Caloric Regulation Linked Thermogenesis in Acute Submaximal Intensity Exercise Model as The Effect of Audio Frequency Exposure

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Abstract. Thermogenesis is an essential physiological mechanism in both bodies thermal and energy balance. Thermal balance is significantly associated with body heat homeostasis linked thermogenesis-caloric regulation. The caloric or energy balance was reported under facultative thermogenesis within skeletal muscle stimulated by exercise. Importantly, decreased energy expenditure, imbalance energy intake, and loss of energy was developed for types of obesity. Recently, music tempo and frequency are proposed as the new raw model of exercise treatment against the progression of overweight in the population. Thus, our preliminary pre-post test randomized study aimed to investigate the physical-physiological connection between thermogenesis, caloric regulation, acute-maximal and submaximal intensity exercise model and musical frequency/tempo on the body thermal homeostasis and physiological performance in the younger athlete. This study involved 45 participants with homogeneity in age, height, weight, heartbeat, and physical fitness. Interestingly, co-treatment high intensity, moderate intensity exercise and moderate intensity exercise with middle musical tempo/frequency decreased body temperature without relevant alteration on caloric production. Furthermore, this exercise model significantly induced caloric production and energy expenditure in a similar pattern with the placebo. Also, musical-moderate intensity exercise exposure enhanced muscle thermogenesis without effect to overheating condition during the treatment. The circulating level of physiological-physical stress marker (cortisol) significantly decreased post musical exposure. Hence, the development of physical combination therapy for individual onset obesity progress to metabolic syndrome can contribute to the prevention of metabolic disease. This combination model may offer an alternative solution to combating overweight and obesity through musical-exercise co-treatment. However, further studies are emerging to widely establish this model for global communities.

Keywords: Caloric regulation, thermogenesis, acute exercise, audio frequency
1. Introduction
The improvement of life standard and the change of lifestyle indicated by the lack of exercise, passive lifestyle and high-fat diet [1], is the stimulation of enhancement of the prevalence of obesity and metabolic syndrome [2]. In the last decade, the prevalence of obesity and metabolic syndrome significantly increases and becomes an epidemic in all countries in the world including developed and developing countries [3]. Obesity is related to heart disease, type 2 diabetes mellitus, cancer disease, and the complication of the other chronic diseases [4], and possibly causes premature death [5]. Obesity reduces not only the physical condition but also the quality of health. The energy imbalance could stimulate a decrease in the quality of health. The energy imbalance also could cause an increase in the prevalence of obesity and metabolic syndrome [2]. The energy imbalance is caused by the change in lifestyle, diet manner, and environmental factor [4]. As one of the alternatives of a fundamental solution, exercise is a necessary intervention to prevent and manage some metabolic diseases. Chronic and acute exercise also brings about the adaptation of metabolism in the muscle and the other organs (adipose and heart tissues), especially the metabolism process in mitochondria [6]. In this context, skeletal muscle has an essential role as an organ that is responsible for secreting irisin. Meanwhile, myokinin secretion functions to manage secrete energy and prevent obesity and metabolic syndrome [7]. However, exercise is also a stressor that can enhance inflammation due to the excessive muscle contraction and cause damage, and impact on energy metabolism and dismantling of energy reserves [8].

Exercise is essential to manage body weight and adipose tissue. On the other hand, the decrease in exercise is related to the risk of the increase in physical freshness and premature death [9]. Exercise influences not only molecular, myokinin, and autocrine/paracrine paths, but also muscle interaction path with the other organ including endocrine path mechanism [6]. Therefore, exercise could potentially increase oxidation stress as the consequence of the enhancement of energy formation through oxidation in mitochondria that becomes one of the causes of tissue damage [10]. The chronic and acute exercise supports the improvement of energy expenditure in the exercise and recovery time so that it causes the change of energy metabolism and increases the synthesis of adenosine triphosphate/creatine phosphate (ATP/CP) [11]. It has been proven by some discretion metabolisms when doing exercise [12]. Some hormones were secreted when doing exercise are such as the increase in adrenocorticotropic hormone (ACTH) secretion, cortisol, epinephrine, and lactic acid as well as the improvement of fatty acid oxidation [13]. That hormones enhancement is the response of the body to the fulfillment of energy need which increases during exercise [4]. The fulfillment of energy needs is through bio-energetic in mitochondria to improve the capacity of energy production, thermogenesis, metabolic adaptation to hunger, stress, and inflammation system. The response of thermogenesis to regulate the energy balance controlled by sympathetic nerve, the activity of tri-iodothyronine (T3), and leptin [14]. Besides, exercise potentially enhances the interleukin 6 (IL-6) secretion more than 100 times compared to resting time. IL-6 is the indicator of inflammation, and the increase in IL-6 inhibits the production of pro-inflammatory cytokines such as tumor necrosis factor α (TNF-α) [15]. The improvement of IL-6 secretion shows the acute stress which activates hypothalamus-pituitary-adrenal axis (HPA-axis) that stimulates ACTH secretion and cortisol and adrenal gland due to the stimulation of sympathetic nerve influencing immunity [16].

The need for energy during exercise depends on the intensity used, and it is very fluctuating [15]. Exercise is a significant intervention not only to prevent and treat some metabolic diseases, but also to improve the function of the heart, muscle, hormonal system, nerve system, and energy metabolism system [17]. The adaptation of exercise is a complex process involving the change of transcriptional and translational responses, mitochondria function, metabolic management, and signaling path change [8]. Exercise is important to manage the energy balance through metabolism process due to the increase in muscle contraction [15]. Muscle contraction causes irisin secretion [7], the mediator of browning in the adipose tissue that causes the enhancement of uncoupling protein (UCP-1) expression, thermogenesis, and energy expenditure [8]. Irisin causes biogenesis within mitochondria, enhances fat metabolism, increases calorie expenditure without extra movement. Treadmill exercise has been proven that it could increase the irisin concentration of 20.4% for male teen and 24.6% for female teen during 50 minutes-
90 minutes with moderate intensity. It is similar to the exercise of cycling that could enhance irisin for 40 minutes with the submaximal intensity of 70% of maximum oxygen volume [18]. The moderate intensity exercise, for about one hour, increased the capacity of muscle and adipose tissue oxidation caused by irisin expression [12]. This case shows that irisin functions to change the white fat to brown fat which is very important for energy secretion with ATP synthesis conversion with the form of thermogenesis. Thermogenesis depends on protein uncoupling activity through oxidative phosphorylation uncoupling in the mitochondria [19]. Thermogenesis has been explained in the ratio of glycolytic oxidation enzyme with the efficiency level of fatty acid oxidation in the muscle, the cycle of the change of ATP need without the change of ATP formation (for example in triglyceride hydrolysis and the next reesterification in adipocytes). The change of ATP need of each muscle contraction, uncoupling mitochondria in the brown adipose tissue, lipolysis path, and the use of free fatty acid, is influenced by genetic factor and hormonal control such as insulin, thyroid hormone and sympathetic nerve system (SNS) [15]. Exercise gives effect to the improvement of metabolism and thermogenesis and energy expenditure as well as activates irisin to change white fat to brown fat [19]. Doing exercise by listening to music increases the speed of running (economic running) and upgrades the motivation and decreases the cortisol secretion [20]. Music impacts on the decrease in cortisol and the increase in hormone of growth and the activity of HPA-axis that contribute to enhancing the efficiency of metabolism and the use of triglyceride. Listening to music during exercise could repair the profile of body fat and improve physical performance [21].

Exercise is a key determinant of energy expenditure that functions to maintain the energy balance [22] by the increase in metabolism of fat as the energy source with the increase in free fatty acid oxidation [23]. Based on that explanation, this research aimed to find the physiological and psycho-psychological responses of maximal and submaximal exercises using music to the response of energy expenditure and thermogenesis by using the concept of bio-psycho metabolism.

2. Methods

This research has been stated that it is by the ethics of research on health with the certificate of ethics number 106/EC/KEPK/04/2018 from the ethics commission of Faculty of Medicine, Brawijaya University of Malang. This research aimed to know the physiological response on the acute exercise with sub-maximal intensity by listening to middle rhythm music with the experimental design of Randomized Control Group Posttest Design. This research used three experiment groups such as acute exercise with high intensity, acute exercise with moderate intensity collaborated by listening to middle rhythm music. The participants were the students of Sports Science with the age of 18-20 years old, male gender, good VO₂ max (maximal oxygen volume), proportional body height and weight, normal hemoglobin (Hb), and relatively low-stress level and they were willing to sign to be the participant (informed content). Based on the determined provision, 45 people were chosen as the trial people randomly selected and then divided into three treatment groups.

Data collection was done by asking the trial person to run on the treadmill during 20 minutes with the high-intensity exercise, moderate-intensity exercise, and moderate-intensity exercise collaborated with the activity of listening to the middle rhythm music initiated by warming up and cooling for five minutes by running on the treadmill with the low intensity. The high-intensity exercise in this research was similar to 85% of a maximum heartbeat, and that of moderate-intensity exercise was the same with 75% of maximum heartbeat while middle rhythm music is the music with the beat of 109-120 beat/minute. The trial persons listened to the music during running exercise using multi-player 5 (MP5) completed with headset and attached to the ears. The measurement of thermogenesis response used indicator of body temperature measured before and after exercise while the calorie/energy expenditure was measured by doing exercise while the analysis of chronic physiological response with the indicator of cortisol hormone content and acute physio-psychologic response with the indicator of heartbeat/minute. Taking the sample of the blood for checking the content of cortisol hormone was done from vein cubeti which were 10 cc. Taking the blood was executed by a medical officer from the department of health of Malang City while the research was conducted from 06.00-10.00 am. Analysis
of blood sample for measuring the content of cortisol used Elisa kit method while the data analysis using the ANOVA test with 1% significant level.

3. Results and Discussion

The research results of participants’ characteristics with anthropometric indicator and physiological condition are explained in Table 1.

| No | Group | Height (cm) | Body Weight (Kg) | Resting heartbeat /minute | Hemoglobin (g/dL) | VO\(_2\) max ml/kg/bb |
|----|-------|-------------|------------------|--------------------------|-------------------|-----------------------|
| 1  | I     | 170         | 60               | 73                       | 14.79             | 41.7                  |
| 2  | II    | 170         | 59.5             | 70                       | 15.18             | 41                    |
| 3  | III   | 171         | 58.7             | 69                       | 14.27             | 40.9                  |

Group I (High-intensity exercise); Group II (Moderate-intensity exercise); Group III (Moderate-intensity exercise with middle rhythm music)

The research results of the anthropometric condition of sample showed that the body height and body weight of the groups tended to be similar while the physiological aspect was determined by using the indicator of physical freshness level by using VO\(_2\) max measurement tool with the Balke test with the high category and Hb of the sample was averagely normal. The sample was then treated by acute exercise with high intensity without collaboration with listening to the music, moderate-intensity without conjunction with listening to the music and the moderate-intensity exercise with listening to the middle rhythm music. The results are presented in Table 2.

| Parameters                  | Group I | Group II | Group III |
|-----------------------------|---------|----------|-----------|
| Heartbeat (beat/minute)     | 175     | 152      | 153       |
| Energy Expenditure (Calory) | 216     | 153      | 152       |
| Pre-Treatment Body Temperature (°C) | 36 | 35.6     | 36        |
| Post-Treatment Body Temperature (°C) | 37.1 | 36.2     | 35.9      |
| Cortisol level (ng/ml)      | 8.78    | 7.37     | 7.30      |

Group I (High-intensity exercise); Group II (Moderate-intensity exercise); Group III (Moderate-intensity exercise with middle rhythm music)

Based on the research results, there was a difference in energy expenditure and body temperature (p<0.01). The mean of energy expenditure in the high-intensity exercise group (group I) was higher than that of group II and III (Figure 1).
Moreover, the body temperature when doing the acute exercise with high intensity was higher than the body temperature of the group of moderate-intensity acute exercise with and without listening to the music (Figure 2 and Table 2).

The growing passive lifestyle causes low energy expenditure since the primary variable of energy expenditure is physical activity including exercise and doing physical activity during leisure time [24]. The improvement of one-day activity included physical activity related to exercise will possibly increase the energy expenditure, the energy balance, and prevent the excessive energy reserves [25]. Both acute and chronic exercises are the physiological response that impacts on the change of body metabolism in fulfilling the need of energy of which intensity and duration can be managed [8]. The response of exercise to the body is influenced by not only intensity, duration, type, but also the individual’s status included the status of health, physical condition, the composition of body and physiological and psychological conditions [26]. Based on the research results, the participants with an anthropometric
parameter in term of standard height and weight body, proportional body weight, a normal physiological condition such as the average level of physical freshness and the content of Hb, possibly could respond to the exercise intensity well.

The research results showed that there was no significant difference in anthropometric, physiological conditions of participants in each group. It can be seen from the similar body height, and body weight of participants and the physiological aspect using the indicator of the content of hemoglobin and physical condition measured using physical freshness, the mean of VO2 max level was in the best performance. This condition will correlate to the level of energy expenditure. Since the energy expenditure is influenced by the training level, exercise, the metabolic adaptation related to the composition of free fat mass, and the activity of mitochondria [22]. Also, the physio-psychological parameter ay changed by the different physical treatment that confirmed by the serum level of cortisol. The concentration of circulating cortisol hormone before doing exercise was relatively low. The low cortisol hormone influences the metabolism that will impact the energy expenditure and thermogenesis [21]. The participants’ anthropometric averagely had the body mass index of 21 that categorized as normal since the normal level of body proportion, the excessive body weight, and obesity influence the response of exercise and the level of energy expenditure [27]. The imbalance between the energy intake and energy expenditure are the leading causes of the increase in some metabolic syndrome diseases [22].

Based on the research results, there was a significant caloric expenditure in the three groups (P<0.01). This data proved that the high-intensity exercise was caused by the increase in the need for energy so that the change of metabolism also enhanced [28]. Someone’s metabolism adaptation is also related to the change of energy release [25]. Besides, the energy expenditure is influenced by basal energy expenditure or resting of metabolism rate (RMR), the energy released when doing energy, and the energy expenditure related to adaptive thermogenesis [29]. The energy release is also correlated to the intensity of exercise and the type of exercise. An individual with normal body mass index with the high intensity is more beneficial for energy expenditure.

On the contrary, the high-intensity exercise done by the individual with body mass index ≥ 24 will cause chronic fatigue and not optimal energy expenditure [24]. The intensity of exercise and factor of music are the aspects that cause the difference in the level of calorie expenditure and thermogenesis in the high-intensity exercise group. The high-intensity exercise needs higher energy than the other groups caused by the increase in more active skeletal muscle contraction that will stimulate the other metabolism systems such as cardiorespiratory system and energy metabolism system. It is proven in the high-intensity acute exercise of irisin secretion in the higher skeletal muscle [12]. Irisin causes the improvement of biogenesis in mitochondria that stimulates the use of fat as the energy source and the increase in irisin secretion will enhance the energy expenditure [18]. Irisin in the muscle and adipose is the derivation of chemokines that will activate thermogenesis in white adipose tissue and increase glycemia. Besides, irisin also gives signal through the activation of adenosine monophosphate kinase (AMPK) to enhance the glucose metabolism and fatty acid oxidation. This case showed that muscle is an endocrine organ that has an active role in keeping the metabolic balance that communicates with some tissues including adipose tissue and heart. Exercise increases the energy expenditure of about 400 kcal [30]. The irisin secretion enhances the energy expenditure by activating brow fat tissue through activation of PPARγ co-activator 1 alpha (PGC1-α) that stimulates type III-fibrinogen that is dominant 5 (FNDC5) [31]. The skeletal muscle is an excretory organ that has the ability with the other tissues of organs. The muscle contraction increases peroxisome proliferator-activated receptor gamma coactivator 1 alpha (PGC-1α) that will enhance type III-fibronecin domain-containing protein 5 (FNDC5), to increase irisin; the secretion of irisin is influenced by the intensity of exercise [12]. The secretion of irisin is influenced by not only the intensity of exercise but also the anthropometric factor, age, and gender. It is proven by the correlation between age, gender, skeletal muscle mass, body fat mass, and the number of calories entered to the secretion of irisin [32]. Meanwhile, the secretion of irisin is related to the increase in calorie and thermogenesis that are also influenced by fat metabolism and the intensity of exercise. However, in the group of individuals with the level of physical freshness categorized as
good and the body proportion categorized as normal, the intensity of exercise was up to 85% of VO$_2$ max that still uses fat as the energy source [33].

Based on the research results, the difference in the energy release, thermogenesis, heartbeat, and secretion of cortisol was caused by the factor of the intensity of exercise results in the difference in the activation of muscle contraction, activation of the sympathetic nervous system and hypothalamus-pituitary axis (HPA-axis). The high-intensity exercise caused the response of muscle system was more active that would respond the active sympathetic nerve and HPA axis, as the effort to maintain the homeostatic related to the fulfillment of energy and to keep the stable body temperature in facing the stressor caused by the exercise intensity [16]. The response of exercise to hypothalamus will secrete corticotrophin releasing hormone then activate pituitary gland that releases an adrenocorticotropic hormone that stimulates adrenal cortex to secrete the cortisol so that the higher the intensity, the longer the exercise done, the secreted cortisol was higher as well [34]. The high secretion of cortisol hormone indicated the chronic stress while the catecholamine secretion that caused the increase in a heartbeat as the indicator of acute stress, chronic stress activates HPA axis and acute stress activates sympathetic nerve, the activeness of both stresses in the exercise was also influenced by the exercise intensity [35]. The enhancement of acute and chronic stress impacts on the suppression of immunity and the increase in inflammation in muscle [16], while the exercise with the intensity of 60% of VO$_2$ max in an untrained individual has upgraded the cortisol and heartbeat [34]. Therefore, the effort to inhibit the stress while doing exercise is necessary so that the exercise could influence the health and physical performance and optimize the body function. The music used during exercise could enhance the physical performance and make the exercise playful so that it can inhibit the stress, improve the motivation, increase the energy expenditure but reduce the perception of feeling tired [36]. The decrease in stress in facing the exercise with the good intensity and physical performance could increase the stress due to the cortisol secretion and increase the blood pressure. It has been proven that listening to music could reduce the blood pressure and heartbeat, decrease muscle tension, pain, discomfort feeling, and influence the nervous system [20]. Besides, music in the exercise also could enhance the physical performance influenced by music rhythm such as moderate and fast rhythm music could improve the work efficiency caused by the decrease in the anxiety and muscle tension caused by the stimulation of parasympathetic nerve [37]. Music also influences the increase in growth hormone directly related to HPA-axis. The growth hormone as the anabolic hormone could stimulate the triglyceride breaking and become the media to encourage the growth in some tissues to activate the secretion of insulin-like growth factor-1 (IGF-1).

Music influences the increase in the efficiency of metabolism. In the previous study mentioned that someone with obesity and stress then listens to classical music showed the increase in energy expenditure in resting time (resting expenditure). Furthermore, listening to enjoyable music indicated the enhancement of the amplitude of gastric myoelectrical activity that can stimulate the increase of gastric motility and gastric emptying [21]. Listening to music does not influence anaerobic exercise. It will be more useful for submaximal-intensity exercise compared to the higher intensity exercise. However, with the music that is relevant in Wingate anaerobic test is done to 12 males and three females showed the excessive reaction of fatigue, index of fatigue, the mean of energy expenditure and the increase in higher maximal energy when listening to music than without music. The increase in fast rhythm music with was more significant than the low rhythm music [36].

The increase in the heartbeat in the submaximal-intensity exercise with listening to the music compared to the submaximal-intensity exercise without listening to the music showed that music influenced the stimulation of sympathetic nerve that activated catecholamine hormone to improve the performance of heart [20]. Thakare et al. in their research using 19-21 years old participants showed the higher increase in a heartbeat in the high-intensity exercise with listening to the slow rhythm music compared to submaximal-intensity exercise without music; moderate-intensity exercise with jazz music tempo caused the heartbeat higher than in slow rhythm music [38]. Physiologically, music enhances the heart working system and cardiac stress. The heartbeat increases when listening to fast rhythm music in the increase in the sympathetic nervous system that functions to control the speed and the power of heart performance [39]. On the other hand, submaximal-intensity exercise with listening to music caused
cortisol hormone secretion is lower than submaximal-intensity exercise without music. Music influences the response of the lower HPA axis so that it causes the low stress indicated by the decrease in cortisol hormone secretion [35]. Besides, music influences the central nerve and autonomic nerve fiber and hormonal system that results in the decrease in the activity of sympathetic nerve and the increase in parasympathetic stimulation so that the secretion of stress hormone decreases [40]. Listening to music has a positive role in reducing stress, pain, increasing the function of the heart, and enhance the relaxation. Music regulates the performance of HPA axis, sympathetic nerve system (SNS) and immunity system, metabolism regulation, energy balance, and metabolism in recovery from the increase of fat metabolism and elimination of fatty acid after doing exercise [41]. The research results showed that submaximal-intensity exercise with music could save the energy and keep the body temperature with the lowest level of cortisol hormone secretion over three groups. Based on the research results, it is recommended to have exercise as a strategy in increasing the caloric expenditure, the significant change of thermogenesis to prevent the increase in obesity and metabolic syndrome disease but it should take into account the intensity of the exercise. The intensity of the exercise should be by the individual’s condition and the exercise done should be interesting and playful. Therefore, collaborating with exercise and music with the right tempo is necessary.

4. Conclusion
Based on the research results it can be summarized that acute maximum/high-intensity exercise without musical treatment could be a stimulator for increased the energy expenditure, thermal body temperature, cardiovascular tension, and physio-psychological stressor. The gradual changes of excess heat production related thermogenesis and body temperature significantly observed in the combination of moderate intensity exercise with middle rhythm music. Moreover, the co-treatment of middle rhythm music and moderate intensity exercise could decrease psychological stressor hormone without any significant alteration on energy expenditure. Further study is necessary to explore the physio-psychological changes due to the combination of chronic moderate intensity exercise with musical co-treatment as the future model combating obesity and metabolic syndrome through physical therapy.

References
[1] Pang M, Yang J, Rao J, Wang H, Zhang J, Wang S, Chen X and Dong X 2018 Time-Dependent Changes in Increased Levels of Plasma Irisin and Muscle PGC-1α and FNDC5 after Exercise in Mice Tohoku J. Exp. Med. 244 93–103
[2] Dulloo A G, Seydoux J and Jacquet J 2004 Adaptive thermogenesis and uncoupling proteins: a reappraisal of their roles in fat metabolism and energy balance Physiol & Behavior 83 587–602
[3] Brondani L de A, Assmann T S, Duarte G C K, Gross J L, Canani L H and Crispim D 2012 The role of the uncoupling protein 1 (UCP1) on the development of obesity and type 2 diabetes mellitus Arq Bras Endocrinol Metabol 56 215–25
[4] Fenzl A and Kiefer F W 2014 Brown adipose tissue and thermogenesis Hormone Molecular Biology and Clinical Investigation 19
[5] Müller M J, Enderle J and Bosy-Westphal A 2016 Changes in Energy Expenditure with Weight Gain and Weight Loss in Humans Curr Obes Rep 5 413–23
[6] Fatouros I G 2018 Is irisin the new player in exercise-induced adaptations or not? A 2017 update Clinical Chemistry and Laboratory Medicine (CCLM) 56 525–48
[7] Biniaminov N, Bandt S, Roth A, Haertel S, Neumann R and Bub A 2018 Irisin, physical activity and fitness status in healthy humans: No association under resting conditions in a cross-sectional study PLoS ONE 13 e0189254
[8] Huh J Y 2018 The role of exercise-induced myokines in regulating metabolism Archives of Pharmacal Research 41 14–29
[9] Villablanca P A, Alegria J R, Mookadam F, Holmes D R, Wright R S and Levine J A 2015 Nonexercise Activity Thermogenesis in Obesity Management Mayo Clinic Proceedings 90 509–19

[10] Stöcker F, Von Oldershausen C, Paternoster F K, Schulz T and Oberhoffer R 2016 Relationship of post-exercise muscle oxygenation and duration of cycling exercise BMC Sports Sci Med Rehabil 8

[11] Foureaux G 2006 Effects of excess post-exercise oxygen consumption and resting metabolic rate in energetic cost Rev Bras Med Esporte 12 5

[12] Archundia-Herrera C, Macias-Cervantes M, Ruiz-Muñoz B, Vargas-Ortiz K, Komhauser C and Perez-Vazquez V 2017 Muscle irisin response to aerobic vs HIIT in overweight female adolescents Diabetol Metab Syndr 9

[13] Foureaux G 2006 Effects of excess post-exercise oxygen consumption and resting metabolic rate in energetic cost Rev Bras Med Esporte 12 5

[14] Müller M J and Bosy-Westphal A 2013 Adaptive thermogenesis with weight loss in humans Obesity 21 218–28

[15] Müller M J, Enderle J and Bosy-Westphal A 2016 Changes in Energy Expenditure with Weight Gain and Weight Loss in Humans Curr Obes Rep 5 413–23

[16] Koelsch S, Boehlig A, Hohenadel M, Nitsche I, Bauer K and Sack U 2016 The impact of acute stress on hormones and cytokines, and how their recovery is affected by music-evoked positive mood Scientific Reports 6 23008

[17] Fatouros I G 2018 Is irisin the new player in exercise-induced adaptations or not? A 2017 update Clin. Chem. Lab. Med. 56 525–48

[18] Kraemer R R, Shockett P, Webb N D, Shah U and Castracane V D 2014 A transient elevated irisin blood concentration in response to prolonged, moderate aerobic exercise in young men and women Horm. Metab. Res. 46 150–4

[19] Lee M-S, Shin Y, Jung S and Kim Y 2017 Effects of epigallocatechin-3-gallate on thermogenesis and mitochondrial biogenesis in brown adipose tissues of diet-induced obese mice Food Nutr Res 61

[20] Ramezanpour M, Moghaddam A and Sadifar E 2018 Comparison the Effects of Listening to Three Types of Music during Exercise on Heart Rate, Blood Pressure, Rating of Perceived Exertion and Fatigue Onset Time

[21] Yamasaki A, Booker A, Kapur V, Tilt A, Niess H, Lillemoe K D, Warshaw A L and Conrad C 2012 The impact of music on metabolism Nutrition 28 1075–80

[22] Lam Y Y and Ravussin E 2016 Analysis of energy metabolism in humans: A review of methodologies Mol Metab 5 1057–71

[23] Mülller M J, Enderle J and Bosy-Westphal A 2016 Changes in Energy Expenditure with Weight Gain and Weight Loss in Humans Current Obesity Reports 5 413–23

[24] Drenowatz C, Hand G A, Shook R P, Jakicic J M, Hebert J R, Burgess S and Blair S N 2015 The association between different types of exercise and energy expenditure in young nonoverweight and overweight adults Appl Physiol Nutr Metab 40 211–7

[25] Pontzer H, Durazo-Arvizu R, Dugas L R, Plange-Rhule J, Bovet P, Forrester T E, Lambert E V, Cooper R S, Schoeller D A and Luke A 2016 Constrained Total Energy Expenditure and Metabolic Adaptation to Physical Activity in Adult Humans Curr. Biol. 26 410–7

[26] García-Hermoso A, Ceballos-Ceballos R J M, Pobleto-Aro C E, Hackney A C, Mota J and Ramírez-Vélez R 2017 Exercise, adipokines and pediatric obesity: a meta-analysis of randomized controlled trials Int J Obes (Lond) 41 475–82

[27] Drenowatz C, Hand G A, Shook R P, Jakicic J M, Hebert J R, Burgess S and Blair S N 2015 The association between different types of exercise and energy expenditure in young nonoverweight and overweight adults Appl Physiol Nutr Metab 40 211–7

[28] Jabour G and lancu H-D 2017 High-intensity exercise training does not influence body weight but improves lipid oxidation in obese adults: a 6-week RCT BMJ Open Sport Exerc Med 3
[29] Brondani L de A, Assmann T S, Duarte G C K, Gross J L, Canani L H and Crispim D 2012 The role of the uncoupling protein 1 (UCP1) on the development of obesity and type 2 diabetes mellitus *Arq Bras Endocrinol Metabol* 56 215–25

[30] Winn N C, Grunewald Z I, Liu Y, Heden T D, Nyhoff L M and Kanaley J A 2017 Plasma Irisin Modestly Increases during Moderate and High-Intensity Afternoon Exercise in Obese Females *PLOS ONE* 12 e0170690

[31] Anon 2018 The Effect of Endurance Training on Inflammatory Biomarkers and Lipid Profiles in Wistar Rats - Научные статьи - Библиотека международной спортивной информации

[32] Kim H-J, Lee H-J, So B, Son J S, Yoon D and Song W 2016 Effect of aerobic training and resistance training on circulating irisin level and their association with change of body composition in overweight/obese adults: a pilot study *Physiol Res* 65 271–9

[33] Purdom T, Kravitz L, Dokladny K and Mermier C 2018 Understanding the factors that effect maximal fat oxidation *J Int Soc Sports Nutr* 15

[34] Budde H, Machado S, Ribeiro P and Wegner M 2015 The cortisol response to exercise in young adults *Front Behav Neurosci* 9

[35] Thoma M V, Marca R L, Brönnimann R, Finkel L, Ehler U and Nater U M 2013 The Effect of Music on the Human Stress Response *PLOS ONE* 8 e70156

[36] Ghaderi M, Azerbaijani M A, Alinejad H A, Atashak S, Mahdieh Molanouri Shamsi and Davod Ghaderi 2012 Influence of Music Type Listening on Anaerobic Performance and Salivary Cortisol in Males Athletes

[37] Desai R, Thaker R, Patel J and Parmar J 2015 Effect of music on post-exercise recovery rate in young healthy individuals *International Journal of Research in Medical Sciences* 3 896

[38] Thakare A E, Mehrotra R and Singh A 2017 Effect of music tempo on exercise performance and heart rate among young adults *Int J Physiol Pathophysiol Pharmacol* 9 35–9

[39] Arazi H, Asadí A and Purabed M 2015 Physiological and Psychophysical Responses to Listening to Music during Warm-Up and Circuit-Type Resistance Exercise in Strength Trained Men *Journal of Sports Medicine*

[40] Siritunga S, Wijewardena K, Ekanayaka R and Mudunkotuwa P 2013 Effect of music on blood pressure, pulse rate and respiratory rate of asymptomatic individuals: A randomized controlled trial *Health* 05 59

[41] Rahmaty S, Dehghan P, Khoramipour K and Saboory M 2015 The Effect of Listening to Brain Waves’ Relaxing and Exciting Music during Intense Endurance Training on Blood Cortisol Levels of Adult Men *American Journal of Sports Science and Medicine, American Journal of Sports Science and Medicine* 3 77–81

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