The impact of Badminton on health markers in sedentary females.

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Introduction

The benefits of exercise and physical activity are well established, including improved physical health and psychological wellbeing, reduced obesity levels, decreased risk of developing cardiovascular disease, stroke, type 2 diabetes and some forms of cancer (US Department of Health, 2010). For example, a larger fat-free mass is associated with a lower risk of all-cause mortality (Bigaard et al., 2005), and reduced abdominal obesity decreases the risk of adverse health outcomes (Bigaard et al., 2005; de Koning et al., 2007). Furthermore, higher levels of cardiorespiratory fitness are associated with lower risks for poorer health (Barlow et al., 2006; Stofan et al., 1998).

Lack of physical activity is the fourth highest risk factor for chronic diseases (Scholes & Mindell, 2014), and in 2012, 50-60% of the adult population in England reported that they met the government physical activity guidelines of 150 minutes of moderate or 75 minutes of vigorous exercise per week (Health Survey for England 2012). However, when this was measured using an objective measure of physical activity (i.e. accelerometer) this number actually fell to 4 and 6% for men and women respectively (Health Survey for England 2008). Clearly problems exist with firstly the use of self-reporting physical activity levels, but more importantly the large proportion of the population that are not meeting the recommended levels of physical activity. Furthermore more focus should be placed on females due to the fact they are less physically active than males (Talbot et al., 2000).

Most training intervention studies have used endurance based training, such as walking, jogging or cycling to improve a range of health markers. For example a recent systemic review and meta-analysis demonstrated that systolic and diastolic blood pressure is reduced by 6.4 and 4.0 mmHg, respectively in interventions lasting between 4-10 weeks (Cornelissen & Smart, 2013). The authors suggest the largest change in blood pressure is associated with individuals with the largest change in body mass. Endurance exercise has been shown to have a positive effect on body mass, more importantly, with evidence suggesting a decrease in overall and abdominal body fat levels (Donges et al., 2010; Mendham et al., 2014). With respect to cardiorespiratory fitness, endurance training has been shown to elevate maximal oxygen uptake by 9-14% in 8 weeks (Farrell & Barboraik, 1980; Meridith et al., 1990; Mendham et al., 2014) and improve blood lipid profiles by decreasing total cholesterol, triglycerides, low-density lipoprotein (LDL) and increasing high-density lipoprotein (HDL) (Farrel & Barborail, 1980; Isler et al., 2001; Whitehurst & Mendez, 1991). However, in recent years there has been a focus on intermittent exercise, sometimes in the form of sports such as football (Krustrup et al., 2009) and tennis (Ferrauti et al., 1997) as a tool to improve health markers. The use of sport activities as a training tool in recreational populations has been demonstrated to enhance aerobic fitness, cardiovascular function, metabolic fitness, adiposity, cardiac adaptation, muscular performance (Ferrauti et al., 1997; Krustrup et al., 2009; Mendham et al., 2014).

Despite the known health benefits of exercise and physical activity there are numerous barriers to physical activity, particularly in women. Some of the proposed barriers include exercise milieu (eg. cost of exercise, places to exercise, how people look in exercise clothes etc.), time expenditure and family discouragement (El Ansari & Lovell, 2009). Furthermore family priorities, care giving duties and lack of energy (Eyler et al., 2002) alongside not enjoying physical physical exertion (Lovell et al., 2010) have been shown to be significant barriers to women's participation in exercise. The perception that physical activity is tiring and hard work is of concern and could initiate a vicious circle: as women regress in their physical fitness condition, they could perceive that subsequent physical activity will therefore be even harder. In a review of qualitative studies focusing on physical activity participation Allender et al. (2006) identified that fun, enjoyment and social support for aspects of identity were reported more often as predictors of participation and non-participation than perceived health benefits. Thus the use of sports activities may be beneficial in increasing physical activity engagement.

Badminton is one of the most popular sports in the world with approximately 200 million players worldwide (Phomsoupha & Laffaye, 2015), played by both males and females across a range of ages, and skill levels. It is a racket sport characterized by actions of short duration and high intensity coupled with short rest periods (Cabello et al., 2003). Players are required to move quickly, with multiple changes of direction throughout a rally. It is generally played in either 1 v 1 or 2 v2 format, with singles more demanding than doubles (Liddle et al., 1996), with approximately 80 % of rallies lasting less than 10 s (Cabello et al., 2003). Due to the intermittent nature of badminton, high demands are placed on both the aerobic and anaerobic systems for delivery during play and recovery. Research on elite level players suggest that 60–70 % of the energy yield during games is derived from the aerobic system, while 30 % is obtained from the anaerobic system (Chin et al., 1995). Alongside the high frequency and intensity of play during a match, maximum and average heart rate (HR), indicate that badminton demands a high percentage of individual aerobic power (Cabello et al., 2003; 2004; Faude et al., 2007). The literature reports an average HR in both males and females over 90 % of the HRmax (Cabello et al., 2003; Faude et al., 2007), or 170–180 beats/min (Chin et al., 1995), with those values linked to the skill level of the individual players. The high HR sustained throughout the game leads to considerable stress on the cardiovascular system (Majumdar et al., 1997). To date much research has focussed on the determinants of elite badminton performance or the physiological characteristics of elite players. However due to the obvious high physiological demands of the game and the high numbers of players' worldwide, badminton may be a possible candidate to help improve health characteristics in sedentary and untrained women.

Thus the purpose of the study was to examine the effect of regular participation in recreational badminton in untrained women throughout an eight week intervention and compare it with a similar period of running. The use of a running group acted as an exercise control group to investigate the impact of sport (badminton) on physiological and psychological adaptations.

Methods

Participants

Thirty-six healthy untrained premenopausal women (mean ± standard deviation [SD]) aged 34.3 ± 6.9 years with a body mass, height, fat percentage, body mass index (BMI) and maximal oxygen uptake (VO_{2max}) of 68.7 ± 11.3kg, 1.66 ± 0.05 m, 33.8 ± 8.9%, 24.9 ± 4.1 kg/m^2 and 32.6 ± 6.2 mL/min/kg, respectively, volunteered to take part in this study. None of the participants were taking any medications or were smokers, or were currently meeting the recommended exercise guidelines (Department of Health, 2011). The participants were informed of all the risks procedures associated with the experiment and all proved written consent. The study was carried out in accordance with the guidelines contained in the Declaration of Helsinki and was approved by the local St Marys University ethics committee.

Design

Participants were matched for VO_{2max} and body fat percentage and randomly assigned to a badminton group (BG, n = 14) or a running group (RG, n = 14) and compared with a matched

control group performing no physical training (CO, n = 8). One individual in the badminton group and two in the running group withdrew from the study due to illness or minor injury occurring during training.
The participants in the badminton and running groups were trained for 8 weeks, whereas the participants in control group continued their daily life activities during the same period. The participants in all groups were tested before the training period and at the end of the 8 week period. The testing protocol included resting blood pressure, fasting capillary blood samples, body composition assessment, jump height assessment, submaximal and progressive maximal treadmill tests and psychological wellbeing questionnaires

Training Intervention
The training intervention lasted 8 weeks and training was carried out for 1 h three times a week at St Marys University, Twickenham. The badminton group training was performed in indoor badminton courts and the running group training was performed outdoors. The training sessions were on a Tuesday, Thursday and Saturday throughout the 8 week intervention. The badminton sessions consisted of double or single (half court) matches on a 6.1 m wide and 13.4 m long indoor court. Each training session started with a brief 10 minute warm up consisting of jogging and dynamic stretching. One session per week was focussed towards learning skills and shots, whilst two sessions per week were dedicated to matches. All sessions were taken by a fully qualified badminton coach. The endurance running sessions consisted of endurance running of a moderate intensity within and around the grounds of St Marys University. Each session started with a 10 minute low intensity warm up consisting of jogging and dynamic stretches.

The training adherence was 2.6 ± 0.2 and 2.7 ± 0.3 sessions per week for badminton and running group, respectively. The average training intensity during the badminton group sessions was 75 ± 5 % of maximal HR. The intensity of each session increased as the participants became more accustomed to the skills and rules of the game, with an average heart rate of 73 ± 7% and 77 ± 6% maximal HR for the first and second half of the intervention, respectively. In the running group, the running speed was individually adjusted to elicit the same average heart rate as for badminton group (75 ± 3% of maximal HR). HR was determined during all training sessions.

Measurements and Test Procedures
Participants reported to the laboratory prior to the start of the exercise interventions for the assessment of baseline variables. Following an overnight fast capillary blood samples were collected into two 300 µl microvettes (CB 300, Sarstedt, Germany). Microvettes were immediately centrifuged at 5000 rpm (Eppendorf 4515C, Eppendorf UK ltd, Cambridge) for 5 minutes in order to separate the plasma from the cells. Blood measurements of total cholesterol, high density lipoprotein (HDL) and triglyceride were analysed (Randox Monza UK). Low density lipoprotein (LDL) was calculated using a calculation previously described by Friedewald et al. (1972). Blood glucose was also analysed from a capillary puncture sample using the Biosen C-Line analyser (EKF diagnostic, Ebendorfer Chaussee 3, Germany).

Following resting blood sampling, participants body fat percentage (BF%) was assessed via air-displacement plethysmography using a BODPOD ((Life Measurement Instruments, Concord, California). Firstly, stretch stature (m) and body mass (kg) measurements were taken to a precision of 0.01 m and 0.1 kg, respectively using a Seca free standing height measure and calibrated Seca scales. Each participant was then seated comfortably in the BODPOD chamber to enable a measurement of body volume to be made, lasting approximately 35-45 s. During the test, participants were asked to breathe normally while computerized pressure sensors determined the amount of air displaced by the body. Each test was repeated twice and providing the body volume measurements obtained were within 150 ml the test was complete. If they did not correspond a third measurement was taken. For all measurements participants wore a tight-fitting swimsuit (for this test minimal clothing is essential for accuracy), a bathing cap, and removed all jewellery and before each test the BODPOD was calibrated according to manufacturer's instructions using a cylinder of known volume (50L). Prediction equations based on gender, age, and height were used to estimate thoracic lung volume (Wagner, 2000) and then using this data, body mass and body volume data computer software determined body density and then %BF using the Siri (1961) equation.

In addition, the following girth measures were obtained in accordance with International Society for the Advancement of Kinanthropometry (ISAK) guidelines (Marfell-Jones et al., 2006); arm (relaxed), arm (flexed and tensed), waist (minimum), gluteal (maximum), thigh (mid), and calf (maximum). All circumference measures were taken using a flexible steel tape (Lufkin W606PM) by a level 3 ISAK accredited anthropometrist. Body mass index (BMI; $kg.m^{-2}$) and waist to hip ratio (WHR; waist girth/gluteal girth) were calculated.

Participants rested in a supine position for 15 minutes before systolic and diastolic blood pressure were measured using a digital sphygmomanometer on the upper arm (Omron M5, Omron Healthcare, Europe B.V., Netherlands) on three separate occasions and the average value was calculated. Mean arterial pressure was calculated as 1/3 systolic blood pressure + 2/3 diastolic blood pressure. Resting HR was measured during the same time interval as the blood pressure recordings.

Muscle power output was assessed via a maximal vertical jump using bilateral countermovement jumping (CMJ). In brief two Pasco force platforms (PS 2142 Roseville, CA, USA) were used to evaluate vertical ground reaction forces at a sample rate of 1000 Hz. The force platforms were connected to an interface (Pasport Power Link PS-2001). Force platforms were calibrated by using the shunt technique provided by the company. Data were collected and analysed with DataStudio software (Pasco, Roseville, CA, USA).

Pulmonary gas exchange, HR and capillary blood sampling were performed during a standardized treadmill test with 6-min bout of walking at 6.0 km/h and a 4-min bout of submaximal running at 8.0 km/h, interspersed with 2-min rest periods. For the participants who had RER values below 0.90 and heart rates below 80% of maximal heart rate at the end exercise at 8.0 km/h, another 4-min running bout was performed at 9.0 km/h. After a 15-min rest period, the participants carried out an incremental test to exhaustion, consisting of 4 min of running at the last submaximal running speed followed by stepwise 1% gradient increments each minute until exhaustion. Respiratory gas exchange was measured during the entire exercise protocol through breath-by-breath analysis using an open spirometric system (Oxycon Pro, Jaeger, Hoechburg, Germany). The gas analyser was calibrated prior to each trial using oxygen and carbon dioxide gases of known concentrations (Cryoservice, Worcester, UK), and the turbine volume transducer was calibrated using a 3 L precision syringe (Hans Rudolph Inc, Shawnee, USA). During the trials participants breathed room air through a facemask (Hans Rudolph, Kansas City, MO, USA) that was secured in place by a head-cap assembly (Hans Rudolph, Kansas City, MO, USA).. The time to exhaustion in the incremental treadmill test was noted as the treadmill test performance.

Motivation to exercise was assessed using the Exercise Motives Inventory-II (Markland and Ingledew 1997), which has been shown to be a reliable and valid measure of motives for exercising in a range of population samples, including older adults (Dacey et al. 2008). The inventory has 51 questions examining exercise motives across 14 subscales: Affiliation, Appearance, Challenge, Competition, Enjoyment, Health Pressures, Ill-Health Avoidance, Nimbleness, Positive Health, Revitalisation, Social Recognition, Strength and Endurance, Stress Management, and Weight

Management. Each sub-scale comprises of three or four items. Scores for each subscale are calculated from the mean of item scores. Physical self-esteem was assessed using the assessed using the Physical Self-Perception Profile (Fox & Corbin, 1989), which is designed to assess self-perceptions within sub domains of the physical self. These are sport competence, physical condition, body attractiveness and muscular strength and development and a fifth subscale measures overall physical self-worth. Each scale contains six items on a structured alternative scale, offering two opposing statements. The participant is first asked which of two statements best describes them and then decides whether it is really true or somewhat true of them. The item score can range from 1 (low) to 4 (high).

Statistical analysis

All statistical analyses were conducted using Predictive Analytics Software Statistics (Version 22; SPSS: IBM Company, New York, NY) software. Repeated measures ANOVAs were used to assess any differences for pre and post measurements. The respective significant interactions were followed-up using *post hoc* tests with Bonferroni adjustments for multiple comparisons. A significance level of $p<0.05$ was set.

Results

Resting blood pressure, heart rate and blood lipid profile

The results for blood pressure, resting heart rate and blood lipid profile are shown in Table 1. Following 8 weeks, mean arterial pressure and systolic blood pressure were lowered in badminton and running group, but not in the control group. Diastolic blood pressure was reduced in the badminton and running group, respectively, but unaltered in the control group. Resting HR was lower in both badminton and running groups but was unaltered in the control group. Total cholesterol, HDL, LDL, HDL:LDL ratio and triglycerides were unaltered across all three groups during the 8 week intervention.

Physiological responses to submaximal and maximal exercise.

The physiological responses to submaximal walking and running are shown in Table 2. Briefly, HR during walking at 6 km/h was lower after 8 weeks of training in both badminton and running groups. No changes were found in the control group. In the badminton group, HR during running at 8.0 km/h was lower after 8 weeks than before training. In the running group, heart rate during running at 8 km/h was lowered during the same time period, with no changes observed in the control group. Following 8 weeks, blood lactate during walking was unchanged in all three conditions. However in the badminton group, blood lactate whilst running at 8 km/h, was lower than before the training period. In the running group, blood lactate was lower following 8 weeks of training, with no change observed in the control group. Peak blood lactate after the incremental test was 8.3 ± 2.2, 7.2 ± 1.8 and 8.5 ± 1.7 mmol/L in the badminton, running and control groups, respectively and did not change in any of the groups following the 8 week intervention. Oxygen uptake during 6 km/h walking and 8.0 km/h running was unchanged in badminton, running and control groups after the 8 week intervention.

Table 1. Resting blood pressure, heart rate and blood lipid profile of untrained women, before and after 8 weeks of badminton training (BG), running training (RG) or inactive control (CO).

	BG			RG			CO		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Resting Heart Rate (bpm)	75 ± 11	67 ± 9	↓	74 ± 9	66 ± 8	↓	72 ± 9	72 ± 11	↔
Systolic Blood Pressure (mmHg)	120 ± 13	112 ± 9	↓	119 ± 13	115 ± 12	↓	122 ± 8	123 ± 9	↔
Diastolic Blood Pressure (mmHg)	75 ± 8	69 ± 8	↓	75 ± 11	71 ± 10	↓	77 ± 6	78 ± 5	↔
Mean Arterial Pressure (mmHg)	89 ± 9	82 ± 8	↓	89 ± 11	84 ± 10	↓	91 ± 5	92 ± 6	↔
Total Cholesterol (mmol /L)	4.51 ± 0.26	4.41 ± 0.23	↔	4.36 ± 0.32	4.30 ± 0.42	↔	4.47 ± 0.50	4.46 ± 0.46	↔
HDL Cholesterol (mmol/L)	1.56 ± 0.08	1.58 ± 0.08	↔	1.55 ± 0.10	1.57 ± 0.09	↔	1.54 ± 0.10	1.55 ± 0.12	↔
LDL Cholesterol (mmol/L)	2.42 ± 0.30	2.31 ± 0.29	↔	2.34 ± 0.33	2.26 ± 0.47	↔	2.42 ± 0.47	2.41 ± 0.43	↔
LDL:HDL ratio	1.56 ± 0.22	1.47 ± 0.22	↔	1.52 ± 0.25	1.45 ± 0.36	↔	1.58 ± 0.34	1.57 ± 0.35	↔
Triglycerides (mmol/L)	1.17 ± 0.16	1.14 ± 0.20	↔	1.04 ± 0.12	1.01 ± 0.13	↔	1.11 ± 0.24	1.09 ± 0.22	↔

↓ denotes significant decrease from pre values. ↔ denotes no change over the 8 week intervention.

Table 2. Physiological responses of untrained women to submaximal walking at 6 km/h and running at 8 km/h, before and after 8 weeks of badminton training (BG), running training (RG) or inactive control (CO).

	BG			**RG**			**CO**		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Oxygen uptake @ 6 km/h (L/min)	1.37 ± 0.33	1.38 ± 0.21	↔	1.34 ± 0.20	1.33 ± 0.17	↔	1.64 ± 0.29	1.52 ± 0.31	↔
Oxygen uptake @ 8 km/h (L/min)	1.95 ± 0.45	2.10 ± 0.26	↔	2.01 ± 0.36	2.09 ± 0.23	↔	2.08 ± 0.32	2.01 ± 0.40	↔
Heart rate @ 6km/h (bpm)	139 ± 18	129 ± 13	↓	130 ± 12	117 ± 12	↓	151 ± 21	144 ± 23	↔
Heart rate @ 8 km/h (bpm)	176 ± 13	162 ± 12	↓	170 ± 8	153 ± 10	↓	175 ± 16	174 ± 15	↔
Blood lactate @ 6 km/h (mmol/L)	1.72 ± 0.87	1.38 ± 0.98	↔	1.13 ± 0.52	0.99 ± 0.33	↔	2.98 ± 2.12	2.35 ± 1.61	↔
Blood Lactate @ 8 km/h (mmol/L)	4.65 ± 2.33	3.08 ± 1.78	↓	3.60 ± 1.49	2.47 ± 1.38	↓	4.93 ± 2.04	4.80 ± 2.80	↔

↓ denotes significant decrease from pre values. ↔ denotes no change over the 8 week intervention.

In the badminton group, VO_{2max} was 16% higher after 8 weeks, with corresponding increases in the running group of 14%. No change in VO_{2max} was observed for the control group (Figure 1). As shown in Figure 2, time to exhaustion in the incremental treadmill test was 19% longer after 8 weeks of badminton training. In the running group, time to exhaustion was increased by 19% with no change observed in the control group.

In the badminton group, maximal power output was increased after 8 weeks but was unchanged in both the running and control groups (Figure 3).

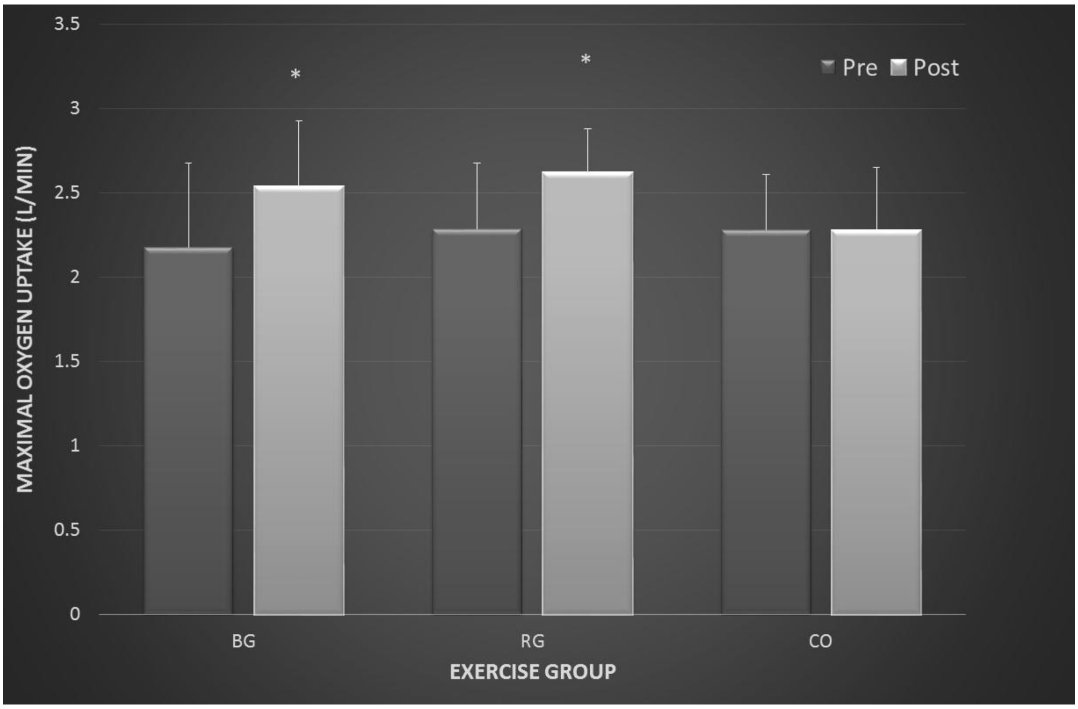

Figure 1. Maximal Oxygen Uptake (VO_{2max}) of untrained women to before and after 8 weeks of badminton training (BG), running training (RG) or inactive control (CO). * denotes significant increase from pre values.

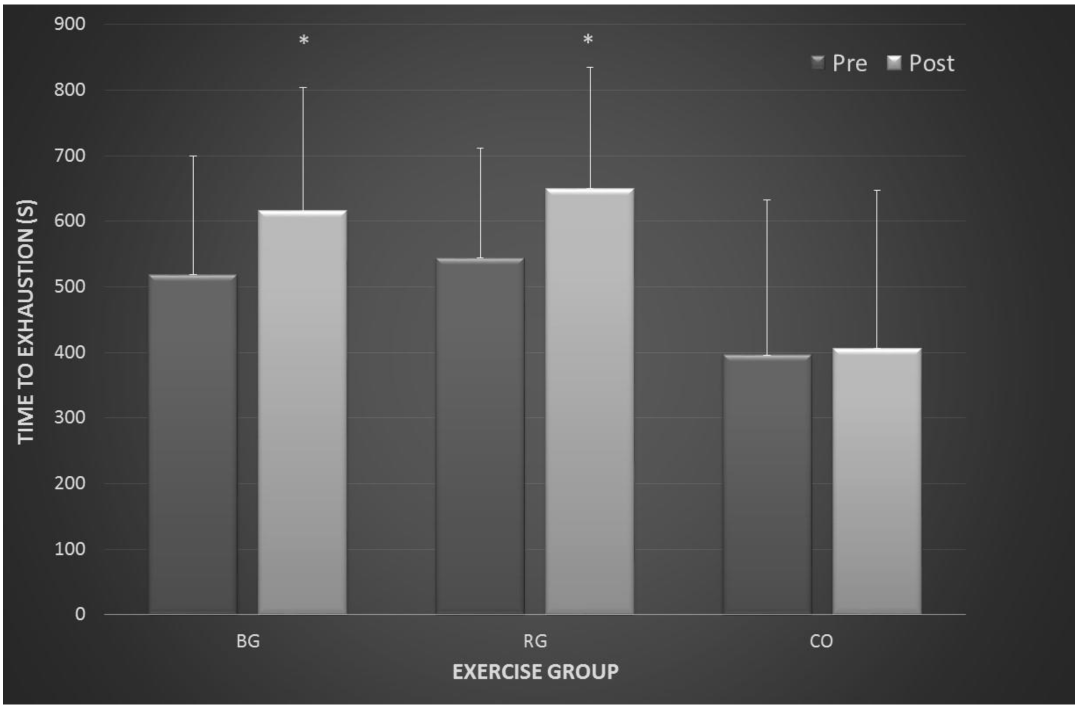

Figure 2. Time to exhaustion of untrained women, during incremental treadmill running test, before and after 8 weeks of badminton training (BG), running training (RG) or inactive control (CO). * denotes significant increase from pre values.

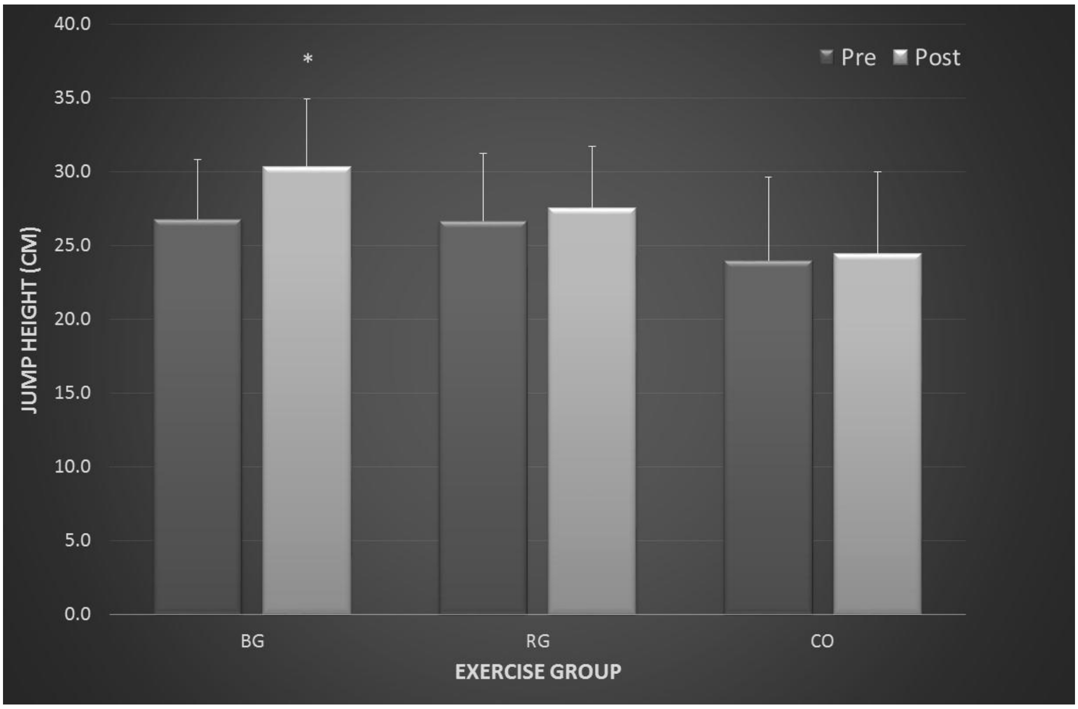

Figure 3. Maximal power output measured via vertical jump height of untrained women before and after 8 weeks of badminton training (BG), running training (RG) or inactive control (CO). * denotes significant increase from pre values.

Body Composition

The body composition changes to 8 weeks of exercise are shown in Table 3. Mass, BMI, BF%, fat free mass and WHR were unchanged in all three groups across the 8 weeks intervention. Arm circumference was unchanged in both the badminton and running groups but was significantly reduced in the control group. Flexed and tensed arm circumference was unchanged in the running and control group but was increased in the badminton group. There were no other changes, over the 8 week intervention, for waist circumference, hip circumference, thing circumference and calf circumference in all three groups.

Table 3. Body composition and anthropometric measures in untrained women, before and after 8 weeks of badminton training (BG), running training (RG) or inactive control (CO).

	BG			**RG**			**CO**		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Mass (kg)	66.1 ± 12.1	66.3 ± 11.2	↔	67.7 ± 9.4	67.9 ± 9.1	↔	74.5 ± 11.9	74.4 ± 12.2	↔
BMI ($kg.m^{-2}$)	23.8 ± 3.6	24.0 ± 3.3	↔	23.9 ± 3.4	23.8 ± 3.5	↔	28.0 ± 4.6	27.9 ± 4.7	↔
BF %	32.7 ± 9.2	31.3 ± 8.6	↔	30.9 ± 8.7	29.0 ± 8.6	↔	40.0 ± 6.5	39.5 ± 6.8	↔
Fat free mass (kg)	43.6 ± 3.2	44.8 ± 3.4	↔	46.1 ± 2.9	47.5 ± 3.0	↔	44.1 ± 4.2	44.4 ± 4.3	↔
WHR	0.76 ± 0.05	0.76 ± 0.05	↔	0.75 ± 0.04	0.75 ± 0.04	↔	0.82 ± 0.10	0.82 ± 0.09	↔
Relaxed Arm Circumference (cm)	29.2 ± 2.5	29.5 ± 2.3	↔	29.6 ± 3.1	29.5 ± 2.8	↔	32.1 ± 2.5	31.7 ± 2.6	↓
Flexed arm circumference (cm)	29.0 ± 2.1	29.4 ± 1.9	↑	29.3 ± 2.5	29.4 ± 2.6	↔	31.3 ± 2.7	31.1 ± 2.7	↔
Waist Circumference (cm)	77.2 ± 8.4	76.9 ± 7.7	↔	77.0 ± 7.4	76.6 ± 7.1	↔	87.6 ± 11.9	87.0 ± 11.7	↔
Hip Circumference (cm)	101.3 ± 9.6	101.5 ± 8.6	↔	102.5 ± 6.7	101.4 ± 7.0	↔	106.8 ± 9.5	106.5 ± 9.4	↔
Thigh circumference (cm)	52.2 ± 5.3	51.8 ± 4.6	↔	53.0 ± 4.3	52.7 ± 4.2	↔	55.6 ± 5.2	55.2 ± 5.0	↔
Calf Circumference (cm)	37.1 ± 2.7	37.8 ± 3.6	↔	37.4 ± 2.6	38.2 ± 2.5	↔	39.2 ± 5.1	38.4 ± 3.5	↔

↓ denotes significant decrease from pre values. ↑ denotes significant increase from pre values. ↔ denotes no change over the 8 week intervention.

Psychological Wellbeing

There was an increase in the sport construct as demonstrated by higher post scores than pre across all groups. A significant increase was present for conditioning in both the badminton and running groups but there was no change over the 8 week intervention for the control group. There was no change in the stress management construct across all three groups. A significant increase in the revitilisation construct was demonstrated across all three groups as evidenced by the higher post scores compared to the pre intervention values. The enjoyment construct was higher in the running group following 8 weeks exercise compared to no change in both the badminton and control groups. Affiliation was higher for the badminton group with an increase demonstrated over the 8 week intervention, with no changes observed in both the running and control groups. The health avoidance construct was improved in the running group only with no changes observed for the badminton or control groups.

Discussion

The main finding of the current study was that 8 weeks of recreational badminton in untrained females resulted in marked increases of maximal oxygen uptake, TTE in an endurance exercise test, vertical jump height, and favorable reductions in heart rate and blood lactate during walking and running exercise. Furthermore reductions in resting heart rate, systolic and diastolic blood pressure and mean arterial pressure were all observed in the badminton group. Similar adaptations were demonstrated in the running group, except the changes in vertical jump height, whilst no changes were observed in the control group demonstrating the effectiveness of the interventions.

Following 8 weeks of badminton training, heart rate was reduced on average by 10-15 bpm during submaximal walking and running, indicating a large improvement in aerobic fitness. This is further evidenced by the 16% improvement in maximal aerobic capacity, this, despite the fact that 11/13 (85%) of the women had no previous experience of playing badminton. These adaptations in aerobic fitness compare favorably to other sporting interventions in females, despite the shorter 8 week time frame. HR was found to decrease by 10 - 20 bpm during walking and jogging at after 16 weeks of twice-weekly 1-h soccer sessions for untrained females in conjunction with an increased maximal oxygen uptake of 15% (Bangsbo et al., 2010; Krustrup et al., 2010) and HR decreased by 7 bpm during submaximal cycling exercise after 12 weeks of twice-weekly 1-h soccer sessions for female hospital employees, who also had a 5% increase in maximal oxygen uptake over the course of training (Barene et al., 2014). Further evidence for improved aerobic fitness is seen in the 19% improvement in TTE test following the badminton group training. Thus despite the training program consisting of badminton play, individuals were able to increase the time they spent running during a treadmill test. Similar improvements in aerobic fitness were demonstrated in the running group but no changes were seen in the control group across the 8 week intervention.

For the badminton group, systolic and diastolic blood pressure were lowered by 8 and 6 mmHg, with decreases observed in 12 of 13 participants. The favourable effects observed for blood pressure were also similar to the changes observed in other studies involving sport (mainly soccer), in individuals with mild-to-moderate hypertension showing decreases of 12/6, 12/8 and 8/8 after 3 - 4 months of training (Andersen et al., 2010; Knoepfli-Lenzin et al., 2010; Mohr et al., 2014). This underlines the notion that intermittent sports such as badminton efficiently lowers blood pressure. For the running group, systolic blood pressure decreased by 5mmHg and diastolic blood pressure reduced by 5mmHg, which is similar in magnitude to previously observed aerobic training interventions for women (average reductions of 5 and 3 mmHg, respectively) (Cornelissen & Fagard, 2005; Kelley & Kelley, 1999) The lowered blood pressure was associated with a reduction of 8 bpm in resting HR both in badminton and running groups, which may reflect a training induced reduction of resting sympathetic outflow. Mechanisms behind the change in blood pressure in the current study have not been elucidated and further studies are needed to evaluate whether it is the dynamic nature of badminton which is associated with the positive impact on blood pressure. However this study does demonstrate that even in normotensive individual's badminton is a useful intervention to reduce blood pressure and may be a useful tool to reduce blood pressure in hypertensive groups.

Alongside aerobic and cardiovascular changes, badminton had a positive effect on power development over the training period. There was a 13% increase in jump height (Figure 3) of the badminton group with no changes observed in either the running or control group. The intermittent nature of badminton means that players are required to move quickly, with multiple changes of direction throughout a rally, involving lunges and jumping. These movements place a large demand on the neuromuscular system and bones / joints, similar to specific plyometric training and thus may explain the increase in jump height / power output in comparison to the running group. From a health perspective the ability to produce force becomes very important as we age. Along with a decrease in strength seen with ageing, explosive power has also been shown to decrease initially after 40 years of age (Metter et al., 1997) and occurs across both genders. Skelton et al. (1994) demonstrated strength declined at a rate of 1-2% per year, whereas leg muscle power declined at a rate of approximately 3.5% per year, with similar decrements across genders. This suggests a greater more rapid decline in power when compared to strength. Metter et al. (1997) demonstrated a similar power decline, at a rate 10% greater than strength losses, from the 4th decade onwards. This loss of power has been shown to have an impact on functional capabilities such as stair climbing, rising from a chair and walking (Bassey et al., 1992; Suzuki et al., 2001) whilst lower levels of strength may be associated with functional limitations in normal daily activities, as well as the risk of falling (Wolfson et al. 1995), hip fractures (Langlois et al., 1998) and maximal and habitual gait velocities (Suzuki et al., 2001). Therefore badminton may play an important role in preventing loss of power and strength as we age.

The findings indicated that both the badminton and running programmes were effective at increasing participants' perceptions of their physical condition when compared to the participants in the control group. This suggests that the two exercise programmes helped increase participants' perceptions of their ability to maintain exercise and confidence in an exercise and fitness setting, perceptions of their physical condition, stamina and fitness. This is backed up by the actual changes observed in physical fitness such as increased maximal oxygen uptake, TTE and the decreased effort in the running and walking trials, as demonstrated by reduced heart rate and blood lactate during submaximal exercise. Overall the physical self-perceptions of the participants increased in both the badminton and running programmes over the 8 week programmes with a significant increase in perceptions of sport competence. These findings provide partial evidence that both running and badminton are effective at enhancing physical self-esteem and confidence in exercise and fitness settings, which in turn could increase future motivation and adherence to exercise.

The badminton programme was effective at increasing participants' social engagement motives to exercise when compared with both the running group and the control group. This suggests that participants in the badminton programme increased their motivation to exercise to spend time with friends, they enjoyed the social aspects of playing badminton, had fun being active with friends and making new friends. This provides partial evidence that badminton can increase individual's social engagement motives to exercise and social engagement could be considered as a potential reason for people to join badminton groups, particularly for females. This has been shown in previous research on motives to exercise in adults (Allender et al., 2006) who concluded that enjoyment and social networks offered by sport and physical activity are clearly important motivators for many different groups of people aged between 18 and 50 years. Participating in exercise for social reasons is considered an intrinsic motive and is associated with better long-term adherence and behaviour change. It is also worth noting that there were increases across the 8 week programme in all of the 14 reasons to exercise that were assessed, indicating that their overall motivation to exercise increased as a result of both the badminton and running programmes.

In conclusion, this study has shown for the first time that regular recreational badminton training can improve a range of health markers in sedentary females and to a similar extent as running training over an 8 week intervention. Recreational badminton led to large aerobic adaptations such as increased maximal oxygen uptake, TTE in an endurance exercise test and favorable reductions in heart rate and blood lactate during walking and running exercise. Furthermore reductions in resting heart rate, systolic and diastolic blood pressure and mean arterial pressure were all observed in the badminton group. Alongside this an increase in vertical jump height was observed showing the possible use of badminton to increase strength and power. This evidence should encourage BWF and other organizations to promote the health improvements that are possible with sports such as badminton due to their fun and interactive nature. Future research should focus on similar interventions in other population groups such as children and older adults as well as those with current medical conditions.

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