RESEARCH ARTICLE

European Journal of Sport Sciences
www.ej-sport.org

The Effect of High Intensity Interval Training on Body Composition in Obesity Patients: Literature Review

Muh Alif Kurniawan Sam, M. Furqon Hidayatullah, and Febriani Fajar Ekawati

ABSTRACT

Obesity is a major threat to health in various parts of the world. This study will also elaborate further on the effects of HIIT on body composition in obese people. This study uses the literature review method using articles from the last 3 to 9 years. Articles searched through ScienceDirect were 348, MDPI were 29 articles, Scopus was 178 and Springer were 317, so the total population of articles found was 872. This study used Preferred Reporting Items for Systematic Reviews and Meta Analyzes and found a sample of 12 articles. The results of the study revealed that there was a decrease in fat mass of 0.16 kg, 1.81 kg to 4.7 kg, and as much as 0.4 liters of total body water reduction, besides that waist circumference also decreased, but it was different from fat-free body mass which increased by 0.55 kg. In conclusion, HIIT can reduce body composition in the form of fat mass, total body water and waist circumference for obese people, but there is an increase in fat-free body mass.

Keywords: body composition, high-intensity interval training, obesity.

Published Online: May 06, 2023

ISSN: 2796-0048

DOI: 10.24018/ejsport.2022.2.3.76

M. A. K. Sam*
Department of Sport Science, Faculty of Sport, Universitas Sebelas Maret Surakarta, Indonesia
(e-mail: a122108021@student.uns.ac.id)
M. F. Hidayatullah
Department of Sport Science, Faculty of Sport, Universitas Sebelas Maret Surakarta, Indonesia
(e-mail: mohammadfurqon@staff.uns.ac.id)
F. F. Ekawati
Department of Sport Science, Faculty of Sport, Universitas Sebelas Maret Surakarta, Indonesia
(e-mail: febriani@staff.uns.ac.id)

****Corresponding Author***

I. Introduction

Obesity is a major threat to health in various parts of the world because obese people will usually avoid sports and physical activity to avoid stigma and shame (Balyi *et al.*, 2013, p. 1). In 2016 data results were obtained which stated that if someone aged 18 years and over experienced a condition of being overweight with a total of more than 1.9 billion people, and out of this total there were more than 650 million people who were included in the obesity category (WHO, 2021). The number of people in Indonesia who experience cases of obesity (Body Mass Index or BMI ≥25 – 27 and BMI ≥27), aged ≥ 15 years is 35.4%, while people who are obese with BMI ≥27 are only 21.8 %. In this case, for residents who were ≥15 years old and had obesity, the prevalence was higher in women by 29.3% compared to only 14.5% in men. The results of the data obtained stated that obesity was higher in urban areas (25.1%) than in rural areas (17.8%). When compared by age group, the highest obesity is in the age group of 40-44 years (29.6%) (Kementrian Kesehatan RI, 2020, p. 206).

Whether or not a person is obese can be seen from the body composition of the patient where the body composition has 5 levels, namely level I (whole body), level II (tissue and organ system), level 3 (cellular), level IV (molecular), and level V (atomic). One of the causes of excess weight gain is the increase in body fat that is under the skin and around various internal organs. In women, about 90% of body fat is under the skin and about 80% in men. Measurement of fat distribution, and in particular internal or visceral fat, is an important element in clinically assessing body composition because it has a strong association with the risk of future development of cardiometabolic diseases (Bray, 2011, pp. 34–42).

One exercise that has a short time, namely HIIT, research related to this exercise in adults, especially those who are obese, is still very minimal in Indonesia. Therefore, this research will be a first step before conducting experiments or giving training doses directly to humans. This study will also elaborate further on the effects of HIIT on body composition in obese people.

II. Method

A. Design Study

The research method used in this research is library research with a type of literature review using articles from the last 3 to 9 years (Hadi *et al.*, 2020, pp. 54–55; Hidayatullah, 2022, pp. 1–2).

European Journal of Sport Sciences
www.ej-sport.org

B. Population and Sample

Based on the results of the search conducted, the studies ranged from 872 articles. A total of 348 articles were obtained on ScienceDirect, 29 articles on MDPI, 178 articles on Scopus, and 317 articles on Springer. The research population can be seen in Fig. 1 below.

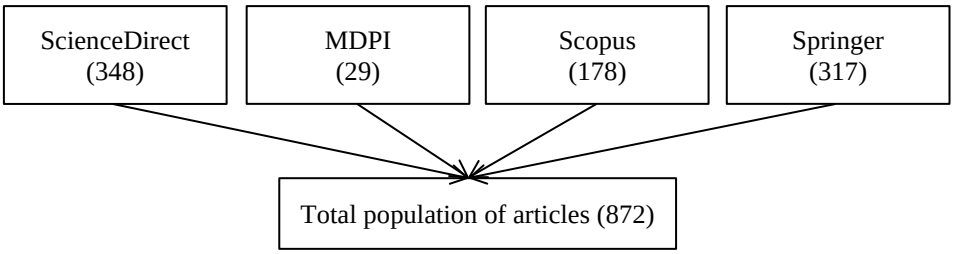

Fig. 1. Total population of articles.

The quality procedure of the total population of 872 will use the Preferred Reporting Items for Systematic Reviews and Meta Analyzes (PRISMA). The flow of information from the prism can be seen in Fig. 2 below.

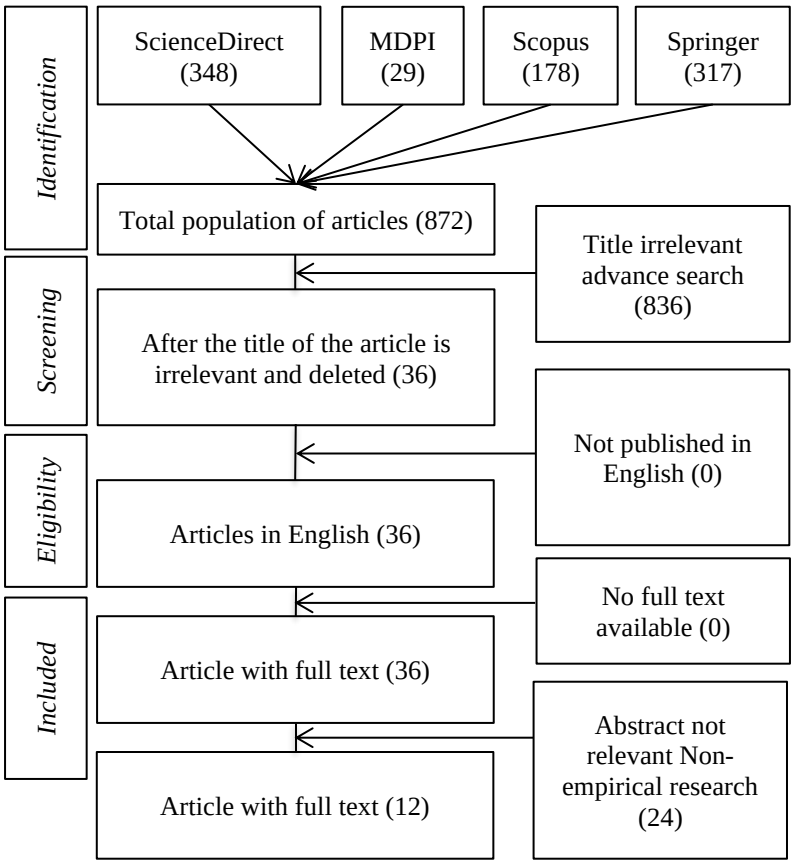

Fig. 2. PRISMA.

C. Data Collection

1) Use of digital libraries

The digital library is used to search for several articles by limiting the date the article was published, usually the date of articles that have been published in the last 5 years or starting from 2018 to 2022 which has been set.

2) Keyword determination

Keyword determination can be seen in Table I.

3) Operationalization of keywords in the digital library

Search for articles using predetermined keywords, namely "HIIT" or "SIT" or "IT" and "obesity" or "adiposity" and "body composition" in 5 digital libraries, namely ScienceDirect (https://www.sciencedirect.com/), MDPI (https://www.mdpi.com/), Scopus (https://www.scopus.com/) and Springer (https://link.springer.com/) with publication date set from 2018 until 2022.

European Journal of Sport Sciences
www.ej-sport.org

TABLE I: KEYWORD DETERMINATION

Keywords	Operational definition
HIIT	
High Intentisity Interval Training (HIIT), *Sprint Interval Training* (SIT), *Interval Training* (IT)	HIIT is a form of cardiovascular exercise with a frequency of exercise that is carried out repeatedly and an intensity that is included in the high-intensity category.
Obesity	
Obesity, Adiposity	Obesity is a disorder in which body fat is involved in increasing the risk of these health problems.
Body Composition	
Body Composition	Body composition is the relative proportion of fat and fat-free tissue in the body

4) Assessment of Physiotherapy Evidence Database (PEDro scale)

The purpose of the PEDro scale is to help users of the PEDro database quickly identify known or suspected randomized clinical trials i.e. RCTs or controlled clinical trials (CCT) archived in the PEDro database that are likely to be internally valid, and can have sufficient statistical information to make research results can be interpreted (PEDro, 1999).

III. RESULT

The purpose of this study was to determine the effect of HIIT on body composition for obese people. After searching several databases, using a combination of keywords related to the research that had been determined, ScienceDirect obtained 348, MDPI 29 articles, Scopus 178 and Springer 317, so the total population of articles found was 872. After screening, eligibility, and included, obtained a sample of 12 articles.

The research articles that will be used as a basis for this research certainly have various journal values, from Q1 to Q3, and all of the articles used have eligibility criteria. For clearer details about the PEDro journal quartile and checklist, see Table II.

TABLE II: PEDRO SCALE AND QUARTILE

Articles	PEDro Scale	Quartile
Blue *et al.* (2018)	8/11	1
Vaccari *et al.* (2020)	6/11	1
Saeidi *et al.* (2022)	7/11	1
Mendelson *et al.* (2022)	8/11	1
D'Amuri *et al.* (2021)	10/11	1
Nobari *et al.* (2022)	6/11	1
Tsirigkakis *et al.* (2021)	6/11	1
Zhang *et al.* (2020)	8/11	1
Roy *et al.* (2018)	6/11	1
Gripp *et al.* (2021)	7/11	1
Batitucci *et al.* (2022)	7/11	1
Berge *et al.* (2022)	7/11	1

After finding several articles that are in accordance with Q1 to Q3 and have gone through the assessment process through the Pedro scale, then the PICO (P: Population, I: Intervention, C: Comparison, O: Outcome) will be described for each article used in Table III.

TABLE III: PEDRO SCALE AND QUARTILE

No	Articles	Population	Intervention	Comparison	Outcome
1	Blue *et al.* (2018)	44 samples of adults with overweight and obesity	HIIT (SIT)	HIIT (LIT), Control group	HIIT is an effective training modality for influencing muscle size in obese conditions.
2	Vaccari *et al.* (2020)	32 adult patients with obesity	MICT	HIIT	HIIT is more effective in increasing and maintaining VO2peak and fat oxidation.
3	Saeidi *et al.* (2022)	60 adult men with obesity	HIIT	*Circuit Resistance Training* (CRT), MICT, *control group*	HIIT and CRT have a much greater impact when compared to MICT.
4	Mendelson *et al.* (2022)	60 subjects with obesity	HIIT	MICT and HIIT *Recovery Modulation*	HIIT/HIIT-RM has a long-term effect, namely a decrease in total fat mass compared to MICT.
5	Zeng *et al.* (2021)	54 young women with obesity	HIIT	*Resistance Training* (RT), FATmax AT	HIIT and RT are all effective against changes in body composition in obese people.

TABLE III: PEDRO SCALE AND QUARTILE (CONT.)

Articles	Population	Intervention	Comparison	Outcome	
6	Nobari *et al.* (2022)	30 samples of women with obesity	HIIT	Spirulina and combination group	HIIT and spirulina supplements affect body composition.
7	Tsirigkakis *et al. (*2021)	16 obese men	HIIT 10 second	HIIT 60 second	Both groups are effective in reducing body fat, gaining muscle, and fat oxidation
8	Zhang *et al.* 92020)	59 young women with obesity	$SIT_{all-out}$	SIT_{120}, HIIT, MICT, *no training*	The decrease in visceral fat basically occurs with SITall-out, SIT120 and HIIT is greater than MICT.
9	Hirsch *et al.* (2021)	89 samples of adults with obesity conditions	HIIT	*Essential amino acid* (EAA), HIIT+EAA, and control group	HIIT with or without EAA can increase muscle mass in the thigh area.
10	Gripp *et al.* (2021)	22 subjects with BMI >25	HIIT	MICT	HIIT reduces a greater percentage of fat compared to MICT.
11	Batitucci *et al.* (2022)	36 adult female subjects with obesity	*Intermittent Fasting* (IF) + HIIT (Exercise)	HIIT dan IF	Combination group can increase fat free mass.
12	Berge *et al.* (2022)	71 adult patients with obesity	HIIT	HIIT or MICT, MICT	The combined HIIT/MICT group lost an average of 3kg more than the MICT group.

Furthermore, it will be explained in relation to all types of interventions used and the results of this study which discusses body composition. The following Table IV will be attached in detail related to interventions and research results from all articles that match the inclusion criteria of this study.

TABLE IV: PEDRO SCALE AND QUARTILE

No	Articles	Intervention	Result
1	Blue *et al.* (2018)	1. SIT/HIIT (1:1 *work-to-rest*) 2. LIT/HIIT (2:1 *work-to-rest*) 3. *Control group*	There was a significant difference in the muscle cross sectional area between the intervention groups with p = 0.038. All groups did not have a significant difference for the lean mass of the right and left legs with a value of p = 0.064 and the fat mass of the right and left legs with a score of p = 0.500. There was no difference in total body water before and after handling (-: 0.084 ± 2.95, p = 0.850).
2	Vaccari *et al.* (2020)	1. HIIT 2. MICT	Average weight loss was about 0.15 kg, BMI decreased by about 0.05 kgm2, fat mass was 0.16 kg, and there was no change in fat-free mass in both groups.
3	Saeidi *et al.* (2022)	1. HIIT 2. *Circuit Resistance Training*/CRT 3. MICT 4. *Control group*	Percentage of body fat decreased in HIIT by 11%, MICT and CRT each by 8%, compared to the control group (p < 0.05). FFM increased at 11% CRT and 5% HIIT.
4	Mendelson *et al.* (2022)	1. HIIT 2. MICT 3. HIIT *recoveri modulation*/RM	There was a decrease in waist circumference in the HIIT group with a value of p=0.007 and it tended to decrease in the HIIT-RM group p=0.025. Hip circumference decreased significantly in MICT and HIIT-RM with p=0.007 and p <0.001, respectively. HIIT-RM at T2 to T6 decreased leg muscle mass p=0.027. HIIT at T0 to T6, there was a decrease in fat mass and abdominal fat mass with p = 0.011 and p = 0.014 respectively. MICT was able to reduce hip circumference with a value of p=017. HIIT-RM was able to reduce waist circumference not statistically significant p=0.06.
5	Zeng *et al.* (2021)	1. HIIT 2. *Resistance Training*/RT 3. *Fat oxidation intensity continuous aerobic training*/FATmax AT	FATmax AT HIIT or RT reduced BFP and FM mid-intervention with a P<0.05 and continued to decrease over 7-12 weeks (P<0.05). The reduction in BFP and FM was greater in the HIIT group from 0-6 weeks or P < 0.05. The increase in FFM and Muscle Mass in the FATmax AT and HIIT groups, and MM continued to increase for 12 weeks occurred in the RT group with a P value <0.05, the increase in MM for 0-6 weeks was more than 7-12 weeks of treatment in FATmax AT and Both RT groups had P <0.05.
6	Nobari *et al.* (2022)	1. HIIT 2. Spirulina 3. Combination	FFM decreased significantly in the combined group (p=0.012, g= −0.54).
7	Tsirigkakis *et al.* (2021)	1. HIIT 10s 2. HIIT 60s	The decrease in body fat and total fat mass in both groups was 1.45 kg out of a total loss of 1.81 kg. an increase in fat-free body mass in the legs by 0.55 kg.

TABLE IV: PEDRO SCALE AND QUARTILE (CONT.)

No	Articles	Intervention	Result
8	Zhang *et al.* (2020)	1. $SIT_{all-out}$ 2. SIT_{120} 3. HIIT 4. MICT 5. *No training*	There was no difference in body mass and fat between the 5 groups (P>0.05). After 12 weeks of treatment, there were decreases in body mass, FFM, and total fat mass in all-out SIT, SIT120, and HIIT (P<.05), and there was no change in any of the variables between the 3 groups (P>0.05). Decreased FFM and total body fat mass on MICT (P < 0.05), except for body mass and gynoid fat mass (P > 0.05).
9	Hirsch *et al.* (2021)	1. HIIT 2. *Essential amino acid*/EAA 3. HIIT+EAA 4. *Control group*	HIIT and HIIT + EAA from 4-8 weeks, showing improvement in the LM of the thigh. The control group did not change. There was no significant difference between groups (p > 0.05).
10	Gripp *et al.* (2021)	1. HIIT 2. MICT	Significantly, there was a decrease in BMI (p<0.000, g= -0.60) and TC (p<0.0001, g=−0.41) in the HIIT group. This was also the case for MICT (p<0.01, g=−0.13) but BMI almost returned to normal after TC (p>0.05, g=−0.08). BFP was not affected by MICT in post exercise (p>0.05, g=− 0.13) and TC (p>0.05, g=− 0.04). HIIT was able to reduce post-exercise BFP (p<0.0001, g= -0.38) and TC (p<0.001, -0.26).
11	Batitucci *et al.* (2022)	1. *Intermitten Fasting*/IF + HIIT 2. HIIT/EX 3. IF	IF + EX was able to reduce body weight (p=0.012) and decrease BMI (p=0.031). Waist, abdomen and hip circumference decreased in the IF+EX and EX groups (p<0.001). The IF group only showed a reduction in hip circumference (p < 0.001). The decrease in BFP in the IF and IF + EX groups (p <0.001), was approximately −4% (1%), and the EX group only decreased BFP by around -2.3% (1%).
12	(Berge *et al.* (2022)	1. HIIT 2. HIIT or MICT 3. MICT	BMI and fat mass decreased significantly in the HIIT/MICT group compared to the MICT group with a difference between groups of −1.2 (95% CI:−2.3 to −0.2) kg/m2, −3.3 (95 % CI: −6.4 to −0.2) kg, and −2.9 (95% CI: −5.3 to −0.5) kg.

IV. DISCUSSION

Based on the research results in Table II Pedro's Checklist, the results presented are that out of the 12 articles used, there are 4 articles with a value of 6, consisting of 4 articles with a value of 7, and 3 articles with a value of 8, and only 1 article with a value 10. Then from all the journals used, all articles fall into the Q1 category.

Based on the results from Table III, all articles with a total of 12 studies used samples from obese populations in the adult age group, both female and male. All articles use HIIT as the intervention to be used and use MICT, SIT, EAA, IF and others as a comparison of the treatment given in the article.

A. HIIT with Body Composition

HIIT has an effect on body composition, several articles revealed that there was a decrease in fat mass of 0.16 kg, 1.81 kg to 4.7 kg, and as much as 0.4 liters of total body water reduction, besides that waist circumference also decreased, but it is different with free body mass fat which has increased by 0.55 kg (Vaccari *et al*., 2020; Zhang *et al*., 2020; Tsirigkakis *et al*., 2021; Mendelson *et al*., 2022).

Several reasons HIIT or exercise can reduce fat mass, total body water, and fat-free body mass because of energy expenditure, BMR (Basal Metabolic Rate) is the level of energy expenditure of a person when resting supine sleeping position, measured in a thermoneutral environment immediately after sleeping for at least 8 hours and fasted for at least 12 hours (Kenney *et al*., 2012, p. 120).

Muscle has a high metabolic activity, BMR is directly related to an individual's fat-free mass and is generally reported in kilocalories per kilogram of fat-free mass per minute (kcal/kg FFM/min) (Kenney *et al*., 2012, p. 120). The higher the fat-free mass, the more total calories expended in a day, because women tend to have lower fat-free mass and greater fat mass than men, women tend to have a lower BMR than men of the same weight (Kenney *et al*., 2012, p. 120). The amount of energy expended for different activities varies with the intensity and type of exercise performed, in addition to exercise intensity, activity duration must also be considered (Kenney *et al*., 2012, p. 126).

Each activity will add to daily caloric expenditure which varies and depends on many factors, including activity level (by far the biggest influence), age, sex, size, weight, and body composition (Kenney *et al*., 2012, pp. 126–127).

High intensity training not only demands the use of anaerobic energy sources but also that all types of muscle fibers are used especially type IIx fibers, the consequence is the generation of large amounts of ATP at very fast rates, the rate at which ATP is generated will determine how much force is exerted. or the speed that can be produced and also for how long (McLaren & Morton, 2012, p. 146). This exercise requires a

hundredfold increase in the use of ATP when compared to resting conditions, there is a time lag before steady state is reached and during this resting phase, the energy for muscle contraction comes from an anaerobic source, compensating for the inability of the cardiovascular system to provide sufficient oxygen quickly to the body. muscles, after a stable condition is achieved oxygen uptake is then equivalent to oxygen demand (McLaren & Morton, 2012, p. 146).

When you want to go on a diet, of course it will be very difficult not to lose muscle mass accompanied by loss of fat mass, by doing exercises in the form of HIIT it allows for fixed muscle mass which may even increase and is accompanied by weight loss through a decrease in fat mass (Bartram, 2015, p. 18). This can be caused because HIIT is able to increase testosterone levels and also human growth hormone or HGH (Human Growth Hormone) which will be responsible for adding muscle mass without adding fat and even losing fat. HIIT is able to stimulate HGH production by up to 450 percent for 24 hours after finishing a workout. In addition, HGH is not only responsible for increasing metabolism and turning on the fat-burning furnace, but is also able to slow down the aging process (Bartram, 2015, p. 18).

B. Dosage of Exercise for Changes in Body Composition

Exercises were performed 3 times a week for 8 weeks, each session lasting 20 to 45 minutes, and each session separated by at least 48 hours. Every time you finish doing one exercise, you will then recover for 1 minute. The exercise consists of 10 minutes of warming up followed by 3 to 7 repetitions of walking for 3 minutes at high intensity and alternated with 1.5 minutes of walking at low intensity, the last exercise is cooling down with a duration of 5 minutes (Vaccari *et al*., 2020; Zhang *et al*., 2020; Tsirigkakis *et al*., 2021; Mendelson *et al*., 2022).

V. CONCLUSION

HIIT is able to reduce body composition in the form of fat mass, total body water and waist circumference for obese people, but there is an increase in fat-free body mass.

VI. CONFLICT OF INTEREST

HIIT in the findings of this study has an effect on the body of obese people. It should be noted for obese people who have never done any physical activity at all, it is hoped that they will start from level I HIIT in order to avoid muscle injuries, high blood pressure or hypertension and others, or someone who is obese and accompanied by certain diseases. It is advisable to consult before doing the exercise.

REFERENCES

Balyi, I., Way, R. and Higgs, C. (2013). *Long-Term Athlete Development, Human Kinetics*. USA: Human Kinetics.

Bartram, S. (2015). *High-Intensity Interval Training*. New York: Penguin Random House LLC.

Batitucci, G. *et al.* (2022). Impact of Intermittent Fasting Combined With High-Intensity Interval Training on Body Composition, Metabolic Biomarkers, and Physical Fitness in Women With Obesity. *Frontiers in Nutrition*, 9(May), pp. 1–13. Available at: https://doi.org/10.3389/fnut.2022.884305.

Berge, J. *et al.* (2022). Effect of aerobic exercise intensity on health-related quality of life in severe obesity: a randomized controlled trial. *Health and Quality of Life Outcomes*, 20(1), pp. 1–10. Available at: https://doi.org/10.1186/s12955-022-01940-y.

Blue, M.N.M. *et al.* (2018). The effects of high intensity interval training on muscle size and quality in overweight and obese adults. *Journal of Science and Medicine in Sport*, 21(2), pp. 207–212. Available at: https://doi.org/10.1016/j.jsams.2017.06.001.

Bray, G.A. (2011). *A Guide to Obesity and the Metabolic Syndrome*, *A Guide to Obesity and the Metabolic Syndrome*. Baton Rouge: CRC Press. Available at: https://doi.org/10.1201/b10790.

D'Amuri, A. *et al.* (2021). Effectiveness of high-intensity interval training for weight loss in adults with obesity: A randomised controlled non-inferiority trial. *BMJ Open Sport and Exercise Medicine*, 7(3), pp. 1–10. Available at: https://doi.org/10.1136/bmjsem-2020-001021.

Gripp, F. *et al.* (2021). HIIT is superior than MICT on cardiometabolic health during training and detraining. *European Journal of Applied Physiology*, 121(1), pp. 159–172. Available at: https://doi.org/10.1007/s00421-020-04502-6.

Hadi, S., Thahjono, H.K. and Palupi, M. (2020). *Systematic Review: Meta Sintesis Untuk Riset Perilaku Organisasional*. 1st edn, *Journal of Psychiatric Research*. 1st edn. Edited by D.W.P. Ranto. Yogyakarta: Vivavictory.

Hidayatullah, M.F. (2022). *Penelitian Kepustakaan*. 1st edn. Edited by S. Riyadi. Solo: Cakra Wijaya.

Hirsch, K.R. *et al.* (2021). High-intensity interval training and essential amino acid supplementation: Effects on muscle characteristics and whole-body protein turnover. *Physiological Reports*, 9(1), pp. 1–14. Available at: https://doi.org/10.14814/phy2.14655.

Kementrian Kesehatan RI (2020). *Profil Kesehatan Indonesia Tahun 2019*. Jakarta: Kementrian Kesehatan Republik Indonesia. Available at: http://www.kemkes.go.id.

Kenney, W.L., Wilmore, J.H. and Costill, D.L. (2012). *Physiology of Sport and Exercise*. 5th edn. New Zealand: Human Kinetics.

McLaren, D. and Morton, J. (2012). *Biochemistri for Sport and ExercisrMetabolism*. Liverpool: Wiley-Blackwell. Available at: https://www.ptonline.com/articles/how-to-get-better-mfi-results.

Mendelson, M. *et al.* (2022). Effects of high intensity interval training on sustained reduction in cardiometabolic risk associated with overweight/obesity. A randomized trial. *Journal of Exercise Science and Fitness*, 20(2), pp. 172–181. Available at: https://doi.org/10.1016/j.jesf.2022.03.001.

Nobari, H. *et al.* (2022). Effects of 8 weeks of high-intensity interval training and spirulina supplementation on immunoglobin levels, cardio-respiratory fitness, and body composition of overweight and obese women. *MDPI* [Preprint]. Available at: https://doi.org/https://doi.org/10.3390/biolgy11020196.

PEDro (1999). PEDro Scale. *The Physiotherapy Evidence Database* [Preprint]. Available at: https://pedro.org.au/english/resources/pedro-scale/.

Roy, M. *et al.* (2018). High-Intensity Interval Training in the Real World: Outcomes from a 12-Month Intervention in Overweight Adults. *Medicine and Science in Sports and Exercise*, 50(9), pp. 1818–1826. Available at: https://doi.org/10.1249/MSS.0000000000001642.

Saeidi, A. *et al.* (2022). Differential Effects of Exercise Programs on Neuregulin 4, Body Composition and Cardiometabolic Risk Factors in Men With Obesity. *Frontiers in Physiology*, 12(February), pp. 1–9. Available at: https://doi.org/10.3389/fphys.2021.797574.

Tsirigkakis, S. *et al.* (2021). Effects of two workload-matched high-intensity interval training protocols on regional body composition and fat oxidation in obese men. *Nutrients*, 13(4). Available at: https://doi.org/10.3390/nu13041096.

Vaccari, F. *et al.* (2020). Effects of 3-month high-intensity interval training vs. moderate endurance training and 4-month follow-up on fat metabolism, cardiorespiratory function and mitochondrial respiration in obese adults. *European Journal of Applied Physiology*, 120(8), pp. 1787–1803. Available at: https://doi.org/10.1007/s00421-020-04409-2.

WHO (2021). *Obesity and overweight*, *World Health Organization*. Available at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (Accessed: 1 July 2022).

Zeng, J. *et al.* (2021). Effects over 12 weeks of different types and durations of exercise intervention on body composition of young women with obesity. *Science and Sports*, 36(1), pp. 45–52. Available at: https://doi.org/10.1016/j.scispo.2019.10.011.

Zhang, H. *et al.* (2020). Exercise training-induced visceral fat loss in obese women: The role of training intensity and modality. *Scandinavian Journal of Medicine and Science in Sports*, (July), pp. 1–14. Available at: https://doi.org/10.1111/sms.13803.