, Morisaki, & Saito, 1998; Sadar & Eckel, 1982). In subjects with MetS, the pre-heparin mass of LPL is significantly and positively correlated with HDLC, and significantly and negatively correlated with triglyceride, blood glucose, and body weight (Nilsson-Ehle et al., 1980; Saiki et al., 2007). Post-heparin LPL activity is significantly reduced in obese compared to lean subjects, and insulin resistant subjects have lower LPL mRNA and protein content in skeletal muscle than do non-insulin resistant controls (Arai et al., 1994; Morino et al., 2012). Sedentary, overweight, middle-aged men have significantly lower post-heparin LPL activity in both the fasted state and 9 hours following a mixed meal when compared to younger normal weight men (Jackson et al., 2003). Thus, reductions in LPL activity have been observed in obese, insulin
resistant, and overweight sedentary individuals, and likely contribute to reduced TRL clearance.

TRL are cleared in a manner that is dependent on LPL mediated hydrolysis of chylomicrons and VLDL (Nilsson-Ehle et al., 1980). The ability of LPL to hydrolyze TRL may become overwhelmed in the presence of elevated lipids (Bjorkegren et al., 1996; Brunzell, Hazzard, Porte, & Bierman, 1973). In healthy men, the administration of a chylomicron-like lipid emulsion results in substantial increases in plasma triglycerides, and linear increases in large VLDL particles (Bjorkegren et al., 1996). Following the lipid emulsion, Bjorkegren et al. (Bjorkegren et al., 1996), observed that the catabolic rate of large VLDL particles was reduced substantially when compared to a saline infusion control condition, and that the rate of conversion of large VLDL to small VLDL was decreased (Bjorkegren et al., 1996). Thus, it appears that increased chylomicrons in the plasma impede clearance of VLDL particles, and reduce the conversion of large VLDL to small VLDL. Postprandial increases in chylomicrons would lead to increases in circulating TRL and large VLDL particles.

**Insulin Resistance**

Insulin resistance and consequent hyperinsulinemia exacerbate hypertriglyceridemia (Ginsberg et al., 2005). In conditions of metabolic dysfunction, skeletal muscle, with adipose and hepatic tissues, may become resistant to the effects of insulin (Saltiel & Kahn, 2001). As a result, glucose uptake into skeletal muscle is decreased and insulin’s ability to suppress hepatic glucose secretion may be compromised (Consoli, 1992). Plasma NEFA concentrations may be elevated due to insulin resistant adipose tissue (Kissebah et al., 1976). The elevations in plasma NEFA, in conjunction with increased glucose flux resulting from hyperglycemia, provide ample substrate for hepatic VLDL overproduction (Kissebah et al., 1976; Wu, Cappel, Martinez, & Stafford, 2010). In middle-aged men and women, the estimation of insulin resistance using the homeostatic model assessment (HOMA) score has been shown to be significantly correlated with VLDL rate of production (Gill et al., 2004). Furthermore, when compared to lean counterparts, obese subjects have a higher VLDL secretion rate of apoB (Riches et al., 2004). Furthermore, when compared to a saline infusion control condition, and that the rate of conversion of large VLDL to small VLDL was decreased (Bjorkegren et al., 1996). Thus, it appears that increased chylomicrons in the plasma impede clearance of VLDL particles, and reduce the conversion of large VLDL to small VLDL. Postprandial increases in chylomicrons would lead to increases in circulating TRL and large VLDL particles.

**Exercise and Postprandial Lipemia**

Aerobic exercise, performed 1 to 16 hours before a high-fat meal, significantly reduces postprandial triglyceride levels between 18 and 51% below non-exercise control values (Altena, Michaelson, Ball, & Thomas, 2004; Gill et al., 2006; Petit & Cureton, 2003; Zhang, Thomas, & Ball, 1998). Studies that support these effects have used treadmill or cycling exercise of low-, moderate-, and maximal-intensity ranging from 25 to 100% of VO2max (Freese, Levine, Chapman, Hausman, & Cureton, 2011; Gill et al., 2006; Gill, Murphy, & Hardman, 1998; Katsanos, Grandjean, & Moitt, 2004; Mestek et al., 2008). Gill et al. (2006), have shown that 90 minutes of exercise at 50% of VO2peak performed on the day before a high-fat meal significantly reduces postprandial chylomicrons, VLDL, and remnant lipoproteins by 29, 34, and 35% when compared to non-exercise control in middle-aged overweight men. Thus, aerobic exercise is capable of reducing the postprandial increase in TRL, and substantially reducing CVD risk.

Lifestyle

Overweight and obesity, along with dietary composition and physical inactivity are associated with blood lipid abnormalities (Berg, Frey, Baumstark, Halle, & Keul, 1994; C. D. Brown et al., 2000; Lippi et al., 2006; McLaughlin et al., 2004). While insulin resistance is observed in normal weight subjects, a significant increase in BMI has been observed with increasing measures of insulin resistance, as defined as the top 25% of plasma insulin concentration (McLaughlin et al., 2004; Salazar et al., 2011). In obesity, the effect of insulin to suppress hepatic lipid assembly is compromised (McLaughlin et al., 2004). In addition, the activities of CETP and HL have been shown to be increased in obesity, while LPL activity is negatively correlated with bodyweight (Arai et al., 1994; Sandhofer et al., 2006; Xiao et al., 2008). A prospective 6.5 follow up study has shown that, with weight gain of 5% of initial body weight and final BMI of less than 30 kg/m2, the number of large VLDL particles increases significantly, by approximately a third (Mantselka et al., 2012). Thus even those who experience modest gains in body weight may develop secondary dyslipidemia. Elevations in postprandial lipemia are known to occur as a result of a high-fat meal, and individuals consuming a high-fat diet are exposed to postprandial lipemia as a result (Hardman, Lawrence, & Herd, 1998; Wojczynski et al., 2012). The chronic effects of overweight and obesity on dyslipidemia are coupled with the acute detrimental blood lipid alterations that occur as a result of a high-fat meal.

It can be concluded that postprandial increases in triglyceride-rich VLDL and chylomicrons promote atherogenic dyslipidemia. Increases in TRL promote low HDL and increased small, dense LDL. Increased activity of CETP and HL contribute to this effect by creating apo B particles laden with cholesterol ester and triglyceride-rich HDL, meanwhile facilitating the conversion of VLDL to dense LDL (Arai et al., 1994; Sandhofer et al., 2006; Zambon et al., 1993). Reductions in LPL activity lead to compromised ability to clear TRL (Jackson et al., 2003; Zambon et al., 1993). Additionally, the effects of insulin resistance exacerbate postprandial lipemia and processes that contribute to atherogenic dyslipidemia. These alterations in enzyme activity and metabolic function that favor dyslipidemia have been described in MetS and obesity (Arai et al., 1994; Jackson et al., 2003; Sandhofer et al., 2006).

While intensity, per se, does not seem to be the primary determinant of changes in postprandial lipemia, the only studies that have directly compared exercise of differing intensities have used a narrow range of 31 to 60-70% of maximal capacity (Mestek et al., 2008; Tsetsonis & Hardman, 1996a, 1996b). When low- and moderate-intensity exercise is compared, regardless of intensity or duration, a threshold energy expenditure appears to exist below which alterations in postprandial lipemia are not statistically significant (Gill et al., 1998). Zhang et al. (Zhang, Ji, Fogg, & Fretwell, 2007), have shown that the postprandial reduction in triglycerides is significant following exercise at 60% of maximal capacity only after sessions where 450 calories or greater were expended, and not following a session with a 300-calorie energy expenditure. At similar exercise intensity, the postprandial triglyceride reduction is significant following caloric expenditure exceeding 800 calories, but not 400 calories (Tsetsonis & Hardman, 1996a). Mestek et al. (Mestek et al., 2008), has shown that a 500-calorie energy expenditure at 35-45 or 60-70% of maximal capacity lowers postprandial triglycerides similarly and significantly below non-exercise control. Likewise, exercise intensities of 32 and 63% of maximal capacity and equal caloric expenditure of approximately 1,000 calories lower postprandial triglycerides, with no differences between the two conditions (Tsetsonis & Hardman, 1996b). Thus, following low- and moderate-intensity exercise a caloric expenditure of 450-500 calories is sufficient to favorably alter postprandial triglycerides. It is clear that following low- and moderate- exercise, energy expenditure, instead of intensity or duration, appears to determine reductions in postprandial lipemia.
postprandial triglycerides following exercise at 65% of VO2peak were significantly attenuated when compared to non-exercise control, while the postprandial response following exercise at 25% of VO2peak was similar to non-exercise control. One investigation, reporting the effects of maximal-intensity exercise on postprandial lipemia, has shown that 4 30-second all-out sprints separated by 4 minutes of active recovery significantly lowered postprandial triglycerides below non-exercise control (Freese et al., 2011). The approximate caloric expenditure of this session was 287 calories, substantially below the apparent threshold of 450-500 mentioned for low- and moderate- intensity exercise. This finding may indicate that the threshold energy expenditure required for favorable alterations in postprandial lipemia is lower following maximal-when compared to moderate- or low-intensity exercise. Comparisons between low- and high-intensity exercise should be made to examine whether isocaloric exercise sessions affect postprandial lipemia differently.

Support for the hypothesis that exercise energy expenditure determines reductions in postprandial lipemia comes from studies where the energy that was expended during exercise is replaced. Three studies have reported the effects of exercise with and without energy replacement on postprandial lipemia (Burton et al., 2008; Freese et al., 2011; Harrison et al., 2009). The caloric expenditures for these studies are approximately 287, 670, and 1500 calories. The corresponding significant postprandial triglyceride reductions were 21, 14, and 40% following exercise without energy replacement when compared to non-exercise control (Burton et al., 2008; Freese et al., 2011; Harrison et al., 2009).

Burton et al. (Burton et al., 2008), has shown that exercise at 50% of maximal capacity with a caloric expenditure of 670 calories without energy replacement significantly lowers postprandial triglycerides 14% below non-exercise control, and 10% below exercise with energy replacement in obese and overweight men (mean BMI 31.1 kg/m²). The energy expended during exercise was re-fed in the form of a mixed meal. No difference in postprandial triglycerides was observed between the exercise with energy replacement trial and non-exercise control (Burton et al., 2008). When compared to non-exercise control, the postprandial insulin concentration was significantly reduced by 18 and 10% following exercise with energy deficit and exercise with energy replacement (Burton et al., 2008). There was also a 10% statistically significantly lower postprandial insulin response following exercise with energy deficit when compared to exercise with energy replacement. Of the 3 studies examining the effects of energy replacement on postprandial lipemia, this is the only experiment where investigators have reported the effects of exercise with and without energy replacement trial, the participants were fed glucose in an amount equal to the carbohydrate utilized during exercise. Higher-intensity exercise combining continuous exercise at 70% of maximal capacity and maximal-effort bouts, and producing a 1500 calorie energy expenditure, yielded a statistically significant 40% difference in postprandial triglycerides between exercise with energy deficit and non-exercise control. A smaller, but still significant (e.g. approximately 20%) difference between exercise with energy deficit and exercise with energy replacement was also found (Harrison et al., 2009). In agreement with Burton et al. (Burton et al., 2008), no differences in postprandial triglycerides were observed between the exercise with energy replacement and non-exercise control condition. In contrast to the findings of Burton et al. (Burton et al., 2008), insulin levels did not differ across conditions. When compared to the work of Burton (Burton et al., 2008) the caloric expenditure achieved in this study is substantially greater, and the relative reduction in postprandial triglycerides much higher (e.g. 40% compared to 14%), supporting the role of energy expenditure in reducing postprandial triglycerides.

Freese et al. (Freese et al., 2011), completed a similar study using maximal intensity exercise of short duration. The caloric expenditure of the exercise session was approximately 287 calories, and was re-fed in the form of a mixed meal. Participants completed 4 maximal 30 second cycling sprints interspersed with 4 minutes of active recovery (Freese et al., 2011). The significant differences between trials for postprandial triglycerides were equal to 21% between exercise with energy deficit and non-exercise control, 12% between exercise with energy deficit and exercise with energy replacement, and 10% between exercise with energy replacement and control (Freese et al., 2011). Of the 3 studies where the energy expended during exercise has been replaced, this is the only work documenting a significantly lower postprandial triglyceride response following exercise with energy replacement when compared to non-exercise control. This may indicate a specific benefit of higher-intensity exercise on lowering postprandial triglycerides, even when the energy expended during exercise is replaced. This is one of the few studies reporting the effects of only maximal intensity exercise, and it is possible that a lower caloric expenditure is required following this type of exercise to produce significant reductions in postprandial triglycerides.

Excess Post-Exercise Oxygen Consumption

There is evidence for the effect of exercise intensity in increasing post-exercise energy expenditure (Borsheim & Bahr, 2003; LaForgia, Withers, & Gore, 2006). Following isocaloric cycling exercise of 500 calorie energy expenditure, EPOC is significantly greater after a session at 75% of VO2max when compared to one at 50% of VO2max (e.g. 4.8 L vs. 9 L) (Phelain, Reinike, Harris, & Melby, 1997). Even high intensity exercise of low caloric expenditure and short duration produces greater EPOC than lower-intensity exercise of longer duration (Sedlock, Fissinger, & Melby, 1989). When measured for 14 hours post-exercise, 80 minutes of cycling at 75% of maximal capacity results in a 30.1 L EPOC, compared to only 5.7 and 1.3 L following exercise for 80 minutes at 50 and 29% (Bahr & Sejersted, 1991). Gore and Withers (Gore & Withers, 1990), examined the differences in EPOC following treadmill exercise at a variety of intensities and durations. Subjects performed exercise bouts at 30, 50, and 70% of VO2max for 20, 50 and 80 minutes (Gore & Withers, 1990). These authors found no statistically significant difference across time for the bouts at 30% of maximal capacity. Fifty minutes of exercise at 50% and 70% of VO2max produced EPOC values of 5.19 and 10.04 L, and 80 minutes at the corresponding intensities yielded 6.10 and 14.59L (Gore & Withers, 1990). It was concluded that intensity is the primary factor determining increases in EPOC (Gore & Withers, 1990). It is evident that exercise at or above 70% of maximal capacity produces greater EPOC than exercise at or below 50% of maximal capacity. No studies have measured EPOC in order to determine its contribution to changes in postprandial lipemia. Because most studies examining postprandial lipemia have not explored higher-intensity exercise, favorable effects attributable to EPOC energy expenditure have likely been overlooked.

Potential Mechanisms

While energy expenditure has been indicated as a primary explanation for the decrements in postprandial lipemia following exercise, the precise physiological mechanisms are elusive. Increased clearance of VLDL and chylomicrons due to greater LPL activity offers one explanation for the consistent reduction in postprandial lipemia following aerobic exercise (Grewe, Holloszy, & Semenkovich, 2000; Kiens et al., 1989). Increases in skeletal muscle LPL activity have been observed 24 hours following running exercise at 75% VO2max, and at as little as 4 hours after 60 minutes of knee extensor exercise at 75% of maximum capacity (Kiens et al., 1989). LPL protein content in the vastus lateralis is increased significantly 22 hours post exercise following 60 minutes of cycling exercise at 65% VO2max (Grewe et al., 2000) A recent study by Al-Shayji, Caslake, and Gill (Al-Shayji, Caslake, & Gill, 2012) supports the hypothesis that in middle-aged overweight...
men, the clearance of VLDL, particularly in the larger fraction, is increased on the day following exercise at 50% of VO2max. Men with a mean BMI of 31.1 kg/m^2 underwent intraportal infusion designed to block catabolism of large VLDL particles. Following exercise, VLDL triglyceride was significantly lower, and the catabolic rates of VLDL triglyceride and apo B were significantly greater when compared to non-exercise control (Al-Shayji et al., 2012). VLDL production was not changed following the exercise or non-exercise control conditions. The composition of the VLDL particle was changed following exercise when compared to non-exercise control, with each VLDL particle containing a greater amount of triglyceride (Al-Shayji et al., 2012). The authors conclude that alterations in the composition of the VLDL particle itself may in fact lend the particle to being cleared more rapidly (Al-Shayji et al., 2012). This work strongly supports that increased clearance of triglyceride-rich particles following exercise may explain improvements in postprandial lipemia.

Hepatic production of VLDL may decrease following a bout of exercise. A recent study using healthy normal weight women showed that, on the morning following exercise at 60% of VO2peak where 500 calories are expended, fasting VLDL is significantly reduced when compared to non-exercise control (Bellou et al., 2012). When compared to non-exercise control, the exercise trial significantly increased VLDL clearance and significantly reduced hepatic secretion (Bellou et al., 2012). Up to 79% of the postprandial triglyceride reduction on the day following exercise is attributable to hepatically derived large VLDL (Gill et al., 2006; Gill, Frayn, Wootton, Miller, & Hardman, 2001). Together, results from Bellou et al. (Bellou et al., 2012) and Al-Shayji et al. (Al-Shayji et al., 2012), indicate that the reduction in triglycerides in the hours following exercise is due to decreases in VLDL production and increases in VLDL clearance.

The ability of exercise to increase glucose uptake and improve insulin sensitivity may play a role in reducing hepatic VLDL production (King et al., 1995). During exercise glucose uptake is increased in the absence of insulin (Santos, Ribeiro, Gaya, Appell, & Duarte, 2008). Exercise reduces insulin concentration in the postprandial period: exercise absence of insulin (Santos, Ribeiro, Gaya, Appell, & Duarte, 2008). During exercise glucose uptake is increased in the peripheral tissue, may contribute to the beneficial effects of aerobic exercise on postprandial lipemia.

In summary, multiple factors likely contribute to improvements in postprandial lipemia following aerobic exercise. Following moderate- and high-intensity exercise skeletal muscle LPL activity is likely increased, resulting in greater ability to clear TRL (Greive et al., 2000; Kiens et al., 1989). In addition, hepatic VLDL output may be reduced in the hours following moderate-intensity exercise (Al-Shayji et al., 2012; Gill et al., 2006). Reductions in postprandial insulin concentration have been observed following moderate exercise, and glucose disposal has been shown to be increased following higher-intensity exercise (Devlin & Horton, 1985; Zhang et al., 2004). These factors, in combination with increased blood flow to skeletal muscle and hepatic tissue, may contribute to the beneficial effects of aerobic exercise on postprandial blood lipids (Hurren et al., 2011).

Conclusions

Atherogenic disease is the leading cause of death in United States, with the prevalence of obesity and MetS increasing (Ogden et al., 2006; Roger et al., 2011). Blood lipid changes that occur in the postprandial state promote CVD, with triglyceride-rich particles elevated following meals (Woyczynski et al., 2011; Zilversmit, 1979). Low-, moderate-, and high-intensity aerobic exercise is known to favorably alter postprandial lipids, and is a useful modality for reducing CVD risk (Freese et al., 2011; Tsetsonis & Hardman, 1996a). The energy expenditure of exercise appears to dictate alterations in postprandial lipemia (Gill et al., 1998). While multiple studies have compared low- and moderate- intensity exercise, none have directly compared low- and high-intensity exercise. Higher-intensity exercise is known to produce greater post-exercise energy expenditure (Boschim & Bahr, 2003). The contribution of EPOC to changes in postprandial lipemia has not been determined. Because changes in postprandial lipemia have been linked to exercise energy expenditure, it is possible that increased EPOC following high-intensity exercise explains the favorable effects of exercise of greater intensity on postprandial lipemia.

References

Factors Influencing the Accumulation of Recommended Physical Activity among Latinos in the Deep South of the United States

Abstract. Less than 40% of the U.S. population achieves the recommended amount of leisure-time physical activity (LTPA) recommended by the American College of Sports Medicine [ACSM (>150 minutes/week of moderate-intensity or equivalent vigorous-intensity LTPA)]. The number of Hispanic/Latino men and women who report being physically inactive is disproportionately higher than non-Hispanic/Latinos. The purpose of this investigation is to evaluate factors which influence the achievement of meeting ACSM recommendations for LTPA among adults with Hispanic/Latino ethnicity and whites (non-Hispanic/Latino) in the southern United States. Self-reported data collected as part of the Behavioral Risk Factor Surveillance System (BRFSS) was analyzed in male and female Hispanic/Latinos and non-Hispanic/Latino whites using the Andersen Model and Chi Square Analysis to examine the association between variables. Hispanic/Latino men/women were significantly less likely to meet the ACSM recommendations (> 150 minutes/week) compared to non-Hispanic/Latinos. Lower amounts of income, education, and access to health care were all significant factors of whether Hispanic/Latinos in the Deep South achieved the ACSM recommendations for LTPA. Although the percentage of overweight Hispanic/Latinos was considerably higher than White (non-Hispanic/Latino), reported obesity was highest among Whites (non-Hispanic/Latino). LTPA between the two groups differed significantly, suggesting that not achieving the physical activity recommendations is associated with being overweight, but other factors may also contribute to being overweight and obesity.

Key words. physical activity, Hispanics, leisure, obesity, overweight, disease

Introduction

Following years of multiple and conflicting reports on the recommended amount of physical activity needed for healthy adults, the American College of Sports Medicine (ACSM) set forth a clear and concise recommendation to diminish public misperception. In its 2011 Position Stand, ACSM recommends that healthy individuals, 18-65 years, accumulate >30 minutes of moderate-intensity physical activity (> 5 days/week (>150 min/week)) or >20 minutes of vigorous-intensity physical activity (> 3 days a week (> 75 min/week)) (Garber et al., 2011). The recommended volume of physical activity represents the minimum quantity and quality of leisure-time physical activity (LTPA) needed to maintain and improve good health, prevent disease, and reduce the risk of early mortality in adults.

Numerous studies provide evidence that LTPA offers benefits to those who transition from a sedentary lifestyle to one that meets or exceeds the minimum requirements set forth from ACSM (Plaisance, Grandjean, & Mahurin, 2009). Performing the recommended 150 minutes of moderate LTPA per week has been shown to reduce blood pressure, risk of coronary heart disease, stroke, type 2 diabetes, and breast cancer in women and colorectal cancer in men (Plaisance et al., 2009). In addition to the physiological benefits, there are specific psychological benefits that have also been observed in those who meet the ACSM guidelines for LTPA. Studies have shown that LTPA can deter and possibly prevent the effects of mild and moderate depression and increase vigor (Bartholomew, Morrison, & Ciccolo, 2005; Paetz, 2006). In older adults, LTPA reduces the risk of falls and slows the deterioration of bone mass (Nelson et al., 2007) while increasing quality of life (QOL) (Conn, Hafdahl, & Brown, 2009).

While organizations, such as ACSM, have set forth a clear recommendation for weekly physical activity in healthy adults, recent studies have found that most Americans fail to achieve these guidelines. For example, approximately 33% of the American population in 2008 reported not engaging in any form of LTPA. Furthermore, significant disparities exist in the accumulation of LTPA among different race/ethnic groups, such as Hispanics (Latinos) and African Americans, compared to non-Hispanic whites. Indeed, 37% of the U.S. Latino population was considered physically inactive as compared to 33% of the African American population and 22% of the non-Hispanic white population (Ickes & Sharma, 2012). While Latinos and African Americans seem to accumulate lower levels of physical activity compared to non-Hispanic whites, research has also shown that Latino women are the most inactive (Larsen, Pekmezi, Marquez, Benitez, & Marcus, 2013). The authors reported that approximately 48% of Latino women do not participate in LTPA as compared to 29% of non-Hispanic white women. These results highlight the trend that a large majority of Americans are exposed to risks that accompany a sedentary lifestyle and that certain cultural or environmental factors are responsible for the physical activity related disparities that exist between ethnic groups.

The likelihood that an individual will meet the physical activity recommendations set forth by ACSM and pursue a healthy lifestyle may be determined by their health behaviors. Health behaviors include...
actions such as smoking and utilization of available health care facilities which may be influenced by ethnicity and cultural background. Margerison-Zilk and Cubbin found that non-Hispanic Whites had higher smoking rates than Hispanic/Latinos, although Hispanic/Latinos tend to initiate the habit of smoking at a much earlier age (Margerison-Zilk & Cubbin, 2013). Others have shown disparities in healthcare coverage and routine healthcare among Hispanics compared to non-Hispanic Whites (Villa, Wallace, Bagdasaryan, & Aranda, 2012). Since Hispanics typically experience a greater incidence of obesity and diabetes compared to non-Hispanic whites («Health disparities experienced by Hispanics—United States,» 2004), the role of physical activity and factors which increase the adoption of physical activity as part of a healthy lifestyle are crucial to reduce the disparities in health in this population. Therefore, the purpose of this investigation was to explore factors associated with the accumulation of LTPA between Hispanic/Latinos and non-Hispanic whites in the Deep South of the United States (U.S.) through the 2011 administration of the Behavioral Risk Factor Surveillance System (BRFSS).

Methods and Materials

The BRFSS is a collaborative project of the Centers for Disease Control and Prevention (CDC) and U.S. states and territories. The objective of the BRFSS is to collect uniform, state-specific data on preventive health practices and risk behaviors that are linked to chronic diseases, injuries, and preventable infectious diseases that affect the adult population (CDC, 2012c). This study used publicly available data from the 2011 survey administration of the BRFSS from 4 of the 6 Deep South states: Alabama, Georgia, Mississippi, and South Carolina. Response rates ranged from 24.39% to 45.72% (CDC, 2012b).

The Behavioral Model of Health Services Use by Ronald Andersen suggests that health outcomes are affected by health services use and social and individual determinants of health (Anderson, 2008; Gelberg, Andersen, & Leake, 2000). In the Andersen model, predisposing, enabling, and need characteristics predict personal health practices, including the use of health services, and, ultimately, health status. Predisposing characteristics such as gender, age, race/ethnicity, marital status, education, and employment describe the propensity of an individual to use health services such as routine medical checkups or explain personal health practices such as substance use (Anderson, 2008). Enabling characteristics refer to the individual's ability to gain access to needed health services. Potential health care access issues are related to family resources such as insufficient household income, lack of adequate health insurance coverage, not having a regular source of medical care, and lacking the financial means to pay for health care when needed (Anderson, 2008). Perceived need for care is also a component of this model. Need includes both self-perception of health status and clinically diagnosed chronic conditions such as asthma, cardiovascular disease, and diabetes (Anderson, 2008). Self-perception of good health may decrease perceived need for subsequent use of health services or to improve health practices, while individuals with actual health needs are likely to have more health care encounters that may result in more opportunities to discuss other preventive health services with their health care provider (Gelberg et al., 2000).

For this study, there were two main variables of interest: ethnicity [report being Hispanic/Latino or White (non-Hispanic/Latino)] and participating in 150 minutes or more of physical activity outside of work, or LTPA. Ethnicity was ascertained by the variable «RACE2», which included both self-perception of health status and clinically diagnosed chronic conditions such as asthma, cardiovascular disease, and diabetes (Anderson, 2008). Self-perception of good health may decrease perceived need for subsequent use of health services or to improve health practices, while individuals with actual health needs are likely to have more health care encounters that may result in more opportunities to discuss other preventive health services with their health care provider (Gelberg et al., 2000).
Among those included in our sample from the 2011 administration of the BRFSS living in the Deep South; approximately 38% were male and over 96% of study participants were White (Non-Hispanic/Latino). Significant differences were observed between men and women by age. For example, greater proportions of men were observed in age categories below age 65 (Table 1). Differences also existed by education status with greater proportions of women completing high school (31.24%) when compared to men, but men reported receiving greater than high school education in larger proportions (60.52%). Additionally, men reported greater proportions of higher household income and greater proportions of being married (Table 1).

Regarding health indices, greater proportions of men reported better health and lesser proportions of men reported smoking ‘everyday’ or ‘some days’ out of the past 30 days (Table 1). However, men reported greater proportions of heavy drinking when compared to women. Men also reported being overweight (43.70%) and obese (29.69%) in greater proportions than women (Table 1). Furthermore, men in the sample reported having a medical checkup in the past 12 months in lower proportions than women (70.92% vs. 77.21%), while women reported greater proportions of not seeing a doctor due to medical costs during the past year (15.11%) (Table 1). Additionally, men reported being covered by health insurance and having a personal doctor in lower proportions when compared to women. In contrast, men reported greater proportions of the accumulation of at least 150 minutes of physical activity when compared to women (Table 1).

Differences in respondent characteristics were observed among participants who accumulated 150 minutes or more LTPA when compared to respondents who did not meet ACSM guidelines. Weighted estimates detail greater proportions of women (58.46%) not meeting the threshold of 150 minutes or more of LTPA within the study sample (Table 2). Significant differences were also observed between the proportions of Hispanic/Latino survey respondents meeting ACSM guidelines (5.23%) and Hispanic/Latino not meeting guidelines (6.95%) (Table 2). Examining socioeconomic status (SES), 65.29% of persons with greater than high school education reported accumulating 150 minutes or more of LTPA per week compared to 52.99% with similar education not meeting ACSM guidelines. Similar trends of accumulating 150 or more minutes of LTPA were observed for the highest level of income (27.71% vs. 19.50) when comparing meeting ACSM guidelines versus not meeting guidelines. Likewise, a greater proportion of those not meeting ACSM guidelines were observed among those with income levels less than $25,000.00 (37.8%) (Table 2).

Regarding health indices, weighted estimates illustrate greater proportions of lower (fair 16.46%) (poor 9.59%) levels of perceived health, reporting high blood pressure (39.25%), reporting high cholesterol (47.69%), smoking everyday (38.35%), last having a checkup five or more years ago (11.14%), not having a doctor due to medical costs (21.57%), not having a personal doctor (23.10%), and not having health coverage (21.40%) was observed among those accumulating less than 150 minutes of LTPA per week when compared to survey respondents who did meet ACSM guidelines (Table 2). Additionally, survey participants who met ACSM guidelines regarding LTPA reported greater proportions of normal weight (39.81%) and lesser proportions of obesity (21.33%), when compared to participants with less than 150 minutes of LTPA per week (Table 2).
Regarding weighted estimates of different proportions in participant characteristics within our sample, a lesser proportion of the sample were women (52.47%) when compared to White (Non-Hispanic/Latino) (Table 3). The participants of Hispanic/Latino ethnicity self-reported younger age categories in greater proportions when compared to their White (non-Hispanic/Latino) counterparts in the study. Regarding socioeconomic status (SES), the Hispanic/Latino group reported lower household income in greater proportions and lower proportions of education beyond completing high school (Table 3). Survey respondents with Hispanic/Latino ethnicity reported lesser proportions of high blood pressure (19.70%), lesser proportions of high cholesterol (31.53%), lower proportions of heavy alcohol drinking (4.24%), and lower proportions of smoking everyday (26.61%) when compared to White (Non-Hispanic/Latino) respondents (Table 3). When examining BMI, participants with Hispanic/Latino ethnicity reported greater proportions of overweightness (39.6%), but lesser proportions of obesity (24.6%) when compared to White (Non-Hispanic/Latino). Still, survey participants with Hispanic/Latino ethnicity reported meeting the ACSM guidelines of 150 minutes of LTPA in lower proportions than Whites (Non-Hispanic/Latino) (Table 3).

### Discussion

The purpose of this investigation was to examine factors which are associated with achieving the recommended minimum amount of moderate-intensity (or vigorous activity equivalent) physical activity (i.e., 150 minutes/week) for health among participants of Hispanic/Latino ethnicity and non-Hispanic/Latino whites within 4 states in the United States Deep South (Mississippi, Alabama, Georgia, South Carolina). Our results are in agreement with others (Crespo, Smit, Carter-Pokras, & Andersen, 2001) that persons of Hispanic/Latino ethnicity reported lower proportions of meeting ACSM recommendations for the accumulation of LTPA (> 150 minutes/week) compared to non-Hispanic/Latino whites. When comparing physical activity by race/ethnicity, our findings indicate that individuals with lower than high school education and combined annual household income below $25,000 were considerably less likely to achieve the ACSM recommendations for LTPA. In a related fashion, not seeing a physician due to medical costs was highly associated with lower categorical reporting of meeting recommended LTPA levels. The findings also indicate a higher rate of being overweight among Hispanic/Latino compared to White (non-Hispanic/Latino) which is in line with the lower probability of achieving the physical activity recommendations or that being overweight makes it more difficult to initiate LTPA, thereby limiting the number of individuals achieving the recommendations.

Hispanics/Latinos in the U.S., are one of the largest ethnic groups in the country comprising over 45 million individuals or 15.7% of the population (Ikesh & Sharma, 2012). Unfortunately, significant disparities have been observed in overweight and obesity (Flegal, Carroll, Ogden, & Curtin, 2010; “Health disparities experienced by Hispanics—United States,” 2004). The consequences of overweight and obesity include chronic disease conditions such as diabetes, cancer and cardiovascular disease. As the number of Latinos in the U.S. is expected to double by 2050 (Martyn-Nemeth, Vitale, & Cowger, 2010), it is crucial that we explore novel lifestyle interventions to reduce overweight/obesity as a strategy to reduce the personal and economic burden of disease. Previous investigations indicated that lifestyle interventions which combine both energy restriction and exercise provide superior effects on weight loss and weight maintenance than energy restriction or physical activity alone (Redman, et al., 2009). Therefore, physical activity is an important component of a healthy lifestyle for weight maintenance and for reducing the burden of disease even in the presence of weight-regain following energy restriction and exercise (Fisher, Hunter, & Cowger, 2012). While it is clear that physical activity/exercise produces numerous health benefits, the primary issue for the field is how to increase the number of individuals who perform physical activity on a daily basis.

Epidemiological evidence indicates that more than 60% of the U.S. population is physically inactive (Office of the Surgeon General, 2001). Within the population, there are considerable disparities between the accumulation of LTPA with Hispanic/Latinos attaining over 40% less physical activity than non-Hispanic whites (Larsen, et al., 2013). In the current investigation using interview data from the BRFSS, we found that Hispanic/Latino men and women are significantly less likely to report engaging in physical activity that meets or exceeds the ACSM guidelines of 150 minutes of LTPA in lower proportions than Whites (Non-Hispanic/Latino) (Table 3).
meet the ACSM recommendations or not. An interesting finding from this study was that Hispanic/Latinos had a greater proportion of overweightness compared to Whites (non-Hispanic/Latino) suggesting that not achieving the physical activity recommendations is linked with the likelihood of being overweight or that being overweight increases the barrier of performing LTPA, thereby reducing the propensity to achieve the ACSM recommendations. Future studies are required to determine the magnitude of the association between race/ethnicity and physical activity guidelines, and the influence of related factors on the association of ethnicity and LTPA. Additionally, prospective studies should be considered to help determine causal relationships with regards to these findings since previous studies show that exercise improves mechanical efficiency for a given task, thereby increasing the likelihood that an individual will expend a greater amount of activity and non-activity related energy expenditure which would be expected to produce beneficial effects on weight loss and maintenance (Hunter, Bickel, Fisher, Neumeier, & McCarthy, 2013).

One of the primary limitations of this study is that over 96% of the study participants within the BRFSS dataset were White (non-Hispanic/Latino). However, weighted and unweighted measures for each parameter suggest that the interpretation of our data and inference to the larger population of the U.S. Deep South is valid. Another limitation was that we were unable to incorporate any measures of dietary quality or quantity and their influence on the overall prediction of achieving the recommendations. Additionally, due to the cross-sectional nature of the study, we are unable to determine temporal sequence to ascertain causality. Longitudinal studies are required to more thoroughly evaluate the contribution of each of the predictor variables on the achievement of the ACSM recommendations. Thus, we are limited by selection bias and recall bias. Although many persons were asked to be interviewed for the BRFSS, participants self-selected to participate. In addition, participants were asked a series of questions related to different time periods during the past 30 days, past year, and past 5 years. Thus, participants may have recalled events in error, resulting in bias by the respondent. Still, strengths of the study include an exploratory examination of the «Deep South» population regarding physical activity and factors influencing the achievement of ACSM guidelines among a specific minority. Moreover, this study illustrates the importance of individual, contextual, and behavioral factors in influencing physical activity accumulation.

In conclusion, the results of the current investigation indicate that Hispanic/Latino men/women are significantly less likely to meet the ACSM recommendations (> 150 minutes/week) compared to non-Latino/Hispanics. Lower amounts of income, education, and access to health care are all important determinants of whether Hispanic/Latinos in the Deep South achieved the ACSM recommendations.

References


Learning curve and motor retention of a video game in young and older adults

Keven Santamaria-Guzmán, Alejandro Salicetti-Fonseca, & José Moncada-Jiménez

University of Costa Rica

Abstract. The purpose of the study was to compare the learning curve and motor retention of the Dance Dance Revolution (DDR) video game in healthy adults. Twenty young (M= 23.9 ± 2.8 yr.) and 18 older adults (M= 60.7 ± 5.9 yr.), were randomly assigned to two experimental conditions: a) DDR 7 trials and b) DDR 14 trials. Participants danced the same song six sessions, followed by a detraining period of eight days. Then participants returned to the laboratory and danced again in order to detect a motor retention effect. A three-way ANOVA revealed mean score interactions (sessions x groups x trials; p = 0.017). Follow-up analyses revealed differences between young and older participants in both trial sessions (p < 0.05). Compared to young adults, older adults showed a learning curve of four sessions when performing 14 trials per session. After eight days of detraining only older participants in the DDR14 condition reduced motor performance. In conclusion, older subjects can learn the DDR game after playing four sessions; however, those dancing the same song 14 times were more likely to reduce their scores after eight days of detraining. Younger participants scored higher consistently regardless of the number of trials and sessions with little variability.

Key words. exergames, learning curve, elderly, motor learning, video games

Introduction

A recent report (The Entertainment Software Association, 2013), revealed that the videogame industry produced in 2011, approximately $24.75 billion, and these figures are likely to increase in the years to come. Indeed, videogames are becoming an integral part of our daily lives. Both, children and adults, are widely engaged in videogame playing for several hours during a day (Richards, Mccgee, Williams, Welch, & Hancock, 2010; Wethington, Sherry, Park, Blanche, & Fulton, 2013).

Scientific studies regarding the acute and chronic effects of playing videogames on different variables have been done before (Moncada-Jiménez & Chacón-Araya, 2012). In general, the findings are contradictory for psychological variables. Some meta-analysis and other reviews suggest a correlation between excess time video gaming on negative social and psychological aspects such as isolation and aggressive behavior (Anderson, 2004; Anderson & Bushman, 2001; Anderson et al., 2010; Cummings & Vandewater, 2007; Richards et al., 2010; Sherry, 2001); while other research suggests a positive association with motor learning, adoption of healthy habits (including increased energy expenditure), motor re-training and resilience (Baranowski et al., 2011; Thompson, Baranowski, & Buday, 2010; White, Schofield, & Kilding, 2011). The commercial process for promoting new video game systems and consoles such as Nintendo Wii (Nintendo of America Inc., Redmond, WA), Play Move (Sony Computer Entertainment America LLC, USA), Kinect (Microsoft Corporation, USA), and others, is very appealing for potential users. Some of these videogames directly promote increased physical activity since most body parts must be used to play. Other potential positive «side-effects» from unknown doses of videogame playing («exergaming») such as improved balance, better rehabilitation, weight loss, and psychological benefits (e.g., increased memory and other perceptual stimuli) are yet to be confirmed (Gatica-Rojas, Elgueta-Cancino, Vidal-Silva, Cantin-López, & Fuentelba-Arcos, 2010; Gra

Learning curves are also used as a feedback tool for performers since motor learning is unique for a particular subject and a particular skill (Magill, 1993; Schmidt & Lee, 2005; Singer, 1982). Learning curves function describes the degree of success attained during a period of instruction (e.g., score over time) (Singer, 1982). When mastery is achieved it is expected a gradual increase in performance (e.g., speed, accuracy) accompanied by a reduction in variability (Adi-Japha, Kern, Barnes, Loewenschuss, & Vakil, 2008). Learning curves can be used as a feedback tool for performers since motor learning is unique for a particular subject and a particular skill (Magill, 1993; Schmidt & Lee, 2005; Singer, 1982). Skill performance might be impaired or lost due to a lack of practice following training (i.e., detraining) or inappropriate learning and practice, which might be related to motor retention (Magill, 1993; Schmidt, 1975; Singer, 1982). Motor retention has been defined as the ability to maintain high standards of physical performance (e.g., speed, coordination), effectiveness and consistency in a motor task (Bertollo, Berchicci, Carraro, Conmani, & Robazza, 2010; Hynes-Duesil, 2002). Performance in a motor task is impaired when practice is discontinued and this
reduction tends to appear earlier in high demanding tasks as opposed to low demanding tasks (Bertollo et al., 2010).

In spite of a growing body of evidence showing the usefulness of video games for improving health-related variables, there is still scarce information regarding how long does it take for a person to learn how to play a video game; in other words, the motor learning and motor control as it relates to exergaming. Therefore, the purpose of the study was to determine the learning curve of the DDR videogame in a sample of young and older adults, as well as to determine if any retention occurred after a detraining period.

Methodology

Participants

Thirty-eight volunteers were recruited from a university campus and a service program for older adults. Potential participants were naïve to the DDR 2 Hottest Party® (Nintendo Wii) videogame or had little or no experience in exergaming.

Measurement instruments

The DDR videogame was played from a Nintendo Wii console and four control mats of the same brand (Nintendo of America, Inc., Redmond, WA) placed in front of a 36” television screen (Sony Bravia, Japan). Participants wore a heart rate monitor Polar, model T-61 (Polar Group, Oulu, Finland).

Data were collected from the scoring system of the DDR display; however, the original scores were multiplied and transformed into new scores by using the beginner mode of the DDR game. The original scores were multiplied as follows: a) Perfect x 7; b) Great x 6 pts.; c) Good x 5 pts.; d) Almost x 4 pts.; e) Boo x 3 pts.; f) OK x 2 pts.; and g) NG x 1 pt.

The highest achievable score was 322 pts., defined as the number of correct arrow steps shown for the song (46 arrows) multiplied by the maximal score in the scale (i.e., 7 pts.). The lowest achievable score was 48 pts., as defined by lowest number of arrow steps (16 arrows) multiplied by the score of 3 pts. allowed by the software. Notice that the scores OK and NG are not taken into consideration by the videogame software even when a participant stands still in front of the video display.

Procedures

Younger and older participants were randomly assigned to two groups based on the number of trials to be performed in the DDR. Participants in both age groups were randomly assigned to perform either seven (DDR7) or fourteen (DDR14) trials of the same song during six sessions (days) within a three week period (Bertollo et al., 2010). All participants were required to perform the study in the Human Movement Sciences Research Center under controlled environmental conditions and a predefined distance of the mat from the television screen. Participants read and signed an informed consent to participate in the study in accordance to the standards set forth by the Ethics Scientific Committee of the University of Costa Rica.

Participants were required to visit the laboratory to read and sign an informed consent form. During the same visit, participants were instructed on how to play the videogame by an oral explanation of one of the researchers, who read the same document to all participants to avoid confusion and ensuring for homogenous instructions. Physical exertion was monitored at the end of each trial by placing a heart rate monitor to each participant.

The experimental sessions required participants to dance the same song on each of the six exercise sessions. A pilot study on a different group of people with similar characteristics to the participants of this study revealed that the song Black or White (Jackson, 1991) and the Beginner level was the easiest combination of a song and a difficulty level for participants to play. Performance scores and heart rate values were recorded at the end of each trial. Once the experimental protocol was finished, a detraining period of eight days was implemented, followed again by a single exercise session. Participants were instructed on not playing any videogames during eight days. Then, participants were appointed to perform one last time the DDR videogame. The score in this last exercise trial was called the «retention» effect.

Statistical analysis

Statistical analysis was performed with the IBM SPSS Statistics for Windows version 20 (IBM Software Group, Chicago, IL, USA). Values are presented as mean and standard deviation (M ± SD). Statistical significance was set a priori at P < 0.05. Inferential statistics included mixed three-way (groups x experimental treatments x sessions) ANOVA for the score variable and appropriate follow-up analyses. Coefficient of variation ([M/SD] x 100) was also used to describe learning curves (Vincent & Weir, 2012).

Results

Young (n = 20) and older adults (n = 18) participated in the study. Physical characteristics are described in table 1. Mean scores and heart rate response to combined sessions is presented in table 2 for younger and older participants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n = 11)</th>
<th>Female (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs.)</td>
<td>26.8 ± 4.9</td>
<td>29.9 ± 6.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>90.5 ± 16.6</td>
<td>67.5 ± 5.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>178.5 ± 8.3</td>
<td>157.6 ± 4.8</td>
</tr>
</tbody>
</table>

Three-way ANOVA showed triple (p = 0.017) and double significant interactions (groups x sessions) (p = 0.001), and significant main effects for sessions (p = 0.001) and groups (p = 0.001) in DDR scores. Two-way ANOVA comparing the two age groups and the two trial regimens (i.e., DDR7 vs. DDR14) revealed significant interaction (p < 0.05), and main effects for trials (p < 0.05), and sessions (p < 0.05) in DDR scores. One-way ANOVA revealed significant differences in the within-session DDR mean scores in the experimental group DDR7 (p < 0.05). Tukey’s HSD post hoc analysis indicated that significant mean differences were obtained in session 6 vs. sessions 1, 2, 3; session 5 vs. sessions 1 and 2; and between session 1 vs. sessions 3, 4, and 7. One-way ANOVA also revealed significant differences in the within-session DDR mean scores in the experimental group DDR14 (p < 0.05). Tukey’s HSD post hoc analysis indicated that significant mean differences were obtained in sessions 4, 5, 6 vs. sessions 1, 2, 7; sessions 3, 7, 2 vs. session 1; and between session 2 to 6 in both groups.

Among younger participants performing in the DDR7 and DDR14 groups, only the main effect session was statistically significant (p < 0.05) for the DDR scores. One-way ANOVA failed to reveal significant mean differences in DDR scores in the within-sessions factor.

Two-way ANOVA revealed a significant interaction (p < 0.05) and main effect group (p > 0.05) in DDR scores among younger and older participants performing DDR7. One-way ANOVA revealed significant mean differences among all sessions in both age groups (p > 0.05).

Two-way ANOVA revealed a significant interaction (p < 0.05) and main effect group (p > 0.05) in DDR scores among younger and older participants performing DDR14. One-way ANOVA revealed significant mean differences among all
sessions in both age groups (p < 0.05). Younger and older males significantly (p < 0.05) increased heart rates from rest following exercise by 9.4% and 19.9%, respectively. Younger and older females significantly (p < 0.05) increased heart rates from rest following exercise by 11.7% and 16.4%, respectively.

**Discussion**

The processes of movement adaptation are directly related to the activity and the situation (Singer & Berrocal, 1986). In other words, random elements (i.e., external variables) are reduced as more self-control is achieved following practice; therefore, a more stable and consistent motor performance. In this study, performance patterns in younger participants did not change significantly in the DDR videogame. Older participants performing DDR7 and DDR14 per session increased significantly their scores in the DDR videogame. Furthermore, older participants in the DDR14 group improved their performance after five sessions and had a low retention following the detraining period. This means participants were unable to maintain their previous improved performance. However, this response was not found in the group performing DDR7, which were able to maintain their performance following eight days of detraining. Motor performance is expected to decrease following a detraining period especially for difficult tasks requiring complex and coordinated movements and high memory processes (Bertollo et al., 2010; Hynes-Dusel, 2002); therefore, further research is guaranteed in older exergamers.

Motivation, attention, concentration and decision-making processes are enhanced when a motor task is mastered after three stages of skill acquisition are achieved (Fitts & Posner, 1967; Ruskin, Proctor, Neeves, & Fitzgibbon, 2007; Schmidt & Lee, 2005; Singer & Berrocal, 1986). The first stage is cognitive and the performer tries to understand the nature of the motor task. Errors often occur as a result of the novel task (Fitts & Posner, 1967). Older adults in this study indicated that during the first session it was hard to understand the nature of the videogame. The mean scores achieved by these subjects in session one support the later statement. The second stage is associative in nature, and the performer already understands what is needed to do to achieve a superior performance; therefore, the person tries to determine the most effective movements to achieve the task at hand and repeat them to enhance synchronization (Fitts & Posner, 1967). In this stage, less frequent errors appear than in the cognitive stage. Stage two of skill acquisition in older participants in this study was observed in sessions 5 and 6, which may reflect the autonomous stage of skill acquisition (Fitts & Posner, 1967). In this stage, older participants automatically and fluently executed the movement, allowing them to achieve higher scores in the DDR videogame. Fitts and Posner’s three-stage theory of skill acquisition was not found in the younger group of participants of this study under the proposed practice regimens (DDR7 vs. DDR14) and sessions (Figure 1). A reasonable explanation to this finding could have been that the beginner level and song chosen did not represent a challenge to participants in this age group. In fact, this is a limitation of the present study. Younger participants did not achieve the highest possible score (322 pts.); yet, scores were consistently high in participants in both practice regimes, with less than 8% variation between sessions (Figure 2). A plausible explanation of this finding could have been that the processes mentioned earlier by others (Schmidt & Lee, 2005; Singer & Berrocal, 1986) happened so fast that were likely undetected.

Learning curves shown in figure 1 allow for comparison of the practice effect on score precision of a videogame and the mastery time for the motor skill to occur, especially in older adults (Magill, 1993; Schmidt & Lee, 2005; Singer, 1982; Song, 2009; Vendittioli, 2008). It also provides a starting point for further research in younger participants.

In conclusion, no significant differences in scores were observed in younger participants within trials or between sessions. Older adults improved their performance in the DDR videogame either practicing DDR7 or DDR14 from session one to session four, moment when scores became stable (i.e., learning curve). Older adults performing DDR14 achieved significantly higher scores than their counterparts on the DDR7 group; however, only the adults on the DDR14 group reduced their performance scores following eight days of detraining.

**Acknowledgment**

Our gratitude to Prof. Manibel Matamoros-Sánchez for her support in recruiting participants from an outreach elderly program. The authors do not report conflict of interest.

**References**


A single session of aerobic exercise influences paraoxonase 1 activity and concentration

J. Kyle Taylor*, Michael R. Esco**, Li Qian*, Kathryn Dugan*, & Kathy Jones*

*Auburn University at Montgomery, AL, USA, **University of Alabama, AL, USA

Abstract. Our purpose was to examine changes in paraoxonase 1 (PON1) concentration and activity following a single aerobic exercise session. Sixteen men (32 ± 8 yrs.; BMI = 29.4 ± 6.8 kg/m²; % fat = 29 ± 13; VO₂max = 38.3 ± 11.9 ml/min·kg⁻¹; waist circumference = 93.7 ± 16.0 cm; HDL-C = 1.19 ± 0.21 and triglycerides = 1.22 ± 1.04 mmol·l⁻¹; direct LDL = 2.69 ± 0.73 mmol·l⁻¹) expended 400 kcals by treadmill walking at 65% of VO₂max.

Fasting blood samples were collected before (PRE), immediately post-exercise (IPE), 24 hours post-exercise, and 48 hours post-exercise. PON1 concentration, PON1 activity, lipids, apolipoprotein A1 (Apo A1), apolipoprotein B (Apo B), and thiobarbituric acid reactive substances (TBARS) were analyzed for each time point. The men were divided into two groups based on their body mass index (BMI): Normal weight (NW) and Obese Group. At baseline, PON1 concentration and activity were significantly higher in the NW group as compared to the obese group. In addition, PON1 activity was significantly higher in the NW group as compared to the obese group for all time points. Furthermore, PON1 concentration and activity were significantly increased in the combined group immediately post-exercise and returned to baseline levels within 24 hours. PON1 activity was significantly increased in the Obese group IPE and this was observed with increases in HDLc, Apo A1, and TBARS.

Keywords. PON1 activity, Exercise, Lipids, Lipoproteins.

Introduction

Over 32% of U.S. adults do not participate in leisure time physical activity and women were reportedly less active than their male counterparts (Go et al., 2013). Physical activity guidelines provided by the American College of Sports Medicine (ACSM) and American Heart Association (AHA) state that adults between the ages of 18-65 years should accumulate at least 30 minutes of moderate-intensity aerobic exercise on 5 days per week (Haskell et al., 2007). This weekly volume has been shown to be the minimum level of physical activity needed to prevent hypokinetic diseases (Haskell et al., 2007). However, according to the ACSM and Centers for Disease Control and Prevention (CDC), nearly half of all adults do not meet the ASCM and AHA guidelines mentioned above («Adult participation in recommended levels of physical activity—United States, 2001 and 2003», 2005; Haskell et al., 2007).

Health benefits of regular exercise include decrease blood pressure (BP), improved insulin sensitivity, improved glucose regulation, decreased body weight, improved antioxidant defenses, and improved dyslipidemias (Dufaux, Order, Muller, & Hollmann, 1986; Durstine et al., 2001; Grandjean, Crousè, & Rohack, 2000; Lesgards et al., 2002; Miller et al., 1979; Nakamura, Uzawa, Maeda, & Inomoto, 1983; Szostak & Laurent, 2011). Aerobic exercise improves lipid profiles by increasing plasma high-density lipoprotein (HDL) concentrations (Dufaux et al., 1986; Durstine et al., 2001; Grandjean et al., 2000; Miller et al., 1979; Nakamura et al., 1983) and lowering plasma TG levels (Grandjean et al., 2000; Kantor, Cullinane, Herbert, & Thompson, 1984). Even though regular exercise has many benefits, an acute bout of exercise generates free radicals leading to increased oxidative stress (Ji, 1995).

Oxidation of low-density lipoprotein (LDL) and HDL can be attenuated by an important enzyme, PON1 (Aviram et al., 1998; M. I. Mackness, Arrol, Abbott, & Durrington, 1993; M. I. Mackness & Durrington, 1995; Sorenson et al., 1999; Watson et al., 1995), which protects LDL and HDL by hydrolyzing the oxidized phospholipids formed on LDL and HDL particles (Aviram et al., 1998; M. I. Mackness, Arrol, & Durrington, 1991). PON1 is a calcium-dependent enzyme and is the most abundant of the PON family of enzymes that circulates exclusively with the HDL particle (Aviram & Rosenblat, 2004; Borna, 1980; Deakin et al., 2002; Khersonsky & Tawfik, 2005; La Du, 1996; Mackness, Durrington, & Mackness, 2004; Primo-Parno, Sorenson, Teiber, & La Du, 1996). PON1 was first recognized for the ability to detoxify organophosphate compounds and its name was derived from a commonly used substrate, paraoxon (Aldridge, 1953a, 1953b; Mazur, 1946). Recently, two meta-analyses observed an increased risk of coronary heart disease (CHD) in subjects with low PON1 activity regardless of age (Wang et al., 2012; Zhao et al., 2012). The limited research determining the influence of a single session of aerobic exercise on PON1 concentration and activity have yielded conflicting results (Benitez et al., 2002; Iborra et al., 2008; Otocka-Kmiecik et al., 2010; Tomas et al., 2002). For instance, PON1 activity was significantly higher immediately following a single session of aerobic exercise (Otocka-Kmiecik et al., 2010; Tomas et al., 2002). In contrast, PON1 activity was not altered following a single session of aerobic exercise (Benitez et al., 2002; Iborra et al., 2008). In each of the studies above, the investigators did not report concentration of PON1 or caloric expenditure. Increases in PON1 activity have been reported to counter the free radicals produced on lipoproteins associated with exercise (Otocka-Kmiecik et al., 2010; Tomas et al., 2002), but exercise may influence the concentration of PON1 leading to changes in activity.
Furthermore, a single session of aerobic exercise is well documented to improve lipoprotein profiles and increases in HDLc have been seen with caloric expenditures as low as 350 kcal (Crouse et al., 1995). Since PON1 is an HDL-associated enzyme, it may be important to examine if caloric expenditure plays a role in altering PON1.

Therefore, the purpose of this study was to examine the changes in the concentration and activity of PON1 following a single session of aerobic exercise on a treadmill expending 400 kcals of energy at an intensity of 60 to 70%VO₂max.

Methods

Subjects

Sixteen apparently healthy adult male volunteers participated in this study. They were recruited by email and flyers that were posted around campus. Participants were screened and risk stratified by the use of a health history questionnaire. Those who were excluded were if they were smokers or on lipid-altering medications. The subjects that met inclusion criteria were equally assigned to one of two groups based on their body mass index (BMI). A subject with a BMI of ≤ 25 kg/m² would be assigned to the NW group and a BMI > 30 kg/m² would be assigned to Obese group. The Auburn University at Montgomery Institutional Review Board approved the protocol and all participants voluntarily signed an informed consent.

Maximal Graded Exercise

Each participant was asked to complete a maximal graded exercise test (GXT) on a treadmill (Trackmaster, Newton, KS). The Bruce Protocol was employed to determine maximal oxygen consumption (VO₂max). Expired gas (oxygen and carbon dioxide) fractions were sampled continuously using a pneumotach, mixing chamber, and gas analyzers through a Parvo Medics cart (Sandy, UT). Heart rate and blood pressure were assessed throughout the GXT.

Intervention

A schematic is presented in Figure 1. All participants underwent testing on four separate days. The participants were asked to avoid strenuous activity 24 hours prior to coming into the laboratory. The initial testing (Day 1) included preliminary screening of subjects and collection of anthropometric variables. The participants reported to the Human Performance Laboratory at Auburn University at Montgomery seven days following the initial GXT (Day 2).

A fasting blood sample was collected prior to beginning the exercise session. Each participant completed a single session of aerobic exercise on a treadmill at an intensity of 60 to 70%VO₂max to expend 400 kcals. Immediately post-exercise (IPE), 24 hours post-exercise (24), and 48 hours post-exercise (48) were sampled and placed into a -80°C ultralow freezer until testing.

Blood Sampling

Blood samples were drawn 10 to 12 hours following an overnight fast. Blood samples were drawn prior to the exercise session (PRE), immediately post-exercise (IPE), 24 hours post-exercise (24), and 48 hours post-exercise (48) under fasting conditions. Blood samples were centrifuged at 3000 rpm for 15 minutes. An aliquot of serum was prepared and placed into a -80°C ultralow freezer until testing.

Table 1. Baseline values for blood lipids and oxidative stress markers.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Normal Weight (n=8)</th>
<th>Obese (n=8)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL</td>
<td>mmol/L</td>
<td>9.64 ± 1.73</td>
<td>9.69 ± 2.30</td>
<td>0.975</td>
</tr>
<tr>
<td>TG</td>
<td>mmol/L</td>
<td>4.94 ± 1.26</td>
<td>7.44 ± 2.86</td>
<td>0.272</td>
</tr>
<tr>
<td>HDL</td>
<td>mmol/L</td>
<td>5.78 ± 1.71</td>
<td>5.82 ± 1.55</td>
<td>0.969</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>mmol/L</td>
<td>3.36 ± 0.44</td>
<td>2.45 ± 0.42</td>
<td>0.002</td>
</tr>
<tr>
<td>Apo A1</td>
<td>g/L</td>
<td>1.15 ± 0.41</td>
<td>1.15 ± 0.45</td>
<td>0.602</td>
</tr>
<tr>
<td>Apo B</td>
<td>g/L</td>
<td>0.80 ± 0.68</td>
<td>0.63 ± 0.20</td>
<td>0.765</td>
</tr>
<tr>
<td>PON1</td>
<td>kU/L</td>
<td>105.3 ± 26.9</td>
<td>180.0 ± 29.0</td>
<td>0.002</td>
</tr>
<tr>
<td>PON1c</td>
<td>ng/mL</td>
<td>222.5 ± 74.8</td>
<td>148.7 ± 66.4</td>
<td>0.004*</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation. DL, total cholesterol; TG, triglycerides; HDL, high-density lipoprotein; Apo A1, Apolipoprotein A1; Apo B, Apolipoprotein B; HDL, high-density lipoprotein; PON1, Pancreon D activity; PON1c, Pancreon D concentration; TBARS, Thiolobarbituric acid reactive substances. Statistical significance (p < 0.05,* between groups).
Lipids, lipoproteins, PON1, and TBARS were measured at baseline for NW and Obese groups and results are presented in Table 2. There were no differences for lipids, lipoproteins, and TBARS at baseline between groups (p > 0.05). However, PON1 concentration and activity were both significantly higher at baseline in the Obese group (p = 0.031 and p = 0.048).

A single session of aerobic exercise on a treadmill expending 400 kcal at an intensity of 60 to 70% VO2peak was performed by the NW and Obese groups. The results for lipids, lipoproteins, PON1, and TBARS are presented in Table 3. Total cholesterol (TC), triglycerides (TG), direct low density lipoprotein (dLDL), and low density lipoprotein (LDLc) were not altered PON1 for either group. However, TG were significantly reduced 24 hours post exercise as compared to PRE in the NW group (p = 0.021). HDLC were significantly increased in the Obese group IPE (p = 0.008). HDLC were significantly increased IPE in the NW group (p = 0.028) and Obese groups (p = 0.001) IPE and returned to pre-exercise levels within 24 hours (Figure 2).

In the NW group, PON1 activity was not altered following a single session of exercise immediately post-exercise (Figure 2) (p < 0.05). This was similar in the Obese group.

Apolipoprotein B (ApoB) was significantly increased in the Obese group IPE (p = 0.041). TG were not altered following a single session of exercise immediately post-exercise. The dLDL were significantly increased IPE in the NW group (p = 0.008). Apo A1 were significantly increased IPE (p = 0.003) and 24 hours post exercise (p = 0.033) as compared to PRE. Apo B were only significantly increased IPE (p = 0.008). PON1 activity were significantly increased IPE (p = 0.002). PON1c was not altered IPE, but were significantly reduced 24 hours post exercise (p = 0.006).

TBARS were significantly increased IPE (p = 0.001). The dLDL were significantly increased IPE (p = 0.008). Apo A1 were significantly increased IPE (p = 0.003) and 24 hours post exercise (p = 0.033) as compared to PRE. Apo B were only significantly increased IPE (p = 0.008). PON1 activity were significantly increased IPE (p = 0.002). The NW group, HDLC and Apo A1 were significantly correlated with one another following a single session of aerobic exercise (r = 0.919, p < 0.001). In the Obese group, HDLC and Apo A1 were significantly correlated following the exercise session (r = 0.991, p < 0.001). In the Obese group, exercise-induced changes in TBARS were significantly correlated following the exercise session (r = 0.991, p < 0.001). In the Obese group, exercise-induced changes in TBARS were significantly correlated with exercise-induced changes in HDLC inactivity (r = 0.730, p = 0.040), HDLC (r = 0.799, p = 0.017), and Apo A1 (r = 0.773, p = 0.024). Furthermore, PON1 activity had a positive correlation with HDLC (r = 0.462, p = 0.249) and Apo A1 (r = 0.458, p = 0.254) following the bout of exercise, but they were not significant. In the combined group, exercise-induced changes HDLC and Apo A1 were significantly correlated (r = 0.917, p < 0.001).

Discussion

Aerobic exercise is generally prescribed to control weight and improve overall health. There is limited research on the influence of aerobic exercise on PON1 status (concentration and activity) as previously described. Mackness et al. (B. Mackness et al., 2001) suggests that determining the concentration and activity of PON1 are critical in determining the status of PON1. This study examined changes in the concentration and activity of PON1 following a single session of aerobic exercise in NW and Obese men.

Table 3.

<table>
<thead>
<tr>
<th>Variable</th>
<th>NW</th>
<th>Obese</th>
<th>NW</th>
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<th>Obese</th>
<th>NW</th>
<th>Obese</th>
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<tbody>
<tr>
<td>TC (mmol/l)</td>
<td>5.73 ± 1.24</td>
<td>4.00 ± 1.24</td>
<td>5.73 ± 1.04</td>
<td>4.00 ± 1.04</td>
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<td>4.00 ± 1.04</td>
<td>5.73 ± 1.04</td>
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<tr>
<td>HDLc (mmol/l)</td>
<td>1.95 ± 0.12</td>
<td>1.95 ± 0.12</td>
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<tr>
<td>dLDL (mmol/l)</td>
<td>2.54 ± 0.51</td>
<td>2.54 ± 0.51</td>
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<td>2.54 ± 0.51</td>
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<tr>
<td>Apo A1 (g/l)</td>
<td>0.11 ± 0.24</td>
<td>0.11 ± 0.24</td>
<td>0.11 ± 0.24</td>
<td>0.11 ± 0.24</td>
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<tr>
<td>PON1a (g/l)</td>
<td>0.46 ± 0.12</td>
<td>0.46 ± 0.12</td>
<td>0.46 ± 0.12</td>
<td>0.46 ± 0.12</td>
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<tr>
<td>PON1c (g/l)</td>
<td>0.24 ± 0.08</td>
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<td>0.24 ± 0.08</td>
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<tr>
<td>TBARS (nmol/ml)</td>
<td>1.54 ± 0.54</td>
<td>1.54 ± 0.54</td>
<td>1.54 ± 0.54</td>
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</table>

Results are presented as mean ± SD.

Pearson-Product Moment Correlations were performed to evaluate relationships following exercise-induced changes between PON1 activity, HDLc, Apo A1, and TBARS. In the NW group, HDLC and Apo A1 were significantly correlated with one another following a single session of aerobic exercise (r = 0.919, p = 0.001). In the Obese group, HDLC and Apo A1 were significantly correlated following the exercise session (r = 0.991, p < 0.001). In the Obese group, exercise-induced changes in HDLC were significantly correlated with exercise-induced changes in PON1 activity (r = 0.730, p = 0.040), HDLC (r = 0.799, p = 0.017), and Apo A1 (r = 0.773, p = 0.024). Furthermore, PON1 activity had a positive correlation with HDLC (r = 0.462, p = 0.249) and Apo A1 (r = 0.458, p = 0.254) following the bout of exercise, but they were not significant. In the combined group, exercise-induced changes HDLC and Apo A1 were significantly correlated (r = 0.917, p < 0.001).

Figure 2. Paraoxonase 1 Concentration

Figure 3. Paraoxonase 1 Activity

Figure 4. TBARS Concentration

Baseline, before exercise; IPE, immediately post-exercise; 24 Post, 24 hours post-exercise; 48 Post, 48 hours post-exercise; NW, Normal Weight; TG, triglycerides; dLDL, direct low-density lipoprotein; HDLc, high-density lipoprotein; Apo A1, Apolipoprotein A1; Apo B, Apolipoprotein B; HDLc, high-density lipoprotein; PON1a, Paraoxonase 1 activity; PON1c, Paraoxonase 1 concentration; TBARS, Thiobarbituric acid reactive substances. Statistical significance (p < 0.05); * between groups; † within group versus PRE. Results are presented mean ± SD.
Acute bout of aerobic exercise has been previously shown to increase PON1 activity (Otocka-Kmiecik et al., 2010; Tomas et al., 2002). In contrast, two additional investigators did not find an increase in PON1 activity following a single session of aerobic exercise (Benitez et al., 2002; Ibrah, et al., 2008). In this current study, PON1 activity was only significantly increased in the Obese group IPE, but not in the NW group. This significant increase in PON1 activity was seen along with increases in HDLc in the Obese group. These HDLc findings are consistent with other studies (Crouse et al., 1995; Grandjean et al., 2000). HDLc was not altered in the NW group. The increases in PON1 activity and HDLc in the Obese group may suggest that these individuals may benefit more from a single session of aerobic exercise than men who are NW. In the combined groups, PON1 activity was significantly higher immediately post exercise and returned to baseline levels within 24 hours as we and other investigators have reported (Ibrah, et al., 2008; Otocka-Kmiecik et al., 2010; Tomas et al., 2002). This is the first study to examine changes in PON1 activity following a single session of aerobic exercise changes expending 400 kcal of energy.

Apo A1, a key HDL-associated lipoprotein, is not necessary for the attachment of PON1 with HDL or phospholipids (Sorenson et al., 1999). However, the stability and activity of PON1 is enhanced in the presence of Apo A1 as compared to without Apo A1 (Sorenson et al., 1999). Investigators have suggested that Apo A1 be determined along with PON1 activity (Otocka-Kmiecik et al., 2010). In our study, a single session of exercise significantly increased Apo A1 in the Obese group IPE, but not in the NW group. Correlations between Apo A1 and PON1 activity exhibited a modest positive association in the Obese group. When the Obese and NW groups were combined the Apo A1 was significantly increased IPE. Our results are similar to investigators that reported an increase in Apo A1 following exercise (Rector et al., 2007).

TBARS was analyzed to determine lipid peroxidation following a single session of aerobic exercise. In our cohort, TBARS was significantly higher at baseline in the Obese group as compared with the NW group, which is consistent with other published data (D’Archivio et al., 2012). TBARS was significantly increased in the both groups IPE indicating an increase production of free radicals from the exercise session. The increased TBARS was positively correlated with PON1 activity indicating the activity may be in response to lipid peroxidation. This is consistent with findings from other studies (Otocka-Kmiecik et al., 2010; Tomas et al., 2002). Additionally, the same was true when the two groups were combined.

In conclusion, PON1 concentration was not altered by a single session of aerobic exercise in either group. However, a single session of aerobic exercise was shown to significantly increase PON1 activity in the Obese group IPE, but not in the NW group. However, our data may suggest that Apo A1 may be a potential mechanism to explain the increased PON1 activity following aerobic exercise. We did not investigate this potential mechanism in this study. Furthermore, accumulating 400 kcal of exercise per day may be effective intervention for individuals that are Obese to reduce weight and provide additional health benefits as well as improve PON1 status.

References


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