Korean J Physiol Pharmacol
Vol 16: 175−180, June, 2012
http://dx.doi.org/10.4196/kjpp.2012.16.3.175

Yoga Training Improves Metabolic Parameters in Obese Boys

Dae Yun Seo[1], SungRyul Lee[1], Arturo Figueroa[2], Hyoung Kyu Kim[1], Yeong Ho Baek[3], Yi Sub Kwak[4], Nari Kim[1], Tae Hoon Choi[5], Byoung Doo Rhee[1,6], Kyung Soo Ko[1,6], Byung Joo Park[7], Song Young Park[2], and Jin Han[1]

[1]National Research Laboratory for Mitochondrial Signaling, Department of Physiology, College of Medicine, Cardiovascular and Metabolic Disease Center, Inje University, Busan 614-735, Korea, [2]Department of Nutrition, Food and Exercise Sciences, College of Human Sciences, Florida State University, Tallahassee, FL 32306, USA, [3]Department of Physical Education, Pusan National University, Busan 609-735, [4]Department of Physical Education, Dong-Eui University, Busan 614-714, [5]Department of Sport and Leisure Studies, Andong Science College, Andong 760-709, [6]Department of Internal Medicine, College of Medicine, Inje University, Seoul 100-032, [7]Division of Leisure & Sports Science, Dong Seo University, Busan 617-716, Korea

Yoga has been known to have stimulatory or inhibitory effects on the metabolic parameters and to be uncomplicated therapy for obesity. The purpose of the present study was to test the effect of an 8-week of yoga-asana training on body composition, lipid profile, and insulin resistance (IR) in obese adolescent boys. Twenty volunteers with body mass index (BMI) greater than the 95th percentile were randomly assigned to yoga (age 14.7±0.5 years, n=10) and control groups (age 14.6±1.0 years, n=10). The yoga group performed exercises three times per week at 40～60% of heart-rate reserve (HRR) for 8 weeks. IR was determined with the homeostasis model assessment of insulin resistance (HOMA-IR). After yoga training, body weight, BMI, fat mass (FM), and body fat % (BF %) were significantly decreased, and fat-free mass and basal metabolic rate were significantly increased than baseline values. FM and BF % were significantly improved in the yoga group compared with the control group ($p<0.05$). Total cholesterol (TC) was significantly decreased in the yoga group ($p<0.01$). HDL-cholesterol was decreased in both groups ($p<0.05$). No significant changes were observed between or within groups for triglycerides, LDL-cholesterol, glucose, insulin, and HOMA-IR. Our findings show that an 8-week of yoga training improves body composition and TC levels in obese adolescent boys, suggesting that yoga training may be effective in controlling some metabolic syndrome factors in obese adolescent boys.

Key Words: Yoga (asana), Obesity, Body composition, Lipid profile, HOMA-IR

INTRODUCTION

The primary cause of obesity is a chronic storage of excess energy [1], and physical inactivity is pivotal in its development [2]. The epidemic of obesity in adolescents has been expanded in the past several years [3]. Increases in body fat mass during adolescence may be related to the development and acceleration of cardiovascular risk factors [4], including hyperlipidemia [5], and insulin resistance [6]. Long-term insulin resistance may cause type 2 diabetes and a subsequent increase in morbidity and impaired glucose tolerance [7]. Thus, controlling obesity is critical for the reduction of future health problems and morbidity [8,9].

Potential therapeutic regimes for severe obesity are hospitalization, dietary modification, medication therapy, and bariatric surgery [3]; however, pharmacological agents for managing obesity are not approved in adolescents [3]. Although controlling adolescent obesity is important for quality of life and adult health, few non-invasive and non-pharmaceutical treatment options are available. Existing options that may be used alone or in combination are improving nutritional habits, increasing physical activity, and modifying behavior, and psychological outlook [10].

Yoga was developed in India to facilitate a vibrant lifestyle and meditation [11]. Currently, yoga is widely used to improve health and to attenuate or cure diseases. Dhyyana, pranayama and asana yoga practice emphasize in controlled breathing, meditation, and physical posture, respec-

Received February 21, 2012, Revised April 25, 2012, Accepted May 12, 2012

Corresponding to: Jin Han, National Research Laboratory for Mitochondrial Signaling, Department of Physiology, College of Medicine, Cardiovascular and Metabolic Disease Center Inje University, 633-165, Gaegeum-dong, Busanjin-gu, Busan 614-735, Korea. (Tel) 82-51-890-6727, (Fax) 82-51-894-5714, (E-mail) phyhanj@inje.ac.kr

ABBREVIATIONS: IR, insulin resistance; BMI, body mass index; HRR, heart rate reserve; HOMA-IR, homeostasis model assessment of insulin resistance; FM, fat mass; FFM, fat free mass; BF %, body fat %; TC, total cholesterol; TG, triglyceride; ACSM, American college of sports medicine; CDC, centers for disease control; RPE, rate of perceived exertion; THR, targeted heart rate; BMR, basal metabolic rate.

tively [12,13]. Asana yoga uses various postures to develop physical strength, flexibility, and endurance [13], and can be used as a moderate-intensity exercise for patients with limited aerobic capacity or restricted ability to exercise [14]. Furthermore, yoga has been shown to decrease hypertension and cardiac inflammation, stabilize the sympathetic nervous system, and improve psychological health and cardiac function [15-17].

Although the American College of Sports Medicine (ACSM) and Centers for Disease Control (CDC) suggest moderately intense physical activity for obese subjects [18,19] because exercise training has been shown to improve metabolic factors in subjects with obesity [20-23], obese adolescents engage in less physical activity during school days and on weekends than their non-obese peers [24]. In that context, yoga training may help obese adolescents to achieve the recommended levels of physical activity, and it may be an attractive alternative exercise training programs because it increases heart rate and muscle strength, has limited harmful side effects, and requires virtually no equipment [13,25].

Limited information is accessible regarding the impact of yoga-asana training, on cardiovascular-metabolic risk factors in obese adolescents. Accordingly, we hypothesized that yoga-asana training may have beneficial effect on metabolic parameters in obese adolescent boys. Therefore, we evaluated the effect of an 8-week of yoga-asana training on body composition, lipid profile, and the homeostasis model assessment of insulin resistance (HOMA-IR) in obese adolescent boys.

METHODS

Subjects and study design

Obese adolescent boys between the ages of 13 and 15 years with body mass index (BMI) was greater than the 95th percentile, as defined by French population standards [26], were recruited in Busan, Korea, through flyers posted in middle schools and outpatient waiting rooms and through advertisements in the school newspaper. We have fully explained the potential risks and benefits in the study before written informed consent was provided by parents and participants, according to the guidelines of the Ju Rae middle school research ethics committee. Participants who had hypertension (blood pressure >140/90 mmHg), were using medication, or had an injury in the 6 months previous the study were eliminated. We enrolled 19 subjects in the yoga (asana) group and 15 in the control group, who did not participate in physical activity program before 6 months. However, 14 subjects overall were excluded from the analysis because of low compliance to the yoga training (n=9), defined as missing more than three sessions, or use of medication during the study in the control group (n=5). Girls were excluded from our study because of confounding hormonal effects and possible difficulty in performing yoga asana during menstruation. The yoga and control groups received general health-education regarding risk factors associated with type 2 diabetes, consuming a balanced diet and engaging in physical activity. Subjects in the control group did not participate in any after school and were encouraged not to perform >30 min of exercise weekly, which is below the minimum exercise required to improve health and fitness [27]. Subjects were advised not to change their diet and physical activity lifestyles during the study. The 8-week study was successfully completed by 20 participants (Table 1).

Yoga (asana) training protocol

Yoga training was conducted by a certified yoga in-

Table 1. Baseline clinical characteristics of the study population

	Participants (n=20)[1]
Age (years)	14.65±0.74[2]
Height (cm)	164.28±8.39
Weight (kg)	77.91±9.09
BMI (kg/m^2)	28.80±1.70
Fat-free mass (kg)	26.31±5.28
Fat mass (kg)	30.01±4.58
Body fat (%)	38.81±6.24
BMR	1403.50±191.23

[1]All participants were Korean adolescent males recruited in Busan. [2]Values are presented as means±SEM. BMI, body mass index; BMR, basal metabolic rate.

Table 2. Design of the yoga-asana training protocol

Time	Contents (Intensity)	Type
10 min	Warm up	
40 min	Sitting	Seated forward bend
		Bound angle pose
		Head to knee pose
		Wide angle seated forward bend
		Stretches the lower back and the shoulders
	Standing	Weight over to the right foot, lifting the left foot off the floe
		Extended triangle pose
		Stretches legs and arms
	Lying	Bend from the hip joints to slowly lower toes to the floor above and beyond head
		Lie on back on the floor with knees bent, feet on the floor
		Lie on your belly with hands alongside torso, palms up
		Sit on the floor with knees bent, feet on the floor, and lean back onto forearms
10 min	Relaxation	Deep relaxation pose

HRR, heart-rate reserve; RPE, rating of perceived exertion (RPE); THR, the targeted heart rate (intensity% ×(HRR+$HR_{resting}$).

structor (Dae Han Institute of Social Education, Korea) three times per week for 8 weeks using a slightly modified previously published protocol (Table 2) [28]. Each yoga session consisted of 10 min of warm-up, 40 min of asana (yoga postures), and 10 min of relaxation. The program was divided into three stages, including an adaptation stage (first 2 weeks), an improvement stage (weeks 3 and 4), and a maintenance stage (weeks 5～8). Dividing the program into stages helped to gradually increase exercise intensity. ACSM guidelines for the obese population were followed during the adaptation and improvement stages and 40～50% of heart-rate reserve (HRR) and a 12～13 level rate of perceived exertion (RPE) were enforced. During the maintenance stage, the guidelines suggested a 50～60% HRR and a 14～15 RPE [28]. HRR was calculated using the targeted heart rate (THR)=Intensity%×(HRR+HR_{rest}), following a previous method [29]. To maintain THR during exercise, we measured heart rate using the carotid artery pulse 1 min after the exercise started.

Measures and biochemical analyses

Body composition and blood sample were obtained before and after 8 weeks. Body weight and height were measured with subjects wearing light clothes and without shoes. Body composition including fat mass (FM), body fat percentage (BF %), fat-free mass (FFM), and basal metabolic rate (BMR) were measured using a multi-frequency electrical impedance analyzer. BMR was calculated using a Harris Benedict formula (X-scan Plus II, Jawon Medical, Seoul, Korea) [30-32]. BMI was calculated using the equation of weight (kg)/height $(m)^2$.

Participants were asked to abstain from alcohol and caffeine consumption for at least 24 h and from physical exercise for 48 hr prior to blood withdrawal and testing. Overnight fasting blood was collected in Vacutainer (BD Bioscience, San Jose, CA, USA) from the antecubital region of the arm. After centrifugation at 1,500×g for 15 min, separated serum and plasma were stored frozen in multiple aliquots at $-80^{\circ}C$ until assayed. Plasma glucose, total cholesterol (TC), high density lipoprotein-cholesterol (HDLc), low density lipoprotein-cholesterol (LDLc), and triglyceride (TG) concentrations were measured in an automatic blood analyzer (Hitachi 7600-210 and Hitachi 7180, Tokyo, Japan) using enzymatic techniques based on a colorimetric assay. Plasma insulin was measured using an enzyme-linked immunosorbent assay kit (Mercodia, Winston Salem, NC, USA). Insulin resistance was determined using the HOMA-IR index as [fasting insulin level (mU/ml)×fasting plasma glucose (mmol/l)/22.5] [33].

Statistical analysis

The results are expressed as the mean±standard deviation. Within-group comparisons were made using paired sample t-tests. The unpaired *t*-test was used for baseline group comparisons and changes in differences before and after in the control and yoga groups. All statistical analyses were performed using the Statistical Package for the Social Sciences version 19.0 for Windows (SPSS, Inc., Chicago, IL, USA). Statistical significance was set at p-value$<$0.05.

RESULTS

The study included 20 Korean boys 14.7±0.7 years of age who were classified as obese (BMI 28.80±1.70 kg/m^2). No significant differences in all parameters were found between groups at baseline (Table 1). Changes in body composition before and after 8 weeks the control and yoga groups are summarized in Table 3. Body weight and BMI significantly ($p<0.05$) decreased after yoga training but not after the control period. FM was significantly ($p<0.05$) decreased with yoga training and control period, but the change was significantly ($p<0.05$) greater in the yoga group. BF % decreased with yoga training by 4.3% compared with no significant decrease in the control group. BMR was increased in the yoga training group by 44 Kcal/day but there was no significant change in the control group.

The changes in blood lipids, glucose, and insulin in both groups are shown in Table 4. The lipid profile, glucose, and insulin were normal range in all participants before and after the study. TC was significantly ($p<0.01$) decreased in the yoga group. TG was not significantly decreased in the yoga group. LDLc was slightly increased and HDLc was decreased in the control and yoga groups ($p<0.05$). No significant changes were found in glucose, insulin, and HOMA-IR in both groups. The change in glucose, insulin, and HOMA-IR was less in the yoga group than the control group.

Table 3. Changes in body composition following an 8-week yoga-asana training

	Control (n=10)			Yoga (n=10)			p-value[2]
	Pre	Post	Diff (mean)	Pre	Post	Diff (mean)	
Age (years)	14.60±0.96[1]			14.70±0.48			
Height (cm)	165.19±10.33			163.85±6.34			
Weight (kg)	79.43±10.83	78.13±10.44	−1.30	76.39±7.20	74.49±7.06*	−1.90	0.566
BMI (kg/m^2)	29.04±2.11	29.57±2.97	0.53	28.57±1.23	27.56±1.50***	−1.01	0.174
Fat-free mass (kg)	27.51±5.92	28.06±5.79	0.55	25.12±4.53	26.51±4.47**	1.39	0.181
Fat mass (kg)	29.65±4.86	27.58±5.29**	−2.07	30.38±4.52	26.45±4.44***	−3.93	0.015
Body fat (%)	37.65±6.49	36.15±6.55	−1.50	39.97±6.10	35.66±6.05***	−4.31	0.031
BMR (kcal/day)	1443.20±216.52	1459.10±205.51	15.90	1363.80±163.76	1408.10±160.48**	44.30	0.195

[1]Values are presented as means±SEM. [2]Control versus Yoga group. Diff, post value−pre value; BMI, body mass index; BMR, basal metabolic rate. *$p<0.05$, pre value vs post value; **$p<0.01$, pre value vs post value; ***$p<0.001$, pre value vs post value.

Table 4. Changes in metabolic risk factors following an 8-week yoga-asana training

	Control (n=10)			Yoga (n=10)			p-value[2]
	Pre	Post	Diff (mean)	Pre	Post	Diff (mean)	
TC (mg/dl)	168.60±26.14[1]	156.70±21.90	−11.90	183.90±29.58	169.60±31.01*	−14.30	0.773
TG (mg/dl)	123.10±63.35	111.40±49.17	−11.70	146.70±64.43	98.60±30.78	−48.10	0.202
HDLc (mg/dl)	58.70±18.54	36.80±14.09**	−21.90	55.60±15.19	27.90±14.09**	−27.70	0.304
LDLc (mg/dl)	85.20±26.92	90.50±15.10	5.30	98.70±31.54	104.40±24.49	5.70	0.965
HDLc/LDLc	0.79±0.46	0.40±0.15	−0.38	0.67±0.50	0.25±0.16	−0.39	0.658
Glucose (mg/dl)	86.60±4.83	85.60±3.89	−1.00	84.10±5.04	83.90±4.38	−0.20	0.731
Insulin (mU/l)	5.62±1.88	9.93±7.94	4.30	6.15±2.65	6.63±2.74	0.47	0.137
HOMA-IR	7.19±2.38	12.74±10.51	5.54	7.92±0.78	8.08±0.93	0.16	0.105

[1]Values are presented as means±SEM. [2]Control versus Yoga group. Diff, post value−pre value; TC, total cholesterol; TG, triglyceride; LDLc, LDL-cholesterol; HDLc, HDL-cholesterol; HOMA-IR, Homeostasis Model of Assessment-Insulin Resistance. *$p<0.01$, pre value vs post value; **$p<0.001$, pre value vs post value.

DISCUSSION

The present study was designed to determine the impact of an 8-week of yoga-asana training on body composition, lipid profile, and insulin resistance in obese adolescent males. We studied adolescent boys because males are typically unfamiliar with yoga and most have not explored the benefits of yoga training. The major finding of the present study was that an 8-week of yoga-asana training improved body weight, BMI, FM, BF %, FFM, BMR, and TC compared with baseline values in obese adolescent boys.

The physiological effects of yoga training that have been previously reported include the inhibition of body weight gain, reductions in cholesterol levels, and blood pressure, and improvement in immune function as well as beneficial psychological effects [34-39]. In the study, our subjects participated in less physical activities than their non-obese peers during school days and at weekends, and their physical activity during the evenings and weekends was much lower than that during school days. Home- and family-based physical activity that can be performed alone may be the best way to increase energy consumption in obese adolescents because they are less likely to participate in group physical activities [24]. Although the obese person do not participate in dynamic exercise programs, they can participate in static exercise program, such as pilates exercise [40].

Body weight is a main metabolic syndrome factor [41]. Weight loss is related to the reduction in the risk for diabetes and cardiovascular disease through improvements in blood pressure, TG, and HDLc in obese subjects [42,43]. In the present study, the small body weight loss observed after yoga training is explained by the combined decrease in FM and the increase in FFM. Consistent with our findings, similar increase in FFM have been reported after 8 weeks of resistance exercise training in obese and lean adolescent [44,45] and Benavidses and Caballero [46] reported that yoga training was a significantly decreased body weight in children. In contrast to our findings, 8 weeks of endurance exercise training did not show changes in body composition in obese adults [47]. The increase in FFM was a significant predictor for the decreases in body weight and FM [44]. Our findings of weight loss accompanied by reduced FM and increased FFM, major determinants of resting energy expenditure, indicate that yoga training is a potential adjunct treatment for obesity in adolescents. The decrease in body weight, BMI, FM, and BF % in the yoga group may have been related to an increase in FFM, and BMR following yoga training. In this context, yoga-asana training provides an alternative option for increasing the physical activity levels required to improve body composition and BMR in obese adolescents, as shown with conventional exercise training programs [48,49].

We did not observe a clear positive effect of yoga on blood lipids, with the exception of a decrease in TC. Cholesterol is a key contributor to the development of heart disease, stroke, and other vascular diseases [50]; thus, a reduction in TC following the yoga-asana training is a promising finding. Several studies have confirmed that the yoga training significantly increases HDLc and decreases TG, and LDLc [51-53]. It is well known that yoga training, which is alternative exercise training, provides health benefits. In the present study, however, a significant decrease in HDLc was observed in both the yoga and control groups. Although significant reductions in HDLc following a high-fiber, low-fat diet, and exercise intervention have been reported [54,55], the effect of lifestyle interventions on HDLc are controversial [56]. Our finding is similar to those of Sun et al. [56] who observed that a decrease in HDLc following exercise with dietary intervention in overweight adolescents. Moreover, decreases in TC and HDLc have been reported in the control group and after 12 weeks of resistance and aerobic exercise training in overweight and obese adults with type 2 diabetes [57]. Of note, improvement in HDLc is not observed after resistance exercise training in adolescents [44]. However, the mechanism for the decreased in HDLc is not clear, and the clinical relevance of this small reduction warrants further investigation. Because the adolescent period is highly metabolically active, it is possible that an unknown factor may have interfered with or masked the positive effects of yoga training on HDLc levels that has been demonstrated in previous studies.

Damodaran et al. [58] reported that 3 months of yoga training significantly decreased plasma glucose concentrations, whereas a study by Elder et al. [59] showed no significant impact of yoga training on glucose levels. Obese adolescents who participated in regular exercise had lower insulin levels and HOMA-IR than those who did not exercise regularly [60]. Our results showed no significant between or within the group differences in glucose, insulin, and HOMA-IR. This may be related to the fact that participants in both groups had normal glucose and insulin levels, and practicing yoga-asana training did not have an impact on relatively normal glucose homeostasis. Matthews et al. [33] also found no changes in these markers of glucose control with 8 weeks of resistance exercise training in adolescents, suggesting the need of long-term interventions. Long-term yoga training has been shown to have a beneficial effect on insulin resistance in patients with diabetes [61].

Some limitations of the current study are the relatively small sample size, and 10 participants in each group may not have been sufficient to obtain statistically significant results. A future study with a larger number of participants is necessary. Furthermore, obesity is a chronic condition and thus long-term treatment and follow-up will is required. Finally, we did not monitor the diet during the study, which explains the small decrease in FM in the control group. However, the decrease in FM was smaller compared with the yoga group and did not affect other body composition and BMR.

The finding of the study demonstrate that yoga-asana training is a suitable exercise for attenuating obesity in adolescent boys, as indicated by improvements in BMI, FM, BF %, FFM, BMR, and TC, compared with baseline values. Consequently, yoga training may be effective in controlling some metabolic syndrome factors in obese adolescent boys. Future investigations are demanded to establish and expand the results of the present study and to compare the metabolic effects of yoga training with those of conventional exercise.

ACKNOWLEDGEMENTS

This work was supported by Priority Research Centers Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2010-0020224).

REFERENCES

1. **Goran MI, Treuth MS.** Energy expenditure, physical activity, and obesity in children. *Pediatr Clin North Am.* 2001;48:931-953.
2. **Kennedy RL, Chokkalingham K, Srinivasan R.** Obesity in the elderly: who should we be treating, and why, and how? *Curr Opin Clin Nutr Metab Care.* 2004;7:3-9.
3. **Quak SH, Furnes R, Lavine J, Baur LA.** Obesity Working Group. Obesity in children and adolescents. *J Pediatr Gastroenterol Nutr.* 2008;47:254-259.
4. **Freedman DS, Dietz WH, Srinivasan SR, Berenson GS.** The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics.* 1999;103:1175-1182.
5. **Kavey RE, Daniels SR, Lauer RM, Atkins DL, Hayman LL, Taubert K.** American Heart Association. American Heart Association guidelines for primary prevention of atherosclerotic cardiovascular disease beginning in childhood. *J Pediatr.* 2003; 142:368-372.
6. **Caceres M, Teran CG, Rodriguez S, Medina M.** Prevalence of insulin resistance and its association with metabolic syndrome criteria among Bolivian children and adolescents with obesity. *BMC Pediatr.* 2008;8:31.
7. **Fagot-Campagna A, Pettitt DJ, Engelgau MM, Burrows NR, Geiss LS, Valdez R, Beckles GL, Saaddine J, Gregg EW, Williamson DF, Narayan KM.** Type 2 diabetes among North American children and adolescents: an epidemiologic review and a public health perspective. *J Pediatr.* 2000;136:664-672.
8. **Steinberger J, Daniels SR; American Heart Association Atherosclerosis, Hypertension, and Obesity in the Young Committee (Council on Cardiovascular Disease in the Young); American Heart Association Diabetes Committee (Council on Nutrition, Physical Activity, and Metabolism).** Obesity, insulin resistance, diabetes, and cardiovascular risk in children: an American Heart Association scientific statement from the Atherosclerosis, Hypertension, and Obesity in the Young Committee (Council on Cardiovascular Disease in the Young) and the Diabetes Committee (Council on Nutrition, Physical Activity, and Metabolism). *Circulation.* 2003;107:1448-1453.
9. **Seo E, Park EJ, Park MK, Kim DK, Lee HJ, Hong SH.** Differential expression of metabolism-related genes in liver of diabetic obese rats. *Korean J Physiol Pharmacol.* 2010;14: 99-103.
10. **Tzotzas T, Evangelou P, Kiortsis DN.** Obesity, weight loss and conditional cardiovascular risk factors. *Obes Rev.* 2011;12: e282-289.
11. **Jayasinghe SR.** Yoga in cardiac health (a review). *Eur J Cardiovasc Prev Rehabil.* 2004;11:369-375.
12. **Vaze N, Joshi S.** Yoga and menopausal transition. *J Midlife Health.* 2010;1:56-58.
13. **Collins C.** Yoga: intuition, preventive medicine, and treatment. *J Obstet Gynecol Neonatal Nurs.* 1998;27:563-568.
14. **Birdee GS, Legedza AT, Saper RB, Bertisch SM, Eisenberg DM, Phillips RS.** Characteristics of yoga users: results of a national survey. *J Gen Intern Med.* 2008;23:1653-1658.
15. **Innes KE, Selfe TK, Taylor AG.** Menopause, the metabolic syndrome, and mind-body therapies. *Menopause.* 2008;15:1005-1013.
16. **Pullen PR, Nagamia SH, Mehta PK, Thompson WR, Benardot D, Hammoud R, Parrott JM, Sola S, Khan BV.** Effects of yoga on inflammation and exercise capacity in patients with chronic heart failure. *J Card Fail.* 2008;14:407-413.
17. **Vempati RP, Telles S.** Yoga-based guided relaxation reduces sympathetic activity judged from baseline levels. *Psychol Rep.* 2002;90:487-494.
18. **Menshikova EV, Ritov VB, Toledo FG, Ferrell RE, Goodpaster BH, Kelley DE.** Effects of weight loss and physical activity on skeletal muscle mitochondrial function in obesity. *Am J Physiol Endocrinol Metab.* 2005;288:E818-825.
19. **Weyer C, Linkeschowa R, Heise T, Giesen HT, Spraul M.** Implications of the traditional and the new ACSM physical activity recommendations on weight reduction in dietary treated obese subjects. *Int J Obes Relat Metab Disord.* 1998;22:1071-1078.
20. **Church T.** Exercise in obesity, metabolic syndrome, and diabetes. *Prog Cardiovasc Dis.* 2011;53:412-418.
21. **Ross R, Després JP.** Abdominal obesity, insulin resistance, and the metabolic syndrome: contribution of physical activity/exercise. *Obesity (Silver Spring).* 2009;17 Suppl 3:S1-2.
22. **Buemann B, Tremblay A.** Effects of exercise training on abdominal obesity and related metabolic complications. *Sports Med.* 1996;21:191-212.
23. **Shubair MM, Kodis J, McKelvie RS, Arthur HM, Sharma AM.** Metabolic profile and exercise capacity outcomes: their relationship to overweight and obesity in a Canadian cardiac rehabilitation setting. *J Cardiopulm Rehabil.* 2004;24:405-413.
24. **Page A, Cooper AR, Stamatakis E, Foster LJ, Crowne EC, Sabin M, Shield JP.** Physical activity patterns in nonobese and obese children assessed using minute-by-minute accelerometry. *Int J Obes (Lond).* 2005;29:1070-1076.
25. **Hagins M, Moore W, Rundle A.** Does practicing hatha yoga satisfy recommendations for intensity of physical activity which improves and maintains health and cardiovascular fitness? *BMC Complement Altern Med.* 2007;7:40.
26. **Cole TJ, Bellizzi MC, Flegal KM, Dietz WH.** Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ.* 2000;320:1240-1243.

27. **ACSM.** ACSM'S Guideline for Exercise Testing and Prescription, 7's ed. *ACSM.* 2006:38-44.
28. **Kim KR, Bang HS.** Effects of incremental asana program of Hatha Yoga on body composition, respire-circulatory response, isokinetic muscular articulation function and bone mineral density. *Korean Alliance for Health, Physcial Education, Recreation and Dance.* 2009;48:389-400.
29. **Karvonen MJ, Kentala E, Mustala O.** The effects of training on heart rate; a longitudinal study. *Ann Med Exp Biol Fenn.* 1957;35:307-315.
30. **Tomoum HY, Badawy NB, Hassan NE, Alian KM.** Anthropometry and body composition analysis in children with cerebral palsy. *Clin Nutr.* 2010;29:477-481.
31. **Cereda E, Klersy C, Rondanelli M, Caccialanza R.** Energy balance in patients with pressure ulcers: a systematic review and meta-analysis of observational studies. *J Am Diet Assoc.* 2011;111:1868-1876.
32. **Douglas CC, Lawrence JC, Bush NC, Oster RA, Gower BA, Darnell BE.** Ability of the Harris Benedict formula to predict energy requirements differs with weight history and ethnicity. *Nutr Res.* 2007;27:194-199.
33. **Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC.** Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia.* 1985;28:412-419.
34. **Madanmohan, Bhavanani AB, Dayanidy G, Sanjay Z, Basavaraddi IV.** Effect of yoga therapy on reaction time, biochemical parameters and wellness score of peri and post-menopausal diabetic patients. *Int J Yoga.* 2012;5:10-15.
35. **Ankad RB, Herur A, Patil S, Shashikala GV, Chinagudi S.** Effect of short-term pranayama and meditation on cardiovascular functions in healthy individuals. *Heart Views.* 2011;12:58-62.
36. **Mody BS.** Acute effects of Surya Namaskar on the cardiovascular & metabolic system. *J Bodyw Mov Ther.* 2011;15:343-347.
37. **Pal A, Srivastava N, Tiwari S, Verma NS, Narain VS, Agrawal GG, Natu SM, Kumar K.** Effect of yogic practices on lipid profile and body fat composition in patients of coronary artery disease. *Complement Ther Med.* 2011;19:122-127.
38. **Telles S, Singh N, Joshi M, Balkrishna A.** Post traumatic stress symptoms and heart rate variability in Bihar flood survivors following yoga: a randomized controlled study. *BMC Psychiatry.* 2010;10:18.
39. **Gopal A, Mondal S, Gandhi A, Arora S, Bhattacharjee J.** Effect of integrated yoga practices on immune responses in examination stress - A preliminary study. *Int J Yoga.* 2011;4:26-32.
40. **Cakmakçi O.** The effect of 8 week pilates exercise on body composition in obese women. *Coll Antropol.* 2011;35:1045-1050.
41. **Yang G, Badeanlou L, Bielawski J, Roberts AJ, Hannun YA, Samad F.** Central role of ceramide biosynthesis in body weight regulation, energy metabolism, and the metabolic syndrome. *Am J Physiol Endocrinol Metab.* 2009;297:E211-224.
42. **Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM.** Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med.* 2002;346:393-403.
43. **Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, Keinänen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M.** Finnish Diabetes Prevention Study Group. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med.* 2001;344:1343-1350.
44. **Benson AC, Torode ME, Fiatarone Singh MA.** The effect of high-intensity progressive resistance training on adiposity in children: a randomized controlled trial. *Int J Obes (Lond).* 2008;32:1016-1027.
45. **McGuigan MR, Tatasciore M, Newton RU, Pettigrew S.** Eight weeks of resistance training can significantly alter body composition in children who are overweight or obese. *J Strength Cond Res.* 2009;23:80-85.
46. **Benavides S, Caballero J.** Ashtanga yoga for children and adolescents for weight management and psychological well being: an uncontrolled open pilot study. *Complement Ther Clin Pract.* 2009;15:110-114.
47. **Vogelsang TW, Hanel B, Kristoffersen US, Petersen CL, Mehlsen J, Holmquist N, Larsson B, Kjaer A.** Effect of eight weeks of endurance exercise training on right and left ventricular volume and mass in untrained obese subjects: a longitudinal MRI study. *Scand J Med Sci Sports.* 2008;18:354-359.
48. **Wong PC, Chia MY, Tsou IY, Wansaicheong GK, Tan B, Wang JC, Tan J, Kim CG, Boh G, Lim D.** Effects of a 12-week exercise training programme on aerobic fitness, body composition, blood lipids and C-reactive protein in adolescents with obesity. *Ann Acad Med Singapore.* 2008;37:286-293.
49. **Slentz CA, Duscha BD, Johnson JL, Ketchum K, Aiken LB, Samsa GP, Houmard JA, Bales CW, Kraus WE.** Effects of the amount of exercise on body weight, body composition, and measures of central obesity: STRRIDE--a randomized controlled study. *Arch Intern Med.* 2004;164:31-39.
50. **Levine GN, Keaney JF Jr, Vita JA.** Cholesterol reduction in cardiovascular disease. Clinical benefits and possible mechanisms. *N Engl J Med.* 1995;332:512-521.
51. **Mahajan AS, Reddy KS, Sachdeva U.** Lipid profile of coronary risk subjects following yogic lifestyle intervention. *Indian Heart J.* 1999;51:37-40.
52. **Manchanda SC, Narang R, Reddy KS, Sachdeva U, Prabhakaran D, Dharmanand S, Rajani M, Bijlani R.** Retardation of coronary atherosclerosis with yoga lifestyle intervention. *J Assoc Physicians India.* 2000;48:687-694.
53. **Bijlani RL, Vempati RP, Yadav RK, Ray RB, Gupta V, Sharma R, Mehta N, Mahapatra SC.** A brief but comprehensive lifestyle education program based on yoga reduces risk factors for cardiovascular disease and diabetes mellitus. *J Altern Complement Med.* 2005;11:267-274.
54. **Roberts CK, Vaziri ND, Barnard RJ.** Effect of diet and exercise intervention on blood pressure, insulin, oxidative stress, and nitric oxide availability. *Circulation.* 2002;106:2530-2532.
55. **Roberts CK, Won D, Pruthi S, Kurtovic S, Sindhu RK, Vaziri ND, Barnard RJ.** Effect of a short-term diet and exercise intervention on oxidative stress, inflammation, MMP-9, and monocyte chemotactic activity in men with metabolic syndrome factors. *J Appl Physiol.* 2006;100:1657-1665.
56. **Sun MX, Huang XQ, Yan Y, Li BW, Zhong WJ, Chen JF, Zhang YM, Wang ZZ, Wang L, Shi XC, Li J, Xie MH.** One-hour after-school exercise ameliorates central adiposity and lipids in overweight Chinese adolescents: a randomized controlled trial. *Chin Med J (Engl).* 2011;124:323-329.
57. **Jorge ML, de Oliveira VN, Resende NM, Paraiso LF, Calixto A, Diniz AL, Resende ES, Ropelle ER, Carvalheira JB, Espindola FS, Jorge PT, Geloneze B.** The effects of aerobic, resistance, and combined exercise on metabolic control, inflammatory markers, adipocytokines, and muscle insulin signaling in patients with type 2 diabetes mellitus. *Metabolism.* 2011; 60:1244-1252.
58. **Damodaran A, Malathi A, Patil N, Shah N, Suryavansihi, Marathe S.** Therapeutic potential of yoga practices in modifying cardiovascular risk profile in middle aged men and women. *J Assoc Physicians India.* 2002;50:633-640.
59. **Elder C, Aickin M, Bauer V, Cairns J, Vuckovic N.** Randomized trial of a whole-system ayurvedic protocol for type 2 diabetes. *Altern Ther Health Med.* 2006;12:24-30.
60. **Balagopal P, George D, Patton N, Yarandi H, Roberts WL, Bayne E, Gidding S.** Lifestyle-only intervention attenuates the inflammatory state associated with obesity: a randomized controlled study in adolescents. *J Pediatr.* 2005;146:342-348.
61. **Sahay BK.** Role of yoga in diabetes. *J Assoc Physicians India.* 2007;55:121-126.