

## The Impact of Badminton on Health Markers in Untrained Females

Stephen Patterson<sup>1</sup>, John Pattison<sup>1</sup>, Hayley Legg<sup>1</sup>, Ann-Marie Gibson<sup>2</sup> and Nicola Brown<sup>1</sup>

<sup>1</sup>St. Mary's University, Twickenham

<sup>2</sup> University of Strathclyde School of Psychological Sciences and Health

This is a peer-reviewed author accepted manuscript. The article was accepted for publication by the Journal of Sports Sciences on 5 July 2016.

## The impact of Badminton on health markers in untrained females.

### Abstract

The purpose of the study was to examine the health effects of eight 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 was 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 (Health Survey for England 2012). 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 (Health Survey for England 2008). 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 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 is 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 4-10 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 eight weeks (Mendham et al., 2014; Meredith et al., 1990) and improve blood lipid profiles (Kin Isler, Kosar, & Korkusuz, 2001; Whitehurst & Menendez, 1991).

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

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, 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 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, & 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).

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

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 HRmax (Cabello Manrique & Gonzalez-Badillo, 2003; Faude et al., 2007), or 170–180 beats/min (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 focussed on the determinants of elite badminton performance or the physiological characteristics of elite players and little is known regarding the physiological responses and adaptations 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 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  $\pm$  standard deviation [SD]) aged  $34.3 \pm 6.9$  years [Range: 19 – 45 years] with a body mass, height, fat percentage, body mass index (BMI) and  $\dot{V}O_{2\max}$  of  $68.7 \pm 11.3$  kg,  $1.66 \pm 0.05$  m,  $33.8 \pm 8.9\%$ ,  $24.9 \pm 4.1$  kg/m<sup>2</sup> and  $32.6 \pm 6.2$  mL/min/kg, 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  $\dot{V}O_{2\max}$  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 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  $\dot{V}O_{2\max}$ . Laboratory assessments were conducted prior to and following an eight 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 eight weeks and was carried out for one hour three times a week. The badminton group training was performed in indoor badminton courts and consisted of double or

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

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 focussed towards learning skills and shots, whilst two sessions per week were dedicated to matches. The sessions consisted of 3 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 minutes 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 xxxxxxxxxxxxxxxx. 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 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

1 arterial pressure was calculated as  $1/3$  systolic blood pressure +  $2/3$  diastolic blood pressure.  
2  
3 Resting HR was measured during the same time interval as the blood pressure recordings.  
4  
5

6  
7 Pulmonary gas exchange, HR and capillary blood sampling were performed during a standardized  
8 treadmill test with 6 min bout of walking at 6 km/h and a 4 min bout of submaximal running at 8  
9 km/h, interspersed with 2 min rest periods. For participants who had RER values below 0.90 and  
10 heart rates below 80% of maximal heart rate at the end exercise at 8 km/h, another 4 min running  
11 bout was performed at 9 km/h. After a 15 min rest period, the participants carried out an  
12 incremental test to exhaustion, consisting of 4 min of running at the last submaximal running speed  
13 followed by stepwise 1% gradient increments each min until exhaustion. Respiratory gas exchange  
14 was measured during the entire exercise protocol through breath-by-breath analysis using an open  
15 spirometric system (Oxycon Pro, Jaeger, Hoechburg, Germany), calibrated prior to each trial using  
16 oxygen and carbon dioxide gases of known concentrations (Cryoservice, Worcester, UK), and via a  
17 3 L precision syringe (Hans Rudolph Inc, Shawnee, USA). During the trials participants breathed  
18 room air through a facemask that was secured in place by a head-cap assembly (Hans Rudolph Inc,  
19 Shawnee, USA). The total time to exhaustion (TTE) in the incremental treadmill test was noted as  
20 the treadmill test performance.  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38

39 Vertical jump height was assessed using a countermovement jump (CMJ) via two Pasco force  
40 platforms (PS 2142 Roseville, CA, USA), measuring at a sample rate of 1,000 Hz. The force  
41 platforms were connected to an interface (Pasport Power Link PS-2001). Force platforms were  
42 calibrated by using the shunt technique provided by the company. Data were collected and analysed  
43 with DataStudio software (Pasco, Roseville, CA, USA) and jump height was calculated from flight  
44 time (Linthorne, 2001). Participants performed a CMJ with hand on their hips and were instructed  
45 to jump as high as possible and avoiding bending their knees whilst airborne. Each jump was  
46 initiated by lowering into a quarter squat followed immediately by an explosive concentric  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



1 contraction. Each participant repeated the test for a total of 3 trials, with 1 minute recovery between  
2 jumps. The best jump height was taken for analysis.  
3  
4  
5  
6  
7

### 8 *Anthropometric measures*

9  
10 Stretch stature (m) and body mass (kg) measurements were taken to a precision of 0.01 m and 0.1  
11 kg, respectively using a Seca free standing height measure and calibrated Seca scales. Participants  
12 body fat percentage (BF%) was then assessed via air-displacement plethysmography (ADP) using a  
13 BODPOD (Life Measurement Instruments, Concord, California), calibrated according to  
14 manufacturer's instructions using a cylinder of known volume (50L). Test-retest reliability for BF%  
15 measured using ADP has been reported to have a technical error of 0.75% and coefficient of  
16 variation of 3.4% (Vescovi et al., 2001), and has been used to assess body composition changes in  
17 previous training studies (Davitt, Pellegrino, Schanzer, Tjonas, & Arent, 2014; Willis et al., 2012).  
18 For all measurements participants wore a tight-fitting swimsuit a bathing cap, and removed all  
19 jewellery. Prediction equations based on gender, age, and height were used to estimate thoracic lung  
20 volume (Wagner, Heyward, & Gibson, 2000) and then using this data, body mass and body volume  
21 data computer software determined body density and then %BF using the Siri (1961) equation.  
22 Additionally, the following girth measures were obtained in accordance with International Society  
23 for the Advancement of Kinanthropometry (ISAK) guidelines (Marfell-Jones et al., 2006) by an  
24 ISAK level 3 anthropometrist using a flexible steel tape (Lufkin W606PM); arm (relaxed), arm  
25 (flexed and tensed), waist (minimum), gluteal (maximum), thigh (mid), and calf (maximum). High  
26 intra-tester reliability for girth measurements was shown with the anthropometrist producing  
27 technical error of measurement (TEM) for repeated measurements of < 1%. Body mass index (BMI;  
28 kg.m<sup>-2</sup>) and waist to hip ratio (WHR; waist girth/gluteal girth) were calculated.  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51

### 52 *Motivation to exercise and self-esteem measures*

53  
54  
55  
56  
57  
58  
59  
60

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) software. Repeated measures ANOVAs (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  $\eta^2$  was used to assess the size of effect for any interactions.

### Results

The training adherence was  $2.6 \pm 0.2$  and  $2.7 \pm 0.3$  sessions per week for the badminton and running groups, respectively. The average training intensity during the badminton group sessions was  $75 \pm 5\%$  of maximal HR. The intensity of each session increased as the participants became

1  
2 more accustomed to the skills and rules of the game, with an average heart rate of  $73 \pm 7\%$  and  $77 \pm$   
3  
4  $6\%$  maximal HR for the first and second half of the intervention, respectively. **Time spent per**  
5  
6 **session in the heart rate zones 70–79, 80–89, and  $> 90\%HR_{max}$  was  $34.8 \pm 6.8\%$ ,  $28.4 \pm 7.8\%$ , and**  
7  
8  **$13.0 \pm 3.4\%$  of the training time.** In the running group, the running speed was individually adjusted  
9  
10 to elicit the same average heart rate as for badminton group ( $75 \pm 3\%$  of maximal HR). **Time spent**  
11  
12 **per session in the heart rate zones 70–79, 80–89, and  $> 90\%HR_{max}$  was  $73.8 \pm 3.5\%$ ,  $14.6 \pm 4.8\%$**   
13  
14 **and  $0.6 \pm 0.3\%$  of the training time.**

### 18 Physiological Measures

20  
21 The results for blood pressure, resting heart rate and blood lipid profile are shown in Table 1. There  
22  
23 was a group x time interaction for mean arterial pressure ( $P < 0.05$ ; partial  $\eta^2 = 0.25$ ), systolic ( $P <$   
24  
25  $0.05$ ; partial  $\eta^2 = 0.20$ ) and diastolic blood pressure ( $P < 0.05$ ; partial  $\eta^2 = 0.21$ ). Post hoc tests  
26  
27 revealed mean arterial pressure, systolic and diastolic blood pressure were reduced in the badminton  
28  
29 and running groups ( $P < 0.05$ ; table 1), with no change observed in the control group. There was a  
30  
31 significant time x group interaction for resting HR ( $P < 0.05$ ; partial  $\eta^2 = 0.22$ ) with post hoc tests  
32  
33 revealing a decrease in both badminton and running groups ( $P < 0.05$ ) with no change observed in  
34  
35 the control group. Total cholesterol, HDL, LDL, HDL:LDL ratio and triglycerides were unaltered  
36  
37 across all three groups during the 8 week intervention.

38  
39  
40  
41  
42  
43 There was a significant group x time interaction for  $\dot{V}O_{2max}$  ( $P < 0.05$ ; partial  $\eta^2 = 0.205$ ), with post  
44  
45 hoc analysis revealing a 14 and 16% increase ( $P < 0.05$ ) for the running and badminton groups,  
46  
47 respectively. No change in  $\dot{V}O_{2max}$  was observed for the control group (Figure 1). As shown in  
48  
49 Figure 2, there was a significant group x time interaction for TTE ( $P < 0.05$ ; partial  $\eta^2 = 0.305$ ),  
50  
51 with post hoc analysis revealing a 19% increase ( $P < 0.05$ ) in both the badminton and running  
52  
53 groups, with no change observed in the control condition. Oxygen uptake was unchanged during  
54  
55 submaximal exercise at 6 and 8 km/h in all groups following the eight week intervention. There was  
56  
57 a group x time interaction for HR during submaximal exercise at 6 ( $P < 0.05$ ; partial  $\eta^2 = 0.191$ ) and  
58  
59  
60

1 8 km/h ( $P < 0.05$ ; partial  $\eta^2 = 0.492$ ). Post hoc tests revealed HR was reduced in the badminton and  
2 running groups ( $P < 0.05$ ; table 1) during exercise at these speeds with no change observed in the  
3 control group. Following the eight week intervention, the blood lactate response during exercise at  
4 6km/h was unchanged across all three groups. However, there was a group x time interaction for  
5 blood lactate during exercise at 8 km/h ( $P < 0.05$ ; partial  $\eta^2 = 0.201$ ), with post hoc analysis  
6 revealing that blood lactate was lower ( $P < 0.05$ ; table 1) in the badminton and running groups only  
7 following the eight week intervention. There was a significant group x time interaction for jump  
8 height ( $P < 0.05$ ; partial  $\eta^2 = 0.407$ ), with post hoc analysis revealing an increase ( $P < 0.05$ ) in jump  
9 height for the badminton group only (Figure 3).  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21

### 22 Anthropometric measures

23  
24 Pre and post anthropometric measures are presented in Table 2. There were no significant group x  
25 time interaction effects for body mass, BMI, BF%, fat free mass, WHR, waist, hip, thigh and calf  
26 circumference. There was a significant group x time interaction for relaxed arm circumference ( $P <$   
27  $0.05$ ; partial  $\eta^2 = 0.288$ ) with post hoc analysis indicating a decrease ( $P < 0.05$ ) in the control group  
28 only. There was a significant group x time interaction for flexed and tensed arm circumference ( $P <$   
29  $0.05$ ; partial  $\eta^2 = 0.359$ ). Following adjustments for multiple post hoc comparisons no significant  
30 differences were revealed.  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42

### 43 Motivation to exercise and self-esteem

44  
45 When examining EMI-2 scores a group x time interaction ( $P < 0.05$ ; partial  $\eta^2 = 0.189$ ) was present  
46 for stress management. Post hoc tests were unable to identify any further significant differences.  
47 There was a significant group x time interaction ( $P < 0.05$ ; partial  $\eta^2 = 0.188$ ) for enjoyment  
48 motives for the running group ( $P < 0.05$ ), with an increase in post scores observed. There were no  
49 differences for the control and badminton groups. For the affiliation motive there was a significant  
50 group x time interaction ( $P < 0.05$ ; partial  $\eta^2 = 0.278$ ) for the badminton group ( $P < 0.05$ ), with an  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2 increase in post scores. There was a significant group x time interaction ( $P < 0.05$ ; partial  $\eta^2 =$   
3  
4 0.195) for ill health avoidance motive, with the post hoc analysis showing a significant increase ( $P$   
5  
6  $< 0.05$ ) in post scores for the running group only. No significant group x time interactions were  
7  
8 observed for the appearance, challenge, competition, health pressure, nimbleness, positive health,  
9  
10 revitalization, social recognition, strength and endurance, weight management motives.

11  
12  
13  
14 Changes in physical self-perceptions during the eight week intervention are shown in Table 3.  
15  
16 There was a significant group x time interaction for Physical Condition ( $P < 0.05$ ; partial  $\eta^2 =$   
17  
18 0.331). The post hoc tests revealed the control group had no change in their pre and post scores yet  
19  
20 both the running and badminton groups demonstrated significantly higher post scores when  
21  
22 compared to their pre scores ( $P < 0.05$ ). There were no significant group x time interaction effects  
23  
24 for Sport Competence, Body Attractiveness, Strength Competence and Physical Self-Worth  
25  
26

## 27 28 **Discussion**

29  
30  
31  
32 The main finding of the current study was that eight weeks of recreational badminton in untrained  
33  
34 females resulted in marked increases of  $\dot{V}O_{2\max}$ , TTE in an endurance exercise test, vertical jump  
35  
36 height, and favorable reductions in heart rate and blood lactate during walking and running exercise.  
37  
38 Furthermore reductions in resting heart rate, systolic and diastolic blood pressure and mean arterial  
39  
40 pressure were all observed in the badminton group. Similar adaptations were demonstrated in the  
41  
42 running group, except the changes in vertical jump height, whilst no changes were observed in the  
43  
44 control group demonstrating the effectiveness of the interventions.  
45  
46

47  
48  
49 Following eight weeks of badminton training, heart rate was reduced by 10-15 bpm during  
50  
51 submaximal walking and running, indicating large improvements in aerobic fitness. **The intensity of**  
52  
53 **the badminton training session were 75% of maximal HR which are lower than those reported**  
54  
55 **during recreational soccer (80-84% of maximal HR) in similarly untrained females (Bangsbo et al.,**  
56  
57 **2010; Krstrup et al., 2010) and lower (89% of maximal HR) than values observed during elite**  
58  
59  
60

1 badminton match play (Faude et al., 2007) . However this intensity of exercise resulted in a 16%  
2  
3  
4 improvement in  $\dot{V}O_{2max}$ , despite the fact that 11/13 (85%) of the women had no previous experience  
5  
6 of playing badminton. These adaptations compare favorably to other sporting interventions in  
7  
8 females, despite the shorter eight week time frame. HR decreased by 10 - 20 bpm during walking  
9  
10 and jogging after 16 weeks of twice-weekly 1-h soccer sessions for untrained females in  
11  
12 conjunction with an increased  $\dot{V}O_{2max}$  of 15% (Bangsbo et al., 2010; Krstrup et al., 2010) and HR  
13  
14 decreased by 7 bpm during submaximal cycling exercise after 12 weeks of twice-weekly 1-h soccer  
15  
16 sessions for female hospital employees, who also had a 5% increase in  $\dot{V}O_{2max}$  over the course of  
17  
18 training (Barene, Krstrup, Jackman, Brekke, & Holtermann, 2014). Further evidence for improved  
19  
20 aerobic fitness is seen in the 19% improvement in TTE test following the badminton group training.  
21  
22 Thus, despite the training program consisting of badminton play, the participants were able to  
23  
24 increase the time they spent running during a running test. Similar improvements in aerobic fitness  
25  
26 were demonstrated in the running group but no changes were observed in the control group across  
27  
28 the eight week intervention.  
29  
30  
31

32  
33  
34 For the badminton group, systolic and diastolic blood pressures were lowered by 8 and 6  
35  
36 mmHg respectively, with decreases observed in 12 of 13 participants. The favourable effects  
37  
38 observed for blood pressure were also similar to the changes observed in other studies involving  
39  
40 sport (mainly soccer), in individuals with mild-to-moderate hypertension following three to four  
41  
42 months of training (Andersen et al., 2010; Knoepfli-Lenzin et al., 2010; Mohr et al., 2014),  
43  
44 suggesting that intermittent sports such as badminton may be effective in lowering blood pressure.  
45  
46 For the running group, systolic blood pressure decreased by 5 mmHg and diastolic blood pressure  
47  
48 reduced by 5mmHg, which is similar in magnitude to previously observed aerobic training  
49  
50 interventions for women (Cornelissen & Fagard, 2005; Kelley, 1999) The lowered blood pressure  
51  
52 was associated with a reduction of 8 bpm in resting HR both in badminton and running groups,  
53  
54 which may reflect a training induced reduction of resting sympathetic outflow.  
55  
56  
57  
58  
59  
60

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44

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 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 for hip and knee joints, during running (Farris & Sawicki, 2012).**

45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

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  $\dot{V}O_{2\max}$ , TTE and the decreased



1 effort in the running and walking trials, as demonstrated by reduced heart rate and blood lactate  
2 during submaximal exercise.  
3  
4

5  
6  
7 The badminton programme was effective at increasing participants' social engagement  
8 motives (i.e., affiliation) to exercise when compared with both the running group and the control  
9 group. This suggests that participants in the badminton programme increased their motivation to  
10 exercise to spend time with friends, they enjoyed the social aspects of playing badminton, had fun  
11 being active with friends and making new friends. This provides partial evidence that badminton  
12 can increase an individual's social engagement motives to exercise and social engagement could be  
13 considered as a potential reason for people to join badminton groups, particularly for females. This  
14 has been shown in previous research on motives to exercise in adults (Allender et al., 2006) who  
15 concluded that enjoyment and social networks offered by sport and physical activity are clearly  
16 important motivators for many different groups of people aged between 18 and 50 years.  
17 Participating in exercise for social reasons is considered an intrinsic motive and is associated with  
18 better long-term adherence and behaviour change.  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34

35 In conclusion, this study has shown for the first time that badminton training, carried out on  
36 an hourly basis, three times per week, can improve a range of health markers in untrained females  
37 and to a similar extent as running training over an eight week intervention. Recreational badminton  
38 led to large aerobic adaptations such as increased  $\dot{V}O_{2max}$ , TTE in an endurance exercise test and  
39 favorable reductions in heart rate and blood lactate during walking and running exercise.  
40 Furthermore reductions in resting heart rate, systolic and diastolic blood pressure and mean arterial  
41 pressure were all observed in the badminton group. Alongside this an increase in vertical jump  
42 height was observed showing the possible use of badminton to increase strength and power.  
43 Recreational badminton also resulted in increased perceptions of physical condition and affiliation  
44 motives. This evidence should encourage organisations to promote the health improvements that are  
45 possible with sports such as badminton due to their fun and interactive nature.  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



## Acknowledgements

The authors would like to thank all the participants who gave up their time over the eight week intervention. They would also like to thank Acentas GmbH ([www.acentas.com](http://www.acentas.com)) for the use of the team HR system that was used for the duration of the study. The study was supported by a grant received by xxxxxxxxxxxx from the Badminton World Federation (BWF).

For Peer Review Only

**References**

- 1  
2  
3  
4  
5  
6 Abian, P. Castanedo, A. Feng, X.Q. Sampedro, J. Abian-Vicen, J. (2014). Notational comparison of  
7  
8 men's singles badminton matches between olympic games in beijing and london. *International*  
9  
10 *Journal of Performance Analysis in Sport*, 14, 42.  
11  
12  
13  
14 Abian-Vicen, J., Castanedo, A., Abian, P., & Sampedro, J. (2013). Temporal and notational  
15  
16 comparison of badminton matches between men's singles and women's singles. *International*  
17  
18 *Journal of Performance Analysis in Sport*, 13(2), 310.  
19  
20  
21  
22 Allender, S., Cowburn, G., & Foster, C. (2006). Understanding participation in sport and physical  
23  
24 activity among children and adults: A review of qualitative studies. *Health Education*  
25  
26 *Research*, 21(6), 826-835. doi:cyl063 [pii]  
27  
28  
29  
30 Andersen, L. J., Hansen, P. R., Sogaard, P., Madsen, J. K., Bech, J., & Krstrup, P. (2010).  
31  
32 Improvement of systolic and diastolic heart function after physical training in sedentary  
33  
34 women. *Scandinavian Journal of Medicine & Science in Sports*, 20 Suppl 1, 50-57.  
35  
36 doi:10.1111/j.1600-0838.2009.01088.x [doi]  
37  
38  
39  
40 Attene, G., Laffaye, G., Chaouachi, A., Pizzolato, F., Migliaccio, G. M., & Padulo, J. (2015).  
41  
42 Repeated sprint ability in young basketball players: One vs. two changes of direction (part 2).  
43  
44 *Journal of Sports Sciences*, 33(15), 1553-1563. doi:10.1080/02640414.2014.996182 [doi]  
45  
46  
47  
48 Azevedo, M. R., Araujo, C. L., Reichert, F. F., Siqueira, F. V., da Silva, M. C., & Hallal, P. C.  
49  
50 (2007). Gender differences in leisure-time physical activity. *International Journal of Public*  
51  
52 *Health*, 52(1), 8-15.  
53  
54  
55  
56 Bangsbo, J., Nielsen, J. J., Mohr, M., Randers, M. B., Krstrup, B. R., Brito, J., . . . Krstrup, P.  
57  
58 (2010). Performance enhancements and muscular adaptations of a 16-week recreational  
59  
60

1  
2 football intervention for untrained women. *Scandinavian Journal of Medicine & Science in*  
3  
4 *Sports, 20 Suppl 1*, 24-30. doi:10.1111/j.1600-0838.2009.01050.x [doi]

5  
6  
7 Barene, S., Krustup, P., Jackman, S. R., Brekke, O. L., & Holtermann, A. (2014). Do soccer and  
8  
9 zumba exercise improve fitness and indicators of health among female hospital employees? A  
10  
11 12-week RCT. *Scandinavian Journal of Medicine & Science in Sports, 24*(6), 990-999.  
12  
13 doi:10.1111/sms.12138 [doi]

14  
15  
16  
17 Cabello Manrique, D., & Gonzalez-Badillo, J. J. (2003). Analysis of the characteristics of  
18  
19 competitive badminton. *British Journal of Sports Medicine, 37*(1), 62-66.

20  
21  
22  
23 Chin, M. K., Wong, A. S., So, R. C., Siu, O. T., Steininger, K., & Lo, D. T. (1995). Sport specific  
24  
25 fitness testing of elite badminton players. *British Journal of Sports Medicine, 29*(3), 153-157.

26  
27  
28  
29 Cornelissen, V. A., & Fagard, R. H. (2005). Effects of endurance training on blood pressure, blood  
30  
31 pressure-regulating mechanisms, and cardiovascular risk factors. *Hypertension, 46*(4), 667-  
32  
33 675. doi:01.HYP.0000184225.05629.51 [pii]

34  
35  
36  
37 Cornelissen, V. A., & Smart, N. A. (2013). Exercise training for blood pressure: A systematic  
38  
39 review and meta-analysis. *Journal of the American Heart Association, 2*(1), e004473.  
40  
41 doi:10.1161/JAHA.112.004473 [doi]

42  
43  
44 Dacey, M., Baltzell, A., & Zaichkowsky, L. (2008). Older adults' intrinsic and extrinsic motivation  
45  
46 toward physical activity. *American Journal of Health Behavior, 32*(6), 570-582.  
47  
48 doi:10.5555/ajhb.2008.32.6.570 [doi]

49  
50  
51  
52 Davitt, P. M., Pellegrino, J. K., Schanzer, J. R., Tjionas, H., & Arent, S. M. (2014). The effects of a  
53  
54 combined resistance training and endurance exercise program in inactive college female  
55  
56 subjects: Does order matter? *Journal of Strength and Conditioning Research / National*  
57  
58  
59  
60

1  
2 *Strength & Conditioning Association*, 28(7), 1937-1945. doi:10.1519/JSC.0000000000000355

3  
4 [doi]

5  
6  
7 Deka, P., Berg, K., Harder, J., Batelaan, H., & McGrath, M. (2016). Oxygen cost and physiological  
8 responses of recreational badminton match play. *The Journal of Sports Medicine and Physical*  
9 *Fitness*, doi:R40Y9999N00A16040702 [pii]

10  
11  
12  
13  
14  
15 Donges, C. E., Duffield, R., & Drinkwater, E. J. (2010). Effects of resistance or aerobic exercise  
16 training on interleukin-6, C-reactive protein, and body composition. *Medicine and Science in*  
17 *Sports and Exercise*, 42(2), 304-313. doi:10.1249/MSS.0b013e3181b117ca [doi]

18  
19  
20  
21  
22  
23 El Ansari, W., & Lovell, G. (2009). Barriers to exercise in younger and older non-exercising adult  
24 women: A cross sectional study in london, united kingdom. *International Journal of*  
25 *Environmental Research and Public Health*, 6(4), 1443-1455. doi:10.3390/ijerph6041443 [doi]

26  
27  
28  
29  
30  
31 Eyler, A. E., Wilcox, S., Matson-Koffman, D., Evenson, K. R., Sanderson, B., Thompson, J., . . .  
32 Rohm-Young, D. (2002). Correlates of physical activity among women from diverse  
33 racial/ethnic groups. *Journal of Women's Health & Gender-Based Medicine*, 11(3), 239-253.  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
doi:10.1089/152460902753668448 [doi]

61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000  
1001  
1002  
1003  
1004  
1005  
1006  
1007  
1008  
1009  
1010  
1011  
1012  
1013  
1014  
1015  
1016  
1017  
1018  
1019  
1020  
1021  
1022  
1023  
1024  
1025  
1026  
1027  
1028  
1029  
1030  
1031  
1032  
1033  
1034  
1035  
1036  
1037  
1038  
1039  
1040  
1041  
1042  
1043  
1044  
1045  
1046  
1047  
1048  
1049  
1050  
1051  
1052  
1053  
1054  
1055  
1056  
1057  
1058  
1059  
1060  
1061  
1062  
1063  
1064  
1065  
1066  
1067  
1068  
1069  
1070  
1071  
1072  
1073  
1074  
1075  
1076  
1077  
1078  
1079  
1080  
1081  
1082  
1083  
1084  
1085  
1086  
1087  
1088  
1089  
1090  
1091  
1092  
1093  
1094  
1095  
1096  
1097  
1098  
1099  
1100  
1101  
1102  
1103  
1104  
1105  
1106  
1107  
1108  
1109  
1110  
1111  
1112  
1113  
1114  
1115  
1116  
1117  
1118  
1119  
1120  
1121  
1122  
1123  
1124  
1125  
1126  
1127  
1128  
1129  
1130  
1131  
1132  
1133  
1134  
1135  
1136  
1137  
1138  
1139  
1140  
1141  
1142  
1143  
1144  
1145  
1146  
1147  
1148  
1149  
1150  
1151  
1152  
1153  
1154  
1155  
1156  
1157  
1158  
1159  
1160  
1161  
1162  
1163  
1164  
1165  
1166  
1167  
1168  
1169  
1170  
1171  
1172  
1173  
1174  
1175  
1176  
1177  
1178  
1179  
1180  
1181  
1182  
1183  
1184  
1185  
1186  
1187  
1188  
1189  
1190  
1191  
1192  
1193  
1194  
1195  
1196  
1197  
1198  
1199  
1200  
1201  
1202  
1203  
1204  
1205  
1206  
1207  
1208  
1209  
1210  
1211  
1212  
1213  
1214  
1215  
1216  
1217  
1218  
1219  
1220  
1221  
1222  
1223  
1224  
1225  
1226  
1227  
1228  
1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
1240  
1241  
1242  
1243  
1244  
1245  
1246  
1247  
1248  
1249  
1250  
1251  
1252  
1253  
1254  
1255  
1256  
1257  
1258  
1259  
1260  
1261  
1262  
1263  
1264  
1265  
1266  
1267  
1268  
1269  
1270  
1271  
1272  
1273  
1274  
1275  
1276  
1277  
1278  
1279  
1280  
1281  
1282  
1283  
1284  
1285  
1286  
1287  
1288  
1289  
1290  
1291  
1292  
1293  
1294  
1295  
1296  
1297  
1298  
1299  
1300  
1301  
1302  
1303  
1304  
1305  
1306  
1307  
1308  
1309  
1310  
1311  
1312  
1313  
1314  
1315  
1316  
1317  
1318  
1319  
1320  
1321  
1322  
1323  
1324  
1325  
1326  
1327  
1328  
1329  
1330  
1331  
1332  
1333  
1334  
1335  
1336  
1337  
1338  
1339  
1340  
1341  
1342  
1343  
1344  
1345  
1346  
1347  
1348  
1349  
1350  
1351  
1352  
1353  
1354  
1355  
1356  
1357  
1358  
1359  
1360  
1361  
1362  
1363  
1364  
1365  
1366  
1367  
1368  
1369  
1370  
1371  
1372  
1373  
1374  
1375  
1376  
1377  
1378  
1379  
1380  
1381  
1382  
1383  
1384  
1385  
1386  
1387  
1388  
1389  
1390  
1391  
1392  
1393  
1394  
1395  
1396  
1397  
1398  
1399  
1400  
1401  
1402  
1403  
1404  
1405  
1406  
1407  
1408  
1409  
1410  
1411  
1412  
1413  
1414  
1415  
1416  
1417  
1418  
1419  
1420  
1421  
1422  
1423  
1424  
1425  
1426  
1427  
1428  
1429  
1430  
1431  
1432  
1433  
1434  
1435  
1436  
1437  
1438  
1439  
1440  
1441  
1442  
1443  
1444  
1445  
1446  
1447  
1448  
1449  
1450  
1451  
1452  
1453  
1454  
1455  
1456  
1457  
1458  
1459  
1460  
1461  
1462  
1463  
1464  
1465  
1466  
1467  
1468  
1469  
1470  
1471  
1472  
1473  
1474  
1475  
1476  
1477  
1478  
1479  
1480  
1481  
1482  
1483  
1484  
1485  
1486  
1487  
1488  
1489  
1490  
1491  
1492  
1493  
1494  
1495  
1496  
1497  
1498  
1499  
1500  
1501  
1502  
1503  
1504  
1505  
1506  
1507  
1508  
1509  
1510  
1511  
1512  
1513  
1514  
1515  
1516  
1517  
1518  
1519  
1520  
1521  
1522  
1523  
1524  
1525  
1526  
1527  
1528  
1529  
1530  
1531  
1532  
1533  
1534  
1535  
1536  
1537  
1538  
1539  
1540  
1541  
1542  
1543  
1544  
1545  
1546  
1547  
1548  
1549  
1550  
1551  
1552  
1553  
1554  
1555  
1556  
1557  
1558  
1559  
1560  
1561  
1562  
1563  
1564  
1565  
1566  
1567  
1568  
1569  
1570  
1571  
1572  
1573  
1574  
1575  
1576  
1577  
1578  
1579  
1580  
1581  
1582  
1583  
1584  
1585  
1586  
1587  
1588  
1589  
1590  
1591  
1592  
1593  
1594  
1595  
1596  
1597  
1598  
1599  
1600  
1601  
1602  
1603  
1604  
1605  
1606  
1607  
1608  
1609  
1610  
1611  
1612  
1613  
1614  
1615  
1616  
1617  
1618  
1619  
1620  
1621  
1622  
1623  
1624  
1625  
1626  
1627  
1628  
1629  
1630  
1631  
1632  
1633  
1634  
1635  
1636  
1637  
1638  
1639  
1640  
1641  
1642  
1643  
1644  
1645  
1646  
1647  
1648  
1649  
1650  
1651  
1652  
1653  
1654  
1655  
1656  
1657  
1658  
1659  
1660  
1661  
1662  
1663  
1664  
1665  
1666  
1667  
1668  
1669  
1670  
1671  
1672  
1673  
1674  
1675  
1676  
1677  
1678  
1679  
1680  
1681  
1682  
1683  
1684  
1685  
1686  
1687  
1688  
1689  
1690  
1691  
1692  
1693  
1694  
1695  
1696  
1697  
1698  
1699  
1700  
1701  
1702  
1703  
1704  
1705  
1706  
1707  
1708  
1709  
1710  
1711  
1712  
1713  
1714  
1715  
1716  
1717  
1718  
1719  
1720  
1721  
1722  
1723  
1724  
1725  
1726  
1727  
1728  
1729  
1730  
1731  
1732  
1733  
1734  
1735  
1736  
1737  
1738  
1739  
1740  
1741  
1742  
1743  
1744  
1745  
1746  
1747  
1748  
1749  
1750  
1751  
1752  
1753  
1754  
1755  
1756  
1757  
1758  
1759  
1760  
1761  
1762  
1763  
1764  
1765  
1766  
1767  
1768  
1769  
1770  
1771  
1772  
1773  
1774  
1775  
1776  
1777  
1778  
1779  
1780  
1781  
1782  
1783  
1784  
1785  
1786  
1787  
1788  
1789  
1790  
1791  
1792  
1793  
1794  
1795  
1796  
1797  
1798  
1799  
1800  
1801  
1802  
1803  
1804  
1805  
1806  
1807  
1808  
1809  
1810  
1811  
1812  
1813  
1814  
1815  
1816  
1817  
1818  
1819  
1820  
1821  
1822  
1823  
1824  
1825  
1826  
1827  
1828  
1829  
1830  
1831  
1832  
1833  
1834  
1835  
1836  
1837  
1838  
1839  
1840  
1841  
1842  
1843  
1844  
1845  
1846  
1847  
1848  
1849  
1850  
1851  
1852  
1853  
1854  
1855  
1856  
1857  
1858  
1859  
1860  
1861  
1862  
1863  
1864  
1865  
1866  
1867  
1868  
1869  
1870  
1871  
1872  
1873  
1874  
1875  
1876  
1877  
1878  
1879  
1880  
1881  
1882  
1883  
1884  
1885  
1886  
1887  
1888  
1889  
1890  
1891  
1892  
1893  
1894  
1895  
1896  
1897  
1898  
1899  
1900  
1901  
1902  
1903  
1904  
1905  
1906  
1907  
1908  
1909  
1910  
1911  
1912  
1913  
1914  
1915  
1916  
1917  
1918  
1919  
1920  
1921  
1922  
1923  
1924  
1925  
1926  
1927  
1928  
1929  
1930  
1931  
1932  
1933  
1934  
1935  
1936  
1937  
1938  
1939  
1940  
1941  
1942  
1943  
1944  
1945  
1946  
1947  
1948  
1949  
1950  
1951  
1952  
1953  
1954  
1955  
1956  
1957  
1958  
1959  
1960  
1961  
1962  
1963  
1964  
1965  
1966  
1967  
1968  
1969  
1970  
1971  
1972  
1973  
1974  
1975  
1976  
1977  
1978  
1979  
1980  
1981  
1982  
1983  
1984  
1985  
1986  
1987  
1988  
1989  
1990  
1991  
1992  
1993  
1994  
1995  
1996  
1997  
1998  
1999  
2000  
2001  
2002  
2003  
2004  
2005  
2006  
2007  
2008  
2009  
2010  
2011  
2012  
2013  
2014  
2015  
2016  
2017  
2018  
2019  
2020  
2021  
2022  
2023  
2024  
2025  
2026  
2027  
2028  
2029  
2030  
2031  
2032  
2033  
2034  
2035  
2036  
2037  
2038  
2039  
2040  
2041  
2042  
2043  
2044  
2045  
2046  
2047  
2048  
2049  
2050  
2051  
2052  
2053  
2054  
2055  
2056  
2057  
2058  
2059  
2060  
2061  
2062  
2063  
2064  
2065  
2066  
2067  
2068  
2069  
2070  
2071  
2072  
2073  
2074  
2075  
2076  
2077  
2078  
2079  
2080  
2081  
2082  
2083  
2084  
2085  
2086  
2087  
2088  
2089  
2090  
2091  
2092  
2093  
2094  
2095  
2096  
2097  
2098  
2099  
2100  
2101  
2102  
2103  
2104  
2105  
2106  
2107  
2108  
2109  
2110  
2111  
2112  
2113  
2114  
2115  
2116  
2117  
2118  
21

1 Friedewald, W. T., Levy, R. I., & Fredrickson, D. S. (1972). Estimation of the concentration of low-  
2 density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge.  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32

33 Kelley, G. A. (1999). Aerobic exercise and resting blood pressure among women: A meta-analysis.  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

61 Kin Isler, A., Kosar, S. N., & Korkusuz, F. (2001). Effects of step aerobics and aerobic dancing on  
62 serum lipids and lipoproteins. *The Journal of Sports Medicine and Physical Fitness*, 41(3),  
63 380-385.

64 Knoepfli-Lenzin, C., Sennhauser, C., Toigo, M., Boutellier, U., Bangsbo, J., Krstrup, P., . . .  
65 Dvorak, J. (2010). Effects of a 12-week intervention period with football and running for  
66 habitually active men with mild hypertension. *Scandinavian Journal of Medicine & Science in*  
67 *Sports*, 20 Suppl 1, 72-79. doi:10.1111/j.1600-0838.2009.01089.x [doi]

68 Krstrup, P., Hansen, P. R., Randers, M. B., Nybo, L., Martone, D., Andersen, L. J., . . . Bangsbo, J.  
69 (2010). Beneficial effects of recreational football on the cardiovascular risk profile in untrained  
70 premenopausal women. *Scandinavian Journal of Medicine & Science in Sports*, 20 Suppl 1,  
71 40-49. doi:10.1111/j.1600-0838.2010.01110.x [doi]

72 Krstrup, P., Nielsen, J. J., Krstrup, B. R., Christensen, J. F., Pedersen, H., Randers, M. B., . . .  
73 Bangsbo, J. (2009). Recreational soccer is an effective health-promoting activity for untrained  
74 men. *British Journal of Sports Medicine*, 43(11), 825-831. doi:10.1136/bjism.2008.053124  
75 [doi]

76 Kuntze, G., Mansfield, N., & Sellers, W. (2010). A biomechanical analysis of common lunge tasks  
77 in badminton. *Journal of Sports Sciences*, 28(2), 183-191. doi:10.1080/02640410903428533  
78 [doi]

- 1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60
- Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., & Lancet Physical Activity Series Working Group. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet (London, England)*, *380*(9838), 219-229. doi:10.1016/S0140-6736(12)61031-9 [doi]
- Liddle, S. D., Murphy, M. H., & Bleakley, W. (1996). A comparison of the physiological demands of singles and doubles badminton a heart rate and time/motion analysis. *Journal of Human Movement Studies*, *30*, 159-179.
- Linthorne, N. (2001). Analysis of standing vertical jumps using a force platform. *American Journal of Physics*, *69*(11), 1198. doi:10.1119/1.1397460
- Lovell, G. P., El Ansari, W., & Parker, J. K. (2010). Perceived exercise benefits and barriers of non-exercising female university students in the united kingdom. *International Journal of Environmental Research and Public Health*, *7*(3), 784-798. doi:10.3390/ijerph7030784 [doi]
- Majumdar, P., Khanna, G. L., Malik, V., Sachdeva, S., Arif, M., & Mandal, M. (1997). Physiological analysis to quantify training load in badminton. *British Journal of Sports Medicine*, *31*(4), 342-345.
- Martinez-Gonzalez, M. A., Varo, J. J., Santos, J. L., De Irala, J., Gibney, M., Kearney, J., & Martinez, J. A. (2001). Prevalence of physical activity during leisure time in the european union. *Medicine and Science in Sports and Exercise*, *33*(7), 1142-1146.
- Mendham, A. E., Duffield, R., Marino, F., & Coutts, A. J. (2014). Small-sided games training reduces CRP, IL-6 and leptin in sedentary, middle-aged men. *European Journal of Applied Physiology*, *114*(11), 2289-2297. doi:10.1007/s00421-014-2953-3 [doi]

- 1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60
- Meredith, I. T., Jennings, G. L., Esler, M. D., Dewar, E. M., Bruce, A. M., Fazio, V. A., & Korner, P. I. (1990). Time-course of the antihypertensive and autonomic effects of regular endurance exercise in human subjects. *Journal of Hypertension*, 8(9), 859-866.
- Milanovic, Z., Pantelic, S., Covic, N., Sporis, G., & Krstrup, P. (2015). Is recreational soccer effective for improving VO<sub>2</sub>max A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.)*, 45(9), 1339-1353. doi:10.1007/s40279-015-0361-4 [doi]
- Mohr, M., Lindenskov, A., Holm, P. M., Nielsen, H. P., Mortensen, J., Weihe, P., & Krstrup, P. (2014). Football training improves cardiovascular health profile in sedentary, premenopausal hypertensive women. *Scandinavian Journal of Medicine & Science in Sports*, 24 Suppl 1, 36-42. doi:10.1111/sms.12278 [doi]
- Oja, P., Titze, S., Kokko, S., Kujala, U. M., Heinonen, A., Kelly, P., . . . Foster, C. (2015). Health benefits of different sport disciplines for adults: Systematic review of observational and intervention studies with meta-analysis. *British Journal of Sports Medicine*, 49(7), 434-440. doi:10.1136/bjsports-2014-093885 [doi]
- Padulo, J., Tiloca, A., Powell, D., Granatelli, G., Bianco, A., & Paoli, A. (2013). EMG amplitude of the biceps femoris during jumping compared to landing movements. *SpringerPlus*, 2, 520-1801-2-520. eCollection 2013. doi:10.1186/2193-1801-2-520 [doi]
- Phomsoupha, M., & Laffaye, G. (2015). The science of badminton: Game characteristics, anthropometry, physiology, visual fitness and biomechanics. *Sports Medicine (Auckland, N.Z.)*, 45(4), 473-495. doi:10.1007/s40279-014-0287-2 [doi]
- Scholes, S., Panesar, S., Shelton, N. J., Francis, R. M., Mirza, S., Mindell, J. S., & Donaldson, L. J. (2014). Epidemiology of lifetime fracture prevalence in England: A population study of adults aged 55 years and over. *Age and Ageing*, 43(2), 234-240. doi:10.1093/ageing/aft167 [doi]

1 Talbot, L. A., Metter, E. J., & Fleg, J. L. (2000). Leisure-time physical activities and their  
2 relationship to cardiorespiratory fitness in healthy men and women 18-95 years old. *Medicine*  
3 *and Science in Sports and Exercise*, 32(2), 417-425.  
4  
5  
6  
7

8  
9 Vescovi, J. D., Zimmerman, S. L., Miller, W. C., Hildebrandt, L., Hammer, R. L., & Fernhall, B.  
10 (2001). Evaluation of the BOD POD for estimating percentage body fat in a heterogeneous  
11 group of adult humans. *European Journal of Applied Physiology*, 85(3-4), 326-332.  
12  
13  
14  
15

16  
17 Wagner, D. R., Heyward, V. H., & Gibson, A. L. (2000). Validation of air displacement  
18 plethysmography for assessing body composition. *Medicine and Science in Sports and*  
19 *Exercise*, 32(7), 1339-1344.  
20  
21  
22  
23

24  
25 Whitehurst, M., & Menendez, R. N. (1991). *Endurance training in older women: Lipid and*  
26 *lipoprotein responses. Physician Sportsmed*, 19, 95-103.  
27  
28

29  
30 Willis, L. H., Slentz, C. A., Bateman, L. A., Shields, A. T., Piner, L. W., Bales, C. W., . . . Kraus,  
31 W. E. (2012). Effects of aerobic and/or resistance training on body mass and fat mass in  
32 overweight or obese adults. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, 113(12),  
33 1831-1837. doi:10.1152/jappphysiol.01370.2011 [doi]  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Table Legends

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

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

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

For Peer Review Only

Table 1.

	Badminton Group		Running Group		Control Group	
	Pre	Post	Pre	Post	Pre	Post
<b>Resting Heart Rate (bpm)</b>	75 ± 11	67 ± 9 *	74 ± 9	66 ± 8 *	72 ± 9	72 ± 11
<b>Systolic Blood Pressure (mmHg)</b>	120 ± 13	112 ± 9 *	119 ± 13	115 ± 12 *	122 ± 8	123 ± 9
<b>Diastolic Blood Pressure (mmHg)</b>	75 ± 8	69 ± 8 *	75 ± 11	71 ± 10 *	77 ± 6	78 ± 5
<b>Mean Arterial Pressure (mmHg)</b>	89 ± 9	82 ± 8 *	89 ± 11	84 ± 10 *	91 ± 5	92 ± 6
<b>Total Cholesterol (mmol /L)</b>	4.51 ± 0.26	4.41 ± 0.23	4.36 ± 0.32	4.30 ± 0.42	4.47 ± 0.50	4.46 ± 0.46
<b>HDL Cholesterol (mmol/L)</b>	1.56 ± 0.08	1.58 ± 0.08	1.55 ± 0.10	1.57 ± 0.09	1.54 ± 0.10	1.55 ± 0.12
<b>LDL Cholesterol (mmol/L)</b>	2.42 ± 0.30	2.31 ± 0.29	2.34 ± 0.33	2.26 ± 0.47	2.42 ± 0.47	2.41 ± 0.43
<b>LDL:HDL ratio</b>	1.56 ± 0.22	1.47 ± 0.22	1.52 ± 0.25	1.45 ± 0.36	1.58 ± 0.34	1.57 ± 0.35
<b>Triglycerides (mmol/L)</b>	1.17 ± 0.16	1.14 ± 0.20	1.04 ± 0.12	1.01 ± 0.13	1.11 ± 0.24	1.09 ± 0.22
<b>Oxygen uptake @ 6 km/h (L/min)</b>	1.37 ± 0.33	1.38 ± 0.21	1.34 ± 0.20	1.33 ± 0.17	1.64 ± 0.29	1.52 ± 0.31
<b>Oxygen uptake @ 8 km/h (L/min)</b>	1.95 ± 0.45	2.10 ± 0.26	2.01 ± 0.36	2.09 ± 0.23	2.08 ± 0.32	2.01 ± 0.40
<b>Heart rate @ 6km/h (bpm)</b>	139 ± 18	129 ± 13 *	130 ± 12	117 ± 12 *	151 ± 21	144 ± 23
<b>Heart rate @ 8 km/h (bpm)</b>	176 ± 13	162 ± 12 *	170 ± 8	153 ± 10 *	175 ± 16	174 ± 15
<b>Blood lactate @ 6 km/h (mmol/L)</b>	1.72 ± 0.87	1.38 ± 0.98	1.13 ± 0.52	0.99 ± 0.33	2.98 ± 2.12	2.35 ± 1.61
<b>Blood Lactate @ 8 km/h (mmol/L)</b>	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 ( $P < 0.05$ ).

Table 2.

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

Table 3.

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

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

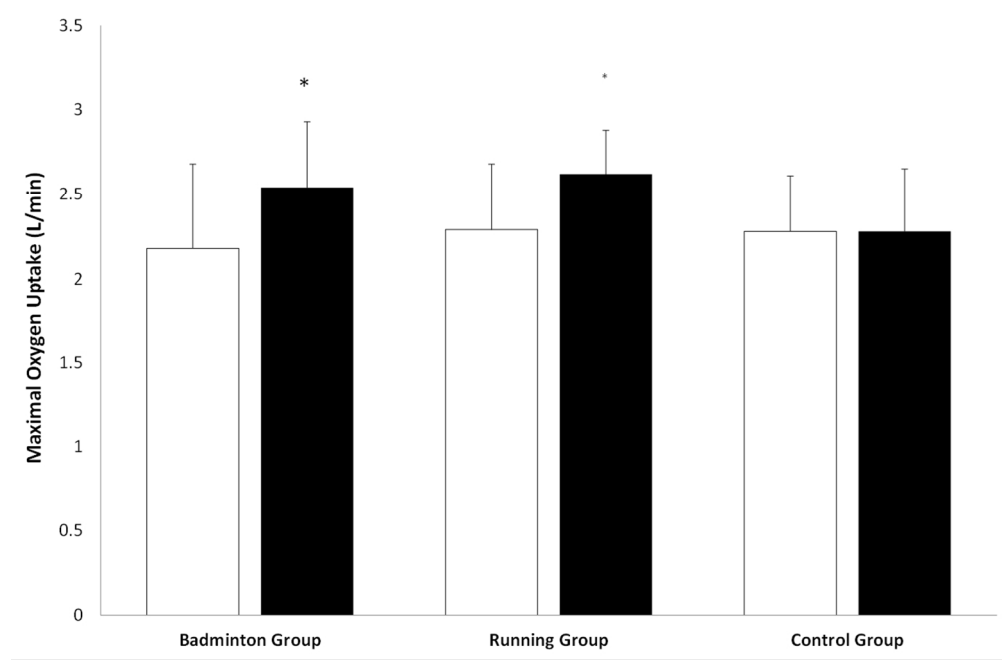


Figure 1. Maximal Oxygen Uptake ( $VO_{2max}$ ) in untrained women before (open bars) and after (solid bars) eight weeks of badminton, running or control intervention. \* denotes significant increase from pre values ( $P < 0.05$ ).

232x151mm (150 x 150 DPI)

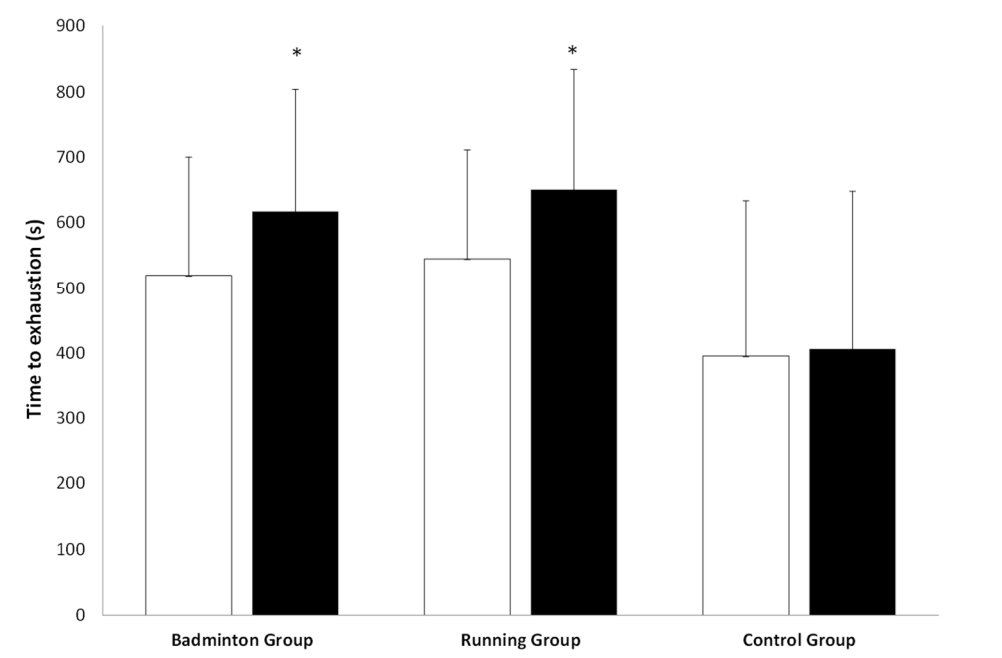


Figure 2. Time to exhaustion in untrained women, during incremental treadmill running test, before (open bars) and after (solid bars) eight weeks of badminton, running or control intervention. \* denotes significant increase from pre values ( $P < 0.05$ ).

232x151mm (150 x 150 DPI)

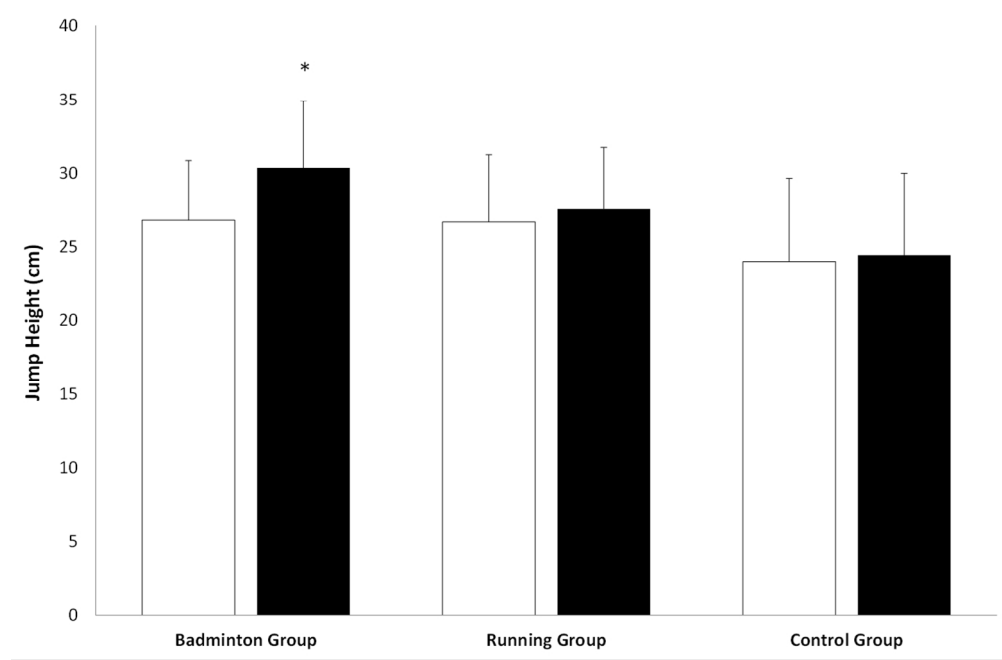


Figure 3. Vertical Jump Height in untrained women before (open bars) and after (solid bars) eight weeks of badminton, running or control intervention. \* denotes significant increase from pre values ( $P < 0.05$ ).

232x151mm (150 x 150 DPI)