International Journal of Applied Sports Sciences
2022, Vol. 34, No. 2, 152-159.
https://doi.org/10.24985/ijass.2022.34.2.152
ISSN 2233-7946 (Online)
ISSN 1598-2939 (Print)


# Differences in Cardiovascular Risk Factors and Upper and Lower Limb Muscle Function according to Waist to Hip Ratio Classification in Obese Women

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## Abstract

The purpose of this study was to differences in cardiovascular risk factors and upper and lower limb muscle function according to the WHR classification in women with obese. Eighty-three obese women with over 30% body fat who aged between 20- and 30-years were divided into 3 groups: normal control group (NCG, n=6), obese women with low WHR group (WHR 0.85 or less+ more than 30% body fat, OLW, n=64), obese women with high WHR group (WHR 0.85 or more+ more than 30% body fat, OHW, n=13). We performed measurements to determine cardiovascular risk factors, basic physical fitness, isokinetic knee and trunk muscle functions according to WHR classification.

As the result of this study, the knee flexor peak torque and hamstring to quadriceps torque ratio (H:Q ratio) as well as isokinetic endurance capacity of the right and left knee flexors were significantly higher in the NCG compared to the OLW and OHW. In addition, sergeant jump was significantly higher in the NCG compared to the OLW and OHW. But other basic physical fitness factors and cardiovascular disease risk factors were no significant difference between all groups. Our findings confirmed that WHR risk level may be an important predictor of lower extremity muscle function in obese women.

Key words: obese women, waist to hip ratio, physical fitness, cardiovascular disease risk factor

## Introduction

Obesity has been known to be one of the most important risk factors for inducing myocardial infarction, angina pectoris, and hypertension (Romero-Corral et al., 2006), suggesting that the diagnosis and evaluation of obesity are essential for a healthy life in modern people (Flegal et al., 2016).

Obese is categorized in various measurement index, which include body mass index (BMI), waist circumference (WC), waist-hip ratio (WHR), and body

Submitted : 30 October 2022
Revised : 14 December 2022
Accepted : 14 December 2022
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fat percentage(%BF). In clinical practice, the BMI is the most common method for diagnosing obesity, which was based on a person's weight in kilograms and height in meters. The Korea medical community has classified 18.6 and 22.9 kg/m$^2$ as normal BMI, 23 to 24.9 kg/m$^2$ as overweight, and 25 kg/m$^2$ and more as obese according to the Asia-Pacific criteria. However, as the obesity prediction methods by BMI has limitations in classifying obesity with high body fat mass and overweight with high muscle mass, the importance of classifying obesity using WHR has recently been emphasized (Lee et al., 2008). In a precious study of Janssen et al. (2002) that reported an association between WHR and obesity, an increase in abdominal adiposity had a more direct influence on cardiovascular disease than an increase in fat mass in other body parts. In addition, Schneider et al. (2010) suggested that WC and WHR were more accurate than BMI as predictive indicators of abdominal obesity in a study of 6355 obese subjects.

The world health organization (WHO) has provided guidelines for the optimal criteria for WHR to be 0.85 or less for women and 0.9 or less for men, because the women usually concentrate body fat mass on the hip and men accumulated on the waist. A WHR value of 1.0 or higher can induce cardiovascular and metabolic diseases as well as various complications related to obesity (Elsayed et al., 2008). In the field of exercise physiology studied on relationship between WHR and physical fitness in obese people, Correa-Rodríguez et al. (2018) provided some information that WHR and physical fitness have a high correlation and may be predictors of hypertension, diabetes, and cardiovascular diseases.

Recent studies have reported that obese people with high maximal oxygen uptake ($VO_2$max) have low WC and WHR, and show high physical fitness in push-ups, sit-up and vertical jump (Ekblom-Bak et al., 2009; Ortega et al., 2019; Ross & Katzmarzyk, 2003). But Lockie et al. (2020) highlighted that WC is most important indicator in predicting obesity because the physical fitness of obese people is further closely related to WC compared to WHR. To date, these previous studies reporting on physical fitness and WHR in obese are not clear. Therefore, it is necessary to confirm the relationship between physical fitness and cardiovascular disease based on WHR criteria in obese women. The purpose of this study was to investigate differences in cardiovascular disease risk factors and upper and lower limb muscle function according to the WHR classification in women with obese.

# Methods

## Participants

The participants of this study were 87 adult women who did not have cardiovascular and musculoskeletal diseases and food allergies within the last six months.

***Table 1.*** *The characteristics of subjects*

| Variables | NCG[a] | OLW[b] | OHW[c] | F | p | Post-hoc |
|---|---|---|---|---|---|---|
| Age (year) | 19.67±0.42 | 21.70±0.26 | 20.77±0.60 | 3.390 | .039 | |
| Height (cm) | 164.37±2.02 | 161.24±0.73 | 160.99±1.77 | .818 | .445 | |
| Weight (kg) | 58.18±2.47 | 65.32±1.56 | 72.33±3.88 | 2.965 | .057 | a<c |
| Waist circumference (cm) | 74.55±2.53 | 80.28±0.96 | 89.80±1.80 | 11.552 | .001 | a<c |
| Hip circumference (cm) | 97.68±1.52 | 100.49±0.92 | 102.30±2.19 | .842 | .435 | |
| Body fat mass (kg) | 16.97±0.60 | 24.04±0.96 | 28.84±2.54 | 5.015 | .009 | a<c |
| Percent body fat (%) | 29.23±0.25 | 36.23±0.59 | 39.58±1.63 | 9.564 | .001 | a<b,c |

NCG[a], normal control group; OLW[b], obese women with low WHR group; OHW[c],obese women with low WHR group

Eighty-thirty participants, excluding 4 subjects with health problem, were included in this analysis. And they were randomly classified into normal control group (NCG, n=6), obese women with low WHR group (WHR 0.85 or less+ more than 30% body fat, OLW, n=64), obese women with high WHR group (WHR 0.85 or more+ more than 30% body fat, OHW, n=13). Participant characteristics was explained in Table 1.

## Body Composition

Height and weight were measured in light clothing using height and weight scale (DS-103M, Dong San Jenix, Seoul, Korea), and body composition was analysed by Inbody 770 (Inbody 770, Inbody, Seoul, Korea). Waist circumference was measured midway between the lower rib margin and iliac crest. Hip circumference was measured at widest circumference over the greater trochanters.

## Cardiovascular Disease Risk Factors

Cardiovascular disease risk factors including blood pressure, fasting glucose (FG) and blood lipid were analysed. Fasting glucose was examined by Accu-Chek® Guide (Roche, Mannheim, Germany) and total cholesterol (TC), triglyceride (TG), High-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were measured using by mission cholesterol meter (Mission Cholesterol Meter, Acon Laboratories, Inc. San Diego, CA). Blood pressure was measured using blood pressure device (BPBIO330, InBody, Korea) after taking a rest for 30 min.

## Basic Physical Fitness

Basic physical fitness consisted of grip strength (T.K.K.-5101, TAKEI, Japan), back strength (T.K.K. 5402, TAKEI, Japan), sit-up (T.K.K.-5505, TAKEI, Japan), sit and reach (T.K.K. 5111, Takei, Japan), sergeant jump (DW 771A, SKARO, Korea), and sit-to-stand (Martinez-Hernandez & Dehghani-Sanij, 2019). Physical efficiency index (PEI) was determined by the equations (100 x test duration in seconds) divided by (2 x sum of heart beats in the recovery periods) after the Harvard step test for 5min.

## Isokinetic Knee and Trunk Muscle Function Test

The isokinetic muscle functions of the trunk (load speed 30°/sec) and knee (load speed 60°/sec and 240°/sec) were measured using isokinetic device (Humac Norm 776, CSMI, Boston, USA). The maximum isokinetic trunk strength was measured 3 times at 30°/sec. The isokinetic knee strength and endurance tests on hamstring and quadriceps muscles was repeated 3 times at 60°/sec and 12 times at 240/sec, respectively. The range of the motion (ROM) of the trunk during the tests were set from −10° to 70° and ROM of the knee ranged from 0° to 90°. All isokinetic variables were presented in absolute and relative values.

## Statistics

The mean and standard deviation of all variables were calculated using IBM SPSS Statistics statistical program (Version 24.0; SPSS, Inc., Chicago, IL, USA). To confirm the difference of between groups was performed using one-way analysis of variance followed by Scheffe post hoc test. The significance level was set at $p<0.05$.

# Results

## Differences in Free-Fat Mass (FFM) and BMI among Groups

The WHR, BMI and FFM have been known as an important maker for diagnosing obesity. As shown in Table 2. But FFM ($F=.321$, $p=.726$) was no significant difference among groups. BMI ($F=4.670$, $p=.012$) was significant differences between groups. BMI were significantly higher in the OHW compared to those in the NCG.

## Differences in Cardiovascular Disease Risk Factors among Groups

To examine the relationship between comparison of cardiovascular disease risk factors according to WHR classification, we investigated blood pressure, blood lipids and fasting glucose. As shown in table 3, TC (F=1.119, p=.332), TG (F=1.625, p=.203), HDL-C (F=.259, p=.772), LDL-C (F=1.025, p=.364), FG (F=.665, p=.517) and SBP (F=1.554, p=.218) were no significant difference between group. But DBP (F=6.528, p=.002) showed a significant difference among groups, suggesting that DBP might be increased in obese women with high WHR values compared to the NCG and OLW.

## Differences in Physical Fitness among Groups

As a result of basic physical fitness according to WHR classification, grip (F=.497, p=.610) and back strength (F=.436, p=.648), sit-up (F=.231, p=.794), sit and reach (F=.313, p=.732), PEI (F=.745, p=.478), trunk back extension (F=.422, p=.657) and sit to stand (F=.138, p=.871) were no significant difference among groups. But sergeant jump showed a significant difference among groups (F=.7.282, p=.001), suggesting that obese people, regardless of abdominal adiposity, have lower power capacity than the normal people (Table 4).

***Table 2.*** *Comparative analysis of fat free mass and body mass index according to WHR classification*

| Variables | NCG[a] | OLW[b] | OHW[c] | F | p | Post-hoc |
|---|---|---|---|---|---|---|
| Fat free mass (kg) | 41.22±1.88 | 41.28±0.75 | 42.67±1.40 | .321 | .726 | |
| Body mass index ($kg/m^2$) | 21.52±0.64 | 25.08±0.51 | 27.60±1.32 | 4.670 | .012 | a<c |

NCG[a], normal control group; OLW[b], obese women with low WHR group; OHW[c], obese women with low WHR group

***Table 3.*** *Comparison of cardiovascular factors according to WHR classification*

| Variables | NCG[a] | OLW[b] | OHW[c] | F | p | Post-hoc |
|---|---|---|---|---|---|---|
| Systolic blood pressure (mmHg) | 108.33±2.70 | 114.11±1.19 | 116.00±1.55 | 1.554 | .218 | |
| Diastolic blood pressure (mmHg) | 64.33±2.03 | 71.91±0.84 | 76.00±1.71 | 6.528 | .002 | a<b,c |
| Total cholesterol (mg/dL) | 176.00±14.33 | 198.97±4.62 | 194.15±9.62 | 1.119 | .332 | |
| Triglycerides (mg/dL) | 104.00±14.45 | 160.80±9.73 | 158.69±17.87 | 1.625 | .203 | |
| High-density cholesterol (mg/dL) | 67.67±5.04 | 62.58±1.96 | 60.54±10.14 | .259 | .772 | |
| Low-density cholesterol (mg/dL) | 88.17±12.81 | 103.01±3.77 | 109.54±8.42 | 1.025 | .364 | |
| Fasting blood glucose (mg/dL) | 91.67±2.69 | 94.72±1.14 | 96.69±2.44 | .665 | .517 | |

NCG[a], normal control group; OLW[b], obese women with low WHR group; OHW[c], obese women with low WHR group

***Table 4.** Comparative analysis of physical strength according to WHR classification*

| Variables | NCG[a] | OLW[b] | OHW[c] | F | p | Post-hoc |
|---|---|---|---|---|---|---|
| grip strength (kg) | 26.57±2.00 | 26.41±0.96 | 29.06±3.87 | .497 | .610 | |
| Back strength (kg) | 58.42±7.03 | 60.25±2.53 | 54.19±7.79 | .436 | .648 | |
| Trunk flexion in sitting position test (cm) | 14.25±3.21 | 14.92±1.44 | 12.34±2.05 | .313 | .732 | |
| Trunk back extension test (cm) | 46.80±2.13 | 44.71±1.09 | 43.07±2.22 | .422 | .657 | |
| Sit-up (reps) | 21.67±2.03 | 18.57±1.40 | 19.23±3.01 | .231 | .794 | |
| Physical efficiency index (score) | 48.68±0.85 | 48.86±0.58 | 47.22±1.11 | .745 | .478 | |
| Sergeant jump (cm) | 30.83±0.54 | 24.94±0.49 | 25.38±0.70 | 7.282 | .001 | b,c<a |
| sit-to-stand (reps) | 34.67±5.57 | 34.00±0.87 | 33.00±1.40 | .138 | .871 | |

NCG[a], normal control group; OLW[b], obese women with low WHR group; OHW[c], obese women with low WHR group

***Table 5.** Comparative analysis of isokinetic muscle function according to WHR classification*

| Variables | | | NCG[a] | OLW[b] | OHW[c] | F | p | Post-hoc |
|---|---|---|---|---|---|---|---|---|
| Knee extension/Flexion peak torque (60°/sec) | Right | Extensors (Nm) | 112.83±11.38 | 101.80±3.52 | 110.00±7.18 | .804 | .451 | |
| | | Extensors (%BW) | 166.17±31.53 | 147.80±5.34 | 154.08±8.23 | .540 | .585 | |
| | | Flexors (Nm) | 66.00±8.76 | 49.17±1.96 | 50.23±3.83 | 3.087 | .051 | c<a |
| | | Flexors (%BW) | 96.67±19.46 | 72.63±3.01 | 71.15±4.96 | 2.559 | .084 | |
| | | H:Q Ratio | 58.67±4.87 | 48.42±1.20 | 45.92±1.77 | 3.983 | .022 | b,c<a |
| | Left | Extensors (Nm) | 110.67±9.47 | 101.20±3.60 | 104.92±7.41 | .369 | .693 | |
| | | Extensors (%BW) | 158.67±29.77 | 150.41±5.09 | 146.46±7.32 | .175 | .839 | |
| | | Flexors (Nm) | 63.17±7.46 | 48.13±1.85 | 49.38±3.19 | 2.911 | .060 | |
| | | Flexors (%BW) | 91.17±18.12 | 71.48±2.80 | 70.31±4.17 | 2.006 | .141 | |
| | | H:Q Ratio | 57.17±3.62 | 48.30±1.41 | 47.92±2.10 | 1.969 | .146 | |
| | Deficit | Extensors | 6.33±2.09 | 9.95±1.07 | 14.62±3.10 | 2.191 | .118 | |
| | | Flexors | 11.83±3.09 | 11.42±1.33 | 8.92±2.39 | .344 | .710 | |
| Knee extension/Flexion average power per repetition (240°/sec) | Right | Extensors (Nm) | 110.67±11.24 | 101.09±3.71 | 94.92±8.97 | .579 | .563 | |
| | | Extensors (%BW) | 161.83±30.76 | 163.25±14.28 | 136.23±11.69 | .364 | .696 | |
| | | Flexors (Nm) | 75.50±9.24 | 56.05±2.32 | 55.54±5.39 | 2.958 | .058 | c<a |
| | | Flexors (%BW) | 108.00±21.41 | 82.52±3.64 | 77.38±6.81 | 2.231 | .114 | |
| | Left | Extensors (Nm) | 108.17±12.43 | 99.41±3.70 | 109.77±7.01 | .848 | .432 | |
| | | Extensors (%BW) | 152.33±29.87 | 146.97±5.28 | 153.38±6.94 | .149 | .862 | |
| | | Flexors (Nm) | 77.50±5.26 | 57.38±2.15 | 61.23±3.75 | 4.185 | .019 | b<a |
| | | Flexors (%BW) | 110.17±20.40 | 85.30±3.44 | 84.00±5.83 | 2.147 | .124 | |
| Trunk flexion/Extension peak torque (30°/sec) | | Extensors (Nm) | 97.00±11.05 | 105.47±4.38 | 123.31±13.14 | 1.547 | .219 | |
| | | Extensors (%BW) | 146.17±27.60 | 155.89±6.02 | 171.38±15.13 | .672 | .513 | |
| | | Flexors (Nm) | 194.00±23.88 | 175.66±6.61 | 179.85±15.81 | .331 | .719 | |
| | | Flexors (%BW) | 281.67±56.51 | 255.97±9.57 | 251.54±18.76 | .316 | .730 | |
| | | H:Q Ratio | 51.50±6.07 | 63.56±3.10 | 73.62±10.51 | 1.505 | .228 | |

NCG[a], normal control group; OLW[b], obese women with low WHR group; OHW[c], obese women with low WHR group; H:Q ratio, hamstring and quadriceps ratio; BW, body weight.

### Differences in Isokinetic Knee and Trunk Muscular Functions among Groups

We performed isokinetic knee flexion and extension test at 60° and 240°/sec, and isokinetic trunk flexion and extension test were measured at the 30°/sec for identifying maximum strength, endurance, and dynamic balance in obese women according to WHR classification. As shown in table 5. Absolute peak flexor torque (F=3.087, p=.051) and hamstring and quadriceps (H:Q) ratio in the right knee (F=3.983, p=.022) were significant difference among groups. In the result of post- hoc, absolute flexion peak torque for the right knee was higher in the NCG than those in the OHW, and H:Q ratio for the right was significantly lower the OLW and OHW compared to the NCG. However, there was no significant difference in other variables in isokinetic knee test at the 60°/sec. At 240°/sec, absolute peak flexor torque of the right and left knee (F=3.087, p=.051) were significant difference among groups. In the result of post-hoc, absolute flexion peak torque for the right knee was significantly higher the NCG compared to those in the OHW. But flexion peak torque for the left knee was higher the NCG compared to those in the OLW. There was no significant difference in other variables in isokinetic trunk test at the 30°/sec.

## Discussion

For decades, percent body fat and BMI has been widely used as an important marker of obesity in daily life and the medical community. But recently WHR or WHtR are found to be a clear indicator for diagnosing obesity (Pischon et al., 2008). In this study, we confirmed differences in body composition according to WHR classification in women with obesity and found that BMI value was significantly higher in the OHW compared to the NCG, but the free fat mass did not show a significant difference between all groups. In previous study of Jahanlou & Kouzekanani (2017) reporting the correlation between BMI and WHR in obese people, although WHR could influence BMI value, there was no interaction effect with FFM. These previous studies support our findings suggesting that WHR is a more important indicator than BMI for predicting obesity. However, we think that relationship between FFM and WHR needs to be systematically studied with more participants.

Obesity contributes directly not only to the pathogenesis of cardiovascular disease risk factors such as visceral adipose tissue, dyslipidaemia, diabetes and hypertension (Van Gaal et al., 2006) but also changes in metabolic syndrome risk factors including TC, TG, HDL-C, LDL-C and FG (Quijada et al., 2008). It has been well known that obese people with high WHR and WC values can be easily exposed to cardiovascular disease or metabolic syndrome (Gill et al., 2020). But, unlike previous studies, there was no statistically significant difference in cardiovascular disease risk factors in the present study. Considering these findings, the present study is inconsistent with previous study emphasized that obese people with high WHR value could be more likely to develop cardiovascular disease rather than obese people without abdominal adiposity (Hu et al., 2004). These contradictory findings in the present study are thought to be due to insufficient participants.

In addition, we confirmed that diastolic blood pressure was significantly upregulated in the OLW and OHW compared to the NCG. But this change in blood pressure is difficult to interpret because it is a difference within the normal range as well as we believe that this is because the subjects in the present study were healthy young women without any metabolic diseases.

Regular exercise is the most effective therapeutic method for preventing obesity and cardiovascular disease (Tian & Meng, 2019), and building up to vigorous level of physical fitness through exercise can bring about decrease of the WHR risk level in obese people (Söderlund et al., 2009). Taken together, these previous studies on exercise and obesity suggest that there may be a high correlation between physical fitness level and WHR in obese people. We investigated basic physical fitness and isokinetic knee and trunk muscle functions according WHR classification in obese women. As a result, we found that the lower extremity muscle function was significantly decreased in the OHW and OLW compared to the NCG. But maximal strength, flexibility, cardiorespiratory endurance, and trunk muscle function were no significant difference among groups. Lockie et al. (2020) reported that obese people with high-risk WHR cut-off value (0.85 or higher for women, 0.9 or higher for men) performed less muscular endurance, agility, and power capacity compared with obese people with low-risk WHR cut-off value (Masitoh et al., 2022). Also, Chen et al. (2020) reported that WHR might be better than BMI in measuring obesity-related decreased physical fitness. These results are consistent with the present results that high WHR values might decrease physical fitness in obese people.

Given these results reported in this study, if obese young women strive to maintain low WHR values, they may have improved health benefits over obese women with high WHR values through preventing decreases in physical fitness and lower extremity muscle functions.

## References

Chen, P. H., Chen, W., Wang, C. W., Yang, H. F., Huang, W. T., Huang, H. C., & Chou, C. Y. (2020). Association of physical fitness performance tests and anthropometric indices in Taiwanese adults. *Frontiers in Physiology*, **11**, 583692.

Correa-Rodríguez, M., Ramírez-Vélez, R., Correa-Bautista, J. E., Castellanos-Vega, R. D. P., Arias-Coronel, F., González-Ruíz, K., ... & González-Jiménez, E. (2018). Association of muscular fitness and body fatness with cardiometabolic risk factors: The FUPRECOL study. *Nutrients*, **10(11)**, 1742.

Ekblom-Bak, E., Hellenius, M. L., Ekblom, Ö., Engström, L. M., & Ekblom, B. (2009). Fitness and abdominal obesity are independently associated with cardiovascular risk. *Journal of Internal Medicine*, **266(6)**, 547-557.

Elsayed, E. F., Tighiouart, H., Weiner, D. E., Griffith, J., Salem, D., Levey, A. S., & Sarnak, M. J. (2008). Waist-to-hip ratio and body mass index as risk factors for cardiovascular events in CKD. *American Journal of Kidney Diseases*, **52(1)**, 49-57.

Flegal, K. M., Kruszon-Moran, D., Carroll, M. D., Fryar, C. D., & Ogden, C. L. (2016). Trends in obesity among adults in the United States, 2005 to 2014. *Jama*, **315(21)**, 2284-2291.

Gill, S., Sumrell, R. M., Sima, A., Cifu, D. X., & Gorgey, A. S. (2020). Waist circumference cutoff identifying risks of obesity, metabolic syndrome, and cardiovascular disease in men with spinal cord injury. *PLoS One*, **15(7)**, e0236752.

Hu, G., Tuomilehto, J., Silventoinen, K., Barengo, N., & Jousilahti, P. (2004). Joint effects of physical activity, body mass index, waist circumference and waist-to-hip ratio with the risk of cardiovascular disease among middle-aged Finnish men and women. *European Heart Journal*, **25(24)**, 2212-2219.

Jahanlou, A. S., & Kouzekanani, K. (2017). The interaction effect of body mass index and age on fat-free mass, waist-to-hip ratio, and soft lean mass. *Journal of Research in Medical Sciences: the Official Journal of Isfahan University of Medical Sciences*, **22**.

Janssen, I., Heymsfield, S. B., Allison, D. B., Kotler, D. P., & Ross, R. (2002). Body mass index and waist circumference independently contribute to the prediction of nonabdominal, abdominal subcutaneous, and visceral fat. *The American Journal of Clinical Nutrition*, **75(4)**, 683-688.

Lee, C. M. Y., Huxley, R. R., Wildman, R. P., & Woodward, M. (2008). Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: A meta-analysis. *Journal of Clinical Epidemiology*, **61(7)**, 646-653.

Lockie, R. G., Ruvalcaba, T. R., Stierli, M., Dulla, J. M., Dawes, J. J., & Orr, R. M. (2020). Waist circumference and waist-to-hip ratio in law enforcement agency recruits: Relationship to performance in physical fitness tests. *The Journal of Strength & Conditioning Research*, **34(6)**, 1666-1675.

Martinez-Hernandez, U., & Dehghani-Sanij, A. A. (2019). Probabilistic identification of sit-to-stand and stand-to-sit with a wearable sensor. *Pattern Recognition Letters*, **118**, 32-41.

Masitoh, N. A. D., Susanto, H., Kumaidah, E., & Supatmo, Y. (2022). The relationship between waist-hip ratio and 60-meter running speed studies on students of the faculty of medicine, Diponegoro University. *Journal Kedokteran Diponegoro (Diponegoro Medical Journal)*, **11(3)**, 181-185.

Ortega, R., Grandes, G., Sanchez, A., Montoya, I., & Torcal, J. (2019). Cardiorespiratory fitness and development of abdominal obesity. *Preventive Medicine*, **118**, 232-237.

Pischon, T., Boeing, H., Hoffmann, K., Bergmann, M., Schulze, M. B., Overvad, K., ... & Riboli, E. (2008). General and abdominal adiposity and risk of death in Europe. *New England Journal of Medicine*, **359(20)**, 2105-2120.

Quijada, Z., Paoli, M., Zerpa, Y., Camacho, N., Cichetti, R., Villarroel, V., ... & Lanes, R. (2008). The triglyceride/HDL-cholesterol ratio as a marker of cardiovascular risk in obese children; association with traditional and emergent risk factors. *Pediatric Diabetes*, **9(5)**, 464-471.

Romero-Corral, A., Montori, V. M., Somers, V. K., Korinek, J., Thomas, R. J., Allison, T. G., ... & Lopez-Jimenez, F. (2006). Association of bodyweight with total mortality and with cardiovascular events in coronary artery disease: A systematic review of cohort studies. *The Lancet*, **368(9536)**, 666-678.

Ross, R., & Katzmarzyk, P. T. (2003). Cardiorespiratory fitness is associated with diminished total and abdominal obesity independent of body mass index. *International Journal of Obesity,* **27(2)**, 204-210.

Schneider, H. J., Friedrich, N., Klotsche, J., Pieper, L., Nauck, M., John, U., ... & Wittchen, H. U. (2010). The predictive value of different measures of obesity for incident cardiovascular events and mortality. *The Journal of Clinical Endocrinology & Metabolism*, **95(4)**, 1777-1785.

Söderlund, A., Fischer, A., & Johansson, T. (2009). Physical activity, diet and behaviour modification in the treatment of overweight and obese adults: A systematic review. *Perspectives in Public Health*, **129(3),** 132-142.

Tian, D., & Meng, J. (2019). Exercise for prevention and relief of cardiovascular disease: prognoses, mechanisms, and approaches. *Oxidative Medicine and Cellular Longevity*, **2019**.

Van Gaal, L. F., Mertens, I. L., & De Block, C. E. (2006). Mechanisms linking obesity with cardiovascular disease. *Nature*, **444(7121),** 875-880.