Badminton specific fitness training improves badminton performance and reduces body fat in Danish college students – a comparison of regular high school badminton and specific badminton fitness training

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Acknowledgements

The study was conducted at Stenhus Gymnasium & HF (Stenhus) and supported by

1) The Badminton World Federation (BWF) (15.000$),
2) Stenhus Gymnasium & HF (10.000$)
3) Danske Gymnastik- og Idrætsforeninger (DGI; The Danish Gymnastic and Sport Unions) (2.000$)

The results of this study do not constitute endorsement of the product by the World Badminton Federation

Abstract

Forty-four high school students were included in the study. For 8 weeks 28 students were engaged in a newly developed badminton fitness program whereas 16 students completed a standard high school badminton program. The badminton fitness program consists of a combination of badminton specific resistance exercises and match play. Before and after the training intervention students were tested in a series of badminton specific and non-specific performance tests and anthropometrics were measured. The badminton fitness program reduced fat mass and fat percentage among the students whereas no difference was observed after the 8-week standard high-school badminton program. Badminton specific endurance improved after both interventions whereas badminton specific speed only improved after the badminton fitness program. The present study demonstrated that 8-weeks of badminton specific fitness training can improve body composition and badminton specific performance more than standard badminton high school training in high school students.

Keywords

Badminton fitness, fat mass, high school students, health.

Introduction

An inactive lifestyle can lead to poor physiological fitness and to an increase in the prevalence of type II diabetes and cardiovascular decease and in modern society metabolic-related risk factors are becoming an increasingly larger health problem[14,24].

Exercise training is well established as a cornerstone for decreasing and preventing risk factors associated with cardiovascular and metabolic disease[12,16]. Increasing body of evidence suggests major beneficial effects of regular soccer training on cardiorespiratory capacity, metabolic fitness and muscle and bone strength[18]. Soccer has even been suggested to be superior to isolated strength and endurance exercise, probably due to its intermittent nature with periods of near maximal heart rates and a substantial anaerobic energy contribution[18]. Of the major racket sports, tennis has been investigated thoroughly from a health perspective and positive health benefits including higher aerobic fitness and less body fat has been associated with regular tennis participation[27] which further reduces the risk of cardiovascular disease and morbidity. Tennis is an intermittent sport eliciting medium- to high mean heart rates (140-155 b/min) and intermediate blood lactate values (3-5 mM), depending on playing surface[6]. In comparison, badminton, claimed to be the world's fastest racket sport with shuttle velocities above 100 m/s[25], elicits higher mean heart rates (157 – 175 b/min) and similar blood lactate levels (2-5 mM) as tennis, suggesting that badminton has at least the same potential impact on health and disease as tennis. However, despite being one of the most popular sports, with more than 200 million players worldwide[8], only one study has investigated the impact of badminton on markers of health[26]. Interestingly, from a physiological point of view, badminton match play may even resemble that of soccer, eliciting near maximal heart rates during match play with an average aerobic workload >90% of maximal heart rate (HRmax)[7]. In addition, the nature of badminton is intermittent with a significant anaerobic energy production [7,22,23] suggesting a huge potential for badminton as a health promoting activity.

It is well documented that physical activity among children affects good behavior as well as cognitive and social function and wellbeing. For children, no direct relationship exists between exercise and health, as many of the lifestyle related diseases do not impact early in the lifespan. However, a relationship exists between precursors for a great number of lifestyle related disease, such as type II diabetes, obesity and cardiovascular disease, and physical activity[1].

In the European Youth Heart Study, a low physical activity level was a strong predictor for accumulation of risk factors associated with lifestyle disease[5] and a great number of kids carry over the higher "prevalence" of risk factors into adulthood[3].

In many schools there is a limitation of facilities with up to 30 students sharing 3-4 badminton courts. At Stenhus, despite having a sports college with badminton, football, basketball and handball, we are limited by having 30 students in one gym with up to 3 badminton courts during physical education classes lasting up to ~100 minutes. This suggests a need for development of new concepts based on traditional sports embracing the physical limitations during physical education class. Thus, the aim of the present study was to investigate a newly developed Danish Badminton Fitness concept (B-FIT) investigating health related markers and specific badminton performance among Danish high school students, some recreationally active but none involved in regular badminton activities, compared to a standard high school 8-week badminton program (BAD).

Methods

Subjects

Forty-four high school students were included in the study. All participants in the project signed informed consent adhering to the Declaration of Helsinki.

Design

The study consisted of an 8-week intervention period (INT) with evaluation of anthropometrics and badminton specific performance, using two newly developed badminton specific on-court tests[21,22] and non-badminton specific performance testing before and after INT. Two freshman high school classes (n=28) were engaged in B-FIT whereas a third freshman class (n=16) completed a standard high school 8-week badminton program (BAD) as planned by the teachers. Students with a compliance less than 85% (7 of 8 sessions attended) were excluded from the analyses.

Testing and training took place at Stenhus in Holbæk, Denmark and students were not allowed to participate in strenuous exercise or allowed ingestion of caffeine or alcohol in 24 hours prior to testing.

Table 1. Anthropometrics in groups performing regular high school badminton training (BAD) and a specific badminton fitness program (B-FIT) prior to the intervention period.

	BAD	B-FIT
Boys (n)	10	10
Girls (n)	6	18
Age (years)	18.5±0.2	18.1±0.1*
Height (cm)	173±2	172±1.5
Body Mass (kg)	69.2±2.6	73.2±2.5
BMI (kg/m^2)	22.9±0.7	24.7±0.7
Fat (kg)	13.9±1.2	18.9±1.6*
Fat (%)	20.4±1.6	25.5±1.6*
SMM (kg)	31.2±1.6	30.3±1.3

*Different ($p<0.05$) from BAD.

BMI: Body mass index, SMM: Skeletal muscle mass

Training

B-FIT consists of a combination of badminton specific resistance exercises and badminton match play, and was developed through a recent collaboration with DGI badminton. B-FIT is divided into six main topics; balance/coordination, upper body, legs, core, footwork and shoulder/stability and consists of core and resisted badminton specific full body exercises in 13 stations with two exercise drills per station. Prior to B-FIT, students warmed up in a standardized manner with light running using exercises such as high knees, heel kicks, one legged jumping and backwards and side-ways running for 5 min. Each of the 26 exercises were completed twice with a 30:15s work:rest period adding up to a total of ~50 min per training session including warm-up.

Each of the main topics is covered in at least 3 exercises (some full-body exercises overlap between topics). Variations within each exercise are proposed in order to increase or decrease the level of difficulty depending of the age and/or fitness level of each individual performing the exercise. The instruction during B-FIT was to complete as many repetitions as possible in each station during the

30s work periods. In addition to B-FIT, 25 min of badminton match play was conducted per training session with 6-8 students playing on each of the available courts.
BAD consisted of ~50 min of badminton match play in combination with ~25 min of running and light core training once a week for 8 weeks.

Testing

Testing was completed on two separate days (>36 h apart) before and after the training intervention (INT), with anthropometrics, countermovement jump and the badminton speed test (B-SPEED[22]) on one day and a 5+20m sprint test and the badminton endurance test (B-ENDURANCE[21]) on a separate day.

Anthropometrics

Body mass, body fat and skeletal muscle mass (SMM) were measured with a body composition analyzer (InBody230, BioSpace, Korea) under standardized conditions.

B-ENDURANCE

The badminton-specific endurance test was conducted in accordance with Madsen et al., [21]. The test consists of exercise intervals including eight actions in each interval bout, followed by 10 s of recovery. The pace in each exercise bout gradually increased as the test progressed. Each interval was initiated from the center of the court and consisted of two actions toward each of the four corners performed in randomized order as dictated by a computer with audiovisual output**.** Before, during, and after the test, heart rate was recorded using a Polar heart rate monitor FS2c with matching T-31 heart rate belt weighing ~100 g (Polar, Kempele, Finland).

B-SPEED

The badminton-specific speed test was conducted in accordance with Madsen et al., [22]. The test consisted of five maximal actions to each of four sensors located in the corners of the court. The 20 actions were performed in a randomized order as dictated by computer screen shots displayed one second following completion of the previous action. Following a familiarization (a warm-up) trial, three attempts were made, and the fastest performance was recorded as the B-SPEED performance.

Sprint test

Subjects sprinted 20 m from a standing start position. Time (0, 5 and 20m) was recorded by photocells (Witty, Microgate, Italy) and stored electronically. Each subject completed three sprints separated by 1 minute of passive rest The best sprint time was used as the test result for each subject.

Counter Movement Jump

Counter movement jump (CMJ) performance was recorded using a force platform with 200 Hz precision (Pasco force platform, PS-2141, Rosewille, California, U.S,). Arms were fixed with hands positioned on the hips and players were asked to perform a flexion of the legs followed by a maximal jump and the highest of three attempt recorded as the maximal CMJ.

Statistics

Training and group characteristics prior to the intervention were compared using a student's unpaired t-tests. To test for differences between groups (B-FIT & BAD) and within time (Pre vs. Post) a two-way ANOVA for repeated measures were used. When an overall statistical difference was obtained, a Student-Newman-Keulls post hoc test was used as a multiple-comparison procedure to isolate specific differences. A significance level (α) of 0.05 was used. Data are presented as means±SE

Results

Training

Total time spent on training during INT was not different between B-FIT and BAD (677±14 vs. 688±19 min).

Anthropometrics

B-FIT decreased ($p<0.05$) body fat mass by 0.7±0.4 kg after INT, corresponding to a decrease in body fat percentage of 0.9%. No change in body fat mass (0.1±0.4kg) and body fat percentage was observed in BAD. B-FIT and BAD increased ($p<0.05$) SMM by 0.4±0.3 and 0.7±0.4 kg, respectively with no difference between groups.

Badminton specific performance

B-FIT and BAD both improved ($p<0.05$) B-SPEED performance (7.2 vs. 3.0% respectively) with no difference between groups. B-FIT improved ($p<0.01$) B-END performance by 42% which is more ($p<0.05$) than BAD who did not improve (6%; $p=0.70$).

Counter movement jump and sprint ability

No change was observed in the CMJ height or in the 5 and 20m sprint test in either group.

Discussion

The present study demonstrated that 8-weeks of B-FIT, but not BAD, decreased fat mass and fat percentage in high school students. In addition, B-FIT improved both badminton specific performance (B-ENDURANCE and B-SPEED) whereas BAD only improved in B-SPEED.

In the present study, B-FIT decreased ($p<0.05$) body fat mass by 0.7±0.4 kg. This is lower than reported after 12 weeks of football training in sedentary males (2.7 kg)[17]. Discrepancies may be due to subjects (untrained males aged 30 vs high school students aged 16 yrs), differences in training period (12 vs. 8 weeks) and weekly training volume (2-3x60min vs. 1x80-90 min per week).

The prevalence of obesity in Denmark has increased more than 5-fold since the 1940's. Many of the lifestyle related diseases do not impact early in the lifespan and no direct relationship between exercise and health exists in children. However, it is well documented that there is a relation between precursors for a great number of lifestyle related diseases, such as type II diabetes, obesity and cardiovascular disease, and physical activity[1]. In addition, many more kids of today carry over the higher "prevalence" of risk factors into adulthood than previously[3]. Together with inactivity, obesity is related to the complex of metabolic syndrome, a syndrome with increased prevalence of e.g. insulin resistance and cardiovascular risk factors[2]. Thus, the findings in the present study, of a significant reduction in fat mass among the otherwise healthy students after only 8 weeks of specific B-FIT training once a week, are significant. The fact that this was only observed in B-FIT and not in BAD suggests the need for specific training focusing on full body exercises in order to bring a health perspective in to PE classes in schools . However, it has to be mentioned, that the B-FIT group had a significant higher amount of body fat and higher percent body fat prior to the intervention period, mainly due to a higher relative number of girls, which we cannot exclude as a confounder to the results.

The exercises in B-FIT can be conducted in every school with a high number of participants. Furthermore, badminton specific movements together with badminton match play are an inspiring way to make children and adolescents move in a fun and effective way. This is likely because badminton is a fast movement game where performance rely on explosive movements and specific muscle strength for accelerations and decelerations, jumping and for maintaining balance before returning to the center of the court[7,9–11,15,30] and it has previously been reported that the rate of perceived exertion (RPE) is lower in team sports compared to individual sports (e.g. soccer vs. running)[17]. The integrated badminton ability requires a complex interplay between specific muscle groups and a high rate of force development and superior strength in specific muscle groups such as the quadriceps and gluteus muscles in the dominant leg, used to decelerate many of the fast movements such as lunges[4,13,19,20], which may explain part of the better performance observed in the

B-SPEED test after B-FIT compared to BAD. The superior B-ENDURANCE performance after a period of badminton specific training (B-FIT) is supported by Walklate et al.,[28] reporting improved performance in a 300-meter shuttle run test, as well as a custom-made badminton sprint test following four weeks of badminton-specific repeated-sprint training in Australian elite players, with no change in straight line sprint performance.

Elite youth badminton players gradually improve their badminton specific endurance capacity with age but is not correlated to simple growth. This suggests that regular training, with explicit focus on specific motor skills as specific badminton footwork in combination with match play or match-like training exercises, may lead to marked improvements in the specific badminton performance. In agreement, Wilkinson et al.[29] found no difference in a running speed test, but superior performance in elite squash players in a squash-specific speed tests compared to non-squash players. In addition, Young et al.,[31] observed training specific improvements in sprint performance (improved change-of-direction but not straight-line sprint performance) among recreationally active male subjects suggesting a need for badminton specific tests when evaluating long-term effects of badminton specific training.

In summary, B-FIT was shown to have significant benefits on health-related changes in body-composition which was in contrast to BAD, and badminton specific performance in young and healthy Danish college students with a higher improvement in B-END and similar in B-SPEED. These changes occurred in spite of a limited intervention period (1x/week for 8 weeks).

Perspectives

B-FIT can be integrated in normal PE lessons once a week and is effective in improving badminton specific performance and body composition, which may have a broad impact on general fitness and health. Further studies should provide an insight into the effects of this type of training in groups varying in age, gender, social background. In addition, investigate the long-term effects and compliance in recreational B-FIT training, including the influence of training volume and intensity on a range of physiological adaptations.

Acknowledgements

The authors are grateful to the Badminton World Federation (BWF), Danske Gymnastik Foreninger (DGI) and Stenhus Gymnasium & HF (Stenhus) for supporting the study. In addition, we would like to thank the students of Stenhus for participating in the study and to Larsen Elektronik, Praestoe, Denmark for helping in constructing the sensors used in the badminton specific tests.

Reference list

1. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet (London, England)* 2006;368(9532):299-304.
2. Andersen LB, Sardinha LB, Froberg K, Riddoch CJ, Page AS, Anderssen S a. Fitness, fatness and clustering of cardiovascular risk factors in children from Denmark, Estonia and Portugal: the European Youth Heart Study. *Int. J. Pediatr. Obes.* 2008;3 Suppl 1(December 2015):58-66.
3. Andersen LB. Tracking of risk factors for coronary heart disease from adolescence to young adulthood with special emphasis on physical activity and fitness. A longitudinal study. *Dan. Med. Bull.* 1996;43(5):407-418.
4. Andersen LL, Larsson B, Overgaard H, Aagaard P. Torque–velocity characteristics and contractile rate of force development in elite badminton players. *Eur. J. Sport Sci.* 2007;7(3):127-134.
5. Anderssen S a, Cooper AR, Riddoch C, et al. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *Eur. J. Cardiovasc. Prev. Rehabil.* 2007;14(4):526-531.
6. Buchheit M, Spencer M, Ahmaidi S. Reliability, usefulness, and validity of a repeated sprint and jump ability test. *Int. J. Sports Physiol. Perform.* 2010;5(1):3-17. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20308692.
7. Cabello Manrique D, González-Badillo JJ. Analysis of the characteristics of competitive badminton. *Br. J. Sports Med.* 2003;37(1):62-66.
8. Chin M, Wong AS, So RC, Siu OT, Steininger K, Lo DT. Sport specific fitness testing of elite badminton players. *Br. J. Sports Med.* 1995;29(3):153-157.
9. Faude O, Meyer T, Fries M, Kindermann W. Physiological testing in badminton. *A. Lees , D. Cabello, G. Torres, (Eds.), Sci. racket Sport. IV* 2009;IV:5-13.
10. Faude O, Meyer T, Rosenberger F, Fries M, Huber G, Kindermann W. Physiological characteristics of badminton match play. *Eur. J. Appl. Physiol.* 2007;100(4):479-85.
11. Fuchs M, Faude O, Wegmann M, Meyer T. Critical Evaluation of a Badminton-Specific Endurance Test. *Int. J. Sports Physiol. Perform.* 2014;9(2):249-255. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23751868.
12. Halbert J, Silagy C, Finucane P, Withers R, Hamdorf P, Andrews G. The effectiveness of exercise training in lowering blood pressure: a meta-analysis of randomised controlled trials of 4 weeks or longer. *J. Hum. Hypertens.* 1997;11(10):641-649.

13. Hong Y, Wang SJ, Lam WK, Cheung JTM. Kinetics of badminton lunges in four directions. *J. Appl. Biomech.* 2014;30(1):113-118.

14. Hu G, Tuomilehto J, Silventoinen K, Barengo NC, Peltonen M, Jousilahti P. The effects of physical activity and body mass index on cardiovascular, cancer and all-cause mortality among 47 212 middle-aged Finnish men and women. *Int. J. Obes. (Lond).* 2005;29(8):894-902.

15. Hughes MG, Andrew M, Ramsay R. A sport-specific endurance performance test for elite badminton players. *'Commmunications to 12th Commonw. Int. Sport Conf. J. Sport. Sci.* 2003;36(21):277-278.

16. Jeon CY, Lokken RP, Hu FB, Van Dam RM. Physical activity of moderate intensity and risk of type 2 diabetes: A systematic review. *Diabetes Care* 2007;30(3):744-752.

17. Krustrup P, Nielsen J, Krustrup B, et al. Recreational soccer is an effective health-promoting activity for untrained men. *Br. J. Sports Med.* 2009;43(October):825–831.

18. Krustrup P, Aagaard P, Nybo L, Petersen J, Mohr M, Bangsbo J. Recreational football as a health promoting activity: a topical review. *Scand. J. Med. Sci. Sports* 2010;20 Suppl 1:1-13.

19. Kuntze G, Mansfield N, Sellers W. A biomechanical analysis of common lunge tasks in badminton. *J. Sports Sci.* 2010;28(2):183-191.

20. Lin C-F, Hua S-H, Huang M-T, Lee H-H, Liao J-C. Biomechanical analysis of knee and trunk in badminton players with and without knee pain during backhand diagonal lunges. *J. Sports Sci.* 2015;33(14):1429-1439.

21. Madsen CM, Højlyng M, Nybo L. Testing of badminton specific endurance. *J. Strength Cond. Res.* 2016;2 In Press.

22. Madsen CM, Karlsen A, Nybo L. Novel speed test for evaluation of badminton specific movements. *J. Strength Cond. Res.* 2015;29(5):1203-10.

23. Majumdar P, Khanna GL, Malik V, Sachdeva S, Arif M, Mandal M. Physiological analysis to quantify training load in badminton. *Br. J. Sports Med.* 1997;31(4):342-5.

24. Mokdad AH, Marks JS, Stroup DF, Gerberding JL. Actual Causes of Death in the United States. *J. Am. Med. Assoc.* 1993;270(18):2207-2213.

25. Ooi CH, Tan A, Ahmad A, et al. Physiological characteristics of elite and sub-elite badminton players. *J. Sports Sci.* 2009;27(14):1591-9.

26. Patterson S, Pattison J, Legg H, Gibson A-M, Brown N. The impact of badminton on health markers in untrained females. *J. Sports Sci.* 2016;00(00):1-9.

27. Pluim BM, Staal JB, Marks BL, Miller S, Miley D. Health benefits of tennis. *Br. J. Sports Med.* 2007;41(11):760-8.

28. Walklate BM, O'Brien BJ, Paton CD, Young W. Supplementing Regular Traing with Short-

Duration Sprint-Agility Trainning Leads to a Substantial Increase in Repeated Sprint-Agility Performance With National Level Badminton Players. *J. Strength Cond. Res.* 2009;23(5):1477-1481.

29. Wilkinson M, Leedale-Brown D, Winter EM. Validity of a Squash-Specific Test of Change-of-Direction Speed. *Int. J. Sports Physiol. Perform.* 2009;4:176-185.
30. Wonisch M, Hofmann P, Schwaberger G, von Duvillard SP, Klein W. Validation of a field test for the non-invasive determination of badminton specific aerobic performance. *Br. J. Sports Med.* 2003;37(2):115-118..
31. Young W, McDowell M, Scarlett B. Specificity of sprint and agility training methods. *J Strength Cond Res* 2001;15(3):315-319.