

Acute high-intensity intermittent exercise reduces fasting glucagon-like peptide-1 (GLP-1) levels in overweight sedentary women

ULUL AZMY¹, ALDI KARIMULLAH², ANGELIA INDRA DEVI³, SITI ZAHROTUL ILMI⁴,
YOSNENGSIH⁵, TRI HARTINI YULIAWATI⁶, IRFIANSYAH IRWADI⁷, MOHD NAHAR AZMI
MOHAMED⁸, LILIK HERAWATI⁹

^{1,2,3,4,5} Master of Sport Health Science, Faculty of Medicine, Universitas Airlangga, INDONESIA

⁶ Department of Anatomy, Histology, and Pharmacology, Faculty of Medicine, Universitas Airlangga, INDONESIA

⁸ Department of Sports Medicine, Faculty of Medicine, University Malaya, MALAYSIA

^{7,9} Department of Physiology, Faculty of Medicine, Universitas Airlangga, INDONESIA

Published online: November 30, 2023

(Accepted for publication : November 15, 2023)

DOI:10.7752/jpes.2023.11333

Abstract

Overweight remains a complex public health and global health challenge, with a lack of physical activity being a significant contributor to its prevalence and the associated heightened risk of degenerative diseases. Glucagon-like peptide-1 (GLP-1), an incretin hormone linked to overweight conditions, exhibits an increase in response to physical exercise. This study aimed to assess the impact of acute high-intensity intermittent exercise (HIIE) on fasting GLP-1 concentrations in overweight women. The research employed an experimental pre-post-test control group design, involving a sample of 20 overweight sedentary women aged 19–29 years, divided into experimental (EXP) and control (CON) groups. Both groups were required to observe a minimum fasting period of eight hours before the exercise (with water allowed). The EXP group engaged in high-intensity interval exercise (HIIE) using an ergocycle for 60 s at an intensity level ranging from 80% to 90% of the maximum heart rate (HRmax) at 120 rpm. Active rest was maintained at a low intensity (40 rpm for 60 s), and this cycle was repeated 10 times. Blood samples were collected both before and 60 min after exercise, which were subsequently analyzed using the Elabscience E-EL-H6025 human GLP-1 enzyme-linked immunosorbent assay (ELISA). The results indicated a more significant reduction in fasting GLP-1 concentrations in the EXP group (pre: 17.23 ± 6.39 pg/mL; post: 15.11 ± 8.02 pg/mL; $p = 0.07$), compared to a non-significant decrease in the CON group ($p = 0.17$). Fasting delta GLP-1 exhibited a greater decrease in the EXP group (CON: -1.93 ± 4.11 pg/mL; EXP: -2.11 ± 3.29 pg/mL). In conclusion, this study found that acute HIIE influences the fasting GLP-1 concentrations, result in a decrease in fasting GLP-1 concentrations in the EXP group.

Keywords: overweight, HIIE, GLP-1, sedentary, healthy lifestyle

Introduction

Overweight and obesity become global health problem. In 2016, 44% (more than 2 million) adult people in the world were overweight and obese. Overweight is a condition with excess body weight according to weight and height, caused by many factors: genetic, lifestyle, social economy, and environment (Hruby & Hu, 2014). Overweight is known associated with increased risk of degenerative diseases such as hypertension, hyperlipidemia, type 2 diabetes, coronary heart disease, and other health problems (Porth, 2015). Overweight is a complex health problem that is usually accompanied by insulin resistance and increased oxidative stress and expression of inflammatory markers leading to increased fat mass in the body (Hossain et al., 2016).

Sedentary lifestyle is a major factor causing overweight and obesity. Regular physical activity and exercise are known to increase muscle mass and decrease body fat mass, so physical inactivity is associated with decreased muscle mass and increased fat accumulation (Guyton & Hall, 2016). High Intensity Intermittent Exercise (HIIE) can be one of the exercises that can be used to reduce body fat accumulation so as to reduce the risk of obesity. Research shows that HIIE can significantly reduce abdominal fat in untrained normal or obese women and men. In addition, HIIE induces fat oxidation during and after exercise, and increases aerobic and anaerobic capacity (Boutcher, 2011). Based on a study conducted by Vigriawan et al. (2022) the effect of high intensity interval training (HIIT) on fitness components (VO₂max) was shown to be effective in improving physical fitness in overweight young adult women with a sedentary lifestyle. HIIT is an effective exercise protocol to increase maximal aerobic capacity in female subjects with a sedentary lifestyle with a frequency of 3 times per week exercise duration of 18-30 minutes per session (Syamsudin, et al., 2021). Physical activity is also known to cause the body's response by stimulating the secretion of peptide hormones produced by the digestive organs, one of which is glucagon-like peptide-1 (GLP-1) (Ueda et al., 2013). GLP-1 is an amino acid polypeptide secreted by L cells via secretory granules on the basolateral membrane of the gastrointestinal tract

(ileum) (Anandhakrishnan & Korbonits, 2016). Increased GLP-1 is associated with improved β -cell function for insulin stimulation (Ferch et al., 2015). Increased GLP-1 is associated with improved insulin sensitivity and inhibits glucagon secretion, decreases hepatic gluconeogenesis, increases satiety, and slows gastric emptying (Prasad-reddy & Isaacs, 2015). Abnormalities in GLP-1 expression and secretion are common in obesity, diabetes, and hyperlipidemia. A study conducted by Ferch et al. (2015) showed that GLP-1 response was lower in overweight and obese people compared to normal weight people. Increased GLP-1 levels post-exercise were also observed in obese men with acute high intensity interval exercise (HIIE) and moderate intensity continuous exercise (MICE), in addition to an increase in GLP-1 levels there was a decrease in hunger but not lasting (Matos, Souza, Santos, & Medeiros, 2018). However, the acute effect of high-intensity exercise (HIIE) in sedentary overweight women on plasma GLP-1 under fasting conditions is unknown.

Material & Methods

This research was quantitative experimental research with pre - post test control group design. The sampling used purposive sampling technique. Subjects were divided into two groups, namely the experiment group (EXP) and the control group (CON) using simple random sampling technique and each subject had the same opportunity in the grouping. All participants were provided with informed consent prior to their enrolment into this study. This study has been approved by the ethical committee of Faculty of Medicine, Airlangga University with reference number: 245/EC/KEPK/FKUA/2022.

Participants

This study was conducted on 20 sedentary overweight women (10 EXP, 10 CON). The inclusion criteria for subjects in this study were adult women aged 19-29 years with overweight body mass index (BMI) criteria of 23-24.9 kg/m². Not actively doing exercise (<150 minutes of moderate physical activity or <60 minutes of vigorous physical activity per week) and have normal blood pressure.

HIIE Procedure

The EXP group performed the HIIE protocol using the Astrand ergocycle 10 repetitions for 60 seconds at intensities of 80 - 90% heart rate maximal (HRmax) 120 rpm with active rest performed at a low intensity of 40 rpm for 60 seconds. The CON group did not perform any exercise. The exercise protocol included a 3-minute warm-up and 2-minute cool-down at 40 rpm. Exercise was performed acutely or once in the study. The participant's heart rate was monitored using a Polar H7 and accompanied by the research team. Figure 1 shows the exercise protocol in this study.

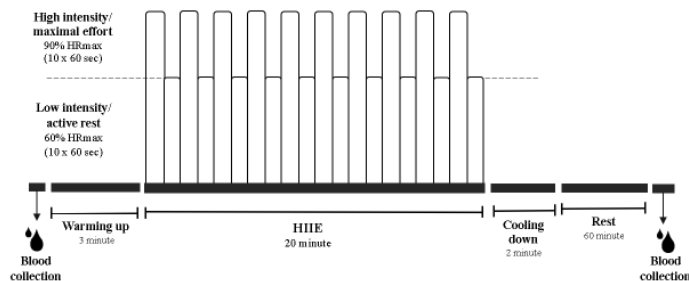


Figure 1. Research Protocol. HRmax: heart rate maximal; sec: second; HIIE: high intensity intermittent exercise

Blood Analysis

Blood samples were taken twice before and after treatment in the EXP and CON groups. Subjects were asked to fast 8 hours before blood collection and intervention. Blood was taken through a vein as much as 5 ml. In the EXP group, blood was taken after 60 minutes of rest along with the CON group. GLP-1 concentration was analyzed using the Human GLP-1 Enzyme-Linked Immunosorbent Assay (ELISA) Elabscience E-EL-H6025 with a concentration unit of pg/ml. GLP-1 concentration was also calculated to determine the difference before and after treatment (Δ GLP-1 = post - pre).

Statistical Analysis

Data were analyzed using SPSS software which includes descriptive analysis, normality and difference test. Parametric statistical tests used in this study were paired t-test, while the non-parametric test used was Mann Whitney to analyze the difference in Δ GLP-1 between EXP and CON groups with 95% of significant level.

Results

The results of this study showed that the age characteristics of respondents were normally distributed and there was no difference between the control group and the HIIE group ($p > 0.05$). The characteristics of the respondents are shown in Table 1. The mean fasting GLP-1 concentration in Table 2 shows that there was no significant change before and after treatment in both groups ($p > 0.05$). Figure 1 shows that Δ GLP-1 decrease was greater in the EXP group (-2.11 ± 3.29 pg/ml) compared to the CON group (-1.93 ± 4.11 pg/ml). The results of the Δ GLP-1 difference test using the Mann-Whitney Test showed no difference between the control group and the treatment group.

Table 1. Characteristics of Sample

Variable	EXP (n = 10)	CON (n = 10)	p
Age (year)	24.3 ± 1.63	23.6 ± 1.71	0.37
Height (cm)	155.1 ± 4.22	158.7 ± 7.45	0.21
Weight (kg)	57.48 ± 3.7	60.31 ± 6.47	0.24
BMI (kg/m ²)	23.91 ± 0.60	23.88 ± 0.62	0.91

Note: Data are presented as mean±SD; CON (control group); EXP (experimental group); BMI (body mass index)

Table 2. Fasting GLP-1 Concentration

GLP-1 (pg/mL)	EXP (n = 10)	CON (n = 10)
Pre	17.23 ± 6.39	18.41 ± 6.74
Post	15.11 ± 8.02	16.48 ± 6.13
p ^a	0.07	0.17

Note: Data are presented as mean±SD; CON – control group; EXP – experimental group; GLP-1 – glucagon-like peptide-1; ^apaired t-test analysis.

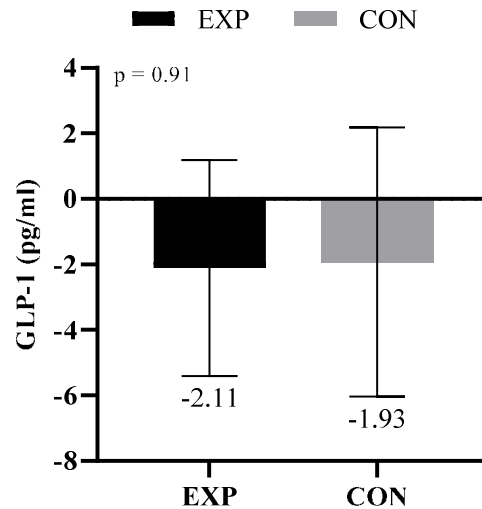


Figure 2. Δ GLP-1 Concentration
Statistical analyzes: Mann Whitney

Discussion

This study analyzed the acute effect of HIIIE on fasting GLP-1 concentrations before and after exercise between the EXP and CON groups. We found that fasting GLP-1 concentrations were not significantly different before and after treatment in both groups. Fasting GLP-1 decreased in both groups with a greater decrease occurring in the EXP group 60 minutes after exercise. Study conducted by Kullman *et al.*, (2016) in obese people with nonalcoholic fatty liver disease (NAFLD) showed a reduction in GLP-1 after aerobic exercise under fasting conditions. In line with a study conducted by Hamilton *et al.* (2020) moderate intensity exercise performed on overweight subjects without food consumption before exercise, decreased GLP-1 concentrations one hour after exercise for 45 minutes at moderate intensity. Another study also showed that there was a decrease in GLP-1 in the control group who did not do the exercise. In contrast, a study conducted by Santos-Parker *et al.* (2017) showed that post-acute moderate-intensity exercise increased GLP-1 concentrations in both normal and overweight people. The GLP-1 response after acute exercise increases in normal weight adults, but in overweight people shows various results, some studies state that there is no change, an increase or even a decrease in GLP-1 in response to acute exercise (Janus *et al.*, 2019). Changes in GLP-1 concentrations were found to increase from 30 to 60 minutes post-exercise, with increased 29% after 30 minutes of exercise, increased 49% after 45 minutes of exercise, and no increase was found immediately and after 15 minutes of exercise (Holliday & Blannin, 2017b). In addition, a study conducted by applying chronic high-intensity interval training showed that GLP-1 increased after 12 weeks of training (Wang & Wang 2022). Several studies have shown an increase in GLP-1 concentrations in obese people after moderate to high intensity exercise with high volume (60 minutes, 50-70% VO₂max), as well as high intensity exercise (Douglas *et al.* 2017; Martins *et al.* 2015).

GLP-1 is secreted from enteroendocrine L cells that are influenced by nutritional, hormonal, pharmacological, and neural signals (Fujiwara *et al.*, 2019). Increased GLP-1 may be related to increased catecholamines and circulating FFAs that stimulate L cells during exercise (Hazell *et al.*, 2016). Increased GLP-1 secretion can reduce gastric motility, thus reducing the appetite, and exercise is known to lead to a faster decline in GLP-1 concentrations. GLP-1 in digestion increases satiety secreted by intestinal L cells in response to food, GLP-1 concentrations are known to be low under fasting conditions and increase during food consumption (Schubert *et al.*, 2013). This study is also in line with a study conducted by Janus *et al.*, (2019) fasting GLP-1 concentrations were found lower especially for each additional hour spent doing moderate intensity physical activity. Lower fasting GLP-1 concentrations were associated with higher levels of cardiorespiratory fitness and total activity volume. In addition, it is also associated with being overweight, which will reduce fasting GLP-1 levels as well as the GLP-1 response after meals (Holts, 2007; Ueda, 2013). The study conducted by Borer *et al.*, (2021), which analyzed changes in GLP-1 concentration in exercise before food and changes in GLP-1 concentration after food consumption. The results of the study showed that GLP-1 concentrations were higher in the group that had a meal before exercise compared to the group that did not have a meal before exercise and was sedentary. Exercise inhibits insulin secretion through sympathetic response to alpha receptors on pancreatic beta cells, which may suppress the incretin hormone response. Insulin concentrations were significantly lower during the postprandial period in the pre-exercise meal consumption group than in the non-exercise meal consumption and sedentary groups. However, other studies have shown different effects of glucose consumption on GLP-1 response, a study conducted by Vollmer *et al.* (2008) showed that a person with impaired glucose tolerance has a high average GLP-1 response, while a study conducted by Rask *et al.* (2004) showed a low average GLP-1 response to glucose.

Plasma glucose levels showed an increase after breakfast and a decrease in the recovery phase after acute aerobic exercise until 90 minutes back to pre-breakfast levels. These changes occurred along with increased levels of insulin and GLP-1 (Bock, Monteiro, Berlanda, Casali, & Schaan, 2022). In line with the study conducted by Devi *et al.*, (2023) with HIIE exercise showed that 1-hour post-exercise glucose concentration increased. Based on a study conducted by De Lima *et al.* (2021) also shows that the acute effect of high-intensity intermittent exercise reduces glycemic variability in patients with type 1 diabetes. In addition, it is known that GLP-1 is positively correlated with insulin, HOMA-IR, and obesity markers (Abou-Samra *et al.*, 2022). Some studies have also found that GLP-1 levels are higher in obese individuals, therefore circulating GLP-1 levels might be used as a potential indicator in the early detection of metabolic syndrome risk in women without a disease diagnosis (Seon *et al.*, 2021). Studies conducted by Ruslan *et al.* (2022) also showed that high-intensity and moderate-intensity interval training can lead to a larger proportion of muscle fibers and improve insulin sensitivity which can provide a positive response in patients with metabolic diseases.

Increased glucose concentration can increase insulin secretion which is influenced by the secretion of GLP-1 and GIP, the potential insulin secretion produced is estimated to be up to 50% of the total produced (Röder *et al.*, 2016). Physical activity is known to affect GLP-1 secretion, where under fasting conditions GLP-1 levels are at a transient minimum concentration and have the potential to increase significantly when there is nutritional intake with increased postprandial GLP-1 secretion (Janus *et al.*, 2019). Based on the previous discussion, it is known that glucose concentration is inversely proportional at 1 hour post-exercise, where during high-intensity exercise with a short time can affect carbohydrate metabolism (glycogenolysis) in the liver which causes an increase in blood glucose. Increased adrenaline during exercise increases plasma glucose concentration due to stimulation of the sympathetic nervous system (Sheerwood, 2016). However, this study showed that GLP-1 was decreased, which may affect the decrease of insulin secretion, thus affecting the high glucose level.

Some factors that may affect the decrease in GLP-1 concentration in this study are fasting before exercise, exercise intensity, and time of blood collection after exercise. Future research ideas can analyze the effect of exercise on GLP-1 concentration by considering the time of blood collection, glucose concentration, insulin, IL-6 and several other factors that may correlate with GLP-1 secretion such as food consumption before and after exercise, and diversity of gut microbiota.

Conclusion

Acute high intensity intermittent exercise influences the fasting GLP-1 concentrations 60 minutes post-exercise. The findings in this study suggest that sedentary overweight women who performed acute HIIE under fasting conditions caused GLP-1 concentrations to decrease. As previously known, GLP-1 is a treatment for overweight people to lose weight that works to reduce appetite. Therefore, it is necessary to further analyze the various types of exercise that can increase GLP-1. This may be influenced by the fasting state before exercise and thus related to glucose concentrations before, during, and after exercise.

Conflict of Interest The authors declare no conflicts of interest related to this manuscript.

Acknowledgements - We expressed our gratitude to the Physiology Department, Faculty of Medicine Universitas Airlangga for providing facilities for this research from planning to completion. The authors would like to thank the Airlangga Hospital Laboratory for assisting in the process of analyzing blood serum for irisin levels. The authors also would like to thank Falcon Scientific Editing (<https://falconediting.com>) for proofreading the English language in this paper.

References

- Abou-Samra, M., Venema, K., Ayoub Moubareck, C., & Karavetian, M. (2022). The Association of Peptide Hormones with Glycemia, Dyslipidemia, and Obesity in Lebanese Individuals. *Metabolites*, 12(11). <https://doi.org/10.3390/metabo12111051>
- Anandhakrishnan, A., & Korbonits, M. (2016). Glucagon-like peptide 1 in the pathophysiology and pharmacotherapy of clinical obesity. *World Journal of Diabetes*, 7(20), 572–598. <https://doi.org/10.4239/wjd.v7.i20.572>
- Bock, P. M., Monteiro, R. B., Berlanda, G., Casali, K. R., & Schaan, B. D. (2022). Maintenance of plasma glucose variability after an acute session of aerobic exercise despite changes in insulin and glucagon-like peptide-1 levels in type 2 diabetes. *Archives of Endocrinology and Metabolism*, 66(3), 324–332. <https://doi.org/10.20945/2359-3997000000482>
- Borer, K. T., Lin, P., & Wuorinen, E. (2021). Timing of Meals and Exercise Affects Hormonal Control of Glucoregulation, Insulin Resistance, Substrate Metabolism, and Gastrointestinal Hormones, but Has Little Effect on Appetite in Postmenopausal Women. *Nutrients*, 13(4342). <https://doi.org/10.3390/nu13124342>
- Boutcher, S. H. (2011). High-Intensity Intermittent Exercise and Fat Loss. *Journal of Obesity*, 2011. <https://doi.org/10.1155/2011/868305>
- De Lima, V. A., Junior, F., Cordeiro, G. R., Decimo, J. P., Franca, S. N., Mascarenhas, L. P. G., & Leite, N. (2021). Glycemic variability after high intensity continuous and intermittent exercises in children and adolescents with Type 1 Diabetes. *Journal of Physical Education and Sport*, 21(3), 2237–2243. <https://doi.org/10.7752/jpes.2021.s3284>
- Devi, A. I., Rejeki, P. S., Shakila, N., Yosnengsih, Ilmi, S. B. Z., Karimullah, A., ... Herawati, L. (2023). Response of TNF- α Levels and Blood Glucose Levels after Acute High-Intensity Intermittent Exercise in Overweight Women. *Retos*, 2041(48), 101–105.
- Douglas, J. A., King, J. A., Clayton, D. J., Jackson, A. P., Sargeant, J. A., Thackray, A. E., ... Stensel, D. J. (2017). Acute effects of exercise on appetite, ad libitum energy intake and appetite-regulatory hormones in lean and overweight / obese men and women. *Nature Publishing Group*, 41(12), 1737–1744. <https://doi.org/10.1038/ijo.2017.181>
- Ferch, K., Torekov, S. S., Vistisen, D., Johansen, N. B., Witte, D. R., Jonsson, A., ... Jorgensen, M. E. (2015). GLP-1 response to oral glucose is reduced in prediabetes, screen-detected type 2 diabetes, and obesity and influenced by sex: The ADDITION-PRO study. *Diabetes*, 64(9), e30–e31. <https://doi.org/10.2337/db15-0743>
- Fujiwara, Y., Eguchi, S., Murayama, H., Takahashi, Y., Toda, M., Imai, K., & Tsuda, K. (2019). Relationship between diet exercise and pharmacotherapy to enhance the GLP-1 levels in type 2 diabetes. *Endocrinology, Diabetes & Metabolism*. <https://doi.org/10.1002/edm2.68>
- Guyton, A. C., & Hall, J. E. (2016). *Medical Physiology* (Thirteenth). Philadelphia: Elsevier.
- Hamilton, C. C., Wiseman, S. B., Copeland, J. L., & Bomhof, M. R. (2020). Influence of post-exercise fasting on hunger and satiety in adults. *Applied Physiology, Nutrition, and Metabolism*, 45(9), 1022–1030. <https://doi.org/10.1139/apnm-2019-0947>
- Hazell, T. J., Islam, H., Townsend, L. K., Schmale, M. S., & Copeland, J. L. (2016). Effects of exercise intensity on plasma concentrations of appetite-regulating hormones: Potential mechanisms. *Appetite*, 98, 80–88. <https://doi.org/10.1016/j.appet.2015.12.016>
- Holliday, A., & Blannin, A. (2017). Appetite, food intake and gut hormone responses to intense aerobic exercise of different duration. *Society for Endocrinology*, 235, 193–20. <https://doi.org/10.1530/JOE-16-0570>
- Hossain, M. K., Dayem, A. A., Han, J., Yin, Y., Kim, K., Saha, S. K., ... Cho, S. G. (2016). Molecular Mechanisms of the Anti-Obesity and Anti-Diabetic Properties of Molecular Mechanisms of the Anti-Obesity and Anti-Diabetic Properties of Flavonoids. *International Journal of Molecular Sciences*, 17(569). <https://doi.org/10.3390/ijms17040569>
- Hruby, A., & Hu, F. B. (2014). The Epidemiology of Obesity: A Big Picture. *Pharmaco Economics*, (August). <https://doi.org/10.1007/s40273-014-0243-x>
- Janus, C., Vistisen, D., Amadid, H., Witte, D. R., Lauritzen, T., & Brage, S. (2019). Habitual physical activity is associated with lower fasting and greater glucose-induced GLP-1 response in men. *Endocrine Connections*, 8, 1607–1617. <https://doi.org/10.1530/EC-19-0408>
- Kullman, E. L., Kelly, K. R., Haus, J. M., Fealy, C. E., Scelsi, A. R., Pagadala, M. R., ... Kirwan, J. P. (2016). Short-Term aerobic exercise training improves gut peptide regulation in nonalcoholic fatty liver disease. *Journal of Applied Physiology*, 120(10), 1159–1164. <https://doi.org/10.1152/jappphysiol.00693.2015>
- Martins, C., Stensvold, D., Finlayson, G., Holst, J., Wisloff, U., Kulseng, B., ... King, N. A. (2015). Effect of moderate- and high-intensity acute exercise on appetite in obese individuals. *Medicine and Science in Sports and Exercise*, 47(1), 40–48. <https://doi.org/10.1249/MSS.0000000000000372>
- Matos, V., Souza, D. C. De, Santos, V. O. A., & Medeiros, I. F. (2018). Acute Effects of High-Intensity Interval and Moderate-Intensity Continuous Exercise on GLP-1, Appetite and Energy Intake in Obese Men: A Crossover Trial. *Nutrients*, 10(889). <https://doi.org/10.3390/nu10070889>
- Porth, C. M. (2015). *Essentials of Pathophysiology* (Fourth Ed). Philadelphia: Wolters Kluwer.

- Prasad-reddy, L., & Isaacs, D. (2015). A clinical review of GLP-1 receptor agonists : efficacy and safety in diabetes and beyond. *Drugs in Context*, 4(212283), 1–19. <https://doi.org/10.7573/dic.212283>
- Rask, E., Olsson, T., Söderberg, S., Holst, J. J., Tura, A., Pacini, G., & Åhrén, B. (2004). Insulin Secretion and Incretin Hormones after Oral Glucose in Non-obese Subjects with Impaired Glucose Tolerance. *Metabolism: Clinical and Experimental*, 53(5), 624–631. <https://doi.org/10.1016/j.metabol.2003.11.011>
- Röder, P. V., Wu, B., Liu, Y., & Han, W. (2016). Pancreatic regulation of glucose homeostasis. *Experimental & Molecular Medicine*, 48(e219). <https://doi.org/10.1038/emm.2016.6>
- Ruslan, S., Ilias, N. F., Azidin, R. M., Omar, M., Ghani, R. A., & Ismail, H. (2022). Effect of high intensity interval training and moderate intensity continuous training on blood pressure and blood glucose among T2DM patients. *Journal of Physical Education and Sport*, 22(10), 2334–2339. <https://doi.org/10.7752/jpes.2022.10297>
- Santos-Parker, J. R., Strahler, T. R., Vorwald, V. M., Pierce, G. L., & Seals, D. R. (2017). Habitual aerobic exercise does not protect against micro-or macrovascular endothelial dysfunction in healthy estrogen-deficient postmenopausal women. *Journal of Applied Physiology*, 122(1), 11–19. <https://doi.org/10.1152/jappphysiol.00732.2016>
- Schubert, M. M., Sabapathy, S., Leveritt, M., & Desbrow, B. (2013). Acute exercise and hormones related to appetite regulation: A meta-analysis. *Sports Medicine*, 44(3), 387–403. <https://doi.org/10.1007/s40279-013-0120-3>
- Seon, M. J., Hwang, S. Y., Son, Y., Song, J., & Kim, O. Y. (2021). Circulating glp-1 levels as a potential indicator of metabolic syndrome risk in adult women. *Nutrients*, 13(3), 1–11. <https://doi.org/10.3390/nu13030865>
- Sheerwood, L. (2016). *Human Physiology: From Cel to Systems* (Ninth). USA: Graphic World Inc, ed.
- Syamsudin, F., Wungu, C. D. K., Qurnianingsih, E., & Herawati, L. (2021). High-intensity interval training for improving maximum aerobic capacity in women with sedentary lifestyle : a systematic review and meta-analysis. *Journal of Physical Education and Sport*, 21(4), 1788–1797. <https://doi.org/10.7752/jpes.2021.04226>
- Ueda, S., Nakahara, H., & Miyamoto, T. (2013). Effects of exercise on glucagon-like peptide-1 (GLP-1). *J Phys Fitness Sport Med*, 2(2), 221–224. <https://doi.org/10.7600/jpfs.2.221>
- Vigriawan, G. E., Putri, E. A., Rejeki, P. S., Qurnianingsih, E., Kinanti, R. G., Mohamed, M. N. A., & Herawati, L. (2022). High-intensity interval training improves physical performance without C-reactive protein (CRP) level alteration in overweight sedentary women. *Journal of Physical Education and Sport*, 22(2), 442–447. <https://doi.org/10.7752/jpes.2022.02055>
- Vollmer, K., Hoist, J. J., Bailer, B., Ellrichmann, M., Nauck, M. A., Schmidt, W. E., & Meier, J. J. (2008). Predictors of incretin concentrations in subjects with normal, impaired, and diabetic glucose tolerance. *Diabetes*, 57(3), 678–687. <https://doi.org/10.2337/db07-1124>
- Wang, H., & Wang, Y. (2022). Effects of Different Intensity Exercise on the Patients of Oxidative Stress Factors and Glycemic Control Type 2 Diabetes Mellitus. *Mathematical Problems in Engineering*. <https://doi.org/10.1155/2022/1992117>