The impact of Badminton on health markers in untrained females.

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Abstract

The purpose of the study was to examine the health effects of 8 weeks of recreational badminton in untrained women. Participants were matched for maximal oxygen uptake ($\dot{V}O_{2max}$) and body fat percentage and assigned to either a badminton (n = 14), running (n = 14) or control group (n = 8). Assessments were conducted pre- and post-intervention with physiological, anthropometric, motivation to exercise and physical self-esteem data collected. Post-intervention, $\dot{V}O_{2max}$ increased ($P < 0.05$) by 16% and 14% in the badminton and running groups, respectively, and time to exhaustion increased ($P < 0.05$) by 19% for both interventions. Maximal power output was increased ($P < 0.05$) by 13% in the badminton group only. Blood pressure, resting heart rate and heart rate during submaximal running were lower ($P < 0.05$) in both interventions. Perceptions of physical conditioning increased ($P < 0.05$) in both interventions. There were increases ($P < 0.05$) in enjoyment and ill health motives in the running group only, whilst affiliation motives were higher ($P < 0.05$) for the badminton group only. Findings suggest that badminton should be considered a strategy to improving the health and wellbeing of untrained females who are currently not meeting physical activity guidelines.

Keywords: Racquet Sports, running, exercise motives.

Introduction

Physical inactivity increases the risk of many adverse health conditions and shortens life expectancy (Lee et al., 2012; Scholes et al., 2014). In 2012, 60% of the adult population in England self-reported that they met the government physical activity guidelines of 150 or 75 min of moderate or vigorous exercise per week, respectively. However, when assessed via an objective measure of physical activity (i.e., accelerometer) this number decreased to 6% and 4% for men and women respectively. Clearly problems exist with self-reporting of physical activity levels, but more importantly the large proportion of individuals not meeting the recommended levels of physical activity. Furthermore more focus should be placed on females due to the fact that they are less physically active than males (Talbot, Metter, & Fleg, 2000). It has previously been reported that men have higher activity levels than women in terms of moderate intensity, vigorous intensity as well as total leisure time (Azevedo et al., 2007; Martinez-Gonzalez et al., 2001); therefore effective strategies to target increased physical activity amongst females are warranted.

Most training intervention studies have used endurance training, such as walking, jogging or cycling to improve health markers. 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 and 10 weeks, with the largest reduction in blood pressure associated with the largest decrease in body mass (Cornelissen & Smart, 2013). Endurance exercise has a positive effect on body mass, more importantly, with evidence suggesting a decrease in overall and abdominal body fat levels (Donges, Duffield, & Drinkwater, 2010; Mendham, Duffield, Marino, & Coutts, 2014). With respect to cardiorespiratory fitness, endurance training has been shown to elevate maximal oxygen uptake ($\dot{V}O_{2max}$) by 9-14% in 8 weeks (Mendham et al., 2014; Meredith et al., 1990) and improve blood lipid profiles (Kin Isler, Kosar, & Korkusuz, 2001; Whitehurst & Menendez, 1991). Alongside steady-state exercise, the use of intermittent exercise in the form of sporting activities, such as football, has been demonstrated to enhance aerobic fitness, cardiovascular function, metabolic fitness, adiposity, cardiac adaptation and muscular performance (Krustrup et al., 2009; Mendham et al., 2014; Milanovic, Pantelic, Covic, Sporis, & Krustrup, 2015; Oja et al., 2015).

Despite the known health benefits of physical activity there are numerous barriers to engaging in regular physical activity, particularly for women. The proposed barriers include exercise milieu (e.g., cost of exercise, places to exercise, how people look in exercise clothes), 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 exertion (Lovell, El Ansari, & Parker, 2010), are significant barriers to women's participation in physical activity. In a review of qualitative studies focusing on physical activity participation, Allender, Cowburn, and Foster (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 as they have the potential to include elements of fun, enjoyment and social 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 characterised by actions of short duration and high intensity coupled with short rest periods (Cabello Manrique & Gonzalez-Badillo, 2003). Players are required to move quickly, with multiple changes of direction throughout a rally. It is played in singles or doubles format (Liddle, Murphy, & Bleakley, 1996), with approximately 80% of rallies lasting less than 10 s (Cabello Manrique & Gonzalez-Badillo, 2003). Due to the intermittent nature, high demands are placed on both the aerobic and anaerobic systems during play and recovery, equating to 60-70% and 30% of the energy demands respectively (Phomsoupha & Laffaye, 2015).

Alongside the high frequency and intensity of play during a match, maximum and average heart rate (HR) indicates that badminton demands a high percentage of individual aerobic power (Cabello Manrique & Gonzalez-Badillo, 2003; Faude et al., 2007). Average HR in both males and females is over 90 % of the HR_{max} (Cabello Manrique & Gonzalez-Badillo, 2003; Faude et al., 2007), or 170–180 beats.min^{-1} (Chin et al., 1995), with these values linked to the skill level of 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 focused on the determinants of elite badminton performance or the physiological characteristics of elite players and little is known regarding the physiological responses and adaptions in untrained recreational players. However due to the obvious high physiological demands of the game and the high numbers of players worldwide, participating in badminton could help improve health characteristics in untrained women. To date the only research assessing physiological responses to badminton play in recreational players suggests that it can be categorised as vigorous intensity exercise and thus may provide similar physiological demands as those observed in elite players (Deka, Berg, Harder, Batelaan, & McGrath, 2016).

Thus the purpose of the study was to examine the effect of regular participation in recreational badminton in untrained women throughout an 8-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 (Range: 19 – 45 years) with a body mass, height, fat percentage, body mass index (BMI) and $\dot{V}O_{2max}$ of 68.7 ± 11.3 kg, 1.66 ± 0.05 m, 33.8% ± 8.9%, 24.9 ± 4.1 $kg.m^{-2}$ and 32.6 ± 6.2 $mL.min^{-1}.kg^{-1}$, respectively, volunteered to take part in this study. Participants were not taking any medications, were non-smokers and were not currently meeting the recommended exercise guidelines. All participants provided written consent and full institutional ethical approval was obtained.

Design

Participants were matched for $\dot{V}O_{2max}$ and body fat percentage and randomly assigned to a badminton (n = 14), running (n = 14) or control group performing no physical training (n = 8). One individual in the badminton group and two in the running group withdrew from the study due to illness or a minor injury occurring during training. For the participants that completed the study (Badminton group n = 13; Running group, n = 12; Control group, n = 8) no group differences were present in pre-intervention values for body fat percentage and $\dot{V}O_{2max}$. Laboratory assessments were conducted prior to and following an 8-week period of badminton or running training sessions or habitual activity (control group) and 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 was carried out for 1 h three times a week. The badminton group training was performed in indoor badminton courts and 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 10 min warm up consisting of jogging and dynamic stretching. One session per week was focused towards learning skills and shots, whilst two sessions per week were dedicated to matches. The sessions consisted of three blocks of 15 minutes, whereby the participants were either taught and practised specific badminton shots on a progressive basis or where they played a match for 15 min before rotating to play against other members of the group. All sessions were taken by a fully qualified badminton coach. The endurance running sessions consisted of endurance running of a moderate intensity (75% maximum HR) within and around the grounds of St Marys University. Each session started with a 10 min low-intensity warm up consisting of jogging and dynamic stretches. HR was determined during all training sessions.

Measurements and Test Procedures

Physiological Measures

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 min. Total cholesterol, high-density lipoprotein (HDL) and triglyceride were analysed by a semi-automated clinical chemistry analyser (Randox Monza UK). Low-density lipoprotein (LDL) was calculated using a calculation previously described (Friedewald, Levy, & Fredrickson, 1972). Blood glucose was also analysed from a capillary puncture sample using the Biosen C-Line analyser (EKF diagnostic, Ebendorfer Chaussee 3, Germany).

Participants rested in a supine position for 15 min before systolic and diastolic blood pressures were measured using a digital sphygmomanometer on the upper arm (Omron M5, Omron Healthcare, Europe B.V., the 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.

Pulmonary gas exchange, HR and capillary blood sampling were performed during a standardised treadmill test with 6 min bout of walking at 6 $km.h^{-1}$ and a 4 min bout of submaximal running at 8 km.h^{-1}, interspersed with 2 min rest periods. For participants who had RER values below 0.90 and HRs below 80% of maximal HR at the end exercise at 8 km.h^{-1}, another 4 min running bout was performed at 9 km.h^{-1}. 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), calibrated prior to each trial using oxygen and carbon dioxide gases of known concentrations (Cryoservice, Worcester, UK) and via a 3 L precision syringe (Hans Rudolph Inc, Shawnee, USA). During the trials participants breathed room air through a facemask that was secured in place by a head-cap assembly (Hans Rudolph Inc, Shawnee, USA). The total time to exhaustion (TTE) in the incremental treadmill test was noted as the treadmill test performance.

Vertical jump height was assessed using a countermovement jump (CMJ) via two Pasco force platforms (PS 2142 Roseville, CA, USA), measuring 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) and jump height was calculated from flight time (Linthorne, 2001). Participants performed a CMJ with hand on their hips and were instructed to jump as high as possible and avoiding bending their knees whilst airborne. Each jump was initiated by lowering into a quarter squat followed immediately by an explosive concentric contraction. Each participant repeated the test for a total of three trials, with 1 min recovery between jumps. The best jump height was taken for analysis.

Anthropometric measures

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. Participants’ body fat percentage (BF%) was then assessed via air-displacement plethysmography (ADP) using a BODPOD (Life Measurement Instruments, Concord, Ca, USA), calibrated according to manufacturer's instructions using a cylinder of known volume (50L). Test-retest reliability for BF% measured using ADP has been reported to have a technical error of 0.75% and coefficient of variation of 3.4% (Vescovi et al., 2001) , and has been used to assess body composition changes in previous training studies (Davitt, Pellegrino, Schanzer, Tjionas, & Arent, 2014; Willis et al., 2012). For all measurements, participants wore a tight-fitting swimsuit, a bathing cap and removed all jewellery. Prediction equations based on gender, age and height were used to estimate thoracic lung volume (Wagner, Heyward, & Gibson, 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. Additionally, the following girth measures were obtained in accordance with International Society for the Advancement of Kinanthropometry (ISAK) guidelines (Marfell-Jones et al., 2006) by an ISAK level 3 anthropometrist using a flexible steel tape (Lufkin W606PM); arm (relaxed), arm (flexed and tensed), waist (minimum), gluteal (maximum), thigh (mid) and calf (maximum). High intra-tester reliability for girth measurements was shown with the anthropometrist producing technical error of measurement for repeated measurements of < 1%. BMI ($kg.m^{-2}$) and waist to hip ratio (WHR; waist girth/gluteal girth) were calculated.

Motivation to exercise and self-esteem measures

Motivation to exercise was assessed using the Exercise Motives Inventory-II (EMI-2;Markland & Ingledew 1997), which has been shown to be a reliable and valid measure of motives for exercising in a range of population samples, including female adults (Dacey, Baltzell, & Zaichkowsky, 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. Physical self-esteem was assessed using the Physical Self-

Perception Profile (PSPP), which is designed to assess self-perceptions within the sub domains of the physical self (Fox & Corbin, 1989). These are Sport Competence, Physical Condition, Body Attractiveness, Strength Competence 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,USA) software. Repeated-measures analysis of variances (time x group) were used to assess any differences between the exercise conditions. Significant interactions were followed up using post hoc tests with Bonferroni adjustments for multiple comparisons. A significance level of $P < 0.05$ was set. Partial η^2 was used to assess the size of effect for any interactions.

Results

The training adherence was 2.6 ± 0.2 and 2.7 ± 0.3 sessions per week for the badminton and running groups, 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 HR of 73% ± 7% and 77% ± 6% maximal HR for the first and second half of the intervention, respectively. Time spent per session in the HR zones 70–79%, 80–89%, and > 90%HR_{max} was 34.8% ± 6.8%, 28.4% ± 7.8%, and 13.0% ± 3.4% of the training time. In the running group, the running speed was individually adjusted to elicit the same average HR as for badminton group (75% ± 3% of maximal HR). Time spent per session in the HR zones 70–79%, 80–89%, and > 90%HR_{max} was 73.8% ± 3.5%, 14.6% ± 4.8% and 0.6% ± 0.3% of the training time.

Physiological Measures

The results for blood pressure, resting HR and blood lipid profile are shown in Table 1. There was a group x time interaction for mean arterial pressure ($P < 0.05$; partial $\eta^2 = 0.25$), systolic ($P < 0.05$; partial $\eta^2 = 0.20$) and diastolic blood pressure ($P < 0.05$; partial $\eta^2 = 0.21$). Post hoc tests revealed mean arterial pressure, systolic and diastolic blood pressure were reduced in the badminton and running groups ($P < 0.05$; table 1), with no change observed in the control group. There was a significant time x group interaction for resting HR ($P < 0.05$; partial $\eta^2 = 0.22$) with post hoc tests revealing a decrease in both badminton and running groups ($P < 0.05$) with no change observed in the control group. Total cholesterol, HDL, LDL, HDL:LDL ratio and triglycerides were unaltered across all three groups during the 8-week intervention.

There was a significant group x time interaction for $\dot{V}O_{2max}$ ($P < 0.05$; partial $\eta^2 = 0.205$), with post hoc analysis revealing a 14% and 16% increase ($P < 0.05$) for the running and badminton groups, respectively. No change in $\dot{V}O_{2max}$ was observed for the control group (Figure 1). As shown in Figure 2, there was a significant group x time interaction for TTE ($P < 0.05$; partial $\eta^2 = 0.305$), with post hoc analysis revealing a 19% increase ($P < 0.05$) in both the badminton and running groups, with no change observed in the control condition. Oxygen uptake was unchanged during submaximal exercise at 6 and 8 km.h^{-1} in all groups following the 8-week intervention. There was a group x time interaction for HR during submaximal exercise at 6 ($P < 0.05$; partial $\eta^2 = 0.191$) and 8 km.h^{-1} ($P < 0.05$; partial $\eta^2 = 0.492$). Post hoc tests revealed HR was reduced in the badminton and running groups ($P < 0.05$; table 1) during exercise at these speeds with no change observed in the control group. Following the eight week intervention, the blood lactate response during exercise at 6km/h was unchanged across all three groups. However, there was a group x time interaction for blood lactate during exercise at 8 km.h^{-1} ($P < 0.05$; partial $\eta^2 = 0.201$), with post hoc analysis revealing that blood lactate was lower ($P < 0.05$; table 1) in the badminton and running groups only following the 8-week intervention. There was a significant group x time interaction for jump height

(P < 0.05; partial $\eta^2 = 0.407$), with post hoc analysis revealing an increase (*P* < 0.05) in jump height for the badminton group only (Figure 3).

Anthropometric measures

Pre- and post-anthropometric measures are presented in Table 2. There were no significant group x time interaction effects for body mass, BMI, BF%, fat free mass, WHR, waist, hip, thigh and calf circumference. There was a significant group x time interaction for relaxed arm circumference ($P < 0.05$; partial $\eta^2 = 0.288$) with post hoc analysis indicating a decrease ($P < 0.05$) in the control group only. There was a significant group x time interaction for flexed and tensed arm circumference ($P < 0.05$; partial $\eta^2 = 0.359$). Following adjustments for multiple post hoc comparisons no significant differences were revealed.

Motivation to exercise and self-esteem

When examining EMI-2 scores, a group x time interaction ($P < 0.05$; partial $\eta^2 = 0.189$) was present for stress management. Post hoc tests were unable to identify any further significant differences. There was a significant group x time interaction ($P < 0.05$; partial $\eta^2 = 0.188$) for enjoyment motives for the running group ($P < 0.05$), with an increase in post scores observed. There were no differences for the control and badminton groups. For the affiliation motive there was a significant group x time interaction ($P < 0.05$; partial $\eta^2 = 0.278$) for the badminton group ($P < 0.05$), with an increase in post scores. There was a significant group x time interaction ($P < 0.05$; partial $\eta^2 = 0.195$) for ill health avoidance motive, with the post hoc analysis showing a significant increase ($P < 0.05$) in post scores for the running group only. No significant group x time interactions were observed for the appearance, challenge, competition, health pressure, nimbleness, positive health, revitalisation, social recognition, strength and endurance and weight management motives.

Changes in physical self-perceptions during the 8-week intervention are shown in Table 3. There was a significant group x time interaction for Physical Condition ($P < 0.05$; partial $\eta^2 = 0.331$). The post hoc tests revealed the control group had no change in their pre and post scores yet both the running and badminton groups demonstrated significantly higher post scores when compared to their pre scores ($P < 0.05$). There were no significant group x time interaction effects for Sport Competence, Body Attractiveness, Strength Competence and Physical Self-Worth

Discussion

The main finding of the current study was that eight weeks of recreational badminton in untrained females resulted in marked increases of $\dot{V}O_{2max}$, TTE in an endurance exercise test, vertical jump height, and favourable reductions in HR and blood lactate during walking and running exercise. Furthermore reductions in resting HR, 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, HR was reduced by 10-15 bpm during submaximal walking and running, indicating large improvements in aerobic fitness. The intensity of the badminton training session was 75% of maximal HR which is lower than those reported during recreational soccer (80-84% of maximal HR) in similarly untrained females (Bangsbo et al., 2010; Krustrup et al., 2010) and lower (89% of maximal HR) than the values observed during elite badminton match play (Faude et al., 2007) . However, this intensity of exercise resulted in a 16% improvement in $\dot{V}O_{2max}$ despite the fact that 11/13 (85%) of the women had no previous experience of playing badminton. These adaptations compare favourably to other sporting interventions in females despite the shorter 8-week time frame. HR decreased by 10 - 20 bpm during walking and jogging after 16 weeks of twice-weekly 1 h soccer sessions for untrained females in conjunction with an increased $\dot{V}O_{2max}$ 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 $\dot{V}O_{2max}$ over the course of training

(Barene, Krustrup, Jackman, Brekke, & Holtermann, 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 programme consisting of badminton play, the participants were able to increase the time they spent running during a running test. Similar improvements in aerobic fitness were demonstrated in the running group but no changes were observed in the control group across the 8-week intervention.

For the badminton group, systolic and diastolic blood pressures were lowered by 8 and 6 mmHg respectively, 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 following 3-4 months of training (Andersen et al., 2010; Knoepfli-Lenzin et al., 2010; Mohr et al., 2014), suggesting that intermittent sports such as badminton may be effective in lowering blood pressure. For the running group, systolic blood pressure decreased by 5 mmHg and diastolic blood pressure reduced by 5mmHg, which is similar in magnitude to previously observed aerobic training interventions for women (Cornelissen & Fagard, 2005; 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.

Alongside aerobic and cardiovascular changes, badminton had a positive effect on jump height over the training period. There was a 13% increase in jump height 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, mainly lunging and jumping. Lunging allows players to rapidly stop, form a secure base from which to play the necessary shot and move back into the court to prepare for the next movement and accounts for 18% of all actions during a game (Kuntze, Mansfield, & Sellers, 2010). A ‘smash’ consists of an aggressive overhead shot with a downward trajectory and usually involves a jump and landing and has been reported to account for 29% of all shots played (Abian et al., 2013). 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 in comparison to the running group. The results in this study compare favourably to previous research which has demonstrated that exercise involving repeated changes of direction (such as those observed in badminton) can have a positive enhancement in jump height performance (Attene et al., 2015). This is likely as a result of more instances of braking and acceleration which require high muscular forces and are not observed during continuous running (Padulo et al., 2013). Moreover, peak joint powers of between 8 and 12 $W.kg^{-1}$ have been reported for the hip and knee, respectively during badminton lunging tasks (Kuntze et al., 2010)whereas lower powers have been observed, 2-4 $W.kg^{-1}$ for hip and knee joints, during running (Farris & Sawicki, 2012).

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, and increased perceptions of their physical condition, stamina and fitness. This is further supported by the actual changes observed in physical fitness such as increased $\dot{V}O_{2max}$, TTE and the decreased effort in the running and walking trials, as demonstrated by reduced HR and blood lactate during submaximal exercise.

The badminton programme was effective at increasing participants' social engagement motives (i.e., affiliation) 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 and had fun being active with friends and making new friends. This provides partial evidence that badminton can increase an 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.

In conclusion, this study has shown for the first time that badminton training, carried out on an hourly basis, three times per week, can improve a range of health markers in untrained females and to a similar extent as running training over an 8-week intervention. Recreational badminton led to large aerobic adaptations such as increased $\dot{V}O_{2max}$, TTE in an endurance exercise test and favorable reductions in HR and blood lactate during walking and running exercise. Furthermore reductions in resting HR, 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. Recreational badminton also resulted in increased perceptions of physical condition and affiliation motives. This evidence should encourage organisations to promote the health improvements that are possible with sports such as badminton due to their fun and interactive nature.

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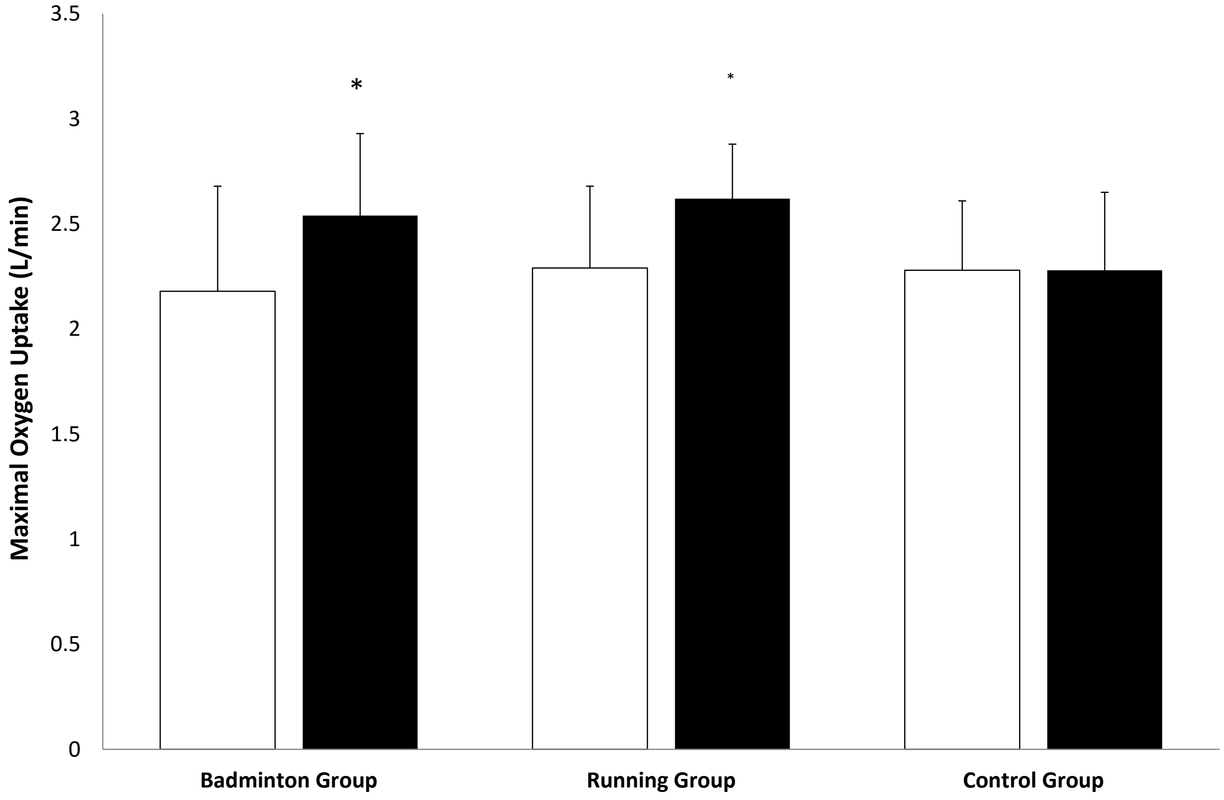

Figure 1. Maximal oxygen uptake ($\dot{V}O_{2max}$) in untrained women before (open bars) and after (solid bars) 8 weeks of badminton, running or control intervention.

*Significant increase from pre values ($P < 0.05$).

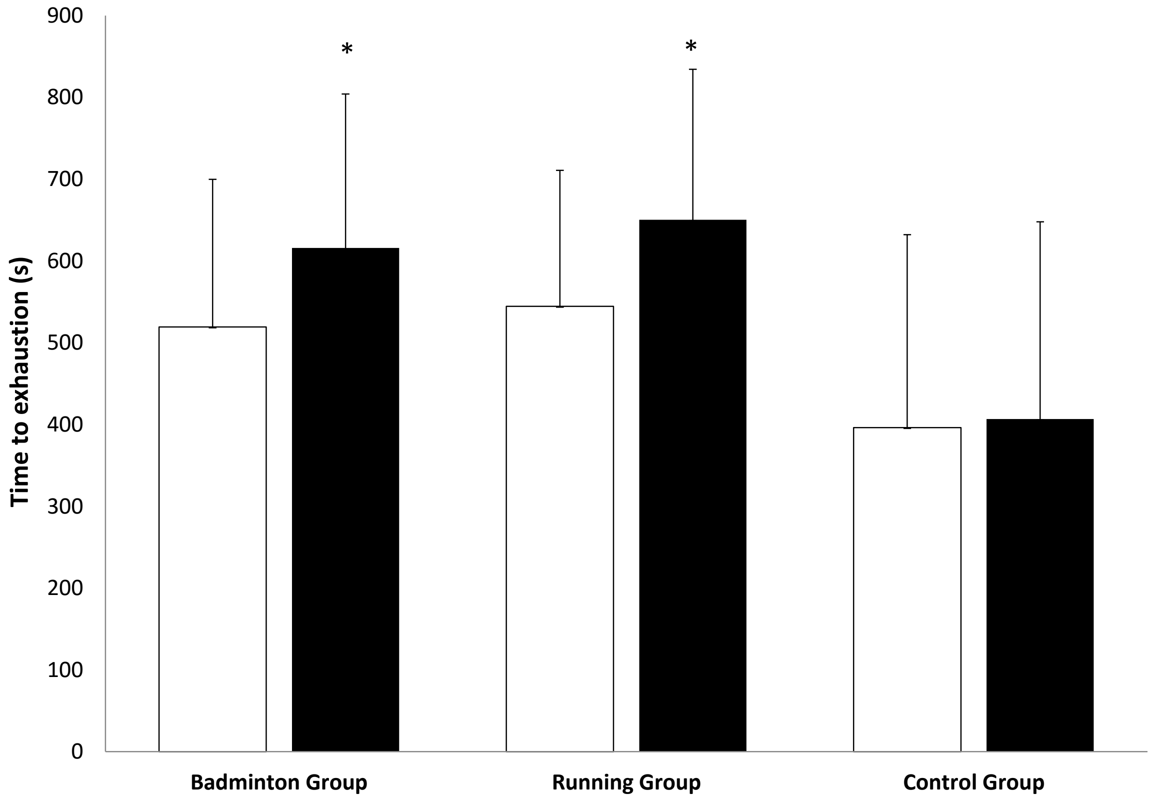

Figure 2. Time to exhaustion in untrained women, during incremental treadmill running test, before (open bars) and after (solid bars) 8 weeks of badminton, running or control intervention.

*Significant increase from pre values ($P < 0.05$)

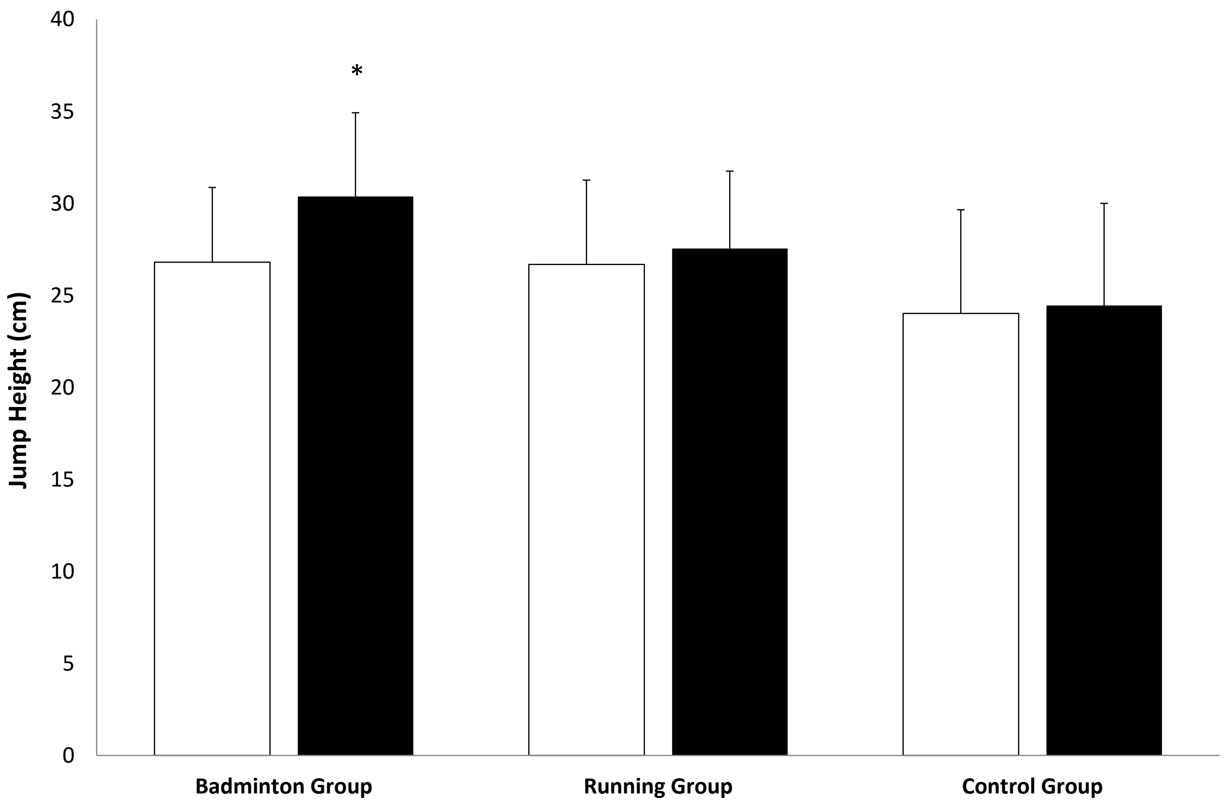

Figure 3. Vertical jump height in untrained women before (open bars) and after (solid bars) 8 weeks of badminton, running or control intervention. *Significant increase from pre values ($P < 0.05$).

Table 1. Physiological measures in untrained women, before and after 8 weeks of badminton, running or control intervention

	Badminton Group		**Running Group**		**Control Group**	
	Pre	Post	Pre	Post	Pre	Post
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^{-1})	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})	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^{-1})	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})	1.17 ± 0.16	1.14 ± 0.20	1.04 ± 0.12	1.01 ± 0.13	1.11 ± 0.24	1.09 ± 0.22
Oxygen uptake @ 6 km.h^{-1} (L.min^{-1})	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^{-1} (L.min^{-1})	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^{-1} (bpm)	139 ± 18	129 ± 13 *	130 ± 12	117 ± 12 *	151 ± 21	144 ± 23
Heart rate @ 8 km.h^{-1} (bpm)	176 ± 13	162 ± 12 *	170 ± 8	153 ± 10 *	175 ± 16	174 ± 15
Blood lactate @ 6 km.h^{-1} (mmol.L^{-1})	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^{-1} (mmol.L^{-1})	4.65 ± 2.33	3.08 ± 1.78 *	3.60 ± 1.49	2.47 ± 1.38 *	4.93 ± 2.04	4.80 ± 2.80

* significant decrease from pre values ($P < 0.05$).

Table 2. Anthropometric measures in untrained women, before and after 8 weeks of badminton, running or control intervention.

	Badminton Group		**Running Group**		**Control Group**	
	Pre	Post	Pre	Post	Pre	Post
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

* significant decrease from pre values ($P < 0.05$).

Table 3. PSPP and EMI-2 construct measures in untrained women, before and after 8 weeks of badminton, running or control intervention

	Badminton Group		**Running Group**		**Control Group**	
	Pre	Post	Pre	Post	Pre	Post
			PSPP			
Max score = 4						
Body	2.03 ± 0.58	1.79 ± 0.61	2.08 ± 0.87	2.10 ± 0.93	2.02 ± 0.66	1.96 ± 0.70
Conditioning	1.75 ± 0.65	2.03 ± 0.48*	1.72 ± 0.30	2.26 ± 0.31*	1.92 ± 0.68	1.90 ± 0.67
PSW	2.13 ± 0.46	1.97 ± 0.44	2.11 ± 0.81	2.19 ± 0.79	2.42 ± 0.56	2.35 ± 0.73
Sport	2.01 ± 0.65	1.99 ± 0.79	2.03 ± 0.37	2.25 ± 0.44	2.06 ± 0.77	2.08 ± 0.85
Strength	2.46 ± 0.63	2.41 ± 0.68	2.24 ± 0.51	2.29 ± 0.62	2.38 ± 0.47	2.38 ± 0.47
			EMI-2			
Max score = 5						
Affiliation	2.23 ± 1.39	3.21 ± 1.24*	1.85 ± 1.25	2.43 ± 1.26	2.00 ± 1.41	1.66 ± 1.37
Appearance	3.00 ± 1.43	3.25 ± 1.07	3.35 ± 1.06	3.64 ± 1.03	2.38 ± 1.12	2.25 ± 1.22
Challenge	2.87 ± 1.08	2.88 ± 0.74	1.94 ± 1.08	2.36 ± 1.40	1.59 ± 1.60	1.44 ± 152
Competition	2.54 ± 1.35	2.69 ± 1.24	1.52 ± 1.26	1.45 ± 1.03	1.63 ± 1.60	1.41 ± 1.63
Enjoyment	2.92 ± 1.01	3.13 ± 0.70	2.19 ± 1.05	3.02 ± 1.19*	2.63 ± 1.58	2.69 ± 1.71
Health Pressures	1.44 ± 1.21	1.31 ± 1.08	0.75 ± 0.63	0.79 ± 0.56	1.71 ± 1.35	1.46 ± 1.44
Ill Health Avoidment	3.21 ± 1.49	3.23 ± 1.15	2.58 ± 1.23	3.36 ± 0.84*	2.06 ± 1.01	2.88 ± 1.13
Nimbleness	3.05 ± 1.58	3.44 ± 0.95	2.61 ± 1.55	3.24 ± 1.45	2.88 ± 0.97	2.75 ± 1.00
Positive Health	3.90 ± 1.16	4.15 ± 0.70	3.61 ± 0.64	4.27 ± 0.49	3.63 ± 0.68	3.42 ± 1.15
Revitilisation	3.23 ± 1.24	3.49 ± 0.90	2.39 ± 0.69	3.15 ± 0.83	2.50 ± 1.05	2.46 ± 1.25
Social Recognition	1.40 ± 1.03	1.56 ± 0.98	1.08 ± 0.88	1.30 ± 1.09	1.00 ± 0.85	0.97 ± 0.77
Strength & Endurance	3.27 ± 1.25	3.56 ± 0.95	2.69 ± 0.90	3.23 ± 1.30	3.09 ± 0.33	3.00 ± 0.60
Stress Management	2.87 ± 1.09	2.94 ± 0.80	2.17 ± 1.17	3.23 ± 0.90	3.16 ± 1.26	3.00 ± 1.49
Weight Management	3.58 ± 1.63	3.69 ± 1.47	3.98 ± 1.21	4.18 ± 1.15	3.78 ± 1.27	3.56 ± 1.13

* significant increase from pre values ($P < 0.05$)