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Effects of combined aerobics and abdominal strengthening exercises on abdominal adiposity in sedentary adults

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Abstract

Background: Excess abdominal adiposity has been associated with increased morbidity and mortality. Though aerobic exercises significantly reduce general adiposity, it has no effect on abdominal adiposity. However the effects of a combination of aerobic and abdominal strengthening exercises on abdominal adiposity are not known.

Objective: This study was designed to evaluate the effects of a 12-week aerobic and abdominal strengthening exercise programme on abdominal adiposity in sedentary adults.

Methods: A total of 105 consenting sedentary adults participated in this study. They were randomly recruited from the Ibadan metropolis. Participants went through exercise training which included aerobic and abdominal strengthening exercises. Exercise was carried out thrice weekly for 12 consecutive weeks. Abdominal adiposity indices of Waist Circumference (WC), Waist-to-Hip Ratio (WHR), Sum of Abdominal Skinfold (SAS) were measured at baseline, 4th, 8th and 12th weeks. Data were analyzed using descriptive statistics of mean and standard deviation and repeated measures ANOVA at p=0.05.

Results: 74 participants with mean age (34.8±9.1yrs) completed the study. At the end of the 12 –week exercise, there was significant reduction in WC (94.8±10.2 to 89.2±9.8cm), WHR (0.89±0.06 to 0.86±0.05) and SAS (88.9±10.9 to 77.3±13.5mm) among the female participants. Within the male participants, there was significant reduction in WC (88.5±7.4 to 83.8±4.7cm), and in SAS (60.1±8.4 to 54.5±8.5mm), but no statistically significant difference was observed in the WHR (0.88±0.04 to 0.87±0.06).

Conclusion: Twelve-week aerobic and abdominal strengthening exercise programme, without caloric restriction, reduced abdominal adiposity in apparently-healthy sedentary adults, hence it is recommended for its beneficial effects on abdominal adiposity.

Keywords: *Aerobic exercises, abdominal strengthening exercise, abdominal adiposity*

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Résumé

Contexte: L'excès d'adiposité abdominale a été associé à une morbidité accrue. Bien que les exercices aérobies réduisent considérablement l'adiposité en général, il n' y a pas d'effet sur l'adiposité abdominale. Cependant, les effets de la combinaison d'aérobies et d'exercices de renforcement abdominal sur l'adiposité abdominale sont négatifs.

Objectif: Cette étude a été faite pour évaluer les effets d'un aérobie de 12 semaines et un programme d'exercices de renforcement abdominal sur l'adiposité abdominal chez des adultes sédentaires.

Méthodes: Un total de 105 adultes considérés sédentaires ont pris part à cette étude. Ils ont été recrutés au hasard dans la ville d'Ibadan. Les participants ont pris part à l'entrainement d'aérobies, y compris des exercices de renforcement abdominal. L'exercice a été effectué trois fois par semaine pendant 12 semaines consécutives. Des indices d'adiposité abdominale (WC), les hanches (WHR), des plis cutanés abdominaux(SAS) ont été mesurés au départ, à la 4 e, 8 e et 12 e semaine. Les données ont été analysées à l'aide des statistiques descriptives à moyen et d'écart-type et à mesures ANOVA répétées à p = 0,05.

Résultats: 74 participants avec l'âge moyen de (34,8 ± de 9.1yrs) ont terminé l'étude. A la fin de l'exercice après 12 semaines, il y avait une réduction importante de WC (94,8 ± 10,2 à 89,2 ± 9,8 cm), RTH (0,89 ± 0,06 à 0,86 ± 0,05) et SAS (88,9 ± 10,9 à 77,3 ± 13,5 mm) chez les participants de sexe féminin. Il y avait également d'importante réduction de WC (88,5 ± 7,4 à 83,8 ± 4,7 cm de), et SAS (60,1 ± 8,4 à 54,5 ± 8,5 mm) chez les participants de sexe masculin. Mais aucune différence importante n'a été statiquement observée dans le WHR (0,88 ± 0,04 de 0,87 ± 0,06).

Conclusion: Douze semaines d'aérobie et de programme d'exercices de renforcement abdominal, sans restriction calorique, a réduit l'adiposité abdominale chez les adultes sédentaires, apparemment en bonne santé. Cette pratique est donc recommandée pour ses effets bénéfiques sur l'adiposité abdominale.

Introduction

Excess abdominal adiposity has been linked with increased risk of cardiovascular diseases, diabetes, hypertension, and other chronic diseases and

consequently reduced quality of life [1]. Excess abdominal adipose tissue plays a vital role in the development of systemic inflammatory state, which contributes to obesity-associated vasculopathy and cardiovascular risk [2]. Accruing evidence suggests that the quantity of intra-abdominal fat explains the association between abdominal adiposity, morbidity and mortality [3, 4]. Lifestyle interventions incorporating caloric restriction and/or increased energy expenditure through increased physical activity can help reduce abdominal fat deposit, thereby ameliorating this risk [1]. Exercise therapy is an integral component of obesity management, and may affect the selective loss of abdominal adipose tissue.

There are several measures of assessing abdominal adiposity, but according to WHO report [4], waist circumference and waist hip ratio are specific and valid measures for estimating abdominal fat deposition. Both have been recommended for use in epidemiological studies because of their good correlation with abdominal fat mass estimation using dual-energy x-ray absorptiometry (DXA) [5, 6]. Also abdominal skinfold has been reported to be a reliable means of assessing central fat mass [7].

While it has been advocated that apparently healthy sedentary adults should be the focus of screening and primary prevention strategies to proactively combat the global increase in obesity-related disorders [8], yet this population rarely received adequate clinical attention [9]. This may be due, in part, to the inconsistency in reports of studies that investigated the effect of exercise on abdominal adiposity [10 -12]. A systematic review by Kay *et al*, [13] suggested that interventions involving increased aerobic exercise can beneficially alter abdominal adiposity in overweight and obese individuals, and that this may occur independent of weight loss. Conversely, Thorogood *et al*, [14] undertook a systematic review and meta-analysis of randomized controlled trials (RCTs) to evaluate the efficacy of aerobic exercise with minimal duration of 12 weeks on abdominal adiposity, blood pressure, total cholesterol, triglyceride levels, and weight in overweight and obese populations. They concluded that moderate-intensity aerobic exercise alone is ineffective for abdominal fat loss.

While there are inconsistencies in reports of interventional studies on the effects of exercise with or without caloric restriction on abdominal adiposity, evidence on the influence of different combination of exercise regimen on abdominal adiposity continues to grow [15 - 19]. However, little is known about the effect of a combination of aerobic and abdominal strengthening exercises on abdominal adiposity [20, 21]. Therefore, this study was aimed at investigating the effects of combined aerobic and abdominal strengthening exercise on abdominal adiposity in apparently healthy sedentary adults.

Materials and methods

This was an interventional study with pretest and post-test design. Ethical approval was sought and obtained from the Institution's Health Research Ethics Committee. The study was carried out at the Exercise Laboratory of Physiotherapy Department of the Institution. Participants were recruited through the use of advert posters containing information about the research programme, which was distributed and pasted in various public places like eateries, post-offices, worship centers and hospitals within the city of Ibadan. The nature, purpose and procedure of the research were explained to the prospective participants. Written informed consent was obtained from the prospective participant prior to the baseline assessment. The participants were informed of their freedom to refuse to take part in the study and their right to withdraw at any given time they choose. They were also assured of their confidentiality throughout the study. In order to ensure the safety of each prospective participant, participants completed an Exercise Readiness Questionnaire (ERQ) and any prospective participant who answered yes to any of the questions in the ERQ [22] was referred to the physicians for further examination and medical clearance before such an individual was enrolled in the programme. To ensure that participant will be able to cope with the exercise regimen, they had to complete a 3-minutes step test as described by Siconolfi *et al* [23]. Only participants who were able to complete the step test were included this study. This was to minimize the possible variations in the cardio-respiratory endurance between participants.

Participants' demographic data of age, sex, weight, height and body mass index were obtained and recorded. Participants went through the combined aerobic and abdominal strengthening exercise training programme under supervision, three times per week, on alternate days, for 12 consecutive weeks. Before the commencement of each exercise session, measurements of resting blood pressure and heart rate were taken for each participant. Measurements of Waist Circumference (WC), Waist-to-Hip Ratio (WHR), Sum of Abdominal Skinfold (SSF) were taken at baseline and thereafter after every four weeks. The data of all indices of interest were taken at baseline to enable the researcher evaluate the pre-intervention level and justify the effect of the intervention on the selected parameters.

Exercise protocol

Participants were asked to maintain their usual dietary habit and activity of daily living throughout the duration of the study [24]. Exercises were arranged in two stations. In the first station, participants went through general aerobic class, which began with 5 minutes warm-up exercises, followed by aerobics and rounded-up with 5 minutes cool-down exercises. The warm-up exercise included: alternate high knee raise, shoulder lift, leg and hand swing, while the aerobic exercise comprised of torso twist, abdominal crunch, alternate torso twist and abdominal crunch, shoulder to knee stretch. The cool down exercises consisted of breathing and stretching exercises. The duration of the general aerobic session was maintained at 15 minutes during the first 4 weeks; this was later increased by 5minutes after every four weeks.

The second station consisted of abdominal exercise arranged in circuit. These include: hip rolls, modified bridging, double knee to chest, alternate straight leg raise, and seated knee tucks. The duration in each station was progressed from two minutes to two and half minutes to three minutes every four weeks with a change over period of one minute in-between the stations. All exercise sessions were supervised [16, 24 - 25].

Data analysis

Data obtained from the study were analyzed using descriptive statistics of mean and standard deviation to summarize the data, while tables and graphs were used to present the data on abdominal adiposity. Repeated Measures Analysis of Variance was used to test for within group comparisons. Alpha level was set at 0.05 while alpha level for protected dependent t test was set at 0.017.

Results

A total of 105 (17males, 88females) apparently healthy sedentary adults participated in this study. They were aged between 20 and 58 years and were not engaged in routine exercise either at recreational or competitive level within the last six months. However, 74 participants completed the study. 31 (29.5%) participants opted out of the study for various reasons on their own volition at various stages. Such reasons include inability to make time commitment (18), decision to diet (3), pregnancy (4), excess weight loss (5) and relocation from city of the research (1).

The physical characteristics and baseline parameters of participants at baseline are shown in Table 1. The female participants weighed more than the male counterpart (84.6±13.8 vs 68.6±7.3). On the average the males were overweight (BMI=28.9±4.7), while the females were obese (BMI=34.3±8.4). All the participants were normotensive. Male participants had WC and WHR lower than the CVD risk classification cut-off of 102cm (WC) and 1 (WHR) for men [26]; while the female participants had excess abdominal adiposity with WC and WHR greater than the CVD risk classification cut-off of 88cm (WC) and 0.8 (WHR) for women [26].

Table 1: Physical characteristics, anthropometric and abdominal indices of participants at baseline of study

	Males (n=17) Mean ± S.D	Females (n=88) Mean ± S.D
Age (yrs)	32.4± 8.7	35.4± 10.2
Weight (kg)	68.6± 7.3	84.6± 13.8
BMI (kg/m^2)	28.9± 4.7	34.3± 8.4
SBP (mmHg)	117.3± 11.1	119.5±12.3
DBP (mmHg)	79.4± 9.8	80.9± 10.2
WC (cm)	89.7± 8.2	96.2± 10.8
WHR	0.88±0.05	0.89± 0.06
SAS (mm)	59.7±7.2	88.5± 12.6

Key:
Age (yrs): *Age of participants in years*
Height (cm): *Height of participants in centimeters*
Weight (kg): *Weight of participants in kilogramme*
BMI: *Body Mass Index*
SBP (mmHg): *Systolic blood pressure in millimeter of mercury*
DBP (mmHg): *Diastolic blood pressure in millimeter of mercury*
WC (cm): *Waist circumference in centimeters*
WHR: *Waist- Hip Ratio*
SAS: *Sum of Abdominal Skinfold*

Out of the 74 (10males; 64females) participants who completed the exercise programme, 65 participants (4 males; 61 females) had excess abdominal adiposity with initial waist circumference > 102centimeters for males and > 88centimeters for females (Table 2). Using the National Institute of Health CVD risk classification [26], among the male participants, 4 had increased CVD risk while another 2 had high CVD risk and 1 had very high risk. Among the females, 23 had increased risk, 28 had high risk and another had very high risk while 2 extremely high disease risks. Though all participants recruited for the study were apparently healthy, 65 (88%) out of the 74 participants had CVD risk ranging from increased to extremely high.

Changes in the abdominal adiposity indices of male and female participants from baseline across the various assessment periods are shown in Table 3 and 4 respectively. Male participants had significant

Table 2: Distribution of study participants across obesity class by BMI, waist circumference and associated disease risk (according to NIH Cardiovascular disease risk, 2000)

BMI(kg/m²)/Obesity class	Disease risk+			
	Men		Women	
	WC: ≤102cm (n)	≥102cm (n)	≤88cm (n)	≥88cm (n)
Under weight (<18.5)	-	-	-	-
Normal weight (18.5 – 24.9)	4	1*	7	21*
Overweight (25 – 29.9)	3*	2**	2*	28**
Obesity I (30 – 34.9)	-	1***	-	5***
Obesity II (35 – 39.9)	-	-	-	5***
Obesity III (>40)	-	-	-	2****

Key:
+: Relative to normal weight and waist circumference
**: Increased cardiovascular disease risk*
***: High cardiovascular disease risk*
****: Very high cardiovascular disease risk*
*****: Extremely high cardiovascular disease risk*

Table 3: Comparison of abdominal adiposity indices of male participants at baseline and across the various assessment periods during the study

Week N	Baseline 10 Mean ± SD	4 10 Mean ± SD	8 10 Mean ± SD	12 10 Mean ± SD	Mean change	p-value
WC	88.5±7.4	86.9±6.5	84.8±6.2	83.8 ±4.7*	-4.7	0.02
WHR	0.88±0.04	0.88±0.05	0.87±0.06	0.87±0.06	-0.01	0.15
SAS	60.1±8.4	58.7±7.1	56.5± 6.8	54.5±8.5*	-5.6	0.03

Key
WC (cm): Waist circumference in centimeters
WHR: Waist- Hip Ratio
SAS(mm): Sum of Abdominal Skinfold in millimeter
**: Significant*

Table 4: Comparison of abdominal adiposity indices of female participants at baseline and across the various assessment periods during the study

Week N	Baseline 64 Mean ± SD	4 64 Mean ± SD	8 64 Mean ± SD	12 64 Mean ± SD	Mean change	p-value
WC	94.8±10.2	92.7±9.8	89.8±9.5*	89.2 ±9.8	-5.6	0.01
WHR	0.89±0.06	0.88±0.06	0.87±0.07	0.86±0.05*	0.03	0.02
SAS	88.9±10.9	85.7±11.8	81.9±11.4*	77.3±13.5	11.6	0.001

Key:
WC (cm): Waist circumference in centimeters
WHR: Waist- Hip Ratio
SAS(mm): Sum of Abdominal Skinfold in millimeter
**: Significant*

reductions in the mean WC (88.5±7.4 to 83.8±9.7cm) and SAS (60.1±8.4 to 54.5±8.5mm), at the end of the twelfth week of the study, but there was no statistically significant difference in WHR (0.88±0.04 to 0.87±0.06) Table 3. The female participants had significant reductions in WC (94.8±10.2 to 89.2±9.8cm), WHR (0.89±0.06 to 0.86±0.05) and SAS (88.9±10.9 to 77.3±13.5mm). Significant difference was first observed in WC and SAS at the end of the eighth week of study, while WHR showed significant difference at the end of the twelfth week of study.

Discussion

This study was a single-center study in which the participants served as their own control to eliminate between group variability; however, the interpretation of the result of this study might be limited by the inability of the researchers to objectively monitor the adherence of the participants to their usual dietary habit. The study investigated changes in abdominal adiposity indices following a 12-week exercise programme. It was hypothesized that there would be no significant difference in abdominal adiposity indices of male and female participants from baseline to the end of the study. Statistically significant differences in the mean waist circumference and sum of abdominal skinfolds of female participants were first observed between baseline and the end of the eighth week, while significant changes in WHR were observed at the end of the twelfth week. This finding showed that a combination of aerobic and abdominal strengthening exercise carried out thrice a week resulted in significant reduction in abdominal adiposity without caloric restriction.

It has been demonstrated that when moderate-intensity exercise is performed for long duration (> 45 min/d), there is greater lipid and lower carbohydrate oxidation compared with shorter duration [27]. Longer exercise duration is associated with a marked increase in lipolysis in abdominal subcutaneous adipose tissue in comparison with femoral adipose tissue [28], suggesting that exercise-induced fat loss would be associated with a preferential reduction in abdominal adiposity. In addition, strengthening exercise has been shown to positively affect insulin sensitivity and other processes associated with abdominal fat accumulation [29], and there is evidence that despite incurring significantly lower energy expenditure than aerobic exercise, abdominal muscle strengthening may directly reduce abdominal adipose tissue [13]. These may explain, in part, the reduction in adiposity level observed in this study. This observation might have important public health implications in addressing excess abdominal adiposity and its related health risk among sedentary apparently healthy adults [8, 30-31].

This finding is in line with the report of Slentz *et al*, [32], who tested the effect of different exercise amount on abdominal adiposity in overweight sedentary adults. They found that moderate intensity exercise (55-65% maximum heart rate) lasting 30 minutes carried out thrice weekly prevented increase in abdominal adiposity, and that increase in duration of moderate intensity exercise above 30 minutes resulted in significant decreases in visceral, subcutaneous and total abdominal fat without changes in caloric intake. Negative energy balance created by additional energy expenditure during the exercise sessions in previously sedentary individuals might explain this finding. Aerobic exercise of moderate intensity carried out for more than 30 minutes has been shown to draw on fat deposit in adipose tissue for energy production.

Data from this study suggest that a strictly supervised exercise programme could have positive effect on reducing trans-abdominal fat without caloric restriction. According to Ross and Janssen [15], reduction in abdominal adiposity level in response to exercise training is influenced by baseline adiposity levels and obesity phenotype. This implies that irrespective of the obesity phenotype, the greater the abdominal fat at baseline the more the abdominal fat loss, and the smaller the abdominal fat at baseline the less abdominal fat loss. This also interprets that with the same amount of fat mass, and individual with central obesity phenotype will lose more abdominal fat compared with another individual with peripheral obesity phenotype.

In the present study, out of the 74 (10males; 64females) participants who completed the exercise programme, 65 participants (4 males; 61 females) had abdominal obesity with initial waist circumference > 102centimeters for males and > 88centimeters for females. The observed reduction in abdominal adiposity in this study is supported by the assertion that abdominal fat loss is influenced by adiposity levels at baseline.

It was also observed that supervised exercise programme carried out at moderate intensity exercise for a minimum duration of 45 minutes not only prevented increases in visceral fat but actually resulted in sizable and significant decreases in subcutaneous and total abdominal fat. This suggests that similar exercise prescription might be helpful in reversing excess abdominal adiposity as

modifiable risk factor for metabolic disease. That this amount of exercise can reverse abdominal obesity as a modifiable risk factor for metabolic disease is supported by previous studies that showed improvements in lipids and lipoproteins [33], insulin sensitivity [34], and body mass and fat mass loss [18].

Conclusion

A combination of aerobics and abdominal strengthening exercises significantly reduced abdominal adiposity in previously sedentary, apparently healthy adults. This finding has important public health implications in addressing abdominal obesity and its related health risk among sedentary healthy adults, hence exercise regimen combining aerobics and abdominal strengthening exercises may be recommended for this population for its beneficial effects.

References

1. World Health Organization. Obesity: Preventing and managing the global epidemic. Report of a WHO Consultation on Obesity. 2000; Geneva, Switzerland.(http://www.who.int/ nutrition/ publications/obesity/WHO_TRS_894/en/ index.html accessed on the 11th of May 2012)
2. Calabro P and Yeh TH. Intra-abdominal adiposity, inflammation, and cardiovascular fitness in people at risk of type2 diabetes: early markers for insulin resistance. Curr Hypertens Rep. 2008; 32-38
3. Kuk JL. Visceral Fat Is An Independent Predictor of All-Cause Mortality In Men. Obes Res 2006; 14: 336–341.
4. World Health Organization. Report of Expert Consultation on waist circumference and waist-hip-ration.2008;Geneva,Switzerland. (http:// www.who.int/nutrition/publications/obesity/ WHO_report_waistcircumference_and_waisthip_ratio/ en/index.html accessed on 26th September 2011.)
5. National Institutes for Health and Clinical Excellence 2006. Obesity-Identification and classification.www.nice.org.uk/ download.aspx?o=CG43FullGuideline2 accessed on the 27th of August 2013;7:25pmý
6. Klein S, Allison DB, Heymsfield SB, *et al,* Waist circumference and cardiometabolic risk: a consensus statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. American Journal of Clinical Nutrition 2007; 85:1197–202.
7. Ketel IJG, Volman MNM, Seidell JC, *et al,* Superiority of skinfold measurements and waist over waist-to-hip ratio for determination of body fat distribution in a population-based cohort of Caucasian Dutch adults. Eur J Endocrinol 2007; 156; 655–661
8. Ross R, Freeman J, Hudson R and Janssen I. Abdominal obesity, muscle composition, and insulin resistance in premenopausal women. J Clin Endocrinol Metab 2002; 87: 5044–5051.
9. Sanya, AO. Physiotherapy and Wellness: rungs of the ladder. An Inaugural Lecture at the University of Ibadan in the 25th of March, 2010. University of Ibadan. Ibadan.
10. King NA, Hopkins M, Caudwell P, *et al.* Individual variability following 12 weeks of supervised exercise: identification and characterization of compensation for exercise-induced weight loss. Int J Obes Relat Metab Disord 2008; 32: 177–184.
11. Williams PT. Changes in body weight and waist circumference affect incident hypercholesterolemia during 7 years of follow-up. Obesity 2008; 16: 2163–2168.
12. Nicklas BJ, Wang X, You T, *et al.* Effect of exercise intensity on abdominal fat loss during calorie restriction in overweight and obese postmenopausal women: a randomized, controlled trial. Am J Clin Nutr 2009; 89: 1043–1052.
13. Kay SJ, Fiatarone HN and Singh MA. The influence of physical activity on abdominal fat: a systematic review of the literature. Obes Rev 2006; 7: 183–200.
14. Thorogood A, Mottillo S, Shimony A, *et al.* Isolated Aerobic Exercise and Weight Loss: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Am. J. Med. 2011; 124: 747-755
15. Ross R and Janssen I. Physical activity, total and regional obesity: dose-response considerations. Med Sci Sports Exerc 2001; 33. Suppl 6: S521–S527.
16. Donnelly JE, Hill JO, Jacobsen DJ, *et al.* Effects of a 16-month randomized controlled exercise trial on body weight and composition in young, overweight men and women: the Midwest Exercise Trial. Arch Intern Med 2003; 163: 1343–1350.
17. Ross R, Janssen I, Dawson J, *et al.* Exercise-induced reduction in obesity and insulin

resistance in women: A randomized controlled trial. Obes Res 2004; 12: 789–798.

18. Okura T, Nakata Y, Lee DJ, *et al.* Effects of aerobic exercise and obesity phenotype on abdominal fat reduction in response to weight loss. Int J Obes Relat Metab Disord 2005; 29: 1259–1266
19. Okura T, NakataY, Ohkawara K, *et al.* Effects of aerobic exercise on metabolic syndrome improvement in response to weight reduction. Obesity 2007; 15. 10: 2478-2484
20. Slentz CA, Braun DD, Johnson JL, *et al.* Effects of the amount of exercise on body weight, body composition and measures of central obesity-STRRIDE: Arch Intern Med 2004; 164: 31-39
21. Donnelly JE and Smith BK. Is exercise effective for weight loss with ad libitum diet? Energy balance, compensation, and gender differences. Exerc Sport Sci Rev 2005; 33: 169–174.
22. Church TS, Earnest CP, Skinner JS and Blair SN. Effects of different doses of physical activity on cardiorespiratory fitness among sedentary, overweight or obese postmenopausal women with elevated blood pressure: a randomized controlled trial. JAMA 2007; 297: 2081–2091.
23. Siconofi SF, Garbe CE, Lasater TM and Carleton RA.: A simple, valid step test for estimating maximal oxygen uptake in epidemiologic studies. Am J Epidemiol, 1985; 121: 382 – 90.
24. Albright AFM, Hornsby G, Kriska A, *et al.* Exercise and type 2 diabetes. Med Sci Sports Exerc 2000; 32: 1345–1360.
25. Watts K, Beye P, Siafarikas A, Davis EA, *et al.* Exercise training normalizes vascular dysfunction and improves central adiposity in obese adolescents. J Am Coll Cardiol 2004; 43. 10: 1823 – 1827
26. National institutes of Health National Heart Lung and Blood Institute. Clinical guidelines on the identification, evaluation and treatment of overweight and obesity in adults: the evidence report. Obes Res1998; 6: S51-S210
27. Davis SN, Shavers C and Costa F. Gender-related differences in counter-regulatory responses to antecedent hypoglycemia in normal humans. J Clin Endocrinol Metab 2000; 85: 2148–2157.
28. Horowitz JF, Leone TC, Feng W, *et al.* Effect of endurance training on lipid metabolism in women: a potential role for PPARalpha in the metabolic response to training. Am J Physiol Endocrinol Metab 2000; 279: E348–55.
29. Janssen I, Katzmarzyk PT and Ross R. Body mass index, waist circumference, and health risk: evidence in support of current National Institutes of Health guidelines. Arch Intern Med 2002; 162: 2074-2079.
30. Ross R, Aru J, Freeman J, *et al.* Abdominal adiposity and insulin resistance in obese men. Am J Physiol Endocrinol Metab 2002; 282: E657–663.
31. Kraus, W., Houmard, J., Duscha, B.,*et al*, Exercise training amount and intensity effects on plasma lipoproteins: a randomized, controlled trial N Engl J Med 2002; 347: 1483–1492.
32. Slentz CA, Aiken LB, Houmard JA, *et al.* Inactivity, exercise, and visceral fat. STRRIDE: A randomized, controlled study of exercise intensity and amount. J Appl Physiol 2005; 99: 1613–1618.
33. Schutte JE, Townsend EJ, Hugg J, *et al.*. Density of lean body mass is greater in blacks than in whites. J Appl Physiol 2005; 56: 1647–1649.
34. Houmard J, Tanner C, Slentz C, *et al.* Effect of the volume and intensity of exercise training on insulin sensitivity. J Appl Physiol 2004; 96: 101–106.

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