Obesity Medicine 16 (2019) 100139

Contents lists available at ScienceDirect

Obesity Medicine

journal homepage: www.elsevier.com/locate/obmed

Original research

The effect of high-intensity interval training and L-arginine supplementation on the serum levels of adiponectin and lipid profile in overweight and obese young men

Marziyeh Saghebjoo[a,*], Maryam Farrokhi-Fard[a], Mehdi Hedayati[b], Saber Sadeghi-Tabas[a]

[a] Department of Exercise Physiology, Faculty of Sport Sciences, University of Birjand, Birjand, Iran
[b] Cellular and Molecular Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Keywords:
High-intensity interval training
L-arginine
Adiponectin
Lipid metabolism
Obesity

ABSTRACT

Background: Obesity is currently characterized as a worldwide health pandemic. High-intensity interval training and L-arginine intake are known to exert health benefits as improving obesity. The aim of this study was to investigate the effect of 6 weeks of high-intensity interval training and L-arginine supplementation on serum levels of adiponectin and lipid profile in overweight and obese young men.

Methods: In this quasi-experimental study, 40 overweight and obese young men (age: 24.5 ± 6.5 years and body mass index of 29.4 ± 3.6 kg/m2) were randomly assigned to 4 equal groups including high-intensity interval training (3 sessions/week), L-arginine (6 g/day), high-intensity interval training along with L-arginine supplementation and placebo. Serum adiponectin level and lipid profile, body weight and fat percentage were measured 24 h before and 36 h after the 6 weeks of intervention. Data were analyzed using one-way analysis of variance (ANOVA) and mixed ANOVA tests ($P < 0.05$).

Results: No significant changes were found in serum adiponectin levels, lipid profile, body mass index, and fat percentage after high-intensity interval training and/or L-arginine intake ($P > 0.05$).

Conclusion: It seems that no change in adiponectin levels and lipid profile in overweight and obese men after high-intensity interval training and L-arginine supplementation intake is due to the lack of weight loss and body fat percentage.

1. Introduction

Obesity, which is the accumulation of ample adipose tissue, is associated with an increased cardiovascular risk factor. Adipose tissue is known as an endocrine gland that produces various hormones called adipokines or adipocytokines (Zhu et al., 2008).

Adipocytokines are proteins primarily secreted from adipose tissue and play a role in the pathogenesis of metabolic syndromes and cardiovascular diseases in obese patients (de Luis et al., 2014). Adiponectin is amongst major anti-inflammatory cytokines and is presented in 3 different oligomers in circulation; high molecular weight (HMW), medium molecular weight (MMW), and low molecular weight (LMW) adiponectin (Garekani et al., 2011). Plasma adiponectin levels are reversely related to body mass index (BMI) and body weight and decrease in obese patients (Racil et al., 2013). On the other hand, reverse relationships have been observed between low-density lipoprotein (LDL-C), triglyceride (TG), serum total cholesterol (TC), with adiponectin, along with positive relations between high-density lipoprotein (HDL-C) and adiponectin levels (Izadi and Azadbakht, 2013). Adiponectin has anti-fibrotic and anti-inflammatory properties (Miczke et al., 2015). Increased adiponectin is effective in producing nitric oxide (NO) and decreasing inflammation through inhibition of nuclear factor kappa B (NF-KB) in endothelial cells and macrophages (Emanuela et al., 2012). The risk of metabolic syndromes in overweight and obese adults with low adiponectin levels is 6 times more than that of individuals with high plasma adiponectin levels (Chu et al., 2012). High levels of LDL-C, particularly oxidized LDL, inhibit endothelial nitric oxide synthesis (eNOS), which in turn decreases NO production and increases oxidative stress. Inversely, high HDL-C levels protect the endothelium through the incremental setting of eNOS gene expression and present anti-inflammatory and anti-coagulation effects through inhibition of NF-KB (Greyling et al., 2015).

One of the methods of weight loss and reducing obesity-related risk factors is exercise training. One of the more recent exercise protocols

* Corresponding author. Department of Sport Sciences, University of Birjand, Avini Blvd, Birjand, South Khorasan, Iran.
E-mail address: m_saghebjoo@birjand.ac.ir (M. Saghebjoo).

https://doi.org/10.1016/j.obmed.2019.100139
Received 21 July 2019; Received in revised form 10 September 2019; Accepted 10 September 2019

studied by physiologists is HIIT which includes repetitive and strenuous exercise bouts with intensity levels higher than lactate threshold and near maximal oxygen consumption (VO2max) followed by a return to the initial low-intensity state, which results in various metabolic adaptations (Hazell et al., 2014). In a study by Abdol-Maleki et al. showed that lipid profile and adiponectin levels improved significantly after 12 weeks HIIT (Abdolmaleki et al., 2014). Buchan et al. investigated the effects of 7 weeks HIIT on adolescents (Buchan et al., 2011). Their results indicated a decrease in adiponectin level after HIIT. The results of these two studies clearly indicate the efficiency of HIIT in regards to improving cardiovascular diseases (CVD) risk factors in adults, all the while under limited time conditions.

In addition to exercise, diet and supplements have also been recognized as a way of weight loss and obesity-related risk factors in recent years. L-arginine is an essential amino acid converted to NO through NOS enzymes in mammalian cells (Cruzat et al., 2014; Hurt et al., 2014). L-arginine can be an effective nutrient for treating obesity through decreasing weight and white adipose tissue bioavailability of NO decreases in obesity (Gruber et al., 2008; Hurt et al., 2014). L-arginine actively decreases bad blood cholesterol through NO; but until now, few data have been available on the effect of L-arginine supplementation in serum adiponectin changes (Pahlavani et al., 2014; Tripathi et al., 2012). For example, oral L-arginine consumption increased adiponectin in obese subjects with type-2 diabetes (Lucotti et al., 2006).

Regarding the separate effect of HIIT and L-arginine supplementation on weight loss, plasma adiponectin levels and lipid profiles, based on our knowledge, no studies have so far been conducted on the effects of HIIT along with L-arginine supplementation on adiponectin levels and lipid profile. Thus, considering the importance of investigating the effects of HIIT along with L-arginine supplementation on decreasing disorders related to overweight and obesity, the present study proposes to investigate the effect of 6 weeks HIIT along with L-arginine supplementation on serum adiponectin level and lipid profile in overweight and obese young men.

2. Materials and methods

2.1. Subjects

Forty overweight and obesity men, non-smoking and sedentary (mean age of 24.5 ± 6.5 yrs, and BMI 29.4 ± 3.6 kg/m2) participated in this study. After the call, they were selected as volunteers from students of general physical education majors of Islamic Azad University (Birjand branch, South Khorasan, Iran) on the basis of the following conditions:

1. All of the subjects had no history of regular physical activity at least in the past year. Information about the physical activity level and health condition of the subjects was gathered via questionnaire.
2. All of the subjects were having no history of diabetes and known cardiovascular, renal, kidney, pulmonary, and hypothyroidism with no previous record of consuming nutritional supplements with no major physical lesions.

It should be noted that the protocol of this study was approved by the committee on the investigation of research projects in faculty of sport sciences at the University of Birjand (Iran) in term of the ethical issue and all experimental procedures were performed in accordance with the ethical standards of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to participation.

2.2. Exclusion criteria

The participant's unwillingness to continue to cooperate, the occurrence of any type of injuries during training, the absence of more than 2 sessions in the exercise training program and the lack of regular consumption of supplementation were criteria of exclusion from the study. Fortunately, all participants completed the study and no exclusion case was witnessed.

2.3. Experimental design

Forty selected subjects were randomly assigned to 4 equal groups (n = 10) including HIIT (3 sessions per week, 6 weeks), L-arginine (6 g per day, 6 weeks), HIIT along with L-arginine, and placebo. The sample size was determined based on a comparison of the mean method using Medcalc, 14.8.1 version. The main analyte (adiponectin) was the variable for this purpose. The nutritional diet of subjects was controlled using a food frequency questionnaire. Food frequency questionnaire results indicated that 45% of individuals used a Western-type diet, 40 percent used a traditional diet, and 15 percent used a healthy diet during the previous year.

2.4. Anthropometric measurements

Initial assessments including height, weight, BMI and fat percentage were measured at the beginning and end of the intervention. Body mass index was obtained by dividing the weight (kg) into the square of height (m). Fat percentage was measured using the Boca-body composition analyzer device (BOCA X1, South Korea) by the bio-electrical resistance method.

2.5. High-intensity interval training

Training protocol included 6 weeks and 3 sessions per week. In each session, individuals performed interval training on a 20-m route. Three cones were placed at the beginning, middle, and end of the path. The protocol began with the individual initially placed at the middle cone (middle of 20 m path) moving towards the first cone (beginning of the path) and finally moving back towards the last cone (end of the path). Subjects performed sprint at maximal heart rate range (220-age) for 30 s with a following 30 s of active rest (walking). The exercises progressed by increasing the number of exercise repetitions from 4 times in the first and second weeks to 5 times in the third and fourth weeks and then 6 times in the fifth and sixth weeks. It is worth mentioning that the heart rate of individuals during training was within the maximal heart rate range (220-age) and heart rate was measured immediately after each repetition by controlling cervical pulse. Subjects also performed 10 min warm-up with 5 min cool down at the beginning and end of each session, respectively. It should be noted that the protocol of 40-m maximal shuttle run test is a valid test for evaluating anaerobic performance (Buchan et al., 2011; Glaister et al., 2009).

2.6. L-arginine supplementation

Subjects of this group were given 6 g of L-arginine on a daily basis for this purpose, individuals consumed two 1-g capsules containing L-arginine with 400 ml of water at half an hour before breakfast, 1 h before lunch, and 1 h before their last daily meal (Alvares et al., 2014). No side effects were reported in the supplemented consumer groups.

2.7. High-intensity interval training with L-arginine supplementation and placebo groups

Subjects of this group performed 6 weeks of HIIT with daily consumption of 6 g L-arginine. To prevent or remove any probable mental effects of supplementation, one group was selected as the placebo group. Subjects of this group did not perform any exercise training during the 6 weeks of intervention and followed their routine diet. They were also given placebo capsules (corn starch) similar to capsules

containing L-arginine. It is worth noting that the high-intensity interval training group was also given placebo capsules.

2.8. Diet restriction

Since L-arginine converts to NO in the body, they recommended keeping away from eating nitrate or nitrite-containing foods (vegetables, meat, and grains) in order to remove any nutritional interventions (Alvares et al., 2014). For this purpose, subjects were given a list of nitrate and nitrite-containing foods 24 h before beginning the experimental period.

2.9. Blood assays

Twenty-four hours before and 36 h after the last intervention session at 08:00 a.m., followed by 12-h fasting, blood sampling (10 ml at each time) was done. Blood samples were drawn into tubes without anticoagulant substances, incubated for 5 min at room temperature until coagulation and centrifuged (3000 rpm for 5 min) until serum removed from the clot. Then serum was frozen at −20 °C for later adiponectin and lipid profile assay. Serum adiponectin was measured by the ELISA method using quantitative research kits for human samples (made by Zell Bio, Germany, Cat#E01550Hu, procured from PadginTeb Company, Tehran, Iran) at 1.25 ng/ml sensitivity. Intra-assay precision was 3.2%. Serum TC and HDL-C levels were measured using a commercial kit manufactured by Parsazmun Company (Tehran, Iran) and enzyme colorimetric (GPO-PAP) method. Intra-assay precision for TC, TG, and HDL-C were 82.62, 1.1, and 0.82 percent, respectively. Serum LDL-C level was also measured using the following equation presented by Friedewald et al. (1972):

LDL-C (mg/dl) = TC (mg/dl)–TG (mg/dl)/5–HDL-C (mg/dl)

2.10. Statistical analysis

Statistical analyses were performed by using the statistical software SPSS version 25. The normality of data was investigated using the Shapiro-Wilk test. Data were analyzed using one-way analysis of variance (ANOVA) and mixed ANOVA tests. All data are reported as mean ± SD, and $P < 0.05$ was considered significant for all tests.

3. Results

Data on individual characteristics of subjects are shown in Table 1. Results did not indicate a significant difference between the mean of variables before intervention ($P > 0.05$).

Based on the results in Table 2, there was no significant difference between serum adiponectin level in pre and post-test in all groups ($P = 0.69$). Also, the results of our study indicated no significant difference between the serum HDL-C, LDL-C, TC and TG levels in pre and post-test ($P = 0.89$, 0.15, 0.31 and 0.22 respectively). Similarly, no significant difference was found between all groups regarding changes in BMI and fat percentage ($P = 0.88$ and 0.91 respectively).

4. Discussion

This study showed that HIIT and L-Arginine had no significant effect on levels of adiponectin, lipid profile and anthropometric characteristics in overweight and obese young men. In addition to significant changes in body composition (weight loss or decreased body fat), high and moderate-intensity exercises are more effective in increasing adiponectin level; also, large alterations in body composition (weight loss or decreased body fat) cause an increase in adiponectin (Garekani et al., 2011; Simpson and Singh, 2008). Weight loss decreases the infiltration of macrophages into adipose tissue, hence reducing inflammation of adipose tissue and increasing circulating adiponectin (Avazpor et al., 2016). The results of this study are not consistent with the results of Avazpoor et al., Racil et al., and Trapp et al. they showed that HIIT increased adiponectin levels and improved lipid profile and weight loss (Avazpor et al., 2016; Racil et al., 2013; Trapp et al., 2008). The mechanism of HIIT's effect on weight loss and body fat mass reduction is not exactly clear. But, it may be due to the increased fat oxidation during HIIT, since it has been shown that levels of hormones and enzymes involved in lipolyses such as catecholamine, cortisol, and growth hormone during HIIT are increased (Limbaugh et al., 2013). Emken et al. indicated that increasing physical activity and fitness may lead to decreased adiponectin levels (Emken et al., 2010). The underlying mechanisms of this reversed relationship include the incremental setting of adiponectin receptors or increase in high molecular weight adiponectin (a most active biological isoform of adiponectin), which was not measured in the present study, which conclusively results in a decreased need for adiponectin, considering the reverse relationship. Overall, it seems that differences in study results are due to the difference in intensity, duration, and exercise mode, individual differences (human vs. animal subjects, gender, and weight), and the presence or absence of diseases such as diabetes.

Another finding of the present study indicated no change in LDL-C, TG, TC, and HDL-C levels after 6 weeks of HIIT. In a review by Kessler et al., it was reported that at least 8 weeks interval aerobic or anaerobic exercise is necessary for the improvement of HDL-C, while no significant differences in lipid profile were observed in interventions lasting less than 8 weeks (Kessler et al., 2012). Also, they concluded that high level of bouts can result in a significant decrease in body weight and the levels of LDL-C, TC, and TG and also change in body composition. It has been recommended that regular physical activity may cause increased mean LDL-C particle size, while total LDL-C concentrations remain constant (Ahmed et al., 2012). Results are also influenced by initial levels of the aforementioned factors at the beginning of the intervention, in other words, individuals with higher levels of TG and LDL-C and lower levels of HDL-C are more influenced by training; such that the higher the initial blood lipid levels the more tangible changes in lipid profile. In addition to low initial HDL-C levels, high volume of training caused to greater increase HDL-C levels (Musa et al., 2009). In this regard, Musa et al. (2009) reported an increase in HDL-C level after 8 weeks HIIT (four 800 m sprint intervals in each session with working to rest ration of 1:1, 3 sessions per week) in young men. Meanwhile, there was no significant change in other components of lipid profile. Abdol-Maleki et al. (Abdolmaleki et al., 2014) observed a significant improvement in lipid profile components of obese young men after 12 weeks of HIIT accompanied by a significant decrease in body weight. Thus, it seems that shortness of training duration, no change in weight fat percentage, and normal initial lipid levels prevented any significant change in lipid profile of the present study.

Positive effects of L-arginine supplementation on insulin resistance

Table 1
General characteristics of the participants (n = 40).

Parameters	HIIT	L-arginine	HIIT + L-arginine	Placebo	P-Value
Age (years)	23.9 ± 1.4	25.1 ± 2.4	26.4 ± 2.5	24.9 ± 0.7	0.07
BMI (kg/m^2)	29.6 ± 1.2	30.5 ± 1.3	28.1 ± 0.9	29.4 ± 1.0	0.83

HIIT, high-intensity interval training; BMI, body mass index, All values are mean ± SD.

Table 2
Alterations of metabolic and anthropometric variables before and after the intervention.

Parameters	HIIT		L-arginine		HIIT + L-arginine		Placebo		P-Value
	Pre	post	pre	Post	Pre	Post	Pre	Post	
Adiponectin (μg/ml)	11.05 ± 3.27	11.24 ± 3.50	10.50 ± 2.36	10.40 ± 2.57	11.90 ± 4.70	12.50 ± 4.01	11.10 ± 2.20	11.60 ± 2.50	0.69
HDL-C (mg/dl)	47.30 ± 7.25	48.50 ± 6.80	46.80 ± 12.50	48.80. ± 3.73	46.30 ± 5.80	49.30 ± 4.08	45.0 ± 6.0	47.60 ± 2.50	0.89
LDL-C (mg/dl)	93.30 ± 26.78	97.40 ± 19.90	98.70 ± 13.10	94.50 ± 26.06	98.30 ± 22.87	98.60 ± 24.67	78.20 ± 20.66	82.30 ± 34.42	0.15
TC (mg/dl)	172.0 ± 30.10	168.30 ± 21.72	175.10 ± 28.70	174.10 ± 33.59	171.20 ± 24.40	174.0 ± 23.85	152.20 ± 28.40	156.90 ± 27.60	0.31
TG (mg/dl)	105.80 ± 28.60	109.80 ± 32.80	153.70 ± 92.17	152.50 ± 75.50	143.90 ± 81.35	197.90 ± 85.17	166.10 ± 63.80	213.0 ± 122.20	0.22
Body fat (%)	29.20 ± 5.60	28.40 ± 5.40	30.30 ± 5.60	30.30 ± 5.50	28.20 ± 3.30	28.07 ± 3.40	28.01 ± 4.20	28.11 ± 3.50	0.91
BMI (kg/m^2)	29.60 ± 1.2	29.40 ± 4.0	30.5 ± 1.3	29.70 ± 4.10	28.1 ± 0.9	28.70 ± 3.20	29.4 ± 1.0	29.0 ± 3.0	0.88

HIIT, high-intensity interval training; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride. All values are mean ± SD.

may be explained by an increase in adiponectin levels (de Luis et al., 2014). In accordance with this finding, chronic inhibition of NO release by L-N-nitro arginine methyl ester in mice resulted in a hypoadiponectinemia state which suggests that NO can regulate adiponectin release and NO synthesis via the consumption of oral L-arginine may adjust adiponectin level (de Luis et al., 2014). Lucotti et al. (2006) investigated the effects of daily usage of 8.3 g L-arginine and decreased caloric intake with aerobic and resistance exercise training on obese individuals with type-2 diabetes. Their results indicated an increase in adiponectin level only in the supplemented group, with a significant decrease in TG, TC, and LDL-C in both supplementation and placebo groups. Lucotti et al. (2006) have shown that a significant decrease in body weight of both groups (L-arginine and placebo), however, 100% of weight loss in L-Arginine group was due to decreased fat mass, not fat-free mass; whereas, 57% of weight loss in the placebo group was due to a decrease in fat mass. It seems that a decrease in fat mass resulting from L-arginine supplementation caused an increase in circulating adiponectin and decreased body weight with improvements in lipid profile. The present study has shown no significant change in fat percentage in experimental groups as compared to the placebo group, it could be supposed as a reason for no alterations in adiponectin levels and lipid profile of HIIT along with L-arginine group. Dashtabi et al. observed a significant decrease in body weight, waist circumference, TG, TC, and LDL-C and a significant increase in HDL-C after 8 weeks of L-arginine supplementation (6 g daily) in obese and overweight individuals (Dashtabi et al., 2016). On the other hand, it has been indicated that a minimum dose of 9 g L-arginine is necessary for increasing circulating L-arginine concentrations with minimum side effects in healthy individuals (Tripathi et al., 2012). Results of the study conducted by Alvares et al. on trained runners (daily dosage of 6 g L-arginine for 4 weeks) indicated no increase in plasma L-arginine level and NO content compared to the placebo group that highlights the importance of dosage (Alvares et al., 2014). On the other hand, physiological L-arginine levels before intervention results in a state of NO bioavailability, in which supplementation no longer effects on NOS enzyme activity and NO production (Alvares et al., 2014). Some studies have reported no significant changes in concentrations of NO metabolites in normal weight and obese men, and L-arginine supplement plays an important role in situations such as endothelial dysfunction (decreased NO production) and is neutral or has limited effects in healthy individuals with normal NO concentrations, so it can be concluded that NO bioavailability of subjects in the present study may also have been in normal ranges with no effects observed when supplementing with L-arginine. However, some studies have reported a significant improvement in lipid profile after supplementing with low doses of L-arginine (Cruzat et al., 2014; Higashi et al., 2003; Pahlavani et al., 2014; Tripathi et al., 2012).

Due to limitations regarding background info on the effects of L-arginine on adiponectin levels, it is difficult to interpret the results of the present study. In a study by Lucotti et al., 6 months L-arginine supplementation (6.4g) in non-diabetic patients with coronary artery disease undergoing coronary artery bypass surgery resulted in a 37% increase in adiponectin level of the supplemented group (Lucotti et al., 2009). Also, Luis et al. reported an increase in adiponectin level after 10 days supplementation with 20 g L-arginine per day in patients with head and neck cancer (de Luis et al., 2014). In general, it seems that the intervention period, supplementation dosage, and individual differences including gender, age, and disease were the reason for contradictory results of correct study with others.

In this study, for the first time, the effect of HIIT along with L-arginine supplementation on cardiovascular risk factors in overweight and obese individuals was investigated. One of the limitations of the present study was the use of overweight and obese subjects, while in order to obtain more accurate results, it was advisable for subjects to have BMI with the same range, and it seems that accurate control of the subjects' nutrition was needed to obtain better results and can be considered as one of the limitations of this study. Further research is required to better understand the effects of different interventions on adiponectin level and lipid profile. Future studies are recommended to study the effect of L-arginine supplementation at higher doses together with HIIT protocols with the longer duration on decreasing body weight and fat.

5. Conclusion

Considering that in this study, there was no significant improvement in serum levels of adiponectin and lipid profile in overweight and obese men after 6 weeks of HIIT and consumption of L-arginine supplementation. These results suggest that if other factors such as weight and body fat percentage were reduced as a result of these interventions, this could lead to these cardiovascular positive changes.

Author contributions statement

MS and MF-F conceived the study and its design and coordination. All authors were involved in the data collection, data analysis, and drafting of the manuscript. Finally, all authors read and approved the final version of the manuscript, and agreed with the order of presentation of the authors.

Declarations of interest

None.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgment

We thank the participating men in this study.

References

Abdolmaleki, A., Samavati sharif, M., Nikbakht nasrabadi, P., Amini, R., 2014. The effects of 12 weeks of low-volume high-intensity interval training and traditional continuous exercise training on adiponectin level and lipids profile in obese young men. J Ilam Univ Med Sci 22, 150–159.

Ahmed, H.M., Blaha, M.J., Nasir, K., Rivera, J.J., Blumenthal, R.S., 2012. Effects of physical activity on cardiovascular disease. Am. J. Cardiol. 109 (2), 288–295. https://doi.org/10.1016/j.amjcard.2011.08.042.

Alvares, T.S., Conte-Junior, C.A., Silva, J.T., Paschoalin, V.M.F., 2014. L-arginine does not improve biochemical and hormonal response in trained runners after 4 weeks of supplementation. Nutr. Res. 34 (1), 31–39. https://doi.org/10.1016/j.nutres.2013.10.006.

Avazpor, S., Kalkhoran, J.F., Amini, H.A., 2016. Effect of 8 weeks of high intensity interval training on plasma levels of adiponectin and leptin in overweight nurses. Novel Biomed 4 (3), 87–92.

Buchan, D.S., Ollis, S., Young, J.D., Thomas, N.E., Cooper, S.M., Tong, T.K., Nie, J., Malina, R.M., Baker, J.S., 2011. The effects of time and intensity of exercise on novel and established markers of CVD in adolescent youth. Am. J. Hum. Biol. 23 (4), 517–526. https://doi.org/10.1002/ajhb.21166.

Chu, S.H., Lee, M.K., Ahn, K.Y., Im, J.A., Park, M.S., Lee, D.C., Jeon, J.Y., Lee, J.W., 2012. Chemerin and adiponectin contribute reciprocally to metabolic syndrome. PLoS One 7 (4), e34710. https://doi.org/10.1371/journal.pone.003471011.

Cruzat, V.F., Krause, M., Newsholme, P., 2014. Amino acid supplementation and impact on immune function in the context of exercise. J Int Soc Sports Nutr 11 (1), 61. https://doi.org/10.1186/s12970-014-0061-8.

Dashtabi, A., Mazloom, Z., Fararouei, M., Hejazi, N., 2016. Oral L-arginine administration improves anthropometric and biochemical indices associated with cardiovascular diseases in obese patients: a randomized, single blind placebo controlled clinical trial. Res. Cardiovasc. Med. 5 (1). https://doi.org/10.5812/cardiovascmed.29419. e29419-e29419.

de Luis, D., Izaola, O., de la Fuente, B., Aller, R.J., 2014. Effect of L-arginine supplementation on insulin resistance and adipocitokines levels in head and neck cancer non diabetic patients after surgery. Nutr. Hosp. 30, 870–875.

Emanuela, F., Grazia, M., Marco, D.R., Maria Paola, L., Giorgio, F., Marco, B., 2012. Inflammation as a link between obesity and metabolic syndrome. J Nutr Metab. https://doi.org/10.1155/2012/476380. 2012, Article ID 476380.

Emken, B.A., Richey, J., Belcher, B., Hsu, Y.W., Spruijt-Metz, D., 2010. Objectively measured physical activity is negatively associated with plasma adiponectin levels in minority female youth. Int. J. Pediatr. Endocrinol. 2010 (1), 846070. https://doi.org/10.1155/2010/846070.

Friedewald, W., Levy, R., Fredrickson, D., 1972. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin. Chem. 18 (6), 499–502.

Garekani, E.T., Mohebbi, H., Kraemer, R.R., Fathi, R., 2011. Exercise training intensity/volume affects plasma and tissue adiponectin concentrations in the male rat. Peptides 32 (5), 1008–1012. https://doi.org/10.1016/j.peptides.2011.01.027.

Glaister, M., Hauck, H., Abraham, C.S., Merry, K.L., Beaver, D., Woods, B., McInnes, G., 2009. Familiarization, reliability, and comparability of a 40-m maximal shuttle run test. J. Sport. Sci. Med. 8 (1), 77–82.

Greyling, A., Hopman, M.T., Thijssen, D., 2015. Endothelial function in health and disease. In: Berbari, A., Mancia, G. (Eds.), In Arterial Disorders: Definition, Clinical Manifestations, Mechanisms and Therapeutic Approaches. Springer International Publishing, Cham, pp. 161–173.

Gruber, H.J., Mayer, C., Mangge, H., Fauler, G., Grandits, N., Wilders-Truschnig, M., 2008. Obesity reduces the bioavailability of nitric oxide in juveniles. Int. J. Obes. 32, 826. https://doi.org/10.1038/sj.ijo.0803795.

Hazell, T.J., Hamilton, C.D., Olver, T.D., Lemon, P., 2014. Running sprint interval training induces fat loss in women. Appl. Physiol. Nutr. Metabol. 39 (8), 944–950. https://doi.org/10.1139/apnm-2013-0503.

Higashi, Y., Sasaki, S., Nakagawa, K., Kimura, M., Noma, K., Sasaki, S., Hara, K., Matsuura, H., Goto, C., Oshima, T., Chayama, K., Yoshizumi, M., 2003. Low body mass index is a risk factor forimpaired endothelium-dependent vasodilation in humans: role of nitric oxide and oxidative stress. J. Am. Coll. Cardiol. 42 (2), 256–263. https://doi.org/10.1016/S0735-1097(03)00630-2.

Hurt, R.T., Ebbert, J.O., Schroeder, D.R., Croghan, I.T., Bauer, B.A., McClave, S.A., Miles, J.M., McClain, C.J., 2014. L-arginine for the treatment of centrally obese subjects: a pilot study. J. Diet. Suppl. 11 (1), 40–52. https://doi.org/10.3109/19390211.2013.859216.

Izadi, V., Azadbakht, L., 2013. Serum adiponectin level and lipid profile. J Health Syst Res 9, 114–123.

Kessler, H.S., Sisson, S.B., Short, K.R., 2012. The potential for high-intensity interval training to reduce cardiometabolic disease risk. Sport. Med. 42 (6), 489–509. https://doi.org/10.2165/11630910-000000000-00000.

Limbaugh, J.D., Wimer, G.S., Long, L.H., Baird, W.H., 2013. Body fatness, body core temperature, and heat loss during moderate-intensity exercise. Aviat. Space Environ. Med. 84 (11), 1153–1158.

Lucotti, P., Monti, L., Setola, E., La Canna, G., Castiglioni, A., Rossodivita, A., Pala, M., Formica, F., Paolini, G., Catapano, A.L., Bosi, E., Alfieri, O., Piatti, P., 2009. Oral L-arginine supplementation improves endothelial function and ameliorates insulin sensitivity and inflammation in cardiopathic nondiabetic patients after an aortocoronary bypass. Metabolism 58 (9), 1270–1276. https://doi.org/10.1016/j.metabol.2009.03.029.

Lucotti, P., Setola, E., Monti, L.D., Galluccio, E., Costa, S., Sandoli, E.P., Fermo, I., Rabaiotti, G., Gatti, R., Piatti, P., 2006. Beneficial effects of a long-term oral L-arginine treatment added to a hypocaloric diet and exercise training program in obese, insulin-resistant type 2 diabetic patients. Am. J. Physiol. Endocrinol. Metab. 291 (5), E906–E912.

Miczke, A., Suliburska, J., Pupek-Musialik, D., Ostrowska, L., Jabłecka, A., Krejpcio, Z., Skrypnik, D., Bogdański, P., 2015. Effect of L-arginine supplementation on insulin resistance and serum adiponectin concentration in rats with fat diet. Int. J. Clin. Exp. Med. 8 (7), 10358–10366.

Musa, D.I., Adeniran, S.A., Dikko, A., Sayers, S., 2009. The effect of a high-intensity interval training program on high-density lipoprotein cholesterol in young men. J. Strength Cond. Res. 23 (2), 587–592.

Pahlavani, N., Jafari, M., Sadeghi, O., Rezaei, M., Rasad, H., Rahdar, H.A., Entezari, M.H., 2014. L-arginine supplementation and risk factors of cardiovascular diseases in healthy men: a double-blind randomized clinical trial. F1000Res 3https://doi.org/10.12688/f1000research.5877.2. 306-306.

Racil, G., Ben Ounis, O., Hammouda, O., Kallel, A., Zouhal, H., Chamari, K., Amri, M., 2013. Effects of high vs. moderate exercise intensity during interval training on lipids and adiponectin levels in obese young females. Eur. J. Appl. Physiol. 113 (10), 2531–2540. https://doi.org/10.1007/s00421-013-2689-5.

Simpson, K., Singh, M., 2008. Effects of exercise on adiponectin: a systematic review. Obesity 16 (2), 241–256. https://doi.org/10.1038/oby.2007.53.

Trapp, E., Chisholm, D., Freund, J., Boutcher, S., 2008. The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. Int. J. Obes. 32, 684. https://doi.org/10.1038/sj.ijo.0803781.

Tripathi, P., Misra, M., Pandey, S., 2012. Role of L-arginine on dyslipidemic conditions of acute myocardial infarction patients. Indian J. Clin. Biochem. 27 (3), 296–299. https://doi.org/10.1007/s12291-012-0188-9.

Zhu, W., Cheng, K., Vanhoutte, P., Lam, K., Xu, A., 2008. Vascular effects of adiponectin: molecular mechanisms and potential therapeutic intervention. Clin. Sci. 114 (5), 361–374. https://doi.org/10.1042/CS20070347.