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Original Article

Effects of sub-maximal exercise on energy expenditure and heart rate recovery in individuals with normal weight, overweight and obesity

MARIA JUSTINE[1], AZIZAH ISHAK[2], HAIDZIR MANAF[1]
[1]Centre for Physiotherapy, Faculty of Health Sciences, Universiti Teknologi MARA Selangor, Puncak Alam, 42300 Bandar Puncak Alam, Selangor MALAYSIA.
[2]Physiotherapy Services, Kluang Utama Specialist Hospital, No 1, Susur 1, Jalan Besar, 86000 Kluang Johor MALAYSIA

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Abstract:
Background: Previous studies have shown that obesity increases the risk of chronic diseases and those with a higher BMI may present with impaired heart rate recovery and reduced exercise capacity. Purpose: This study determined the acute effects of sub-maximal exercise on energy expenditure (EE) and heart rate recovery (HRR), and the association between functional strength and EE. Methods: This is a cross-sectional observational study. Ninety-two participants were categorized according to their BMI, namely; obese (n=31), overweight (n=30), and normal (n=31). Measurements included anthropometric data, hand grip strength, lower limb strength, gastrocnemius-soleus strength, heart rate, and EE. Participants were asked to exercise on a treadmill for 20-min at sub-maximal intensity based on the Karvonen formula. Immediately after the exercise ended, the HRR rate was recorded at 0-min, 5-min, 10-min, 20-min and 30-min, while EE was calculated at the end of the exercise. Results: There is no significant difference in the HRR among normal, overweight and obese groups (p>0.05), whereby all groups showed similar decreases in the HRR after completing the exercise. The EE at 0-min post exercises showed significant differences between normal weight and overweight adults (p=0.009) as well as normal weight and obese adult (p=0.000). There was a significant correlation between EE and hand grip strength (p=0.000) and gastrocnemius-soleus (p=0.000), but not with the hamstring and quadriceps muscle strength (p>0.05). *Conclusion*: Obese individuals presented with the highest EE during a sub-maximal exercise. The EE was associated with hand grip and gastrocnemius-soleus strength.
Key Words: Body mass index, energy expenditure, heart rate, sub-maximal intensity.

Introduction

The global population who are obese and overweight is growing tremendously. In the South Asian region, the rate of obesity has tripled over the past 20 years as the region became more urbanized with adoption of a higher caloric intake combined with a sedentary lifestyle (Popkin, Adair & Ng, 2012). Based on the report from the World Health Organization (WHO), as in 2014, more than 1.9 billion of adults, aged 18 years and older were overweight, while 600 million of these were obese (WHO, 2016). In Malaysia, the prevalence of obesity has also reached epidemic levels. According to the Malaysian National Health and Morbidity Survey (NMHS), from 1996 to 2006, the number of people with obesity has increased from 4.4% to 14%.[3] Similarly, those overweight showed an increase, from 29.1% in 2006 to 29.4% in 2011 (Ghee, 2016).

It is universally known that obesity increases the risks of developing various chronic diseases (Sairenchi, Iso, Yamagishi & Irie, 2017). Additionally, a very high degree of obesity (BMI ≥ 35 kg/m^2) is associated with increased hospitalization, mortality and morbidity due to cardiovascular diseases (Wang, 2015), as well as musculoskeletal disorders (Weitoft, Eliasson & Rosen, 2008). However, the relationship between more modest degrees of overweight and mortality remained unclear (Malnick & Nober, 2006). Furthermore, individuals with a higher BMI are often associated with reduced exercise capacity that may limit them from performing habitual physical activity (Cristina et al., 2015.

A previous study reported that exercise promotes overall well being, physical fitness, exercise tolerance and suppress appetite, which can cause a reduction in daily caloric intake, thus enabling the process of weight loss Hunter, Fisher, Bryan & Zuckerman, 2013). Aerobic exercises and resistance training were the most popular exercises among obese individuals, in which exercise creates a caloric deficit via increased in energy expenditure (EE) (Wiklund, 2016). Apart from fat loss, the moderate intensity of aerobic exercise showed greater improvement in overall cardiovascular fitness compared to the high intensity exercise Fisher et al., 2015). The sub-maximal exercise is a type of aerobic training using moderate intensity at regular intervals, which is 65% to 85% of the maximum heart rate, that is well tolerated and ideal for assessing cardiovascular fitness in individuals

Corresponding Author: MARIA JUSTINE, E-mail: maria205@salam.uitm.edu.my

with obesity (Eng, Dawson & Chu, 2008). The bicycle ergometer, and Bruce treadmill are the most common sub-maximal exercise tests cited in the literature (Ratter, Radlinger & Lucas, 2014).

Previous studies on the effects of sub-maximal exercises on population with obesity showed debatable findings. Hunter et al. (2013) revealed that sub-maximal level of aerobic exercise results in the lowering and maintenance of sub-maximal heart rate. In contrast, Bunn et al.(2017) argued that there is no significant correlation between cardiovascular fitness and body composition with heart rate recovery after sub-maximal exercise. Nevertheless, Bunn et al. (2017) recruited participants with an average level of fitness, furthermore the participants failed to report the intensity of their regular exercise, whereby the intensity of exercise is an indicator of heart rate rather than frequency and mode of exercise (2017). Despite these interesting findings, there is a lack of study that determines the effects of sub-maximal intensity of aerobic exercise on hear rate recovery (HRR) and EE in different BMI groups. Furthermore, there is no study that assesses recovery period as well as overall physiological responses and recovery following sub-maximal exercise for 0 minute to 30 minutes of post exercise. Therefore, the purpose of this study was to determine the acute effects of sub-maximal exercise on EE and HRR, and to determine the association between functional performance (upper and lower limbs strength) and EE. The findings of this study may provide fundamental understanding of the effect of sub-maximal exercise on the HRR and EE, which may guide strategies for weight management programs.

Material & methods

Design and participants

This is a cross-sectional observational study involving 92 subjects, ranging from 19 to 25 years of age, from a publicly funded higher learning institution. To be selected in this study, participants must be between 18 to 25 years old, do not have any previous injuries related to physical health, and not on a any high level of physical competition. They were excluded if they are smokers and on a regular exercise at moderate intensity of more than 150 minutes a week. Ethical approval was obtained from the Research Ethics Committee of the Faculty of Health Sciences, UiTM (Ref. No: REC/109/15) and all procedures conformed to the directive of the Helsinki Declaration. Before admission to this study, all participants were briefed with the study purposes, procedures and signed informed consents, as a proof of agreement to participate in the study.

Outcome Measures

Anthropometric measurement

The anthropometric measurements which include body weight (kg), height (kg), and body mass index (kg/m^2) were taken before the start of the exercise based on standard protocols.

Energy expenditure (EE)

The American College of Sports Medicine (ACSM, 2015) metabolic equations were used to calculate the energy expenditure (EE) at baseline and at the end of the exercise session.

Heart rate recovery (HRR)

The Polar Heart Rate monitor (Polar FT4, Polar Electro Oy, Finland) was used to monitor the heart rate (HR) during the exercise session, in beats per minutes (bpm). The HR was monitored continuously to maintain 65% to 85% of maximum HR during the exercise. The testing procedures for the HR monitoring were as follows: firstly, the participants were asked to stand on the treadmill, preparing for running on it (Sconfelder, Hinterseher, Peter & Spitzenpfeil, 2011). Secondly, the participants were asked to wear the transmitter attached to the strap. The strap was tied around the chest, just below the nipples and the hook was attached to the other end of the strap. Then, the strap length was adjusted to fit snugly and comfortably. After that, the participants were asked to wear the polar heart rate monitor watch on the wrist. The researcher started the HR measurement by pressing the 'OK' button. The HR was monitored before the exercise started, and the heart rate recovery (HRR) at 0-min, 5-min, 10-min, 20-min and 30-min intervals after completing the exercise.

Functional Strength

In this study, functional strength refers to the strength of the hand grip, quadriceps, hamstring and gastrocnemius-soleus muscles.

Hand grip strength: The hand grip strength was measured using the hand dynamometer (Jamar, Sammons Preston Incorporation, Illinois). The hand grip strength test is useful in the context of multi-morbidity, as it is a simple tool to be used and may benefit from closer clinical attention (Leong & Teo, 2015). The testing procedures of hand grip strength were as follows; firstly, participants were positioned in a sitting position, arms to their side, not touching the body and while keeping the elbow bent at 90° (Fernandes et al., 2014). Next, participants were asked to squeeze the dynamometer as strong as possible, being mindful to squeeze only once for each measurement. Three trials were done with a pause of about 10-20 seconds between each trial to avoid the effect of fatigue. The mean average of the three trials was calculated and recorded.

Quadriceps and hamstring muscles strength: The 1-RM (repetition maximum) principle, which is the maximal amount of weight that can be lifted in one repetition was used to determine the strength of both quadriceps and hamstring muscles. This is performed using a machine with an adjustable weight stacks for resistance or with the use of free weights.

The quadriceps strength was measured in a seated leg curl. Firstly, participants sat on the machine (body and head leaning against the padded support) with legs positioned at 90° (Nunn & Mayhew, 1988). Second, the researcher selected the appropriate weight for the participants. The ankle pad was adjusted to a comfortable position and the knee pad was lowered and locked between the participants' knees. The participants were allowed to grasp both handles at the side for support. Next, participants extended their leg using 1-RM principle (determination of the heaviest successful lift) and pause for 4-sec with full contraction then slowly returned to starting position.

Next, to test the hamstring muscle: firstly, participants were instructed to sit on the machine with their back and head against the padded support, and knees positioned at 90° (Sepic, Murray, Mollinger, Spurr & Gardner, 1986). Secondly, the researcher selected the appropriate weight for the participants. The ankle pad was adjusted to a comfortable position and the knee pad lowered and locked between the participants' knees. The participants were allowed to grasp both handles at the side for support. Participants were required to curl their leg towards flexion and pause at 4 seconds with full contraction, and then slowly return to starting position. Next, the participants extended the leg using 1 RM (repetition maximum) principle.

Gastrocnemius-soleus muscles strength: The strength of gastrocnemius-soleus (plantar flexors) was measured using the heel-raise test on the non-dominant leg (Kasahara, Ebata & Takahashi). The participants were instructed to stand straight on the non-dominant limb while flexing the dominant-limb at 90°.

Then, the participants put both palms on the researcher's hands only for balance and they must not push down the researcher's hands while doing the test. Participants were asked to rise and lower down on the balls of their feet in rhythmic motion with the metronome, which was set at a rate of one heel-raise every two seconds. The test was stopped if the participants pushed down on the researcher's hands, or if they leaned or their knee of the non-dominant limb flexed, or the range of motion of the plantar-flexion reduced by more than 50% of the starting range of motion, or the participants quit or asked to stop. One researcher provided the palm-touch support and another researcher controlled the metronome as well as observing the participants laterally for any trunk lean or knee flexion throughout the test.

Sub-maximal exercise testing

Prior to the exercise testing, all participants performed warming-up (slow, static jogging, fast static jogging, dynamic jogging, jumping jacks, and stretching exercises) for 10-min. The modified Bruce Protocol on a treadmill (Kettler Track Performance Treadmill, Kettler, United Kingdom) was used to expose participants to the sub-maximal exercise (Kotte, De Groot, Bongers, Winkler & Takken, 2015). The exercise was initially set for 20 minutes at a sub-maximal intensity of 65% of maximum heart rate (MHR) and increased to 85% of MHR. To determine the intensity, the MHR for each participant were set using the Karvonen method (220-Age) (Powers & Howley, 2011). As the sub-maximal intensity of aerobic training is 65% to 85% of MHR, the value of target heart rate (THR) was obtained. Once the target intensity was reached, the time was started by a stopwatch and participants needed to maintain the heart rate within the THR for 20 minutes.

The THR was controlled by using a polar heart rate monitor at the participants' wrist and the rating of perceived exercise (RPE) Borg scale. During the exercise, participants were not permitted to use the handrails except for touching it with one or two fingers to maintain body position. If the participants exhibited any symptoms or wished to stop, exercise was immediately discontinued (Kotte et al., 2015). After completing the exercise, the following were measured: EE at 0 minute and HRR at 0-min, 5-min, 10-min, 20-min, and 30-min.

Data Analysis

The IBM SPSS statistical software version 22.0 was used for data analysis. Tables were used to display relevant statistics such as mean, standard deviations and ranges. Power analysis was conducted using the G-Power 3software© (Faul, erdfelder, Lang & Buchner, 2007), where power was set at 0.95 and □ at 0.05 using Repeated measures ANOVA: (within factors). Therefore, the total sample size of 90 participants was sufficient to provide a moderate effect for the ANOVA analysis.

The mean difference for measuring variables were statistically tested using an analysis of variance (ANOVA) for group comparison and repeated measures ANOVA for effects within the groups. Graphs were plotted to show the trend of recovery in all related variables. A correlation analysis was conducted to determine whether the selected variables influenced the recovery of the dependent variables. All statistical tests were tested at $p < 0.05$.

Results

Demographic data

The characteristics of participants are shown in **Table 1.** The results based on mean comparisons showed that BMI and the gastrocnemius-soleus strength were significantly different among the groups.

Table 1. Characteristics of participants.

Characteristics	Normal (n=31) Mean ± SD (range)	Overweight (n=30) Mean ± SD (range)	Obese (n=31) Mean ± SD (range)	F-test (*p*-value)
Age (year)	21.32 ±2.02 (19 - 25)	20.93±1.46 (19 - 24)	20.42±1.41 (19 - 24)	2.319 (0.104) NS
BMI (kg/m^2)	21.56±1.57 (19.5 - 24.44)	27.44±1.58 (25 - 29.96)	34.41±3.10 (30.16 - 42.32)	**262.912 (0.000)***
Grip strength (kg)				
Right	29.98±8.48 (17.67-48.67)	32.17±8.56 (18.6 - 59.33)	32.27±9.28 (17.33-54.00)	0.670 (0.514)
Left	27.31±7.81 (14.67-43.67)	30.07±9.39 (4.00 - 57.33)	28.99±8.82 (17.00-49.33)	0.784 (0.460)
Quadriceps strength (kg)				
Right	6.82±2.02 (1.0 - 11.0)	6.18±2.52 (2 - 13)	6.65±1.82 (3 - 11)	0.724 (0.488)
Left	6.45±1.92 (0.5 - 10.0)	5.70±2.54 (2 - 13)	6.36±1.70 (3 - 10)	1.174 (0.314)
Hamstring strength (kg)				
Right	5.87±1.55 (0.5 - 9.75)	5.45±2.00 (2 - 9)	6.15±1.61 (2.0 - 8.5)	1.249 (0.292)
Left	5.72±1.51 (0.5 - 8.8)	5.60±1.95 (1.5 - 10.5)	6.08±1.50 (3 - 8)	0.695 (0.502)
Gastrocnemius-soleus strength (sec)	17.58±7.02 (7 - 30)	13.47±6.65 (3 - 26)	10.48±5.44 (3 - 25)	**9.600 (0.000)***

Note: $p > 0.05$ = not significant, * = significant at $p < 0.05$

The effects of sub-maximal exercise on HRR and EE

The results for HRR show that that there were no significant differences in the baseline measurements between obese, overweight and normal weight subjects (p>0.05). Similar to baseline, at 0-min, 5-min, 10-min and 20-min of post exercises, the HRR between the obese, overweight and normal weight participants showed no significant differences (p>0.05). As demonstrated in **Figure 1**, the trend of HRR from the baseline to 0-min, 5-min, 10-min, 20-min and 30-min after exercise between obese, overweight and normal weight participants were relatively similar.

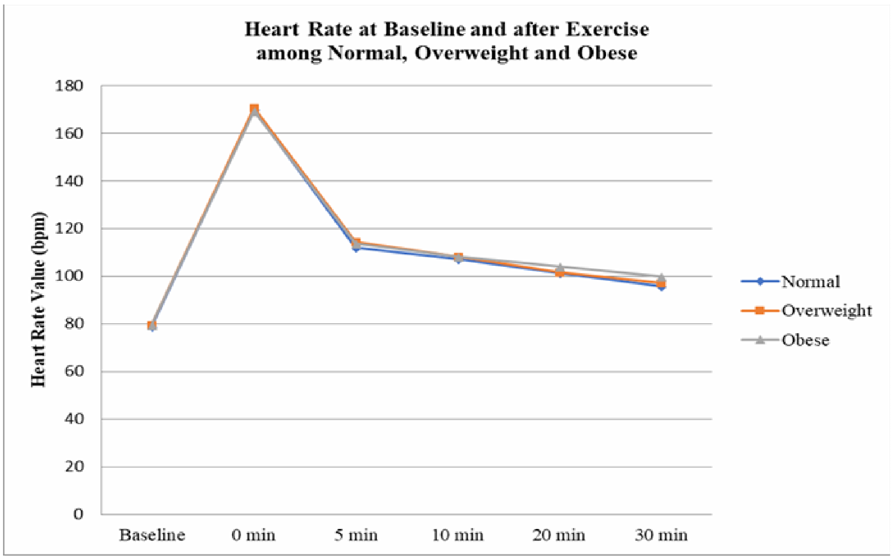

Figure 1. Trend changes on HRR from baseline to 0-min, 5-min, 10-min, 20- min and 30-min following sub-maximal exercise.

The results as demonstrated in **Table 2** indicate that the EE at 0-min post sub-maximal aerobic exercises showed significant differences between normal weight and overweight participants (p=0.009) as well as normal weight and obese participants (p=0.000). However, the results of EE between overweight and obese participants were not significantly different (p=0.122). **Figure 2** indicates that EE increased tremendously, in which the obese participants presented with the highest EE, followed by the overweight and normal participants.

Table 2. Energy expenditure between groups at 0-min.

Time (min)	Normal (n=31) Mean±SD (range)	Overweight n=30) Mean±SD (range)	Obese (n=31) Mean±SD (range)	ANOVA *p* value	Post Hoc *p* value
0 min	6.02±1.77 (0.2 - 9.8)	7.53±1.37 (5.4 - 10.97)	8.52±2.49 (2.07 - 14.55)	0.000**	AB=0.009** AC=0.000** BC=0.122

Comparisons were tested using ANOVA. ** The mean difference was significant at the level of $p < 0.01$

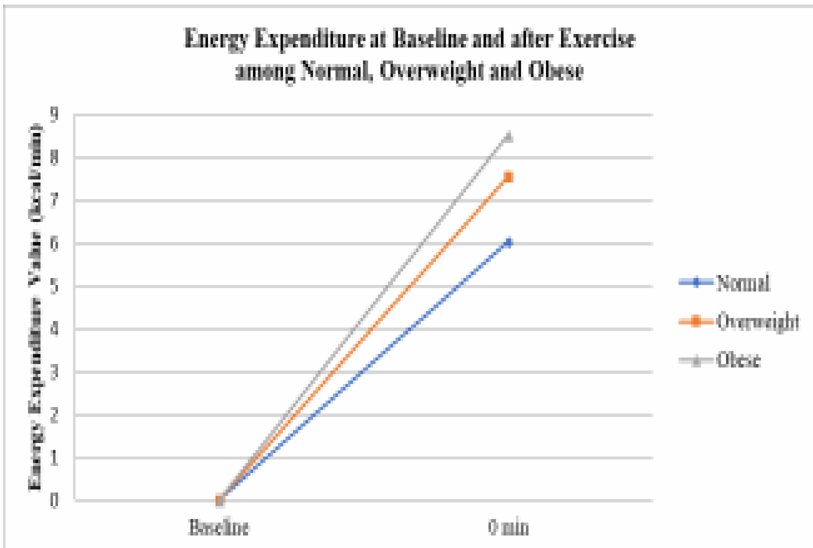

Figure 2. Trend changes of energy expenditure from baseline to 0-min.

The association between functional strength and EE

The results as presented in **Table 3** show that there is a significant correlation between EE and hand grip strength (both right and left) (p=0.000). Besides, there was a significant correlation between gastrocnemius-soleus strength with EE (p=0.000). However, the quadriceps and hamstring muscle strength showed insignificant correlation with EE for both right and left sides (p>0.000).

Table 3. Correlation between functional strength and energy expenditure (EE).

Functional strength (N=92)	EE *r* (*p*-value)
Right hand grip	**0.625** (0.000)**
Left hand grip	**0.606** (0.000)**
Right quadriceps	0.198 (0.590)
Left quadriceps	0.154 (0.143)
Right hamstring	0.116 (0.270)
Left hamstring	0.136 (0.197)
Gastrocnemius-soleus	**-0.357** (0.000)**

The correlation was conducted using Pearson's Correlation Coefficient. **Correlation is significant at the level of 0.01 (2-tailed). Note: Rt=right, Lt=Left

Discussion

The effects of sub-maximal exercise on HRR and EE

This study aimed to determine the acute effects of sub-maximal exercise on energy expenditure (EE) and heart rate recovery (HRR) as well as to determine the association between functional strength and EE. Our study presents a few interesting findings which may be added to the body of knowledge of research on overweight and obesity. The results of our study demonstrated that there was no significant difference in the HRR among normal, overweight and obese group at baseline, 0-min, 5-min, 10-min, 20-min and 30-min of post-exercise. The results of the current study are consistent with Dimkpa and Ouji (2010) that discovered the HRR after exercise is independently associated with BMI. The obese group showed almost similar recovery times with normal and overweight adults. The unexpected findings of our study might be explained in this way. Firstly, the study participants were recruited from a higher learning institution, comprising of healthy individuals, which possibly reduced the likelihood of poor performance in the sub-maximal level of exercises. The participants in this study were sedentary and physically inactive or not exercising more than 150 minutes a week at a moderate intensity. This explained the reason why the heart rate did not return to baseline heart rate in all three groups, even after 30-min completing the exercise. Secondly, although obesity affects the response to sympathetic system to exercise due to morphological and functional variations, the epinephrine and norepinephrine levels of individuals with obesity may be similar to individuals with normal BMI (Weber, Neutel & Smith, 2001), making similar HRR between groups. Gondoni et al. (2009) found no significant difference between trained and untrained participants with obesity in the heart rate behaviour. Additionally, Hattiwale (2012) highlighted that the physically active individuals showed faster HRR compared to sedentary individuals. Amann and Calbet (2008) also revealed that athlete showed faster HRR to baseline due to a more rapid oxygen delivery from active muscle that may lead to less peripheral muscle fatigue and improved exercise performance. Therefore, the insignificant different of HRR between individuals with normal weight, overweight and obesity may be due to the similar fitness levels regardless of differences in BMI.

The current study also found that EE were the highest in the group with obesity, followed by the overweight and normal weight participants. These findings are consistent with a previous study that revealed individuals with obesity expended highest energy after the completion of exercise (Zhang et al., 2017). Prentice et al. (1986) agreed that EE was significantly higher in the group with obesity than lean participants. Delany et al., (2013) also supported that EE decreases when the body weight is reduced, indicating that the EE is directly associated with the body weight. The high EE in the group with obesity may indicate that there was an increase in the energy cost of basal metabolism despite the fact that all participants in the three groups performed the same sub-maximal intensity exercise (treadmill). Siervo et al. (2015) highlighted that the body composition of individuals with obesity (fat mass and fat free mass) contributes to a large proportion of the increase in EE, which may be linked to the metabolically active cellular mass, higher dietary induced thermogenesis and energy cost of physical activity. The modifications of the efficiency of metabolic, endocrine and autonomic pathways may also contribute to high energy expended in the group with obesity (Muller & Bosy-Westphal, 2013). Hence, it is clear that high EE in the group with obesity were based on their body weight and fat mass.

The association between physical fitness and EE

The most important finding in this study was hand grip strength showed significant correlation with EE. The possible explanation of this finding is due to the fact that the group with obesity presented with highest EE followed by the overweight and normal group. However, Lad et al. (2013) argued the increase in body fat percentage might reduce the hand grip endurance, but not the hand grip strength in different types of BMI groups. To summarize, it can be said that the strong correlations of hand grip strength with EE in this study could be due influence by the BMI.

Surprisingly, the quadriceps and hamstring strength showed no correlation with EE. The unexpected findings could be due to the short duration of exercise, which was only 20 minutes, may be insufficient to utilise the large muscle group during running. In addition, due to a sedentary behaviour and inactive lifestyle in the group with obesity, treadmill running may cause them to have more difficulties in breathing during maintaining the sub-maximal intensity of running (Kress, Pohlman, Alverdy & Hall, 2000). Mehta et al. (2016) agreed that the fatigability of individuals with obesity was caused by less muscle oxygenation to the muscles at the low force contraction level. Garcia-Vicencio et al. (2015) supported that the high EE in people with obesity may lead them to experience fatigue much faster than those who were overweight and normal weight. Besides, in this study, the stride rate of the participants was not held constant during performing the exercise. Glave et al. (2015) pointed out that the variation of number of strides between participants is an important factor that determines the correlation between knee muscle strength and EE. In the future, the stride rate should be kept constant between participants, to determine whether knee muscle strength showed significant correlation with EE when sub-maximal intensity exercise (treadmill) was done after 20 minutes.

It is noteworthy to mention that gastrocnemius-soleus muscle strength showed significant correlation with EE. In this study, the group with obesity had lower gastrocnemius-soleus strength compared to the overweight and normal-weight participants. Besides, participants with obesity also demonstrated higher energy expenditure after 20 minutes of a sub-maximal intensity of treadmill running rather than overweight and normal-weight participants. The possible explanation could be because the group with obesity, the mechanical loading during running is high (Henriksen et al., 2012), resulting in increased in energy expended to complete the task. Hickner et al. (2001) also supported that there was a direct relationship between body composition and strength decline in 48 hours after downhill running in which, individuals with the highest percentage of body fat exhibited the greatest loss. The authors also suggested that the increased fat mass/fat free mass is the major contributor to increases in muscle damage as the result of this activity.

We noted one major limitation in this study. This study used the sub-maximal intensity of aerobic exercise for 20 minutes only, in which the duration of aerobic exercise might be insufficient to assess the cardiovascular response among the three groups who are at younger age and no history of any chronic diseases, thus giving insignificant findings. In the future, similar study should be conducted, probably with a longer duration at sub-maximal intensity in order to determine the accurate of recovery times in each BMI group.

In conclusion, subjects with different BMI values presented with similar HRR following a sub-maximal exercise, however, the obesity group showed the highest EE. In addition, EE was associated with hand grip and gastrocnemius-soleus muscles strength. This finding may aid in designing exercise prescription for maintaining fitness level in individuals with excess body weight.

Conflicts of Interest

There is no conflicts of interest.

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