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Literature Review

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Salivary Biomarkers in Children: Exercise, Physical Activity and Obesity Studies

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ABSTRACT

Worldwide, overweight/obesity and associated chronic diseases such as type 2 diabetes (T2D), have reached epidemic proportions. The current statistics show that overweight/obesity and chronic disease is prevalent amongst adults and children in South Africa. The aim of the review is to discuss current research investigating how overweight/obesity and inactivity impact on salivary biomarkers of immune and sympathetic activation in children and how these may change with weight-loss and increased activity. There is limited research regarding the effect that these factors have on salivary biomarkers of health status, especially in children. Further, research is required to provide a clearer understanding of how salivary biomarkers may be used for understanding the impact of obesity and physical inactivity on paediatric health. This will play a role in the development of appropriate physical activity and exercise guidelines for children.

KEYWORDS: Physical activity; Obesity; Immunity; Neuro-endocrine; Children; Salivary biomarkers; Sympathetic activation.

ABBREVIATIONS: T2D: Type 2 Diabetes; SIgA: Salivary Immunoglobulin A; URTI: Upper Respiratory Tract Infections; Sc: Salivary Cortisol; sT: Salivary Testosterone; PA: Physical Activity; BF: Body Fat; CRF: Cardiorespiratory Fitness; sCRP: Salivary C-reactive protein; sAA: salivary Alpha-Amylase; HR: Heart Rate; IL-6: Interleukin-6; ELISA: Enzyme-linked immunoassay; SNS: Sympathetic Nervous System; RMSSD: Root Mean Square of Successive Differences; HPA: Hypothalamus-Pituitary-Adrenal.

INTRODUCTION

This paper aims to review the current research on salivary biomarkers of immune and sympathetic activation in the fields of physical activity (PA), exercise, obesity and health with a focus on children. The adult population has been the focus of previous research in this area. Overweight/obesity and/or lack of PA have been suggested to have negative effects on immune and neuro-endocrine function.[1,2] Currently, there is limited research worldwide and in South Africa as to the effect these factors have on salivary biomarkers of immune function and sympathetic activation in children. Understanding the relationship between these variables will help in the development of safe and effective PA and exercise prescription guidelines for health and exercise professionals, coaches and teachers. Such guidelines will be particularly relevant for children whose immune function is compromised and/or sympathetic activation is dysfunctional.

SALIVA AS A DIAGNOSTIC TOOL

Saliva contains a certain level of previously circulating elements/molecules that are secreted consistently into the saliva and can be measured using biological assays.[3] Over the past 2 decades, saliva has been advocated as an alternative to blood as a diagnostic fluid. In addition to being more straightforward and more economical to obtain than blood, saliva has the added advantage of being easier to handle for diagnostic purposes because it does not clot once it comes in to contact with ambient air.[4] Collection of saliva is non-invasive, painless and convenient and is an important research tool for assessing the health of children.[5] Immune, inflammatory, and neuro-endocrine biomarkers can be measured accurately and reliably in saliva. The following sections will provide an overview of the research examining these biomarkers in children.

IMMUNE BIOMARKER: SALIVARY IMMUNOGLOBULIN-A

Salivary IgA (sIgA) is frequently known as the "first-line of defence" against pathogenic microorganisms, viruses, and bacteria within the immune system and is the dominant immunoglobulin in external secretions that bathe respiratory and intestinal mucosal surfaces.[6] Salivary IgA is undetectable at birth but then consistently increases with age.[7] The levels of sIgA reach their approximate peak by seven years of age and remain consistently high during mid-life and then decline during old age.[7] Gender differences in sIgA levels have been reported in healthy young men and women.[8] Serum levels of IgA have not been shown to have direct relationship with those found in saliva.[7,9-11] In children and the elderly, both who are at increased risk of a compromised immune system, a lower concentration of IgA in saliva has been conceptualized as a risk factor for upper respiratory tract infections (URTI).[9-11] Additional studies have also linked mood, academic stress and social support with altered levels of sIgA.[12,13] Lower levels of sIgA have also been shown to be associated with increased risk for periodontal disease and caries.[14,15]

Salivary IgA is a polypeptide complex comprising 2 IgA monomers, the connecting J chain, and the secretory component.[16] The first mechanism of protection by sIgA occurs at the stromal side of the epithelium.[16] At this location, sIgA can complex with antigens present locally in the underlying tissue. Salivary IgA has been shown to have an early morning acrophase followed by a decline to a stable base some 6 h after awakening.[17]

There is limited research on the effect of moderate intensity training on sIgA, namely in children. sIgA levels were reported to be enhanced in children following moderate intensity exercise, but suppressed following high intensity exercise.[18] This is of significance for coaches working with young athletes who need to ensure that the volume and intensity of exercise sessions do not compromise the immune system leaving the athlete more prone to illness. A study by Tharp[19] on 27 prepubescent boys aged 10-12 years, and 23 post-pubescent boys aged 16-18 years examined sIgA before and after 3 games and 3 practice sessions during the basketball season. Results showed that sIgA levels were significantly elevated following basketball practice and games, suggesting that basketball exercise can increase sIgA levels and that chronic exercise over the basketball season may increase the resting levels of sIgA. These changes may give athletes more protection against respiratory infections both after exercise and in the resting state later in the season.[19] Filaire et al[20] examined the effects of physiological and psychological stress on sIgA in young female gymnasts. A significant reduction in sIgA concentration was found following acute exercise and resting sIgA levels did not seem to be affected by periods of training. They also found no relationship between sIgA and cortisol. A study of adolescent female tennis players (included 17 subjects up to the age of 21) examined the incidence of URTIs and sIgA and found that resting sIgA levels were not affected by periods of training. The study showed that players with the greatest exercise-induced reduction in sIgA secretion rate, but not concentration, had the highest incidence of URTI.[21]

Research has also examined the relationship between PA, obesity and sIgA, URTIs and cortisol. Cieslak et al[22] examined the effect of PA, body fat percentage and salivary cortisol on mucosal immunity in children using a 20 m shuttle run for prediction of aerobic fitness in 29 boys, 32 girls ages 10-11 years. The authors found that sIgA was significantly correlated with reported URTIs and that children who spent more time in sport activities had a higher aerobic fitness and reported fewer "sick" days. Children with a body fat >25% reported more sick days. There was no correlation between sIgA and cortisol.

A study examining the incidence of infections in 10-12 years old children participating in sports found that participation in greater than 5 sports activities per week increased the occurrence of the common cold, cough, fever symptoms, where three to 4 activities per week lowered occurrence.[23] This result suggested a protective mechanism whereby moderate exercise may enhance the immune system, and overexertion may increase susceptibility to illness in children. Jedrychowski et al[24] examined childhood respiratory infections in terms of lifestyle factors and found that overweight children (body mass index (BMI)>20) experienced twice as high a risk of respiratory infections than children with low BMI, independent of PA levels, compared to normal weight children. However, they did not include any information regarding immune function, such as sIgA level. An additional study examined the relationship between PA and URTIs in preadolescent children and found that preadolescent children who had low PA levels had an increased risk of recurrent acute respiratory infections, compared to those that were moderately active and highly active.[25] Pallaroa et al[26] examined the total sIgA, serum C3c and IgA in obese and lean school children between 6-13 years of age and found that obese compared to lean children had a compromised secretory immune system, as indicated by lower levels of total sIgA, without an increased incidence of clinical symptoms and infections.[26] This study further suggested the importance of regular PA for children to not only assist in achieving an optimum weight for their age, but also improve mucosal immunity. In conclusion, the limited research examining the effect of moderate intensity exercise on immune function in normal and overweight children highlights the need to perform further research with this age group.

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INFLAMMATION: SALIVARY C-REACTIVE PROTEIN

It has been suggested that salivary C-reactive protein (CRP) may provide information relating to systemic health status associated with chronic disease.[27] Up to half of all events associated with cardiovascular disease (CVD) are reported to occur in apparently healthy individuals who have few or none of the traditional risk factors, including hyperlipidemia.[28] As a result, there has been increased focus on the role of other factors, such as inflammation, in the development of atherosclerosis and CVD.[28] These efforts have led to the search for inflammatory biomarkers to improve the detection of coronary and cardiovascular risk among seemingly healthy individuals.[29] Prominent among the possible candidates for a clinically useful biomarker of CVD risk is circulating CRP as measured by high-sensitivity (hs) assay. Studies have shown that elevated levels of CRP are associated with inflammation and increased cardiovascular risk.[29] Research has suggested a prognostic association between increased CRP production and outcome after acute myocardial infarction and in acute coronary syndromes.[30]

C-reactive protein, a pentameric protein produced by the liver and is part of the nonspecific acute-phase response during inflammation, infection and tissue damage.[30] C-reactive protein secreted by hepatocytes under the transcriptional control of the cytokine interleukin-6 (IL-6).[30] Salivary CRP is likely to originate from the liver and to mirror serum CRP levels. Therefore, salivary CRP could offer an estimate of systemic inflammation.[31] Recently, a high-sensitivity commercially available enzyme-linked immunoassay (ELISA) adapted to measure CRP in human saliva has become available and may offer a valuable strategy to assess salivary CRP levels in various populations.[31] These authors provided initial evidence suggesting that assessment of CRP in saliva allows for a valid prediction of serum CRP. The researchers found a moderate-to-strong association between CRP measured in saliva and in serum (r=.72, p<.001).[31] The research suggested that salivary CRP may thus facilitate and promote research exploring the correlates of low-grade inflammation in epidemiological studies and make it feasible to expand immune, inflammatory and neuro-endocrine research in children. [31]

CRP has been shown to be strongly related to all anthropometric and direct measures of total and central abdominal obesity, diastolic blood pressure, and apolipoprotein and lipid levels.[32] In one particular study the observation made was that CRP levels were strongly and independently related to directly measured total and central obesity and this is consistent with the finding that adipocytes secrete interleukin-6, the main stimulus for CRP biosynthesis.[30]

There have been numerous studies relating serum CRP and markers of inflammation with physical fitness and obesity measurements in children.[33-37] Although a moderate-to-strong association between CRP measured in saliva and in serum was found,[31] there are only 2 studies relating salivary CRP with measures of physical fitness, obesity or health status in children. The first study[38] examined the relationship between salivary CRP, cardio-respiratory fitness and body composition in 170 black South African children (age 9.41±1.55 years, 100 females, 70 males). Results indicated that poor CRF was independently associated with elevated salivary CRP concentration (OR 3.9, 95% CI 1.7-8.9, p=0.001). Poor CRF (OR 2.7, 95% CI 1.2-6.1, p=0.02) and overweight/obesity (BMI≥85th percentile) (OR 2.5, 95% CI 1.1-5.9, p=0.03) were independent predictors of elevated salivary CRP secretion rate. These results suggest a strong association between poor cardio-respiratory fitness and/or overweight/obesity and inflammatory status in children based on elevated salivary CRP levels. The second study[39] aimed to evaluate the oral inflammatory and humoral immune status in 32 children with allergic asthma and 20 control children. A significant correlation between total protein/haptoglobin and IgG/sIgA for children with allergic asthma was found. The results suggest that the higher salivary levels of CRP and haptoglobin may be markers of allergic inflammation and severity of asthma. Further research is needed to better understand the role salivary CRP, as compared to serum CRP, and markers of inflammation have on physical fitness and obesity measurements in children.

SYMPATHETIC NERVOUS SYSTEM: SALIVARY ALPHA-AMYLASE

The sympathetic nervous system (SNS) is an important regulator of the stress response. Catecholamines, secreted as part of the acute SNS stress response, are difficult to assess in saliva because of the low concentrations and rapid degradation of epinephrine and norepinephrine and the difficulty of stabilizing these hormones in the sample.[40] Other substances co-secreted with catecholamines can serve as an alternative index of adrenergic activity within the SNS and can be reliably measurable in saliva owing to their greater stability.[40]

One of these such alternatives or surrogates for SNS activity is alpha-amylase, which, although not a hormone, shows the same excretion patterns as catecholamines.[40] Therefore if catecholamines are elevated there is a corresponding increase in alpha-amylase in the saliva that indicates increased SNS activity. Because assays for amylase are more easily available in smaller clinical laboratories, saliva analysis of this enzyme may offer an interesting alternative for SNS activity testing.[40] Assessment of salivary alpha-amylase (sAA) as a non-invasive biomarker for the SNS, offers a multitude of possibilities in different research areas and may well become an important parameter in stress research.[41]

Alpha-amylase is one of the major salivary enzymes in humans, and is secreted from the salivary glands in response to SNS stimuli. In acinar cells, release of salivary components is under the control of neuronal stimuli where classic neurotransmitters and specific bioactive peptides serve as the main stimuli for sAA secretion.[41] Determining sAA levels and responses to stressors can provide information about the differences in SNS

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stress response. Normal sAA has a pronounced and distinct diurnal rhythm with a strong drop in activity in the first hour after awakening, and a steady increase towards the evening.[42]

A strong activator of the SNS is PA.[42] Exercise is known to increase sympathetic activity, and the high protein level in saliva following exercise may be due to increased adrenergic activity in the salivary glands.[42] It is suggested that sAA response patterns to both physical and psychological stressors correspond to the response patterns of the SNS.[42] A variety of studies have examined the effects of exercise on sAA, however most of the studies have focused on the adult population.[43-47] These studies suggest that exercise can result in a marked increase in sAA as exercise is known to increase sympathetic activity. High protein level in saliva following exercise is suggested[41] to be due to increased adrenergic activity in the salivary glands.

Capranica et al[48] evaluated the effects of an official taekwondo competition (three 1-min rounds with a 1-min recovery in-between) on heart rate (HR), sAA and salivary-free cortisol (sC) in 12 young (10.4±0.2 years) male taekwondo athletes. Peak sAA was observed at the end of the match (169.6±47.0 U/mL) and was different (p=0.0001) from the other samplings (pre-competition 55.0±14.0 U/mL, 30-min recovery 80.4±17.7 U/mL, 60-min recovery 50.5±7.6 U/ml; 90-min recovery 53.2±9.6 U/mL). These findings confirmed that taekwondo competitions pose a high stress on young athletes.[48] The different sAA and sC reactions in response to the physical stressor mirrored the faster reactivity of the sympathetic-adrenomedullary system relatively to the hypothalamic-pituitary-adrenocortical system.[48] An additional study[47] assessed the effect of an acute bout of high-intensity intermittent laboratory cycling exercise on sIgA concentration and sAA activity in 8 well trained games players and found a five-fold increase in sAA activity (p<0.01 compared with pre-exercise). The increased sAA activity after exercise may improve the protective effect of saliva, since this enzyme is known to inhibit bacterial attachment to oral surfaces.[47] It is difficult to deduce the function of short-term increases in sAA while the biological meaning of transient rises in the anti-bacterial action of the enzyme remains unclear. However, such short-term increases may be useful to the body in that energy is made available by increased digestive action in response to stress.[41] Physiological stress reactions comprise orchestrated actions throughout the body, putting the organism in a state of overall preparedness to engage in fight or flight. Thus, increases in amylase activity may be one of many actions involved in activating the body's resources to cope with stressful events or threats to homeostasis.[41] Further studies are needed to examine long-term changes in sAA concentrations.

There appears to be a possible link between sAA and eating behaviour in children. One study reported a positive association between sAA activity and increased BMI (greater obesity) in adolescent males and females.[49] Another study with men and women (average age 26.7 years (8.8)) found that BMI was negatively associated with average morning sAA. Specifically, there was a 3.4% decrease in average sAA level with each increasing point on the BMI scale.[42] sAA stress reactivity was investigated across different age groups, including 62 children (6-10 years, 32 boys, 30 girls), 78 young adults (20-31 years, 45 men, 33 women), and 74 older adults (59-61 years, 37 men, 37 women).[50] BMI, perceived stress scale, chronic stress screening scale as well as cortisol, heart rate, and root mean square of successive differences (RMSSD) response indices failed to predict stress-induced sAA initially with hierarchical linear regression until the children were included in the analysis. With the inclusion of the children, BMI became an even stronger predictor of stress induced alteration of sAA than age. All analysis revealed that age and BMI were the strongest predictors of sAA increases, whereas subjective stress levels as well as cortisol, HR, and RMSSD response indices failed to predict the sAA stress responses.[50] The research related to sAA, PA and obesity in children is very limited compared to the adult population and indicates that the chronic effect of training and the role of obesity have not been fully examined in pre-pubescent children.

HYPOTHALAMIC PITUITARY ADRENAL AXIS: SALIVARY CORTISOL

Salivary cortisol has emerged as an easy-to-collect, relatively inexpensive, biologic marker of stress.[51] In addition, salivary cortisol levels reflect the biologically active (unbound) fraction of cortisol.[52] Cortisol is lipid-soluble, enabling the molecule to diffuse rapidly from the circulation through the acinar cells of the salivary glands into the saliva, without any influence of salivary flow rate.[53] Although its absolute concentration in the saliva is approximately 30-50% lower than in the blood, its measurement may nonetheless be helpful in evaluating subtle alterations of the HPA in many pathophysiological conditions not classically dependent on relevant endogenous hypercortisolism.[53] Researchers have developed methods for collecting salivary cortisol in children, and recent laboratory techniques have made it possible to detect very small concentrations of cortisol in plasma and saliva.[51] Salivary and serum cortisol in children and adolescents have been shown to correlate strongly (r=0.86 to 0.97).[54,55] Salivary cortisol thus enables the study of hypothalamus-pituitary-adrenal (HPA) axis function in epidemiological cohorts.[56]

The HPA axis is a central component of the body's neuro-endocrine response to stress. Its major end-product, cortisol, has profound effects on mood and behaviour as well as metabolism where exposure to increases in cortisol secretion can result in disruption of HPA axis regulation.[57] The cortisol stress response is kept under control through a negative feedback loop including the pituitary, hypothalamus and hippocampus.[58] Cortisol influences a wide variety of processes, including cardiovascular function, fluid volume and haemorrhage, immunity and inflammation, metabolism, neurobiology, and reproductive physiology.[59] Normal circadian rhythm is comprised of high morning and low afternoon-evening cortisol levels and normal feedback control.[60] However, when the final stage of chronic stress with 'burn-out' of central regulatory systems occurs, the

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result is a net decrease of cortisol output, a flattened diurnal secretory pattern, and inhibition of other endocrine axes, and can result in the Metabolic Syndrome.[60] These observations highlight the importance of the HPA axis (and cortisol regulation) in the control of human health.[60]

Increased levels of cortisol has a significant role to play in the body, and so if the HPA axis is not functioning appropriately this will alter obese individuals (including children's) ability to adapt and function metabolically. Numerous laboratories have reported an association between obesity, particularly central adiposity, and high cortisol concentrations in adults. During exercise, cortisol concentrations have been shown to remain higher in obese than in lean adults demonstrating a greater HPA response to the same exercise intensity with obesity.[61] Although there is a large body of literature devoted to the neuro-endocrine response to exercise in adults, namely that increases in intensity and duration of exercise increase salivary cortisol, the relationship between exercise, PA, overweight/obesity and salivary cortisol in children is not fully understood. One study found that salivary cortisol concentration was decreased by 32% in obese children (8-11 years) from pre- to post-exercise compared to lean children.[61] Another study examined the associations between morning cortisol and adiposity in children (9.6+/-0.9 years) at baseline and a 9-month follow-up.[62] Participants included 649 (301 males, 348 females) children for the cross-sectional analysis and 316 (153 males, 163 females) for the longitudinal analysis. A positive relationship was found between morning salivary cortisol and change in waist circumference over 9-months in overweight children. An additional study[1] investigated whether 12 min of high-intensity exercise performed within a regular school break would lead to an increase in cortisol levels in 53, 4th grade (9-10 years) primary school students. They observed a significant group by test interaction indicating a different pre-to-post-test development for the experimental group compared to the control group. However, the interaction effect was caused by an attenuated cortisol concentration in the control group. The authors argued that the control condition, where the students watched a joyful movie, acted as a distracter, which led to a reduction of general school stress.[1] Another study examining serum and salivary cortisol responses to cycling exercise in male children, 10.6+/-0.2 years found that 30 min of submaximal exercise at 70% of VO_{2max} significantly increased serum cortisol level; and salivary and serum cortisol were correlated during and after exercise.[63] Further research measuring salivary cortisol as a marker of the neuro-endocrine stress response in normal and overweight children and associations with PA will assist in promoting understanding of the roles they play in the paediatric *versus* adult population.

CONCLUSION

Participation in regular moderate intensity PA or exercise appears to enhance mucosal immunity (increase sIgA) in preadolescent children. However, research in this area is limited and currently not conclusive. In contrast, poor fitness and inactivity as well as strenuous training appear to compromise the mucosal immune system thereby increasing the risk of URTIs. Children reporting higher levels of body fat and with greater BMI appear to have lower sIgA levels and a greater incidence of infections.

There is very limited research surrounding salivary CRP and PA, obesity and health status in children. The limited research does, however, suggest a strong association between poor cardiorespiratory fitness (CRF) and/or overweight/obesity and inflammatory status in children based on elevated salivary CRP levels.

Research surrounding sAA indicates that exercise can result in a marked increase in sAA as seen by an increase sympathetic activity *via* increased adrenergic activity in the salivary glands. The limited research suggests exercise may also pose a high stress on young athletes as seen with an increase in sAA. Additionally it appears that BMI may be a strong predictor of stress-induced sAA increases in children.

Greater HPA axis response, as seen by increases in salivary cortisol, appears to be influenced greatly by increases in obesity. Higher salivary cortisol secretions have been observed in obese *versus* lean adults and children alike in response to exercise.

Current research surrounding salivary biomarkers in children highlights the vast gaps that are present with regard to PA and obesity. Table 1 includes a summary of research studies that have focused on the relationships between physical activity, body weight, and salivary biomarkers of immune function, inflammatory status and neuroendocrine activation in children (and in some cases adolescents). The majority of research studies currently focus on the adolescent and adult population. However, parallels cannot always be drawn between pre-pubescent children and those individuals in the post-pubescent population. A limitation in current research is how "children" are defined, as Tanner stages are not always identified and pubescent status is not always readily available. Further research is also needed to examine the role that moderate intensity and chronic exercise and obesity have on salivary biomarkers in children as much of the current research on salivary biomarkers is surrounding higher intensity exercise in the athletic adult population. The current research has suggested that markers of immune function and sympathetic activation can be greatly affected by lack of PA and increases in obesity at a young age, which may continue into adulthood. Understanding the relationship between these variables will help in the development of safe and effective PA and exercise prescription guidelines for health and exercise professionals, coaches and teachers. Such guidelines will be particularly relevant for children whose immune function is compromised and/or sympathetic activation is dysfunctional.

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Author, Year	Participants	Research Focus	Findings
Tharp[19]	27 prepubescent boys (10-12 years) and 23 post-pubescent boys (16-18 years) on basketball teams	Examined saliva levels of sIgA before and after three games and three practice sessions during the basketball season	sIgA levels were slightly but significantly elevated following basketball practice and game situations Indicate that basketball exercise can increase sIgA levels and that chronic exercise over the basketball season may increase the resting levels of sIgA
Filaire et al[20]	12 young female gymnasts (12-15 years)	Physiological and psychological stress and sIgA	Significant reductions in sIgA concentration following acute exercise, resting sIgA levels do not seem to be affected by periods of training ; also found no relationship between sIgA and cortisol
Novas et al[21]	17, young female tennis players (14-21 years)	Incidence of URTIs and sIgA	Resting sIgA levels do not seem to be affected by periods of training Those with greatest exercise-induced reduction in sIgA secretion rate, but not concentration, also had the highest incidence of upper respiratory tract infection.
Dorrington et al[18]	15 boys and 14 girls (8-12 years)	Effect of exercise intensity on sIgA in children	sIgA levels were reported to be enhanced following moderate intensity exercise, but depressed following high intensity
Thomas et al[64]	17 old boys (15-16 years)	Effect of repeated bouts of short-term, high-intensity cycling exercise on the sC, sT and sIgA concentrations All participants completed 6×8 s sprints, interspersed with 30 s recovery intervals on a cycle ergometer	The increases in sT and sC reported in this study confirm that repeated bouts of short-term, high-intensity exercise produces significant physiological hormonal responses in adolescent boys, but does not affect mucosal immune function.
Cieslak et al[22]	29 boys, 32 girls (10-11 years)	Effects if of PA, BF, and sC on mucosal immunity in children using 20 m shuttle run for prediction of aerobic fitness	SIgA sig correlated with reported URTIs. Children who spent more time in sport activities and had higher aerobic fitness reported fewer “sick” days. Children with BF >25% more sick days; also no correlation between sIgA and sC.
Pallaroa et al[27]	Obese and lean children (6-13 years)	Examined the total sIgA, serum C3c and IgA levels	Obese children showed lower levels of sIgA than lean children
Thomas et al[65]	19 girls (15-16 years)	Completed 668 s sprints, interspersed with 30 s recovery intervals on a cycle ergometer.	Showed no changes in salivary testosterone, cortisol or IgA following repeated bouts of supramaximal cycling (p>0.05)
Naidoo et al[38]	170 black South African children, 100 females, 70 males (7-12 years)	Relationship between sCRP, CRF, and body composition	Strong association between poor CRF and/or overweight/obesity and inflammatory status with elevated sCRP
Capranica et al[48]	12 male taekwondo athletes (10-11 years)	Examined taekwondo competition on HR, sAA and sC	Peak sAA at end of match was different compared to pre and 30,60, 90 min. recovery values

Table 1: Research studies examining the relationships between physical activity, body weight, and salivary biomarkers of immune function, inflammatory status and neuroendocrine activation in children.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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Promoting the Health Benefits of Walking and Bicycling to Work: A Qualitative Exploration of the Role of Healthcare Providers in Addressing Barriers to Active Commuting

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ABSTRACT

Background: Active commuting (walking or bicycling to work) is a beneficial form of exercise; its health benefits include lower rates of heart disease and stroke, improved mental health, and lower overall mortality. Given these health benefits, healthcare providers are well positioned to promote active commuting. We conducted a study that qualitatively explored the barriers to and solutions for active commuting, and the role of healthcare providers in encouraging active commuting. The study was done in a primary care population that was in close contact with a healthcare provider (within reach of a healthcare intervention).
Methods: Drawing on a sample of 17 participants (11 who actively commute and 6 who do not) recruited through random selection at a family practice, we facilitated focus groups to explore the barriers patients face in active commuting, strategies that patients use or could use in overcoming those barriers, and the role of healthcare providers in promoting active commuting. The focus groups were recorded and transcribed. Responses were organized into themes and analyzed by the research team according to a grounded theory approach until a saturation point was met.
Results: Participants identified a number of internal, external, and cultural barriers to active commuting. Active commuters had a number of motivating factors apart from physical health; these included mental health benefits, interaction with people and the environment, and financial savings. Participants outlined several opportunities for healthcare provider intervention, including individualized education around the health benefits of active commuting, problem solving and motivational interviewing, and advocacy.
Interpretation: The patient-identified barriers to active commuting fell into 3 main categories: internal barriers, external barriers, and cultural barriers. We used these categories to create a framework to understand areas of possible healthcare provider intervention. Motivational interviewing, education, and counseling are all areas of intervention for internal barriers. External and cultural barriers may be more difficult to address, and a physician's most valuable role in addressing systemic barriers may be through advocacy at the local, provincial, and federal level. We suggest that healthcare providers should be some of the many team members required to get the Canadian population more physically active through walking and bicycling to work.

KEYWORDS: Active transport; Qualitative research; Health care; Health promotion; Physical activity.

ABBREVIATIONS: EMR: Electronic Medical Record; OMA: Ontario Medical Association.

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INTRODUCTION

Physical inactivity adds a disease burden to society comparable with smoking.[1] Though physical activity has far-reaching benefits on health and disease,[2-4] many adults and children do insufficient physical activity to maintain good health.[5] Walking or bicycling to work (active commuting) represents one approach to encourage the population to be more active.[6] At an individual level, active commuting is correlated with numerous positive health outcomes, including cardiovascular benefits,[7-9] a reduction in all-cause mortality,[10,11] and reduced obesity.[12]

In spite of these health benefits, in North America only a small proportion of individuals use walking and bicycling as a mode of transport. In Canada in 2006, 6.4 percent of workers walked to work, and just 1.3 percent of workers bicycled to work.[13]

Factors determining whether a person participates in active commuting are complex; variables such as improved esthetics, the presence of sidewalks and bicycle lanes, and workplace supports are associated with an increased likelihood of active commuting.[14-18]

Other studies have reported that personal and psychological factors play a more important role than environmental factors.[19,20] High self-efficacy,[21] positive intentions, and strong habits[22,23] are all associated with active commuting. Barriers include lack of fitness, lack of confidence in abilities[24] and perceived time and distance.[25]

Given the health benefits, healthcare providers are well positioned to recommend and promote active commuting. Yet, there have been no studies to our knowledge that assess the role of primary healthcare providers in increasing population levels of this physical activity. Quantitative studies focus on individual variables and are limited in their ability to address all of the complex and interrelated factors associated with the behavior of active commuting.[26] To address these many interrelated variables, we conducted a study that qualitatively explored the barriers to active commuting and how healthcare providers could be involved in addressing these barriers for their patients. The study was done in a primary care population who were under the care of a healthcare provider (and therefore within reach of a healthcare intervention).

METHODS

We conducted a qualitative research study using 5 separate one-hour focus groups of up to 5 people over a period of 4 months at McMaster Family Practice in Hamilton, Ontario, Canada. Approval was obtained from the McMaster University Research Ethics Board.

Sampling

Participants were recruited from a list of current patients aged 18 to 65 years old that had been randomly generated by the electronic medical record (EMR) system within the practice. Possible participants were telephoned by a member of the research team (RW, SG) to assess eligibility and willingness to participate, and to clarify status as an active or non-active commuter. Patients were informed that if they did not wish to participate in the focus group, their medical care would be unaffected. To be eligible for the study, participants had to be patients at McMaster Family Practice, currently working or attending school, and residing within a 10 kilometre distance to walk or bicycle to their place of work. Exclusion criteria were if patients had any self-identified physical limitation to walking or bicycling.

The active commuters and the non-active commuters were given separate focus groups to allow for adequate space and time for the unique viewpoints of each group. Focus groups were carried on until theme saturation was met. We aimed for up to 5 participants per focus group.

Facilitation Process

The focus groups were held in a semi-structured format to allow for free discussion within defined topics. Our focus group questions were developed to inspire discussion in an open-ended manner:

- Why do you choose driving to work instead of bicycling or walking (or vice versa)?
- What barriers do you face in bicycling or walking to work?
- How could you overcome those barriers?
- How can healthcare providers help you to start or continue walking or bicycling to work?

Data Collection and Analysis

Focus groups were facilitated by RW and SG. The focus groups were recorded using a digital recorder and transcribed. A grounded theory approach was used to analyze the data because it allowed for data collection and analysis to occur simultaneously and for theories to be generated freely from the data without a preconceived hypothesis.[27] All 3 authors read the transcripts independently and devised an initial list of themes and subthemes. These themes were closely examined, negotiated, and consolidated at a series of meetings involving all members of the research team. Upon further analysis, these themes and subthemes were then organized into broader themes upon re-application with the original transcripts. Consensus was obtained a final list of coding themes was generated. Recruitment for new focus groups concluded when a saturation point for all themes was reached and no new themes were being generated.

RESULTS

A total of 5 focus groups took place between May and August 2012. Three groups for active commuters and 2 groups for non-active commuters were held with 3 to 4 participants at each session. A total of 17 participants were recruited (11 active com-

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muters and 6 non-active commuters) before a saturation point was met.

Participant Characteristics

Most of our participants were Caucasian and between 27 and 65 years old with a mean age of 56 (Table 1). Women comprised 47% of the overall sample and made up 33% of active commuters and 66% of non-active commuters. Participants had high levels of education with 16 out of 17 participants (94%) having achieved a college education or higher.

Barriers to Active Commuting

The research team organized the barriers identified by participants into 3 main thematic categories: internal, external, and cultural.

Barriers such as inconvenience were labeled as internal barriers during the thematic analysis if they occurred at the individual and psychological level. External barriers were defined as those that happened outside in the built environment, such as bicycle lanes and workplace accommodations. A barrier was categorized as cultural if it occurred on a larger, societal level. Table 2 summarizes the barriers identified above.

THE ROLE OF HEALTHCARE PROVIDERS IN ADDRESSING THESE BARRIERS

Participants outlined several opportunities for physician intervention, including (1) individualized education around the health benefits of active commuting, (2) problem-solving around barriers to active commuting, (3) motivational interviewing, and (4) advocacy. These are outlined in further detail below.

PATIENT EDUCATION ON THE BENEFITS OF ACTIVE COMMUTING

Participants who actively commuted brought up numerous benefits that motivated them to actively commute. These benefits included mental and physical health benefits, financial savings, and enjoyment of the community and environment. Participants thought that learning about active commuting from their family physician during a clinical encounter would be an effective way to increase physical activity. In particular, patients suggested they would be receptive to hearing about the non-physical health benefits. The key points regarding how physicians could approach these conversations are outlined in Table 3.

PROBLEM-SOLVING AND MOTIVATIONAL INTERVIEWING

Even though both non-active and active commuters identified similar barriers, active commuters were much better equipped to problem-solve logistical issues. Participants suggested that physicians might be well positioned to help patients problem-solve. Active commuters suggested that simple solutions such as bringing a spare change of clothes, watching the weather report, and leaving five minutes earlier would solve common concerns people have about work clothes.

Participant characteristics	Not Active Commuters (n=6)	Active Commuters (n=11)
Age (years) (mean±standard deviation)	56±6.7	49.5±14.8
Ethnicity		
Caucasian	6 (100%)	7 (63.6%)
Blank	0	2 (18.2%)
Non-Caucasian	0	2 (18.2%)
Gender		
Female	4 (66.7%)	4 (36.4%)
Male	2 (33.3%)	7 (63.6%)
Educational status		
Elementary	0	0
Secondary	1 (16.7%)	0
Tech school or college	1 (16.7%)	1 (9.1%)
University or higher	4 (66.7%)	10 (90.9%)
Marital Status		
Single	1 (16.7%)	4 (36.4%)
Living with a partner	4 (66.7%)	7 (63.6%)
Separated or divorced	1 (16.7%)	1 (16.7%)
Number of children		
0	3 (50%)	6 (54.5%)
1	0	1 (16.7%)
≥2	3 (50%)	4 (36.4%)
Employment status		
Working	6 (100%)	10 (90.9%)
Attending School	0	1 (9.1%)
Annual income		
<20,000	2 (33.3%)	0
20,000-50,000	2 (33.3%)	6 (54.5%)
50,000-80,000	1 (16.7%)	5 (45.4%)
>80,000	1 (16.7%)	0

Table 1: Characteristics of study participants (n=17).

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Type of Barrier	Themes	Key Points	Representative Quotes
Internal	Time and Inconvenience	Time is a valuable commodity and drivers perceived active commuting as slow and inconvenient. In contrast, those who walked or bicycled to work saw active commuting as a time saver—functional exercise that saved time otherwise spent on organized physical activity.	*"If I drive I'm there in five minutes and I can just start work and I'm done, so it's hard to…convince yourself it's a good use of your time to actually walk."* - Female, age 57, drives *"If I ride my bike I come home, I have dinner, I relax. If I have taken the bus or driven my car, then I come home… and then I think okay, I've got to go to spin."* - Female, age 58, walks & bicycles
Internal	Habit and Routine	Driving to work was seen as the "default"—easy and logistically simple. Non-active commuters spoke about the extra work required to change their routine.	*"It's really easy… to fall back on your default which is get in the car. It's just simple, it doesn't take any additional planning. There's always room for groceries in the back and if it starts to rain you put the wipers on. I mean all of those things is a default that does not require any thought at all."* - Female, age 58, walks & bicycles
External	Road Safety	A lack of bike lanes and improperly maintained roads were all deterrents to active commuting. Multiple participants were concerned about safety and saw cycling as dangerous.	*"I am not comfortable at all biking in traffic and I have suggested that to friends and family and they have said don't do it."* - Female, age 57, drives
External	Workplace Accommodations	Workplace accommodations, such as showering facilities and secure bike shelters, were also cited as motivators.	*"I've gone here to my workplace, where do I park my bike? Everybody has a place to park their car but where are the bike racks?"* - Male, age 65, walks & bicycles
Cultural	Car-Centric Culture	European and Asian cultures were perceived as more favorable towards active commuting. In contrast, North American culture was described as a car-centric culture.	*"… my generation I suppose was really wrapped up in cars, the car was the great thing that was, gives your great passage into manhood or womanhood or whatever…"* - Male, age 65, walks & bicycles
Cultural	Community Design	People who drove discussed how community design necessitated a vehicle in many instances.	*"So you know, that, that has to be somehow figured into the mechanism to encourage people to be able to either bike or walk you know, to go and do shopping or whatever without having to you know, resort to a vehicle which just clogs city streets and so on."* - Male, age 50, takes the bus
Cultural	Cyclist vs. Motorist Tensions	Cyclists and drivers felt distrustful of each other and users of either mode of transportation cited a lack of understanding of the rules of the road.	*"I've been honked at and yelled at for riding this close to the curb because I'm slowing traffic down. You know, I could ride in the middle of the lane and slow you down more if you want."* - Female, age 51, walks & bicycles

Table 2: Patient-identified barriers to active commuting.

Benefits of Active Commuting	Key Points for Physicians	Representative Quotes
Physical Health	More information on health outcomes beyond weight control might encourage commuters to be more physically active. Physicians can remind patients that exercise does not have to be at a gym	*"If you can identify that [active commuting] counts as exercise then it's an option. Sometimes people think that exercise has to be at a gym or has to be very formal [with machines], or without a purpose."* - Female, age 33, walks & bicycles
Mental Health Benefits	Participants described the negative effect that being in a car had on their mood and how much better they felt walking or bicycling instead. Both active and non-active commuters brought up transition time between work and home as a particularly attractive benefit to active commuting.	*"I know my emotional state improves with [exercise]…so it's worth doing. And rarely in a car, I mean I never feel emotionally relieved, improved, insightful, or anything in a car… I don't feel as angry when I'm riding a bike." - Male, age 59, bicycles*
Financial benefits	Participants discussed the cost of car ownership, insurance, and gas in detail, as well as the high cost of parking and the cost of gym memberships.Financial savings are an attractive incentive to begin active commuting	*"You are going to be paying 45 bucks a day for your membership to go and stand on a treadmill, for free you can go outside and walk home."* - Male, age 65, walks & bicycles
Interactions with People and the Environment	Active commuting provides time not only to exercise but to catch up with family members or converse with other members of the community. Active commuters enjoyed the time spent outdoors and used it as a time to stay in touch with the natural environment.	*"[As far as] interaction with the natural world, there is nothing you can do to see how time passes, growing old and to watch the seasons evolve by walking the same street in the same area, from time to time… If you walk by or ride by under a tree you know, that has come into blossom and you can smell that, that's a stimulation it is terrific that you will not get in a car."* - Male, age 65, walks & bicycles

Table 3: Summary of benefits of active commuting for patient education.

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To motivate patients, apart from discussing the benefits of active commuting, study participants proposed that healthcare providers could encourage small behavioral changes. Participants suggested that physicians could highlight that patients could choose to walk or bicycle to work just a few days a week and still reap health benefits.

The representative quotes that illustrate these themes are found in Table 4.

ADVOCACY

Finally, participants suggested that physicians could act as community advocates to promote safe cycling infrastructure, better work and school accommodations, and greater education. One participant suggested that active commuting could be approached in the same manner that public health, government agencies, and individual healthcare providers have approached smoking cessation. In addition to individual healthcare interventions, there could be a role for workplace incentives for active commuters and for increased media attention around the benefits of active commuting.

Participants brain stormed large-scale societal changes for which physicians could advocate. Participants suggested that if cities were designed better, it would be more convenient to actively commute. One participant suggested that doctors focus on pressuring governments to make a more walk and cycle-friendly environment before asking patients for individual change.

These themes and representative quotes are further explored in Table 5.

DISCUSSION

Through this qualitative study, we identified 3 main kinds of barriers to active commuting in attendees of a family practice—internal, external, and social. The patient-identified barriers helped shape and inform the discussion of healthcare provider intervention. Indeed, the types of interventions participants identified could be categorized into the same main categories.

The barriers cited by members of a family practice in this study were consistent with barriers cited by members of the general public in prior studies.[24-28] Our study population was different in that all participants were known to have easy access to a physician.

The relationship between barriers and other determinants of active commuting is complex. Ogilvie et al[29] have developed a framework to understand the relationship between the multiple determinants of active commuting. Up until now, the role of healthcare providers in assisting patients in overcoming these barriers to start active commuting has not been studied. We sought to bring a patient-centered approach to healthcare provider intervention. Based on the themes of barriers and interventions, we have developed a framework to suggest the ways in which healthcare providers might intervene on modifiable barriers (Figure 1). We discuss the framework in detail below.

Theme	Representative Quotes
Problem-Solving	*“I know people in our office… will say to me, oh, ‘how can you bike today, it’s so cold’… And the answer is you do the Canadian thing, you put on layers of clothing sufficient to cover today’s temperature and it’s more clothes today then yesterday and if tomorrow is warmer it’s less clothing.”* - Male, age 65, bicycles
Motivation	*“Yeah, I think that’s really important, it’s not all or nothing, you can break it into smaller chunks, more achievable distances.”* - Female, age 33, walks & bicycles

Table 4: Themes for problem-solving and motivation.

Theme	Representative Quote
Advocacy to Government and Workplace	*“For many years now… the anti-smoking information that has been available out there is working, the laws are changing... People are quitting smoking; the percentage of people that smoke now as opposed to 20 years ago is dramatically different. And that’s because there was so much information out there and healthcare providers also contributed... And there were incentives in the workplace to [quit smoking]… They really did a lot [with] public advertising and information.”* - Female, age 50, drives
Advocacy for Improved Urban Design	*“So I mean if a lot of those services were a little bit you know, closer in to where the people are living [I would consider active commuting]… So you know, that, that has to be somehow figured into the mechanism to encourage people to be able to either bike or walk…”* - Male, age 50, takes the bus

Table 5: Themes for physician advocacy.

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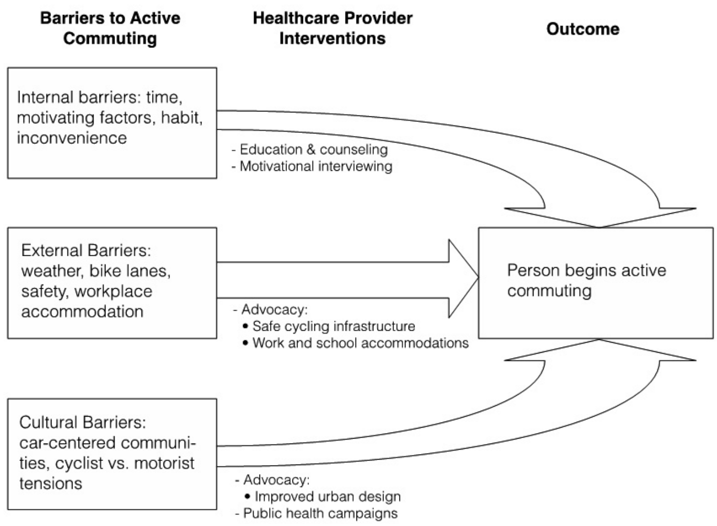

Figure 1: Barriers to active commuting and corresponding healthcare interventions.

Healthcare Intervention on Internal Barriers

Participants proposed that they would be open to hearing from their physician one-on-one about active commuting. Physicians could address the internal barriers on an individual basis through education, support, and motivational interviewing. Motivational interviewing can be defined as "*a collaborative conversation style for strengthening a person's own motivation and commitment to change*".[30] It may include educating patients in a clinical encounter to consider active commuting as a form of exercise; helping patients become motivated; or problem-solving solutions to patient-identified barriers. As an example, if a patient would like to actively commute for exercise but feels that he or she does not have the motivation nor the time, it may be helpful to use motivational interviewing to challenge his or her way of thinking. Motivational interviewing has been shown to be effective in changing health behavior,[31,32] and this form of intervention is the most readily accessible intervention to primary care physicians.

Increasing physical activity through active commuting could be part of a comprehensive management plan for patients with diabetes, hypertension, or obesity. Above and beyond the physical health benefits of active commuting, there were numerous other benefits discussed by participants including mental health improvements, financial savings, and interaction with the community and the environment. Participants were receptive to hearing about the "non-physical" benefits of active commuting and this information could be discussed in various clinical encounters.

Healthcare Intervention on External Barriers

Intervening on external barriers has the potential for a large population health impact. Healthcare providers can act as advocates to promote safe cycling infrastructure and better work and school accommodations. The Ontario Medical Association (OMA) is an example of a physician-led organization doing such advocacy work. The OMA has recommended that the Ontario government increase separated bicycle lanes and make cyclist-vehicle education a component of the Ontario Drivers' Manual.[33] Family physician-led organizations could perform similar advocacy work, as they are a well-respected source of information for policy makers and already do such work on other issues.[34]

The voice of individual family physicians may be beneficial in their community of practice where they have specific insight into their patient population needs. For example, family physicians could speak to their city council in support of bicycle lane additions. Being a health advocate for their patients and communities is one of the seven roles of a family physician identified by the Canadian College of Family Physicians.[35] Healthcare providers can also provide information and research to encourage private companies to invest in workplace active commuting infrastructure.

Much like the campaign for smoking cessation, a variety of stakeholders are needed to fully address systemic issues. These stakeholders may include citizen groups, employers, city councils, and government officials.

Healthcare Intervention on Cultural Barriers

Creating a culture of walking and bicycling requires not only the removal of barriers, but also a re-imagining of city layout to make active commuting an easier option. Physicians could advocate to city councils for an urban design that makes walking to work and other important destinations such as the grocery store logistically possible.

Physicians can also intervene to promote an active commuting culture through public health education campaigns. Media advertising could be used to promote the health benefits

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of active commuting on a large scale and to improve safety on the road. One such initiative is the "Share the Road" campaign[36] that creates television ads to improve the relationship between drivers and cyclists. Media campaigns can be important tools but they need to be done while addressing internal and external barriers. As illustrated by the success story of the anti-tobacco movement, multi-pronged interventions are likely needed to prime the public so that they are open to receiving information from media campaigns.[37]

LIMITATIONS AND STRENGTHS

The study provides an in-depth exploration of the barriers that family practice patients face in active commuting. In addition to providing the first qualitative information about the role of primary healthcare providers in active commuting, we provide a framework of possible areas of intervention.

This study has several limitations. The nature of qualitative studies makes it difficult to generalize the results to a larger population. The number of active commuters participants and non-active commuters participants were not equal in the study. Since all participants were patients at McMaster Family Practice, problems and solutions that are specific to other jurisdictions would not have been captured. The majority of participants were Caucasian and barriers of other ethnic groups may not have been represented. Further qualitative research is required with an emphasis on reaching out to ethnically mixed communities. In addition to soliciting more patient perspectives, it would be helpful to gain information through the lens of healthcare providers or other agencies involved in promoting active commuting. Quantitative studies assessing patient barriers to active commuting and areas of physician intervention would help confirm the patient-identified barriers and proposed physician interventions.

Next steps after identifying interventions would then be to assess their efficacy. This research may include studies that look at the outcome of promoting active commuting through education, counseling, and motivational interviewing. Previous studies have looked at motivational interviewing for increasing physical activity in general and this avenue seems to be a promising wayto promote health behavior change.[31,32]

CONCLUSION

The patient-identified barriers to active commuting fell into 3 main categories: internal barriers, external barriers, and cultural barriers. Correspondingly, there were physician solutions found for each type of barrier. Participants suggested numerous opportunities for healthcare provider intervention, including individualized education regarding the health benefits of active commuting, problem-solving around barriers, motivational interviewing, andadvocacy. Physicians can use the information provided in this study to help guide a one-on-one discussion with a patient to address internal barriers. Physicians can also use this information to advocate for the removal of external and cultural barriers. Healthcare providers are one of the many stakeholders required to create a comprehensive strategy to get the population more physically active through active commuting.

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AUTHOR CONTRIBUTIONS

RW conceived of the study and its design, participated in the data collection, interpretation, and analysis, and drafted the manuscript. SG participated in data collection, interpretation, and analysis and helped to draft the manuscript. GA contributed to study design and participated in data interpretation and analysis, and drafting of the manuscript. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONSENT

The participants has provided written permission for the manuscript publication.

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Research

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Combined Effects of Six Weeks Oat Bran Consumption and Brisk Walking Exercise on Blood Lipid Profiles in Hypercholesterolemia Women Aged 40 to 50 Years

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ABSTRACT

Purpose: The aim of this study was to investigate the additional beneficial effects of combined oat bran consumption and brisk walking exercise compared to oat bran consumption alone and sedentary without oat bran consumption on body weight, body composition and blood lipid profiles among hypercholesterolemia women with age ranged from 40 to 50 years old.
Methods: Thirty-three hypercholesterolemia women were randomly assigned into 3 groups: sedentary without oat bran consumption control (C), oat Bran consumption alone (Ob) and combined oat bran consumption and brisk walking exercise (ObEx) groups. Pre-and post-tests were carried out to measure participant's body anthropometry, body composition and blood lipid profiles, i.e. serum total cholesterol (TC), triglycerides (TG), low density lipoprotein cholesterol (LDL-C) and high density lipoprotein cholesterol (HDL-C). During 6 weeks of study period, participants in Ob and ObEx groups consumed 18 g of oat bran daily. Participants in ObEx executed brisk walking exercise at intensity of 55%-70% of the participants' heart rate maximum for 30 minutes per session, 3 sessions per week for 6 weeks. Participants in ObEx group consumed oat bran 1 hour prior to brisk walking exercise on the exercise days.
Results: After 6 weeks of study period, body weight decreased significantly in both Ob (p=0.013) and ObEx (p=0.02) groups, however there were no significant changes in percentage of body fat and fat free mass in all the groups. There were significant decrease in serum total cholesterol (TC) (p=0.02) and low density lipoprotein cholesterol (LDL-C) (p=0.019) concentrations in ObEx group.
Conclusion: Six-weeks of oat bran consumption with 18 g of oat bran per day combined with brisk walking exercise for 30 minutes per session, 3 sessions per week could significantly reduce body weight, serum total cholesterol (TC) and low density lipoprotein cholesterol (LDL-C) concentrations. Therefore, this combination can be proposed as guidelines in nutritional and exercise promotion programme to improve lipid profiles in 40 to 50 years old hypercholesterolemia women.

KEYWORDS: Oat bran consumption; Brisk walking; Lipid profiles; Hypercholesterolemia women.

ABBREVIATIONS: LDL-C: Low Density Lipoprotein Cholesterol; TC: Total Cholesterol; CVD: Cardiovascular Disease; EFSA: European Food Safety Authority.

INTRODUCTION

Physical inactivity is a state of concern as it leads to major health problems like obesity, hypertension and various metabolic disorders. Physical activity is defined as any bodily movement

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produced by skeletal muscles those results in energy expenditure above the basal level.[1] The world now is in the era where great advances of technology conceal people from doing physical activity, and it leads to the decrement in physical activity regardless of the scientific evidence has increased showing the importance of physical activity for health and well-being. Blair et al[2] stated that low-levels of physical activity are important precursor of mortality and associated with higher rates of disease and premature death. Furthermore, Karmen[3] also mentioned that sedentary lifestyle with lack of exercise can increase the susceptibility of getting cardiovascular disease, which is related to high blood cholesterol. Cardiovascular disease (CVD) continues to be the major cause of morbidity and death in the world. Hypertension, dyslipidemia and excess body weight are among most potent accepted risk factors for CVD. In 2007, the American College of Sports Medicine suggested that adults should complete at least 30 minutes of moderate exercise intensity aerobic activity at 3 days per week.[4]

Although there are many contributing factors to cardiovascular disease (CVD), inactivity has been shown to be one of the major risk factors.[5] Numerous previous studies reported about the positive effects of exercise on blood lipid profiles.[6-8] According to Spate and Keyser,[9] moderate-intensity training over a 12-week period was sufficient to improve HDL-C profile, and high-intensity training appeared to have no further advantage as long as training volume is constant in healthy adult female. It is also known that exercise with moderate activity can improve body composition by decreasing percentage of body fat and increasing lean body mass.[10] Chen[11] stated that brisk walking is an underestimated and underused modality to cope and overcome the issue of obesity in Malaysia and in other parts of the world since it can be performed in minimal instruction and not costly.

Oats contain many health-promoting components, such as dietary fibres, proteins and minerals.[12] Oat bran contains β-glucan, and it has been reported that oat bran can improve lipid profiles level of an individual.[13-15] It has been claimed by both US Food and Drug Administration (USFDA)[16] and European Food Safety Authority (EFSA)[17] as a health benefits supplement. USFDA has passed a ruling that allowed oat bran to be registered as the first cholesterol-reducing food at an amount of 3 grams of β-glucan daily. In 2011, European Union allowed food producers to market products containing 1 g β-glucan per portion with claims to reduce blood cholesterol concentrations and to attenuate post-prandial glycemic response.[17]

Regarding combined effects of nutritional supplementation and exercise, there are several previous studies reported about the positive findings.[18-20] According to animal study by Oh et al,[19] combination of soy supplementation and exercise showed its effectiveness by lowering serum total cholesterol, triglycerides and LDL-C in rats. To date, information are lacking on the additional beneficial of combined effects of brisk walking and oat bran consumption compared to oat bran consumption alone and sedentary without consumption of oat bran on body weight, body composition and blood lipid profiles among hypercholesterolemia women aged 40-50 years old. Thus, this study was proposed.

METHODS AND MATERIALS

Participants

In this study, 33 women participants, with age ranged from 40 to 50 years old were recruited. Participants were screened in order to determine the inclusion criteria and they were asked to provide informed consent form. The inclusion criteria of participants were individuals who were free from any chronic disease, hypercholesterolemia with total cholesterols ranged between 5.2 to 7.0 mmol/L, and non-smokers. The exclusion criteria were individuals who have the habit of taking oat bran as daily consumption prior to the experiment, engaged in any training programmed and exercised more than once per week. This study was approved by the Human Research Ethic Committee of Universiti Sains Malaysia (JEPeM Code: USM/JEPeM/15100389).

Experimental Design

Participant's grouping: The participants were assigned into three groups, with 11 participants per group (n=11), i.e. sedentary without oat bran consumption group (C), oat bran consumption alone group (Ob) and combined oat bran consumption with brisk walking exercise group (ObEx). Participants in the control group (C) did not perform brisk walking exercise or having oat bran consumption for 6 weeks. Meanwhile, participants in oat bran consumption alone group (Ob) consumed 18 g of oat bran per day without performing brisk walking exercise for 6 weeks. Whereas participants in combined oat bran consumption and brisk walking exercise group (ObEx) consumed 18 g of oat bran per day for 6 weeks and performed brisk walking exercise 30 minutes per session, 3 sessions per week for 6 weeks.

Anthropometric measurement and blood sample taking: Anthropometric parameters such as body height, body weight and body composition (percentage of body fat and fat free mass) were measured during pre- and post-tests. A stadiometer (Seca 220, Germany) was used to measure the body height. Meanwhile, body composition and body weight were measured using a body composition analyzer (Tanita, TBF-410). Approximately 6 mL of blood was taken before and after the experimental period. The participants fasted overnight form 10 p.m. until the next morning of blood sample taking at 8.30 a.m. Blood taking sessions for participants in ObEx for the post-test were carried out at 8.30 a.m. the next morning after performing brisk walking exercise, i.e. 14 hours post exercise. The blood sample was then centrifuged for 10 minutes at 4000 rpm and 4 °C (HettichZentrifuger-Rotina 46RS, Germany), only serum was collected and stored at -70 °C for subsequent analysis.

Oat bran consumption: The participants in both oat bran con-

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sumption alone group (Ob) and combined oat bran consumption with brisk walking exercise group (ObEx) consumed oat bran with 2 sachets per day of oat bran powder BG22™ (18 g of oat bran powder containing 3.6 g of β-glucan) diluted with water, 7 days per week for 6 weeks. The participants were required to consume one sachet of oat bran powder which was mixed with 250 ml of plain water before breakfast and another one sachet of oat bran which was mixed with 250 ml of plain water before dinner. On the exercise days, the participants in ObEx group consumed oat bran one hour before performing brisk walking exercise.

Brisk walking exercise: Participants in the combined oat bran consumption with exercise group (ObEx) carried out brisk walking programme for 6 weeks. In the 6 weeks of study period, the participants were required to perform brisk walking 3 times per week in the evening. In each session, five minutes of warming up session with stretching activities was carried out, then followed by 30 minutes of brisk walking exercise and ended with five-minutes of cooling down session with stretching activities. The estimated walking distance covered was approximately 2.0 km. The exercise intensity during brisk walking was set at 55%-70% of the participants' age-predicted HRmax (HRmax=220-age). The intensity of brisk walking exercise was estimated by referring to the heart rate of the participants after finishing the exercise, in which a heart rate monitor (Polar watch) was worn by participant throughout the brisk walking session. In order to ensure that the exercise intensity was maintained with the targeted range, the participants were required to record their post exercise heart rate at the end of brisk walking session. If the walking pace did not elicit a heart rate within the targeted heart rate, the participants were requested to change their pace during the subsequent walking session. This programme was carried out under the supervision of the researchers at the jogging track in Health Campus of Universiti Sains Malaysia.

Blood biochemical analysis: Blood samples were analysed for blood lipid profiles of total cholesterol (TC), triglycerides (TG), low density lipoprotein cholesterol (LDL-C) and high density lipoprotein cholesterol (HDL-C) by enzymatic method using commercial kits (RANDOX laboratories, UK) on ARCHITECT automated analyser.

Statistical Analysis: Data was analyzed using statistical software in the Statistical Package for Social Science (SPSS) Version 22.0. All the data are expressed as means and standard deviation (±SD). Repeated measure ANOVA was performed to determine the significance of the difference between and within the groups. Statistical significance was accepted at $p<0.05$.

RESULTS

Anthropometric Characteristics and Body Composition of the Participants

A total of 33-adult-women participants which were recruited in the present study had completed the study. Table 1 illustrates the mean age of the participants, and the baseline means body weight, body height, body mass index (BMI), percentage body fat and fat free mass of the participants according to groups at the beginning of the study.

Mean body weight, body mass index, percentage of body fat and fat free mass of all the groups at pre- and post-tests are shown in Table 2. At pre-test, there were no significant differences of body weight among all the groups. Similarly, at post-test, there were also no significant differences in body weight among all the groups.After 6 weeks of experimental period, means body weight were significantly lower in post-test compared to pre-test in Ob (p=0.013) and ObEx (p=0.02). The percentage decrease of body weight in ObEx was the highest (-1.4%) among the groups, and the percentage decrease of this parameter in Ob was -1.1%. The percentage change of body weight in C was 1.1%.

Regarding body mass index, there were no significant differences in this measured parameter among all the groups at pre-test. Similarly, there were also no significant differences in body mass index among the entire groups at post-test. After 6 weeks of experimental period no significant difference of body mass index was observed between pre- and post-tests in all the groups. Nevertheless, further analysis showed that the percentage change of body mass index in ObEx was the highest (-11.3%) among the groups.

Parameters	Groups (Mean±SD)		
	C	Ob	ObEx
Age (y)	44.6±4.1	45.3±4.7	45.5±3.5
Body weight (kg)	59.26±11.10	67.69±13.95	65.40±12.47
Body height (cm)	153.50±5.90	153.71±5.39	154.00±4.12
Body mass index (BMI) (kg/m^2)	24.9±5.2	28.5±4.4	32.1±9.2
Percentage body fat (%)	34.1±4.6	40.4±8.4	40.4±8.6
Fat free mass (kg)	35.8±3.5	39.2±7.2	39.7±4.4

Table 1: Mean age and baseline means body weight, body height, body mass index (BMI), percentage body fat and fat free mass.

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Groups	Body weight (kg) (Mean±SD)			Percent difference compared to pre test (%)	Body mass index (kg/m²) (Mean±SD)			Percent difference compared to pre test (%)
	Pre-test	Post-test	Mean difference between pre- and post-test (%)		Pre-test	Post-test	Mean difference between pre- and post-test (%)	
C	59.26±11.10	59.93±11.42	0.67±1.09	1.1	24.9±5.2	25.2±5.3	0.3±0.4	1.1
Ob	67.69±13.95	66.95±13.83*	-0.74±0.93	-1.1	28.5±4.4	28.2±4.4	-0.3±0.4	-1.1
ObEx	65.40±10.78	64.47±10.27*	-0.59±0.71	-1.4	32.1±9.2	28.5±5.8	-3.6±10.2	-11.3
Groups	Percentage body fat (%) (Mean±SD)			Percent difference compared to pre test (%)	Fat free mass (kg) (Mean±SD)			Percent difference compared to pre test (%)
	Pre-test	Post-test	Mean difference between pre- and post-test (%)		Pre-test	Post-test	Mean difference between pre- and post-test (%)	
C	34.1±4.6	35.7±6.5	1.5±4.1	4.5	35.8±3.5	36.1±3.9	0.5±0.2	0.7
Ob	40.4±8.4	39.9±7.8	-0.5±1.9	-1.2	39.2±7.2	38.8±7.6	2.4±0.7	-1.2
ObEx	40.4±8.6	41.3±10.6	0.9±4.9	2.2	39.7±4.4	38.8±5.9	3.6± 1.2	-2.5

*significantly different from pre test (p<0.05)

Table 2: Means body weight, body mass index, percentage of body fat and fat free mass at pre- and post tests.

At pre-test, there were no significant differences of percentage body fat and fat free dry weight among all the groups. Similarly, at post-test, there were also no significant differences in these two measured parameters among all the groups. After 6 weeks of experimental period, results indicated that there were no significant differenceof these two parameters between pre- and post-tests in all the groups.

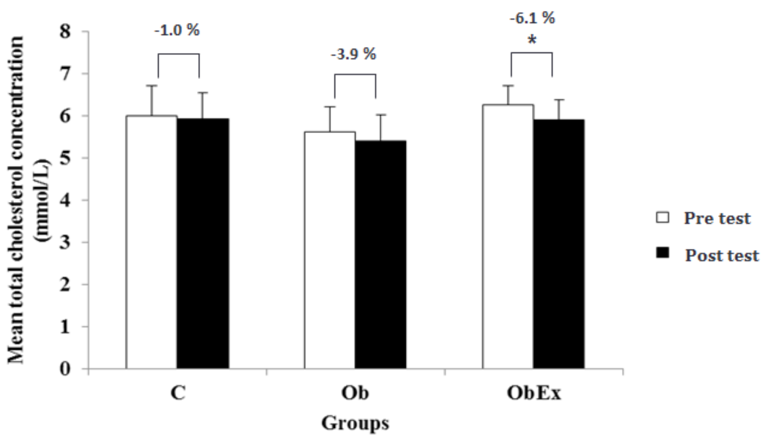
Blood Lipid Profiles

At pre-test, there were no significant differences of total cholesterol concentrations among all groups. Similarly, there were also no significant differences in TC concentrations among the entire groups at post-test. It was found that after 6 weeks of experimental period, total cholesterol concentration was significantly lower (p=0.02) in post-test compared to pre-test in ObEx (Figure 1), and the percentage decrease of total cholesterol concentration in ObEx was the highest (-6.1%) among the groups.

In serum triglycerides, the present data illustrated that there were no significant differences of serum triglycerides concentrations among the entire experimental groups at pre-test (C: 1.03±0.30, Ob: 1.25±0.48 and ObEx: 1.06±0.29 mmol/L). Similarly, there were also no significant differences of serum triglycerides concentrations among the groupsat post-test (C: 0.94±0.23, Ob: 1.12±0.46 and ObEx: 1.13±0.47mmol/L). After 6 weeks of experimental period, results indicated that there were no significant differences in triglycerides in post-test compared to pre-test in all the groups.

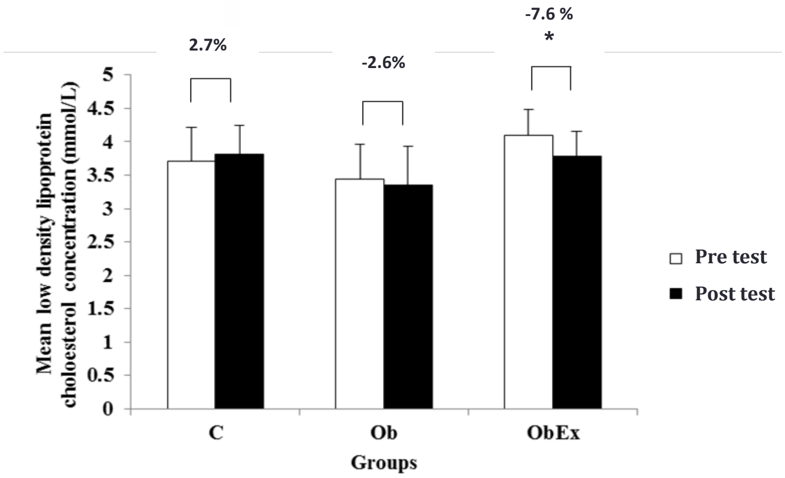
Regarding LDL-C, there was no significant difference of LDL-C concentrations among all groups at pre-test. It was also observed that there were no significant differences in this measured parameter among all the groups at post-test. After 6 weeks of experimental period, there was significant lower (p=0.019) value of LDL-C in post-test compared to pre-test in ObEx group (Figure 2). Further analysis showed that the percentage decrease of LDL-C in ObEx group was the highest (-7.6%) among the groups.

At pre-test, there were no significant differences of



*significantly different from pre-test (p<0.05)

Figure 1: Mean total cholesterol concentration (mmol/L) at pre- and post-tests.



*significantly different from pre-test ($p<0.05$)

Figure 2: Mean low density lipoprotein cholesterol concentration (mmol/L) at pre- and post-tests

HDL-C concentration among all the groups (C: 1.80±0.41, Ob: 1.60±0.19 and ObEx: 1.68±0.25 mmol/L). Likewise, at post-test, there were also no significant differences among all the groups (C: 1.69±0.28, Ob: 1.53±0.21 and ObEx: 1.62±0.11 mmol/L). After 6 weeks of experimental period, results indicated that there were no significant differences in HDL-C in post-test compared to pre-test in all the groups.

DISCUSSION

In the present study, there were no significant differences in all the measured parameters among all the experimental groups at pre-test and post-test respectively. Nevertheless, significant differences were observed in several measured parameters between pre- and post-tests. One of the main findings of this study was that there were significant reduction in body weight in both Ob and ObEx groups. As illustrated in Table 2, participants' body weight significantly decreased in Ob ($p=0.013$) and ObEx ($p=0.02$) groups after 6 weeks of experimental period. The present study also found that there were no significant differences in body composition parameters such as percentage of body fat and fat free mass between pre- and post-tests in all the groups. These findings indicated that Ob alone and ObEx could affect body weight but not body composition of the participants, and implying that 6 weeks of oat bran consumption alone and combination of oat bran consumption and brisk walking could reduce body weight significantly.

In 12 weeks previous study with another type of nutritional supplementation, Hill et al[18] found that in overweight participants with age ranged from 25 to 65 years old, fish oil nutritional supplementation alone group did not appear to have any changes in body weight but there was non-statistically change in the body weight in combined fish oil supplementation and aerobic exercise group. In contrast with Hill et al,[18] the present study found that oat bran consumption alone could reduce body weight, and implying that 6 weeks of oat bran consumption alone has greater potential in reducing body weight compared to 12 weeks of fish oil supplementation.

The present study found that combined oat bran and brisk walking (ObEx) elicited slightly higher percentage of reduction (-1.4%) compared to the oat bran alone (Ob) group (-1.1%) in body weight. This finding implies that combined oat bran and brisk walking may be more effective in reducing body weight than oat bran alone. Slentz et al[21] reported in their study that there was a significant dose-response relationship between amount of aerobic jogging and walking exercise, and amount of weight loss and fat mass loss. Their study was carried for 8 months on sedentary, overweight men and women with the age ranged from 40-65 years old. In the present study, the combined oat bran consumption and brisk walking exercise (ObEx) also elicited significant effect on reducing body weight of the participants, and the positive effect could be obtained in a shorter period, i.e. 6 weeks. Comparison between Slentz et al,[21] and the present study showed that combined exercise with nutritional supplementation such as oat bran may elicit extra beneficial effects in body weight reduction than exercise alone.

Based on a study done by Ghahramanloo et al,[22] there was no reduction in body mass with endurance and concurrent types of exercise. In this previous study 23 to 28 years old healthy untrained men were involved and it was carried out for 8 weeks. Comparison between Ghahramanlooet al[22] with the present study once again indicated that extra beneficial effect in reducing body weight can be obtained from combined nutritional supplementation such as oat bran and brisk walking exercise compared to exercise alone.

In a previous study on effect of exercise training intensity on abdominal visceral fat and body composition with 27 middle-aged and obese women by Irving et al,[23] it was found that there was significant reduction in body fat after 16 weeks of aerobic exercise. Contrary to the above previous study, the

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present 6 weeks study showed that percentage body fat did not change significantly neither in Oat Bran alone (Ob) group nor combined oat bran and brisk walking (ObEx) group. It is speculated that may be longer study period and higher exercise intensity are needed for eliciting beneficial effects of oat bran alone and combined oat with exercise on reducing body fat.

Another main finding of the present study was that combination of oat bran consumption and brisk walking exercise was most effective in reducing total cholesterol (TC) and low density lipoprotein cholesterol (LDL-C) concentrations of the participants. As illustrated in Figures 1 and 2, serum total cholesterol (TC) concentration significantly reduced (p=0.02) and serum low density lipoprotein cholesterol (LDL-C) significantly reduced (p=0.019) after 6 weeks of intervention period in ObEx group. Further analysis also showed that the percentages reduction in total cholesterol (-6.1%) and LDL-C (-7.6%) in ObEx group were the highest among all the groups. However, this combination did not significantly affect the other parameters of lipid profiles, i.e. triglycerides and high density lipoprotein cholesterol (HDL-C) concentrations

The present study found that oat bran supplementation alone did not affect lipid profiles. Regarding previous studies on the effect of nutritional supplementation alone on lipid profiles, in a 6 weeks of study carried out by Momenizadeh et al[24] on 60 hypercholesterolemia patients who consumed at least 5 daily servings of oat bread which contained 6 g of β-glucan, it was found that serum total cholesterol level reduced significantly. In addition, Berg et al[14] which carried out a 4 weeks study by involving hypercholesterolemia patients to investigate the effect of oat bran enriched diet on lipid profiles reported significant decreased in total cholesterol concentration and LDL-C. These two previous studies have shown consumption of oat bran containing β-glucan alone can elicit beneficial effect in reducing serum cholesterol. Biorklund et al[25] conducted a study to investigate changes in serum lipid profiles after consumption of beverages with β-glucan from oats and barley for 3 weeks. Their study also showed that 5 g of β-glucan from oats significantly lowered serum total cholesterol concentration. However, in the present study, the changes of serum total cholesterol level in Ob group was not significant statistically. The reason may be due to the dosage of β-glucan used in this previous study and the present study was different, i.e. 5 g in Biorklundet al[25] and 3.6 g in the present study. These findings implied that higher dosage of β-glucan may elicit better result in reducing total cholesterol of the participants.

The present study found that ObEx could improve lipid profiles. Oh et al[19] demonstrated that combined treadmill running exercise for 30 minutes with supplementation of soy isofalvone lowered serum total cholesterol, triglycerides and LDL-C after 12 weeks of intervention. In the present study, 6 weeks of combined oat bran with brisk walking exercise could reduce serum total cholesterol and LDL-C concentrations. Both Oh et al[19] and the present study showed that combined exercise and nutritional supplementation could give beneficial effect on improving lipid profiles. Nevertheless, comparison between Oh et al[19] and the present study showed that shorter study period as in the present study could only reduce total cholesterol and LDL-C, but not triglycerides as reported by Oh et al.[19] Therefore it is recommended for lengthening the study duration in future in order to get better results, it is speculated that participants may need longer time to adapt to the exercise and supplementation physiologically.

In a study by Carvalho et al[26] with 40 women aged 60-80 years, it was found that 8 months of moderate intensity multicomponent exercise program that included endurance, strength, coordination, balance, and flexibility exercises such as jogging, squatting and single leg stance resulted in improvements of blood lipids profiles. Their study findings showed that there were significant increase in HDL-C and significant decrease in triglycerides. Whereas, the present study found that 6 weeks of combined oat bran with brisk walking could reduce total cholesterol and LDL-C concentration. In Carvalho et al[26] the multicomponent exercise training prescribed was a combination of endurance strength, balance and flexibility activities. The exercises involved almost all parts of the body muscles as the participants did walking, jogging, squatting, etc. These findings showed that exercise alone elicited different results on lipid profiles components compared to combined exercise and nutritional supplementation as the present study. The differences in the type and duration of the exercise prescribed and age of the participants in this previous study and the present study could be the reason of the improvement in lipid profiles components were different.

In a study done by Bashiri[27] on 4 weeks combined garlic supplementation and training exercise with 60-75% of heart rate maximum in 36 young inactive men, it was shown that there were no significant differences among groups in triglycerides, cholesterol, low density lipoprotein (LDL-C) and high density lipoprotein (HDL-C) levels. Nevertheless, HDL-C levels significantly increased in combined exercise training and garlic supplementation group compared to pre-test levels. In the present study, there was no significant difference in HDL-C, however total cholesterol and LDL-C concentration were significantly reduced in the post-test compared to the pre-test with 6 weeks of combined oat bran supplementation and brisk walking exercise. Although the prescribed exercise intensity was almost the same in both Bashiri[27] and present studies, improvement in HDL-C concentration can only be seen in Bashiri.[27] These findings implied that different nutritional supplementation elicited different results in lipid profile components.

The limitation of this present study was that there was absence of exercise alone group for determining the effects of brisk walking alone on the measured parameters. It is suggested to include such a group for future study. It is also recommended to carry out a future study with longer study duration, so that more beneficial effect on the measured parameters can be observed as time is required for physiological adaptation to occur in an individual.

CONCLUSIONS

This study found that 6 weeks of oat bran consumption with 18 g of oat bran per day combined with brisk walking exercise for 30 minutes per session, 3 sessions per week with intensity of 55%-70% of the participants' heart rate maximum can significantly reduce body weight, serum total cholesterol (TC) and low density lipoprotein cholesterol (LDL-C) concentrations in 40 to 50 years old hypercholesterolemia women. Nevertheless, participants' triglycerides (TG) and high density lipoprotein cholesterol (HDL-C) concentrations were not affected significantly with this combination in this study. In conclusion, this combination can be recommended for improving lipid profiles in hypercholesterolemia women.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Pilot Study

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Effects of a Six-Week Randomized Training Program on Speed and Agility in Previously Trained Adolescent Males

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ABSTRACT

Athletes are constantly searching for training regimens to gain performance advantages for competition. Protocols are designed to promote increases in performance over short- and long-term periods but, most of these protocols improve only specific variables such as strength or running speed but not overall performance. The purpose of this study was to determine if increases in speed performance could be seen using a randomized style of sports performance training on adolescents who were familiar with, and had previously trained, using this style. Eight-male subjects, mean age of 14.6±0.9 years, participated in this training study. Mean height and weight were 1.7 m±0.12 m and 77.6 kg±15.3 kg, respectively. The study consisted of 6 weeks of randomized sports performance training. Subjects participating in the study had at least 12 weeks of previous randomized sports performance training. Three performance assessments (Russian box, plank, and timed ladder) were conducted prior to the 1st week of training and after the 6th week. Girth measurements (arm, thigh, and chest) and weight were also assessed pre- and post-training. Following the 6 weeks of training, significant differences ($p<0.05$ two-tailed, paired t-test) were observed in all three performance assessments. Pre/post measurements for the Russian box, plank, and timed ladder were 72.13±20.27 touches/91.13±30.99 touches, 239.86±194.67 seconds/346.57±272.09 seconds, and 281±39.62 seconds/255.75±33.23 seconds, respectively. No significant differences were seen in pre- and post-training subject weight or girth measurements (arm, thigh, and chest). Results support that randomized sports performance training can continue to increase performance in adolescents with previous training experience.

KEYWORDS: Anaerobic capacity; Sports performance; Randomization.

ABBREVIATIONS: RSPT: Randomized Sports Performance Training; IRB: Institutional Review Board.

INTRODUCTION

With the ever changing face of athletics in America, improving sports performance is the primary focus of most athletes. This, however, can be a complicated issue with many conflicting ideas surrounding the best way to improve performance. Obviously, sport selection is the determining factor when shaping a training program. For example, sports that emphasize power, whether anaerobic alactic (baseball, weight lifting) or anaerobic lactic (football, basketball, soccer), are often hindered by training programs that seek to improve aerobic fitness.[1] Most sports require unplanned movements or reactions that require a quick burst of energy intermittently dispersed between bouts of running or sprinting. However, for performance to improve, physiological adaptations must occur to the nervous, muscular, and cardiovascular systems.[2]

This has led to the development of many different modes of training from plyometrics to more systematic approaches like modified resistance training programs, both of which have shown to transfer to certain activities such as sprinting.[3] Because, sports performance is close-

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ly associated with intermuscular coordination (the interaction of many muscles to control a movement[4]); training programs designed to promote intramuscular coordination (neural adaptations within a single muscle) may not be as promising when discussing training and performance transfer.[5] Baker[6] however, demonstrated that beginning athletes could achieve transfer benefits from a more general training program but as they become more adapted to that program, specificity played an increasingly important role in performance. Because neural adaptations to resistance training are the primary contributor during the first 8 to 10 weeks of a training program[7] many beginning athletes will see plateaus in performance shortly after this period. Plateaus can also be traced to other factors such as overtraining, inadequate recovery, lack of nutrition and imagination.[8] These factors have led to the development of programs that manipulate the different variables of training (periodization) in order to continually improve.

Buford et al[9] demonstrated that if volume is kept consistent then different models of periodization (linear, weekly undulating, daily undulating) are all equally effective in improving strength. Because general training programs can improve performance early in training[6] and more variation is needed to continue to elicit gains in long-term performance,[2] can training programs be developed to address both of these needs as well as the need to incorporate variables such as intermuscular coordination while not ignoring other components like anaerobic capacity, power and core strength all while avoiding situations that lead to overtraining? The purpose of this study was to determine if a randomized style of sports performance training could continue to improve performance in previously trained male adolescents. "Randomized" training can best be described as a method of training that has no set training regimen for a given day but looks to improve variables of performance by complex power movements interspersed with traditional and nontraditional strength training, agility and foot work drills, increasing anaerobic capacity, improving balance and core strength all of which play a vital role in "on field" performance. It was hypothesized that randomized sports performance training would continue to improve performance in subjects who were previously trained and familiar with this style of training.

METHODS

Experimental Approach to the Problem

The goal of this investigation was to evaluate the effects of randomized training on performance variables during the time frame when improvement would normally tend to plateau and determine if randomized sports performance training could elicit gains in strength and performance after the neuromuscular adaptation phase of training. In this setting, "randomized training" referred to the inclusion of components of performance: aerobic endurance, speed, agility, explosiveness, flexibility for upper and lower body as well as core. For example, the workouts during any 1 week would include all of the previously listed components as well as 1 day when the volume of work might range from 10,000 to 40,000 lbs during a 1 hour workout.

Each of the participants had already been clients at a sports performance center (RepsUSA) and had a minimum of 12 weeks training experience. Thus, they were familiar with the style of randomized training and may have been getting close to the point where a plateau often occurs. Thus, the beginning of the 6 weeks when measurements were taken was used as the control point for the study.

Subjects

Eight male participants, between the ages of 13 and 16 years, included athletes from high school varsity and junior varsity football, basketball, and baseball teams. Each participant took part in their respective sport-specific training at their high schools and then attended 2 to 3 sessions per week at REPS. This study was reviewed and approved by the Institutional Review Board (IRB) and all potential risks and procedures involved in the study were explained to the subjects. Written informed consent to participate in the study was obtained from the parents along with assent from the adolescents. Participants were disqualified from the study if they failed to train at REPS at least 2 days per week. The training program was performed over a 6 week period and participants underwent benchmark assessments prior to week 1 and after the 6th week. Benchmark assessments included timed ladder drill, Russian box, and plank. (See Appendix A for an explanation of the assessments).

Procedures

Assessment tests were performed after a regular REPS warm-up but prior to training. Participant's body weight was taken during week 1 and 6 using a dial floor scale. Girth measurements of the upper arm, thigh and chest were also taken at week one and six using a Gulick measuring tape (Creative Health Products, Ann Arbor, Michigan, USA). The training protocol consisted of 6 weeks of a randomized style of sports performance training already familiar to the subjects. Because of the nature and style of REPS training the specific daily protocol over the course of the 6 weeks could not be documented as with a standard resistance or other performance-based training styles. Training sessions lasted one-hour per day and on any given day subjects would have been asked to perform simple exercises such as push presses, hurricane squats, log bench presses, isokinetic knee flexion/extension, isokinetic squats, isokinetic hip flexion and extension, deadlifts, lunges, or core work in various sets and repetition schemes. Subjects would have also been asked to participate in performance-based tasks such as slideboard, shuttle runs, sprints, step-ups, footwork drills, complex power movements, etc. Within a given week, however, all major components of performance were addressed (as mentioned previously) but never in the same fashion.

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Statistical Analysis

Descriptive data are reported as means and standard deviations (SD). Data were analyzed using Microsoft Excel and two-tailed, paired *t*-tests were used to determine if there were significant differences between week 1 and 6 in the bench mark assessments as well as girth measurements. Alpha level for significance was set a priori at $p \leq 0.05$.

RESULTS

A total of eight male participants, with a mean age of 14.6±0.9 years participated in this randomized sports performance training study. The means and SD values for age, height and weight are summarized in Table 1. The analysis, using the paired *t*-tests, determined that there were significant differences ($p \leq 0.05$) between pre- and post-training performance assessments (Russian box, plank, and timed ladder), but not for the girth measurements (arm, thigh, chest) and body weight ($p \geq 0.05$). Subjects averaged an increase of 19 touches per minute on the Russian box. A mean decrease of 25 seconds was seen on the timed ladder drill and an average increase of 107 seconds was seen in the plank. Table 2 summarizes the data from the performance assessments.

Figures 1, 2, and 3 graphically depict increases in performance assessments between week 1 and week 6.

	Mean	SD	Max	Min
Height (m)	1.7	0.12	1.96	1.63
Weight (kg)	77.6	15.3	100	55.9
Age (years)	14.6	0.9	16	13

Table 1: Subject data.
Demographic data for the 8 adolescent males who participated in this study.

	Mean	SD	*p*-value
Russian box (number of touches)			0.012
-pre	72.13	20.27	
-post	91.13	30.99	
Plank (seconds)			0.044
-pre	239.86	194.67	
-post	346.57	272.09	
Ladder drill (seconds)			0.008
-pre	281	39.62	
-post	255.75	33.23	

Table 2: Pre- and post-test performance assessment data.
Results of the pre- and post-testing for the measures of strength, agility and speed for the 8 participants.

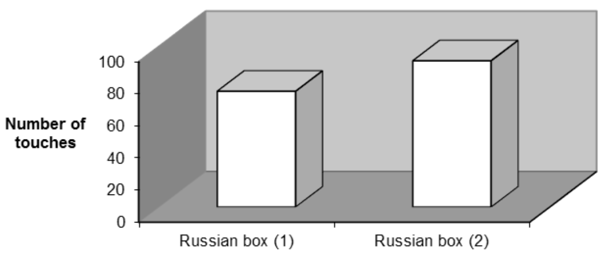

Figure 1: Pre- and post-training Russian box.
These data show the increased number of touches during the Russian box drill that the participants were able to perform following 6 weeks of “randomized” training.

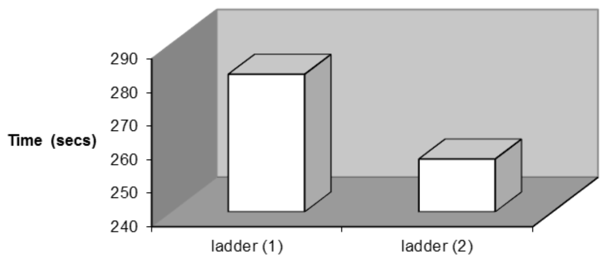

Figure 2: Pre- and post-training timed ladder.
These date indicate the increased speed that occurred in the timed ladder drill following the six weeks of “randomized” training.

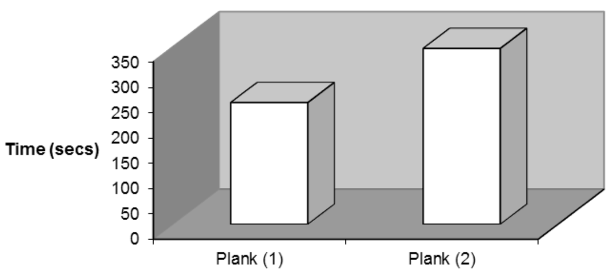

Figure 3: Pre- and post-training plank.
These data show the increase in the number of seconds that the participants were able to hold in the Plank position indicating an increase in strength following “randomized” training.

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	Mean	SD	*p*-value
Weight (kg)			0.945
-pre	77.6	15.3	
-post	78.2	15.6	
Girth Measurements			
Arm (cm)			1.0
-pre	29.9	4.1	
-post	29.9	3.4	
Thigh (cm)			0.118
-pre	50.9	8.0	
-post	50.3	7.6	
Chest (cm)			0.111
-pre	91.9	8.3	
-post	92.8	9.2	

Table 3. Pre- and post-training weight and girth measurements.
The means and standard deviations for the participants prior to and following the 6 weeks of "randomized" training.

The pre- and post-training results from the weight and girth measurements are listed in Table 3.

DISCUSSION

The purpose of this study was to determine if randomized sports performance training (RSPT) could continue to produce significant gains in performance assessments in previously trained children. The significant differences in the pre- and post-training performance assessments were consistent with the predicted hypothesis. Similar to other models of periodization,[2,5,6,9] RSPT did result in increased gains in performance assessments in previously trained male adolescents as seen with faster times (timed ladder, Russian box) and strength (plank). One factor that plays a role in the continued increase in performance is the fact that RSPT addresses both general training (resistance training) and performance specific training (plyometrics, agilities, etc.) either during the same training session or separate sessions. General resistance training has been shown to increase performance in untrained individuals[6] whereas variation and progression has been shown to contribute to further improvements in performance in previously trained athletes.[2] This style of training allows athletes to properly recover from working one group of muscles in a specific way while continuing to train other areas on subsequent days. Since the RSPT practiced at RepsUSA is truly randomized, the nervous system as well as the musculoskeletal system is constantly taxed not allowing the body to fall into specific patterns of movement or joint angles during lifting and drills. This has the potential to constantly alter muscle-firing patterns, increase recruitment and force production because as new movements and exercises are being learned, activity in the primary motor cortex increases, which is where motor unit activation begins.[2] Ideally, electromyography of muscles, determination of any changes in percent body fat as well as levels of blood lactate would have been helpful in documenting intensity of effort had they been available.

A part of the warm up during each session were the ladder drills. Participants were already very familiar with the sequence and the increased motivation that occurs when knowing that they are being timed and tested may have contributed to the decrease in time.

It appears that another advantage to the randomized style of training and its effect on performance might be the potential to continue to train at high intensity and volume levels while avoiding training staleness and subsequent decreases in performance. This could be more of a psychological factor because many athletes become bored with their training regimen and frequently experience performance losses due to the fact that their training intensity is lowered because of lack of motivation.[8] Randomization constantly provides fresh workouts so athletes can look forward to training and continue to train at high intensities and volumes. Training intensity and volume both play roles in performance gains.[2]

One reason why the continued gains in performance might have been seen is that most athletes participating in the study trained at the same time with one another. The competitiveness among the athletes could be considered extra motivation and allow them to produce greater gains in performance.[2,10] A drawback of the study was that these subjects were also in high school and their training there was not controlled. It was also not possible to include a control group, therefore, each participant acted as his own control.

Future considerations in research using RSPT could be to compare other types of training protocols to RSPT and measure improvements in performance between the style or using RSPT over longer periods of time to distinguish if gains in performance can be continued. Also, devising further performance assessments to test all performance variables should be considered.

CONCLUSION

It was concluded from these results that randomized sports performance training can continue to increase gains in performance

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assessments in previously trained adolescent males. These findings support the research hypothesis that stated gains in performance would be seen over a 6 week training period in participants that were previously trained in the randomized style of training.

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AUTHORS CONTRIBUTIONS

Both authors have contributed to the data collection and writing of this manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest to declare.

PARTICIPANTS CONSENT

Statement was approved by the Institutional Review Board for the Protection of Human Subjects at our university.

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APPENDIX A: Explanation of performance assessments

1. **Timed ladder drill:** This drill tests the subject's foot speed and conditioning. With this test the subjects will be asked to perform nine separate footwork sequences in succession in little time as possible the length of a floor agility ladder (approximately 10 yards) and back. The nine drills include: A) Two-feet per space facing forward the entire length and back. B) Two-feet per space facing sideways the entire length of the ladder and back. C) Icky shuffle, which is a pattern of right foot in, followed by the left foot in, followed by the right foot out and then the left foot up one space. D) Single machine gun which is another drill where the shoulders run parallel to the ladder and the pattern is such that if you are going to your left the left foot goes in the first space followed by the right foot in the same space then the left foot out of the space followed by the right all the way down the ladder and back. E) Double machine guns are next in sequence with the subject standing in the first box, shoulders parallel to the ladder. If they are going to their left they will start by moving the left foot out of the box followed by the right and then move the left back into the starting space followed by the right. Once this is achieved the left foot will lead to the next space followed by the right and the L pattern will continue the length of the ladder and back. F) Triple machine guns follow the doubles. With this one the subject will again start in the first space with shoulders running parallel with the ladder. The subject, if moving to their left will start with the left foot out of the space forward followed by the right. The left foot will then return to the starting space followed by the right and then the left foot will step backwards followed by the right. The left foot will again move back to the starting space followed by the right and finally the left foot will move to the next space followed by the right and the pattern will be performed the length of the ladder and back. G) S-drill is next. With this pattern the subject will start with either foot in the first space and just like skipping rope will keep their pivot foot in the space for two small hops until the foot that is moving reaches the space in front of the pivot foot thus becoming the new pivot foot. This pattern is repeated both the length of the ladder and back. H) Eggbeaters are the next drill in the sequence. This one requires the subject to stand sideways and alternate feet with a hop leading with the foot in the direction the subject is traveling. It will be performed the length of the ladder and back. I) Straddle step is the final drill. In straddle step, the subject begins the drill with both feet in the first space facing the long end of the ladder. The subject will then step out of the ladder with one foot and the next foot will step out the other side. After this, the foot that stepped out first will return to the starting space followed by the other foot. The lead foot will then step forward to the next space followed by the other foot. This drill will be performed the length of the ladder and back.

2. **One minute Russian box:** The Russian box is a platform six-inches off the ground and approximately six-feet long and two-feet wide with two-foot panels at both sides angled at 45 degrees. The Russian box test explosiveness laterally as well as balance and endurance. Subjects will be asked to start on one angled panel with the outside leg on the panel and the other leg off the panel with the knee raised and the foot slightly behind the body much like a slide board or speed skater. On go, the subject will push off the angled panel clear the three cones stationed in the center of the apparatus and land with the opposite foot on the other panel clearing the cone center line with the complete body before reversing the motion. The subject will be asked to complete as many passes as possible in the one-minute time limit.

3. **Pushup plank hold:** This assessment will test the subject's core and shoulder strength and stability. Subjects will be instructed to get into the up phase of a pushup and hold as long as possible.

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Relationship Between Pre-Season Testing Performance and Playing Time among NCAA DII Basketball Players

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ABSTRACT

Purpose: The purpose of this study was to investigate the relationships between pre-season testing performance and playing time within a men's Division II basketball team.
Methods: Archival data from pre-season athletic performance testing for ten (n=10) male NCAA Division II basketball players was collected and analyzed to determine if there was a relationship between anthropometric data (height, weight, wingspan), physical performance tests (vertical jump height, lane agility test, 5 and 20 m sprint time, National Basketball League (NBA) line drill and 20 m multi-stage fitness test (MSFT)), and playing time in the subsequent collegiate season.
Results: Pearson's product moment correlations revealed significant correlations were observed between playing time and predicted 1-RM bench press ($r \geq 0.71$) and 1-RM back squat ($r \geq 0.74$).
Conclusion: These results reveal the importance of upper and lower body strength to determine playing time for Division II basketball players. Based on these results, coaches should emphasize the importance of resistance training to develop upper and lower body strength to increase playing time in Division II collegiate athletes.

KEYWORDS: Basketball; Strength; Pre-season testing; Playing time; Collegiate sports.

ABBREVIATIONS: NBA: National Basketball League; MSFT: Multi-Stage Fitness Test; IRB: Institutional Review Board.

INTRODUCTION

Prior to the commencement of a competitive season baseline fitness and performance testing often occur in order to establish normative data, create a baseline for training, and utilized to monitor and profile athletes throughout the season. By selecting tests that best identify the key physical attributes that relate to performance outcomes for a particular sport, coaches are better equipped to make informed tactical decisions regarding starters and non-starts as well as the amount of playing allocated to each athlete.

Basketball is a multifaceted sport that requires a unique blend of various physical attributes to be successful at the elite level. These attributes include strength and power,[1-5] anaerobic and aerobic capacity,[4,6-9] speed and agility.[1,2,5,10-13] While these physical characteristics have been identified as characteristics of elite basketball athletes[4,14]; the percent contribution of these attributes may vary across players, and more specifically playing positions and the level of play.[15] As a result it is therefore difficult to quantify "success" in a manner that is easy to analyze,[4,15] when making comparisons between vastly different playing positions and level of play. Consequently, several research studies have examined the relationship between performance tests and playing time,[11,16] in an attempt to determine the physical attributes associated with

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greater playing time and successful basketball performance.

Change of direction, sprint speed, and vertical jump performance has previously been identified as critical sport-specific movements executed by all players throughout the duration of a basketball game.[17,18] As such it would appear logical that these physical performance variables would determine playing time in basketball athletes. It has been shown in previous research that lower body strength, as measured by a 1-RM back squat (r=0.64) displayed a high correlation to playing time in Division I male basketball players.[11] These authors also observed a low correlation between upper body strength, measured by a 1-RM bench press (r=0.14) and playing time in the same population.[11] Lower body power as measured by a vertical jump (r=0.58)[11] and standing long jump (r=0.67)[16] has shown to have a strong correlation, whereas aerobic capacity (r=-0.42), 27 m sprint performance (r=-0.62) and *t*-test (r=-0.33) to have strong and consistent correlates of playing time in DI male basketball players, respectively. This is consistent with research demonstrating lane agility (r=-0.59), to be a strong and consistent predictor of game performance.[16] These findings indicate the ability of physical performance testing to predict on field performance and subsequent playing time in basketball athletes.

Currently, no study has investigated the relationship between physical attributes and playing time among Division II basketball players. Thus, it is unclear as to whether the same physical attributes can be used to measure playing time at different levels of competition. Therefore, the purpose of this study was to investigate the relationships between pre-season testing performance and playing time within a men's Division II basketball team.

MATERIALS AND METHODS

Performance data for 10 (n=10) male NCAA Division II basketball players (Table 1) was used in the study. Although, 15 players were tested, only 10 were used in the final analysis. Redshirt athletes (n=4) and those who did not complete the entire performance testing battery were not included in the subsequent analysis. The data analyzed in this study was collected as part of the team's normal pre-season performance testing regime. Minutes played for each athlete was retrieved from the World Wide Web on the universities athletics page. Based on the archival nature of this data, this study qualified for exempt review through an Institutional Review Board (IRB) for human subjects.

All testing was performed indoors on a hardwood basketball court, 6 weeks prior to the 1st game of the season to ensure adequate fitness and minimal fatigue as a result of in-season competition. Testing was administered by the team's strength and condition coach, and performed across 4 sessions separated by a minimum of 72 hours to minimize the effect of fatigue on subsequent results. Session one consisted of anthropometric measurements, lower body power, change of direction speed, sprint speed, and an anaerobic capacity assessment. Session 2 assessed subject's aerobic capacity, while session 3 and 4 consisted of an upper and lower body strength assessment, respectively. Basketball players are often required to perform repeated accelerations and decelerations, directional changes, vertical jumping, and high velocity sprints within a game. Therefore, the physical performance tests used within the study were chosen due to their sport-specific relevance to basketball, and have previously been featured in other studies investigating basketball performance.[2,4,10,13,15]

Anthropometric measurements, including height and weight, were collected using standard procedures on a doctors beam scale (Cardinal; Detecto Scale Co, Webb City, MO, USA), with height recorded to the nearest 0.01 cm and weight to the nearest 0.1 kg. Wingspan was measured by placing a measuring tape horizontally on a wall. Each subject was instructed to place their arms out to the sides along the length of the tape measure with their chest against the wall. The distance between the middle finger of each hand was recorded to the nearest 0.01 cm.

Assessment of lower body power was measured by a counter movement jump performed on a Just Jump Mat (Just Jump, Pro Botics Inc, Huntsville, AL, USA). The mat was placed under a basketball goal with athletes performing 3 separate counter movement jumps (with arm swing) intercepted with 10 s recovery between trials. No specific instruction was provided to players regarding the speed or depth of each jump, other than to jump from a standing position and reach as high as possible on the backboard. The best score from 3 trials was retained for analysis and recorded to the nearest 0.01 cm. Compared to vertical jumps measured using a Vertec, the Just Jump Mat system has been shown to be a valid method (r=0.906) of assessing vertical jump height.[19]

Change of direction speed was evaluated using the lane agility test. Cones were positioned at all 4 corners of the key-way on a standard sized basketball court (Figure 1). From a standing start at the left hand corner of the free throw line facing the baseline (cone A), players were instructed to sprint forward to the 1st cone at the baseline (cone B), shuffle right to the 2nd cone at the baseline (cone C), run backward to the 3rd cone at the free throw line (cone D), shuffle left to the 4th cone at the free throw line (cone A), change directions to shuffle to the right back to the 3rd cone (cone D), sprint forward to the 2nd cone (cone C), shuffle left to the 1st cone (cone B), and finish by backpedaling to the 4th cone at the original start position (cone A).[16] Time required to complete each trial was measured using a dual beam electronic system (TC-System, Brower Timing Systems, Draper, UT, USA). Each subject was allowed 3 attempts with the fastest time being recorded to the nearest 0.01 s. The lane agility test has been shown to be a reliable assessment of change of direction ability in basketball athletes (ICC=0.99, CV=8.71%).[20]

Running speed was evaluated with a 5 m and 20 m

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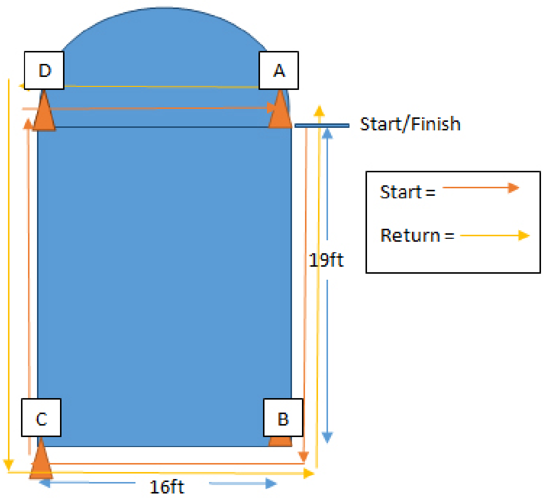

Figure 1: Basketball lane agility test.

timed sprint using a dual beam electronic system (TC-System, Brower Timing Systems, Draper, UT, USA). Timing gates were positioned at a distance of 5 m and 20 m from a pre-determined starting point. The athletes were instructed to run as quickly as possible from a standing start position. Each subject was allowed three attempts with the fastest time being recorded to the nearest 0.01 s.

Anaerobic performance was assessed using the basketball line test, commonly referred to as "suicides". Each player started standing behind the baseline, sprinting to the free throw line (5.74 m) and back to the baseline, then sprinting to half court (14.33 m) and back to baseline, then sprinting to the opposite free throw line (22.92 m) and back to baseline, and finally sprinting the full length of court (28.65 m) and back to the starting position. The total distance covered was 143.28 m. All athletes only performed this test once, with time recorded to the nearest 0.01 s using a hand-held stopwatch (Figure 2).

Aerobic endurance was assessed using the 20 m multistage fitness test, also known as the beep test. Two cones were positioned in a straight line 20 m apart on the basketball court. Each player ran between the 2 cones paced by an audible beep, on a pre-recorded audio file. As the test progressed, the time between each beep decreased, while the distance remaining the same. Warnings were provided if players did not reach the end line on time and the test was terminated when the player could not follow the set pace of the "beeps" and make it to the end of the 20 m lines within the given time on 2 successive shuttles, and/or stopped voluntarily. The highest level attained before disqualification was recorded, and the number of total shuttles performed was retained for analysis. Further the number of shuttles was converted to an estimated maximal aerobic power (VO_{2max}) using the table of normative values provided in Ramsbottom.[21]

Three repetition maximum (3-RM) bench press and back squat were utilized to measure upper and lower body strength, respectively. Players were instructed to complete a warm-up prior to testing consisting of 5 repetitions at 30%, followed by 8 repetitions at 50%, followed by 6 repetitions at 60%, followed by 5 repetitions at 70%, followed by 3 repetitions at 80%, all separated by a three minute rest period.[22] Following the warm-up additional weight was added in a linear progression to determine each athlete's maximum load for each lift within 3

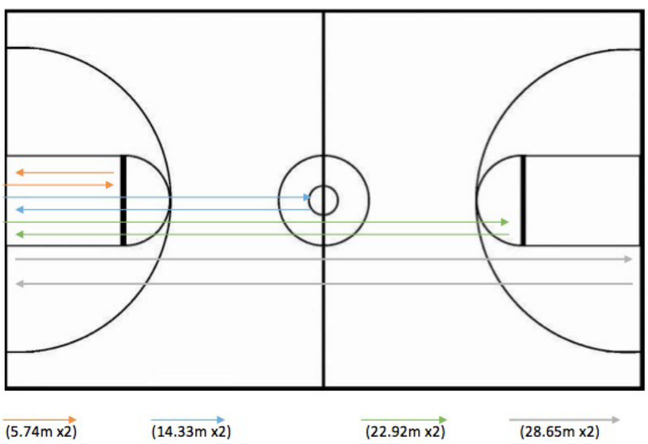

Figure 2: Basketball line drill.

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to 4 attempts, with 4 min rest provided between each attempt. Using previously established equations; the player's 3-RM was converted to a predicted 1-RM, similar to previous research.[23] Bench press was performed using a standard barbell and flat bench. The players lowered the bar to their chest, and then pressed the weight vertically, until the arms were fully extended; bouncing the bar off the chest was not permitted. Back squat was performed in a high bar position, with the bar positioned across the trapezius muscle. The athletes were instructed to squat as deep as they could safely, extending at the hip and knees to lift.

Descriptive statistical analysis was conducted on the total sample to determine the mean and standard deviations across all anthropometric and physical performance tests. Pearson's product-moment correlation (r) was performed to determine the relationships between performance tests and playing time. The strength of the correlation coefficient was described as per Hopkins.[24] An r value between 0 to 0.30, or 0 to -0.30, was considered low; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.50 to 0.69, or -0.50 to -0.69, large; 0.70 to 0.89, or -0.70 to -0.89, very large; and 0.90 to 1, or -0.90 to -1, near perfect for predicting relationships. Multiple regression analysis was used to estimate the best predictor of playing time. The level of significance was set at $p \leq 0.05$ for all the statistical analysis, unless otherwise stated. All statistical analyses were processed using the IBM SPSS statistics (Version 20.0; IBM Corporation, New York, USA).

RESULTS

Descriptive statistics and Pearson's product moment correlations between anthropometric data, physical performance tests, and playing time are displayed in Table 1. The strongest correlations ($r \geq 0.71$) were observed between total playing time, predicted 1-RM bench press and 1-RM back squat. No statistically significant relationships were discovered between any of the other performance scores, or any of the collected anthropometric data. Playing time appeared to have a large non-significant correlation ($r \geq 0.51$) to body weight. Vertical jump and the basketball line drill displayed moderate non-significant correlations ($r \geq 0.31$, p=.09), while 5 m sprint speed demonstrated a moderate negative correlation to playing time. Low negative correlations (r=-0.12 to -0.46) were observed between height, wingspan, lane agility, 20 m sprint, beep test and estimated VO_{2max}, to minutes played.

DISCUSSION

There are a number of factors that contribute to successful sports performance and those athletes who receive greater playing time. Currently, only two studies have investigated the relationship between pre-season performance testing and playing time in male basketball players.[11,16] However, the athletes observed in these studies competed in Division I collegiate level, with athlete competing in this league to be shown to have greater physical attributes compared to Division II and III collegiate basketball athletes.[15] Therefore, findings from these studies may not directly transfer to athletes competing at different levels of competition. Despite this, based on previous research, it was hypothesized that lower body strength and vertical jump would be strongly related to playing time in division two basketball athletes. It was discovered that while lower body and upper body strength was strongly related to playing time no significant relationships were seen between other anthropometrical or physical performance tests and playing time in the population studied.

Several studies have outlined the importance of a greater strength capacity to be a predictor of success in collegiate basketball.[2,4,8,14] Predicted 1-RM back squat displayed the strongest correlation to playing time compared to all the other variables tested in the current study. Similarly, Hoffman[11] reported 1-RM

Variable	Mean±SD	r
Avg. Playing Time (min)	15.98±10.18	-
Total Playing Time (min)	463.50±295.33	-
Weight (kg)	90.23±9.65	0.56
Height (cm)	196.29±10.44	-
Wingspan (cm)	200.15±10.21	-
Vertical Jump (cm)	76.86±7.49	0.39
Lane Agility (s)	11.24±0.54	-
5 m Sprint (s)	0.80±0.04	- 0.57
20 m Sprint (s)	2.80±0.08	-
Line Drill (s)	27.81±0.89	0.24
Beep Test (# shuttles)	65.89±9.90	-
Est. VO2 Max (ml/kg/min)	41.76±3.50	-
Squat Predicted 1-RM (kg)*	134.44±19.28	0.74
Bench Predicted 1-RM (kg)*	96.16±17.04	0.71

*Indicates significant correlation to playing time ($p \leq 0.05$).

Table 1: Pearson product moment correlation between playing time and anthropometrical, and physical performance data.

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back squat displayed a large correlation (r=0.64), to playing time in division I male basketball players. While the average back squat reported in the current study is lower in comparison to previously reported values in division I basketball athletes[4,11]; possessing greater lower body strength to efficiently execute athletic movements and proficiently move around the court is a deterministic factor for greater playing time. The importance of muscular strength for the execution of general and sport specific movements is well established,[25,26] therefore it would appear logical that predicted 1-RM bench press displayed a strong correlation to playing time in the current study. However, this finding contradicts previous research reporting a low correlation (r=-0.04 to 0.14) between upper body strength and playing time division I male basketball players.[11] While differences in upper body strength may be due to different priorities of the strength training program, position specific requirements, specifically power forwards and post players would benefit from greater upper body strength to withstand contact from opposing players when rebounding or contesting for positional advantage within the keyway.

Previous research focusing on collegiate male basketball players has not investigated the relationship between body weight and minutes played. This may be of value to coaches to determine if increasing or decreasing an athlete's body mass to ultimately optimize one's strength to weight ratio would improve performance on court. Findings of the current study reveal body weight has a large but non-significant correlation to playing time, indicating division II basketball athletes with a greater body mass are likely to receive longer playing time. While the composition of lean and fat mass to an athletes overall body weight was not determined in the current study, we can assume that possessing greater lean body mass increased on court efficiency and subsequent playing time. Previous research has demonstrated the importance of increased lean body mass to produce a faster change of direction[5,27,28] and sprinting performance,[29,30] and to achieve a greater vertical jump height[13]; all of which are typical sport-specific movements executed by basketball athletes.[17,18] It should be noted that anthropometric characteristics including body weight, height and wingspan would vary depending on the positional role within the chosen sport.[15] A limitation of the current study is the inability to compare between playing positions as a result of the small sample size. Guards for example are shorter in height and are therefore able to move around the court at a faster pace, compared to centers that are taller and heavier, suited to contest and rebound the ball in the post.[15] This may explain the low correlation observed between height and wingspan in the current study.

In contrast to previous research, vertical jump height was not significantly correlated to playing time in Division II athletes. Findings from Division I basketball have reported strong correlations between measures of lower body power, including vertical jump height (r=0.68)[11] and standing long jump (r=0.67)[16] to playing time. Possessing a greater vertical jump height would provide a substantial defensive advantage for basketball athletes particularly when rebounding or attempting to block an opposing players shot for goal. However, it should be noted that vertical jump performance during a game requires correct timing, anticipation, and sufficient upper and lower body strength to withstand contact from opposing players to successfully rebound the ball. This significantly differs from preplanned testing conditions, as there are varying environmental and task constraints imposed on the athlete at any given time,[31] which may explain the moderate correlation observed between vertical jump height and playing time in the current study.

Basketball involves high-intensity repeated bouts of activity including sprinting, changes in movement direction and vertical jumping,[4,8,11,14] involving both anaerobic and aerobic metabolic pathways. Findings of the current study reveal a moderate correlation between the line drill and playing time, whereas a weak correlation was observed between the beep test and estimated VO_{2max} to playing time. Anaerobic performance assessed *via* a repeat-sprint ability test or line drill has been shown to be a predictor of playing time in elite basketball athletes,[32] and is considered a crucial element across numerous team sports.[21] Therefore, the greater anaerobic capacity a player has to execute these movements, rapidly change direction and move up and down the court, provides them with an offensive and defensive advantage to successfully evade or pursue opponents. While aerobic endurance in basketball has been shown to be important to maintain a high level of activity for the duration of an entire game,[33] it appears the level of aerobic capacity is dependent upon positional requirements. Previous research has reported that guards cover a significantly higher distance executing sport-specific movements at higher intensities, therefore requiring a higher VO_{2max} compared to centers and forwards.[34] While time-motion analysis reveals the importance anaerobic capacity for basketball performance, a high base of aerobic capacity is required to sustain these movements across the duration of a game.[11] However, positional differences may explain the low correlation observed between aerobic performance and playing time in the current population.

While 20 m sprint demonstrated a weak correlation to playing time in Division II basketball athletes, similar to previous research[11]; 5 m sprint demonstrated a moderate inverse relationship to playing time (r =-589, p=.09). This finding suggests that an athlete's acceleration ability contributes to the amount of playing time received, in contrast to maximal speed. Time-motion analysis of Division I basketball reveal athletes complete 55 to 105 sprints, every 21 to 39 s, with each sprinting effort lasting less than 2 s.[34] Further, sprinting efforts over 1 to 5 m throughout a game occurs 57% of overall game time, compared to 5% of sprinting efforts at 20 m or greater.[18,34] As basketball players rarely sprint the full length of the court, a faster 5 m sprint time would enable short burst of acceleration to occur, which is a clear requirement for basketball athletes. Therefore, tests that require athletes to sprint over longer distances should be reconsidered as the performance outcomes and objectives do not appear to correspond well to game requirements.

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Throughout the duration of a game basketball athletes complete 50-60 changes in movement direction,[17,18] highlighting the importance of this physical quality. However, previous research has revealed mixed results indicating playing time shares a strong correlations to the lane agility test (r=-0.59),[16] and weak correlations to the *t*-test (r=-0.30)[11] in Division I athletes. The current study supports the latter, with a weak correlation observed between playing time and the lane agility test in Division II basketball athletes. While the lane agility test assesses change of direction ability and typical movements performed during a game (backpedaling, forward running and side-shuffling),[5] it is a non-specific test failing to replicate the cognitive demand associated with movement execution during a game.[28] Changing direction during a game requires decision-making to read appropriate cues from the opposition and environment to determine subsequent movement direction.[28,35] The lane agility test fails to replicate the unpredictable nature in which movement demands are executed during game environments, and therefore could explain the weak correlation observed to playing time.

CONCLUSION

The findings of the study reveal the importance of upper and lower body strength to determine playing time for Division II basketball players. While body weight, 5 m sprint time and the line drill shared a moderate correlation; 20 m sprint time, the beep test, the lane agility test, height and wingspan shared a weak correlation to playing time and therefore offers minimal insight in determining playing time in the population studied. However, it should be noted that the small sample sized used in the study prevented additional comparisons between positional groups, which may reveal further insight into the physical characteristics that result in greater playing time. From a practical perspective, these findings emphasize the importance of resistance training to develop upper and lower body strength to increase playing time in Division II collegiate athletes.

CONFLICTS OF INTEREST

All authors certify that there are no known or perceived conflicts of interest.

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