

Short Report

Reduction in Visceral Fat and Changes in Arterial Stiffness from Participation in a Health and Fitness Program

Masahiro FUJINO*, Miki TAKEUCHI*, Jihyun CHUN*,
Tsukasa TOBARU** and Mitsushiro NAGAO***(Accepted Jul. 14, 2009)*

Key words: health and fitness program, abdominal ultrasonography, visceral adiposity, pulse wave velocity, middle-aged and older adults

Abstract

The purpose of this study was to show that Brachial-ankle pulse wave velocity (baPWV) is a well-established technique for obtaining a measure of the arterial stiffness, which is correlated with the visceral fat mass determined by CT scan. We used both abdominal ultrasonography and baPWV to investigate the effect of exercise-induced reduction of visceral fat on the arterial stiffness in middle-aged and older adults.

Forty-seven middle-aged and older adults participated in the health and fitness programs for 6 months. Both left and right baPWV and visceral fat thickness were significantly decreased. These results suggest that the increased activity level in middle-aged and older adults reduces the visceral fat mass and improves the arterial stiffness.

Introduction

Obesity in adults aged 60 and over has increased in Japan due to a Westernized diet and decreased exercise. Obesity is a significant problem because of its prevalence, growth rate and association with increased cardiovascular disease in older adults and increased rate of death from vascular lesions before middle age [1]. In addition, metabolic syndrome is linked to visceral adiposity [2, 3]. Excess free fatty acids and cytokines such as TNF- α reportedly pass into the liver and cause fat to accumulate in the muscles and liver, causing increased insulin resistance [3]. As excess visceral fat is attributable to lack of exercise and overeating, physical activity is important for the prevention of lifestyle-related diseases and the improvement and maintenance of health [4]. Pulse wave velocity (PWV) is reported to increase in hypertension, diabetes and cardiovascular disease [5]. Exercise results in improvements in arterial compliance. Low-intensity circuit training, for example, decreases arterial PWV [6]. Research suggests improved muscular strength from low-intensity exercise is effective in improving activities of daily living, and beneficial for patients with chronic medical conditions and in preventing obesity [7]. A study on visceral fat mass by CT and arterial stiffness by PWV reported that visceral fat mass is associated with PWV independent of age and blood pressure, and that increased visceral fat in older adults is linked to atherosclerosis [8]. Reduction of visceral obesity is, thus, of importance; however, due to the costs associated with CT, visceral adiposity is

* Doctoral Program in Health Science, Graduate School of Health Science and Technology, Kawasaki University of Medical Welfare, Kurashiki, Okayama 701-0193, Japan
E-Mail: masahirofujino@hotmail.co.jp

** Department of Health and Sports Science, Faculty of Health Science and Technology, Kawasaki University of Medical Welfare

generally excluded during routine health screenings. As a result, various techniques have been proposed, including a simple method using a tape measure [9]. One such technique is assessment of visceral fat by B-mode ultrasonography, proposed by Suzuki et al. The ratio of the thickness of preperitoneal fat to that of subcutaneous fat is closely correlated to the ratio of visceral fat area to subcutaneous fat area and might, therefore, substitute for CT measurement of visceral adiposity [10]. Saito et al. reported that reduced visceral fat resulted in reduced insulin resistance and improved brachial-ankle pulse wave velocity (baPWV) [11]. A simple method for assessing visceral fat with abdominal ultrasonography has also been reported [12-19]. However, no published reports exist on ultrasound measurements of visceral fat reduction and baPWV assessment of atherosclerosis. We, therefore, used ultrasound and baPWV to determine whether low-intensity exercise intervention reduces visceral fat and improves arterial stiffness in middle-aged and older adults.

Methods

1. Subjects and Methods

A total of 47 middle-aged and older adults (11 males; 66.6 ± 9.2 years of age, 36 females; 62.6 ± 6.7 years of age) participated in the health and fitness program for middle-aged adults at Kawasaki University of Medical Welfare sponsored by Kurashiki City in Okayama Prefecture in 2007. The health and fitness program was approved by the Kawasaki University of Medical Welfare Ethics Committee. In addition, all program participants received an explanation of the research prior to participation and gave consent on the understanding that they could withdraw at any time, in accordance with the principles of the Helsinki Declaration.

Participants in the health and fitness program participated in one of three exercise programs, a knee and hip pain program, weight loss program, or strength training program, for 6 months. The results of a physical strength test and the number of steps in a 400-m walk test were recorded before and after participation in the program.

The exercise routine consisted of stretching and muscle training, with a focus on aerobic exercise, such as walking and stair climbing. Exercises that could be performed readily at home were given to encourage continued exercise outside of the program. Participants were also asked to use a pedometer to measure physical activity in daily life and record the results on a form that was provided.

Blood was sampled before and after participation in the program for blood chemistry tests to be performed early morning under fasting conditions, including total cholesterol (T-C), HDL cholesterol (HDL-C), LDL cholesterol (LDL-C), triglycerides (TG), blood glucose, and non-esterified fatty acids (NEFA). The ratio of HDL cholesterol (HDL-C) to total cholesterol (T-C) was also calculated as an index of insulin

Table 1 Physical characteristics and change in number of steps in the 400-m walk test

	Participants		Males		Females	
	Before	After	Before	After	Before	After
Height (cm)	156.4±7.7	156.6±7.2	164.7±8.2	164.4±8.1	153.6±5.2	153.7±5.2
Weight (kg)	57.7±8.2	56.7±8.1 ***	63.3±8.8	62.0±8.4 *	55.8±7.5	55.1±7.5 **
Waist (cm)	80.2±8.5	79.1±7.8 ***	81.7±8.2	80.4±7.2 *	79.5±8.6	78.7±7.9 *
BMI	23.3±3.0	23±3.0 ***	23.3±2.7	22.8±2.7 *	23.5±3.1	23.2±3.1 **
Systolic blood pressure (mmHg)	135.7±18.5	127.5±16.9 **	135.2±22.6	129.4±19.9*	135.9±17.8	127.6±16.2 *
Diastolic blood pressure (mmHg)	76.3 ±11.5	75.8±10.8	77.5 ±14.0	77.5±9.3	76.1 ±11.1	75.8±11.4
Number of steps in the 400-m walk test	598±65.3	575±56.8 *	560.7±46.4	540.5±49.2 **	601.2±48.2	593.6±52.4 *

*p<0.05, **p<0.01, ***p<0.001

Table 2 Blood chemistry parameters before and after participation

	Participants		Males		Females	
	Before	After	Before	After	Before	After
Total cholesterol (mg/dL)	243.4±37.9	233.9±34.8 **	232.8±42.3	222.5±42.0 *	247.4±36.4	236.9±32.2 *
HDL cholesterol (mg/dL)	68.4±14.2	70.4±14.8 *	58.1±12.1	60.7±14.0 *	70.7±13.2	73.0±13.9 *
LDL cholesterol (mg/dL)	143.6±29.2	149.1±32.3	148.2±37.4	149.3±41.9	144.3±27.9	148.2±28.7
Triglycerides (mg/dL)	121.2±60.6	94.7±35.5 ***	110.3±57.0	80.9±30.8 *	125.6±62.0	99.8±35.5 **
Blood glucose (mg/dL)	96.2±17.5	91.9±14.5 **	97.2±11.2	89.6±11.5 **	96.3±19.5	93.4±15.8 *
Non-esterified fatty acids (mEq/L)	0.7±0.2	0.6±0.2 **	0.7±0.3	0.6±0.3 *	0.8±0.2	0.7±0.2 *
Total cholesterol / HDL cholesterol	3.7±1.0	3.5±0.9 ***	4.1±1.3	3.9±1.3 *	3.6±1.0	3.4±0.9 **

*p<0.05, **p<0.01, ***p<0.001

resistance [20].

Blood pressure and baPWV were measured with the Form PWV/ABI (Nippon Colin) as an index of arterial stiffness [21].

To determine visceral fat thickness, the distance from the rectus abdominis to the abdominal artery, corresponding to the intra-abdominal thickness, was measured by the technique described by Armellini et al [17]., using the Echo Camera (Aloka, SSD-1200CV) ultrasound unit with a linear probe (Aloka, 7.5 MHz) (Figure 1).

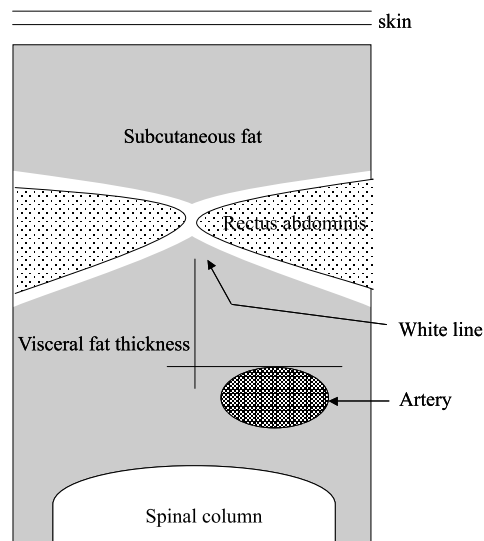


Fig. 1 Pattern diagram of visceral fat thickness (distance from rectus abdominis, white line to abdominal artery) by abdominal ultrasonography.

2. Statistical Methods

Values were expressed as means \pm standard deviations in the statistical analysis. Data were analyzed by paired t-test using SPSS 12.0 statistical software, with $P < 0.05$ treated as significant.

Results

1. Physical Characteristics and Blood Test Findings

Table 1 shows the physical characteristics and change in the number of steps in the 400-m walk test and Table 2 shows the blood chemistry parameters before and after participation in the health and fitness program for middle-aged and older adults. Significant reductions were observed in weight, waist, BMI, systolic blood pressure, and number of steps in the 400-m walk test. In the blood chemistry tests, significant reductions were observed in fasting T-C, TG, blood glucose, and NEFA and a significant increase was observed in HDL-C. The HDL-C, which has an anti-atherosclerosis effect, was significantly higher, and the T-C/HDL-C ratio, which is an index of insulin resistance, was significantly reduced.

2. Brachial-ankle pulse wave velocity

The left and right baPWV decreased significantly after participation in the health and fitness program for middle-aged and older adults ($P < 0.01$, $P < 0.05$). which was more significant in males when compared to females (Figure 2).

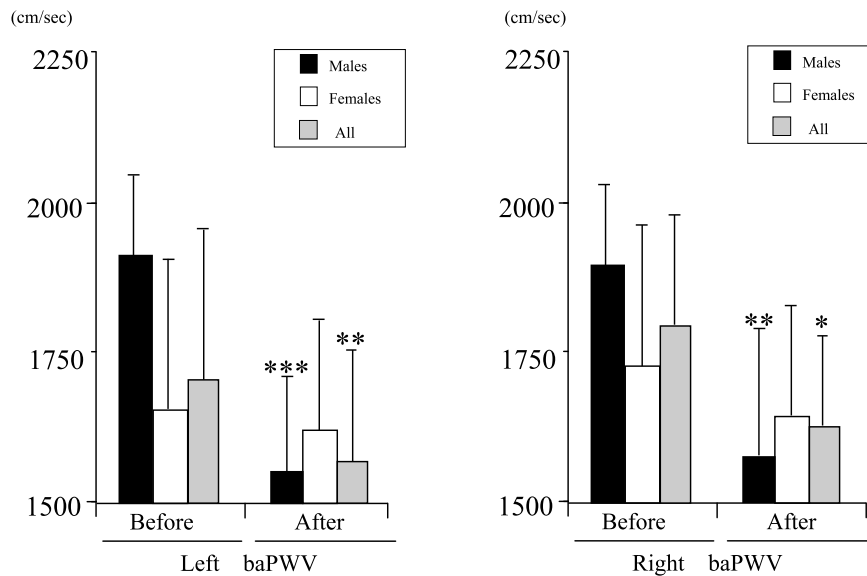


Fig. 2 Changes in Brachial-Ankle Pulse Wave Velocity (baPWV). (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

3. Abdominal Ultrasonography

The visceral fat thickness of the participants in the health and fitness program for middle-aged and older adults measured by abdominal ultrasonography was significantly reduced ($P < 0.01$) (Figure 3). By sex, visceral fat thickness was significantly reduced in both males and females ($P < 0.01$, $P < 0.05$) (Figure 3).

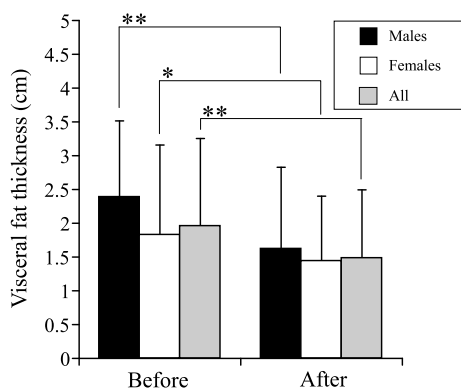


Fig. 3 Changes in visceral fat thickness. (* $p<0.05$, ** $p<0.01$)

Discussion

1. Physical Characteristics and Blood Test Findings

Weight, waist, BMI, systolic blood pressure, and the number of steps in the 400-m walk all showed a pattern of improvement after participation in the health and fitness program. Both males and females exhibited significant reductions. The reduction of visceral fat as indicated by morphometric measurements, including BMI and thigh and waist circumference, has been reported to increase adiponectin levels [22]. It has also been reported that increased blood pressure and blood glucose from obesity may promote increased PWV and that increased PWV is associated with the metabolic syndrome cluster [23]. The blood chemistry tests in the current study showed significant improvement in blood TG and HDL-C, no change in LDL-C, and significant reduction in blood glucose and NEFA. Ongoing exercise is known to produce changes in the muscle considered important for prevention of lifestyle-related diseases [24].

Increased mitochondria are reported to promote beta-oxidation of fatty acids even at rest, thereby facilitating the processing of free fatty acids released by adipose tissue and preventing the accumulation of triglycerides in the body [25]. The T-C/HDL-C ratio, known to correlate highly with insulin resistance [20] and determined by using a glucose clamp, also significantly decreased from 3.7 ± 1.0 to 3.5 ± 0.9 after participation in the Health and Fitness Program. These findings indicate that the weight reduction from increased physical activity in daily life may have improved insulin resistance.

2. Brachial-ankle pulse wave velocity

BaPWV decreased significantly after participation in the health and fitness program for middle-aged and older adults; especially, males exhibited significant reductions.

Age-related changes in the elastic fiber system play a large role in increased arterial stiffness associated with aging. Functional factors also play a role along with these organic factors. Increased tone in the medial smooth muscle results in arterial stiffening as the collagen fibers running parallel to the smooth muscle are stretched. Smooth muscle tone is regulated by the autonomic nervous system and vasoactive material produced by the vascular endothelium [26]. The production of the smooth muscle relaxant nitric oxide (NO) by vascular endothelial cells is reduced in aging [27]. Contrarily, blood concentrations of the smooth muscle contractant endothelin-1 (ET-1) are reportedly high [28]. These age-related functional changes therefore contribute to arterial stiffening. Aerobic and endurance exercise are reported to prevent arterial stiffening [29]. This leads to the assumption that functional changes affecting the stiffness of the vascular wall contributed to the reduced baPWV of participants in the Health and Fitness Program.

Saito et al. reported that participating in a long-term exercise program could effectively relax smooth

muscle through promotion of resting vagus nerve activity [11,30] and reduction of resting sympathetic activity [11,31]. The benefits of exercise training in our participants, therefore, are concluded to have been mediated through the vascular endothelial function and sympathetic activity.

3. Abdominal Ultrasonography

Visceral fat thickness measured by abdominal ultrasonography significantly decreased after participation in the health and fitness program for middle-aged and older adults. Both males and females exhibited significant reductions. Currently, importance is placed on improvement of insulin sensitivity and prevention of obesity leading to insulin resistance because the risk factors such as diabetes, hypertension, and hyperlipidemia caused by insulin resistance are also related to atherosclerotic disease. Included among these factors are adipocytokines, which are secreted by accumulated visceral fat and have a number of physiological functions. Some of these adipose-derived proteins underlie the development of vascular pathology. Among these adipocytokines, leptin potently suppresses appetite and promotes energy expenditure and adiponectin promotes combustion of fatty acids or plays an active role in the prevention of the development and progression of metabolic disease through anti-diabetic and anti-atherosclerotic action [4]. Accurate assessment of visceral adiposity and fat distribution is therefore extremely important.

Armellini et al. measured the thickness of intra-abdominal fat and reported that it is closely correlated to the visceral fat area determined by CT. A high correlation between intra-abdominal fat distance and visceral fat area has been demonstrated more recently as well, using the same method [17, 18].

Reduced visceral fat increases blood adiponectin levels [22], and blood adiponectin was found to stimulate NO production in a study using aortic endothelial cells [32]. As PWV is also reported to decrease with increasing blood adiponectin [22], the reduction in visceral fat thickness measured by abdominal ultrasonography in the health and fitness program for middle-aged and older adults suggests that the reduced fat causes the increase in blood adiponectin levels, which is associated with the reduction of baPWV.

Conclusion

The three exercise programs in the 6-month health and fitness program for middle-aged and older adults held at our university encouraged middle-aged and older adults to increase their activity levels and resulted in improved blood chemistry tests and reduced visceral fat measured by abdominal ultrasound. These changes were associated with improved arterial stiffness as determined by baPWV.

References

1. Nakano H, Okazaki K, Ohba K: Obesity in older Japanese adults. *J Clin Med* 61(6): 880–885, 2003. (in Japanese)
2. Asahikawa H, Tokunaga K: Visceral obesity and visceral fat syndrome. *J Clin Med* 61(6): 431–435, 2003. (in Japanese)
3. Committee on the Diagnosis of Metabolic Syndrome: Definition and diagnosis of metabolic syndrome. *J Jpn Society Int Med* 94(4): 188–203, 2005. (in Japanese)
4. Kinoshita Y, Tsuji E: New research on the efficacy of strength training for maintenance and improvement of health. 22nd Heal Sci Res-Aid Report: 23–30, 2007. (in Japanese)
5. Yamaguchi T, ed.-in-chief, Yokota C: *Metabolic Syndrome: New Findings and Evidence for Prevention of Cerebrovascular and Cardiovascular Events*. Shindan to Iryo Co., Ltd. 2006.
6. Miura H, Aoki S: Effect of low-intensity circuit training on arterial stiffness in adult Japanese women. *J Phy*

- Fitness Sports Med* 25: 205–210, 2005. (in Japanese)
7. Pollock ML, Franklin BA, Balady GJ, Chaitman BL, Fleg JL, Fletcher B, Limacher M, Pina IL, Stein RA, Williams M, Bazzarre T: Resistance exercise in individuals with and without cardiovascular disease benefits, rationale, safety, and prescription. An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association. *Circulation* 101: 828–833, 2000.
 8. Sutton-Tyrrell K, Newman A, Simonsick EM, Havlik R, Pahor M, Lakatta E, Spurgeon H, Vaitkevicius P: Aortic stiffness is associated with visceral adiposity in older adults enrolled in the study of health, aging, and body composition. *Hypertension* 38(3): 429–433, 2001.
 9. Abe T: Methods of assessing body fat distribution: Visceral obesity. *J Health, Phy Edu Recreation* 56(7): 571–576, 2006. (in Japanese)
 10. Suzuki R, Watanabe S, Hirai Y, Akiyama K, Nishide T, Matsushima Y, Maruyama H, Ohshima H, Shinomiya M, Shirai K, Saito Y, Yoshida S, Saisho H and Ohto M: Abdominal wall fat index, estimated by ultrasonography, for assessment of the ratio of visceral fat to subcutaneous fat in the abdomen. *Ame J Med* 95: 309–314, 1993.
 11. Saito K, Kawanishi M, Kitamura N, Hagi Y: Aerobic exercise intervention improves visceral adiposity and arterial stiffness in middle-aged Japanese adults. *J Lifelong Sport* 5(1): 19–24, 2007. (in Japanese)
 12. Kim SK, Kim HJ, Hur KY, Choi SH, Ahn CW, Lim SK, Kim KR, Lee HC, Huh KB, and Cha BS: Visceral fat thickness measured by ultrasonography can estimate not only visceral obesity but also metabolic diseases. *Ame J ClinNut* 79(4): 593–599, 2004.
 13. Stolk RP, Wink O, Zelissen PMJ, Meijer R, Gils APG van , and Grobbee DE: Validity and reproducibility of ultrasonography for the measurement of intra-abdominal adipose tissue. *Int J Obes* 25(9): 1346–1351, 2001.
 14. Stolk RP, Meijer R, Mali WP, Grobbee DE: Ultrasound measurements of intraabdominal fat estimate the metabolic syndrome better than do measurements of waist circumference. *Ame J Clin Nut* 77(4): 857–860, 2003.
 15. Ribeiro-Filho FF, Faria AN, Kohlmann O, Jr, Aizen S, Ribeiro AB, Zenella MT, FerreiraSR.G: Ultrasonography for the evaluation of visceral fat and cardiovascular risk. *Hypertension* 38(3 Pt 2): 713–717, 2001.
 16. Merino-Ibarra E, Artieda M, Cenaarro A, Goicoechea J, Calvo L, Guallar A, Civeira F: Ultrasonography for the evaluation of visceral fat and the metabolic syndrome. *Metabolism* 54: 1230–1235, 2005.
 17. Armellini F, Zamboni M, Castelli S, Micciolo R, Mino A, Turcato E, Rigo L, Bergamo-Andreis IA, Bosello O: Measured and predicted total and visceral adipose tissue in women. Correlations with metabolic parameters. *Int J Obes* 18: 641–647, 1994.
 18. Ribeiro-Filho FF, Faria AN, Azjen S, Zanella MT, Ferreira SR.G: Methods of estimation of visceral fat: Advantages of ultrasonography. *Obes Res* 11(12): 1488–1494, 2003.
 19. Chiba Y, Saito S, Takagi S, Ohnishi H: Abdominal ultrasound assessment of visceral fat mass from the perspective of cardiovascular risk factors: Tanno Shobestu Study. *Obes Res, J Jpn Society Study Obes* 12(2): 142–146, 2006. (in Japanese)
 20. Jeppesen J, Facchini FS, Reaven GM: Individuals with high total cholesterol/HDL cholesterol ratios are insulin resistant. *J Int Med* 243(4): 293–298, 1998.
 21. Yamashina A, Tomiyama H, Takeda K, Tsuda H, Arai T, Hirose K, Koji Y, Hori S, Yamamoto Y: Validity, reproducibility, and clinical significance of noninvasive brachial-ankle pulse wave velocity measurement. *Hyp Res* 25(3): 359–364, 2002.
 22. Yang WS, Lee WJ, Funahashi T, Tanaka S, Matsuzawa Y, Chao CL, Chen CL, Tai TY, Chuang LM: Weight reduction increases plasma levels of an adipose-derived anti-inflammatory protein, adiponectin. *J Clin End Met* 86(8): 3815–3815, 2001.
 23. Tsubakimoto A, Saito I, Mannami T, Nakamura S, Dohi Y, Yonemasu K: Impact of metabolic syndrome on

- brachial-ankle pulse wave velocity in Japanese. *Hyper Res* 29(1): 29–37, 2006.
24. Ezaki O, Miura S: *Mechanism of Prevention of Lifestyle-Related Diseases with Exercise Therapy: Toward an Understanding of Lifestyle-Related Diseases*. Yodosha Co., Ltd: 105–109, 2006. (in Japanese)
 25. Goodpaster, BH, Katsiaras A, Kelley DE: Enhanced fat oxidation through physical activity is associated with improvements in insulin sensitivity in obesity. *Diabetes* 52: 2191–2197, 2003.
 26. Ziemann S, Melenovsky V, Kass DA: Mechanisms, pathophysiology, and therapy of arterial stiffness. *Arterios, Throm, Vasc Bio* 25(5): 932–943, 2005.
 27. Luscher TF, Tanner FC: Endothelial regulation of vascular tone and growth. *Ame J Hypertension* 6(7 Pt 2): 283–293, 1993.
 28. Maeda S, Tanabe T, Miyauchi T, Otsuki T, Sugawara J, Iemitsu M, Kuno S, Ajisaka R, Yamaguchi I, Matsuda M: Aerobic exercise training reduces plasma endothelin-1 concentration in older women. *J App Phy* 95(1): 336–341, 2003.
 29. Tanaka H, Dinunno FA, Monahan KD, Clevenger CM, DeSouza CA, Seals DR: Aging, habitual exercise, and dynamic arterial compliance. *Circulation* 102: 1270–1275, 2000.
 30. Scheuer J, Tipton CM: Cardiovascular adaptations to physical training. *Ann Rev Phy* 39: 221–25, 1977.
 31. Goldsmith RL, Bigger JT Jr, Steinman RC, Fleiss JL: Comparison of 24-hour parasympathetic activity in endurance-trained and untrained young men. *J Ame Coll Cardiology* 20(3): 552–558, 1992.
 32. Chen H, Montagnani M, Funahashi T, Shimomura I, Quon MJ: Adiponectin stimulates production of nitric oxide in vascular endothelial cells. *J Bio Chemistry* 278(45): 45021–45026, 2003.