Original Article

Acute effects of submaximal exercise on respiratory rate and work output among physically inactive young adults

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ABSTRACT

Purpose: This experimental study aimed to determine the effects of exercise at submaximal intensity on respiratory rate (RR) and work output (WO) in physically inactive young adults. Method: A total of 90 participants (Mean age = 20.89 ± 1.68 years) was assigned into three groups (15 males and 15 females in each group) according to their body mass index (BMI = kg/m^2) (Normal weight, NW = 18.5-24.9, Overweight, OW = 25.0-29.9, Obese, OB = ≥ 30.0, n = 30 each). Participants were instructed to walk or run on a treadmill, with a fixed inclination (8%) but the speed was progressed according to the modified Bruce Treadmill Protocol to reach a submaximal intensity which was determined based on the Karvonen Formula (65-85% maximal heart rate) for 20-min. RR was measured at baseline, and after completing the exercise at 0-, 5-, 10-, 20-, and 30-min. WO was measured immediately after the exercise (0-min). Results: There was a significant difference in RR among the groups ($p < 0.05$) with NW showed the lowest while OB showed the highest at all measured times. WO was significantly different among the groups ($p < 0.05$), with OB showed the highest and NW the lowest. Conclusion: Participants with excess body weight may increase their work of breathing and expend more WO due to a higher metabolic demand. Hence, it is suggested that exercise recommendation for physically inactive individuals with excess body weight should be individualized according to their BMI. The exercise prescription should include a longer duration of warming-up and cooling-down and followed by conditioning exercises at a lower intensity. Such strategy may delay fatigue and promote adherence to exercise. **Keywords:** Body mass index; Exercise; Submaximal intensity; Treadmill; Work output.

Cite this article as:
Justine, M., Haziq, F., & Manaf, H. (2020). Acute effects of submaximal exercise on respiratory rate and work output among physically inactive young adults. *Journal of Human Sport and Exercise*, *15(1), 128-136*. doi:https://doi.org/10.14198/jhse.2020.151.12

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Submitted for publication January 2019
Accepted for publication March 2019
Published March 2020 *(in press* April 2019)
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2020.151.12

INTRODUCTION

Body mass index (BMI) has been used universally as a predictor of health and wellbeing (Kopelman, 2010; Lu et al., 2014). Individuals with excess body weight or body mass index, namely those overweight and obese are at risk of various comorbidities (Falkner & Crossrow, 2014; Khuram, Paracha, Khar, Hasan, 2006; LaGrotte et al., 2016; Mitchell et al., 2015; Thijssen, van Caam & van der Kraan, 2015). With the rising prevalence of obesity (Khor, 2012; Lee & Pang, 2012; Ning et al., 2014) in many parts of the world, healthcare providers have a challenging responsibility to provide interventions to lessen the future burden of this issue. One of the strategies that can be recommended to individuals with weight problem is by promoting long term adherence to regular physical activity.

A regular physical activity or exercise at a recommended dosage may be effective for regulating body weight (Alharbi, Gallagher, Kirkness, Sibbritt & Tofler, 2016; Chaput et al., 2011; Jakicic & Otto, 2005). Simple aerobic exercises, such as running on a treadmill (Arend, Maestu, Kivastik, Ramson & Jurimae, 2015), brisk walking (Melam, Alhusaini, Buragadda, Kaur & Khan, 2017), and aerobic dance (Allet et al., 2017) are highly demanding physical activities that may enhance the overall levels of fitness, such as improving cardiovascular fitness and thus maintaining ideal body weight.

Promoting exercise among individuals with excess body weight may pose a great challenge as previous studies have shown that individuals with obesity perceived exercise as inducing physical discomfort (Abolhassani et al., 2012; Egan et al., 2013) and feeling of tiredness (Lidegaard, Schweennesen, Willaing & Farerch, 2016; Stankov, Olds & Cargo, 2012). Understanding how they respond to exercise may determine the specificity of an exercise prescription that not only effective for increasing levels of fitness but also promote long term adherence. Thus, to facilitate exercise participation, we believe that exercise recommendation should be individualized based on their BMI and current levels of fitness and physical activity.

Although maximal exercise testing is considered the gold standard for assessing maximal aerobic capacity, the role of such testing may not be practical for individuals with excess body weight whose performance may be limited (Noonan, 2000). Thus, a submaximal exercise may have the potential for overcoming many of the limitations of maximal exercise. We hypothesized that given the same intensity of exercise, individuals with different BMI classification may differ significantly in their responses to a submaximal exercise. Therefore, in this study, we aimed to determine and compare the effects of exercise at submaximal intensity on respiratory rate (RR) and work output (WO) among physically inactive individuals with normal weight, overweight and obesity.

METHODS

Ninety physically inactive young adults (Mean age=20.89±1.68 years, N=90) were recruited from a purposive sampling and grouped according to their body mass index (BMI) (Normal weight, NW=18.5-24.9 kg/m^2; overweight, OW=25.0-29.9 kg/m^2 and Obese, OB=≥30.0 kg/m^2) (WHO, 2006). Each group comprised of 30 participants with equal number of male and female participants (15 males and 15 females in each group). The participants inclusion criteria were: physically inactive based on the Physical Activity Readiness Questionnaire (PARQ) (Scott, Jeff & Shephard, 1992) or performing less than 150-min of moderate intensity of exercise per week as recommended by the American College of Sports Medicine (Haskel et al., 2007), have not been diagnosed by a doctor for having any diseases, and age between 19 and 25 years old. This study excluded smokers and those who were underweight. The procedure for the study was explained to all participants prior to the enrolment. An informed consent approved by a research ethics committee (Ethics approval reference no. 600-RMI (5/1/6); REC/109/15, Dated Oct 22, 2015) was obtained from each participant.

The sample size for this study was calculated using the GPower3 software (Faul et al., 2009). With the effect size of 0.20 and power (1-β err prob) of 0.91, a total sample of 66 was computed based on three groups with two repetitions of measurement. However, considering an attrition rate of 20 to 30%, a total sample size of 90 participants were deemed appropriate for this study, which made up of 30 participants in each group.

Upon signing the consent form, the participants were set an appointment date of Day 1 for measurement of their anthropometric data. The height (m) was measured in barefoot standing to the nearest 0.1 cm using a stadiometer, while body weight (kg), body mass index (kg/m^2) were measured on a balance scale (Digital Waist High with 750, Detecto, USA), which was calibrated to the nearest 0.1 kg with the participant dressed in standard T-shirts and pants.

On Day 2, participants performed the submaximal exercise on a treadmill with baseline and post-test measurements for the RR. RR was determined by counting the number of times the chest rises per minute (Nielsen, Folkestad, Brodersen & Brabrand, 2015) with participants in standing position. Two research assistants were required to observe and count the number of RR in number of breaths per minute to maintain consistency. WO was measured only at post exercise. To calculate WO, the percent grade (%), namely the inclination of treadmill, was multiplied with body weight (kg), treadmill speed (m/s) and total minutes of exercise (min); WO = Weight x Percent Grade x Treadmill Speed x Total Minutes of Exercise (Power & Howley, 2011).

Prior to the testing, a warming-up exercise with some light stretches of major muscle groups was conducted for about 10-min, followed by the treadmill exercise for 20-min at submaximal intensity of 65 to 85% within the target heart rate (HR). The duration of 20-min began once the heart rate reached 65% of maximum heart rate (MHR) and maintained up to 85% of MHR based on the Karvonen formula (Power & Howley, 2011). The speed of the treadmill followed the modified Bruce Treadmill Protocol (Power & Howley, 2011), in which it began at 1.7 mph and progressed up to 5.0 mph, however, the inclination was fixed at 8%. This was because the treadmill (Kettler Track Performance Treadmill, Kettler, United Kingdom) had a fixed inclination of 4%, 8% and 12%. The HR was monitored by using a polar heart rate monitor, placed at the participant's wrist. After the exercise, the measurement and recording of RR at 0-, 5-, 10-, 20-, 30-min and WO at 0-min were performed for each participant in order to record its recovery rate following the 20-min exercise. Cooling-down exercise was done for 10-min after completing all measurements.

The SPSS version 22.0 was used for descriptive and inferential analysis. The mean differences in RR and WO were statistically tested for between and within groups using an analysis of variance (ANOVA) and repeated measures ANOVA, respectively. All statistical tests were set at $p < 0.05$.

RESULTS AND DISCUSSION

Table 1 shows the characteristics of the participants. Significant differences were found in most characteristics except for age and height. Some of these characteristics has been described elsewhere (Justine, Ishak & Manaf, 2018).

Table 1. Participants' characteristics (N=90)

Characteristics	NW (n=30) Mean±SD (Range)	OW (n=30) Mean±SD (Range)	OB (n=30) Mean±SD (Range)	*F*-test
Age (years)	21.32 ±2.02 (19-25)	20.93±1.46 (19-24)	20.42±1.41 (19-24)	2.319
Body weight (kg)	55.97±7.40 (41.9-70.8)	72.59±7.57 (57.5-88.6)	92.04±14.35 (66.9-131)	94.93*
Height (m)	1.61±0.08 (1.44-1.75)	1.62±0.08 (1.47-1.78)	1.63±0.09 (1.47-1.86)	0.703
BMI (kg/m^2)	21.56±1.57 (19.5-24.4)	27.44±1.58 (25.0-30.0)	34.41±3.09 (30.2-42.3)	262.912*

Notes. RR = respiratory rate. NW = normal weight. OW = overweight. OB = obese.
** = significant at p < 0.05*

Effects on respiratory rate

Table 2 shows the comparisons for RR, in which significant differences were found among the groups at baseline, 0-, 5-. 10-, 20- and 30-min (All p < 0.05). Further analysis using the Post Hoc tests can be seen in Table 2. As further shown in Figure 1, OB presented with the highest RR at all measured times.

Table 2. Respiratory rate in NW, OW and OB at baseline and following exercise

Time (Min)	RR (Breaths/minute)			*F*, between group
	NW Mean±SD (range)	OW Mean±SD (range)	OB Mean±SD (range)	Post-hoc tests
Baseline	17.40±3.243 (12-24)	17.87±2.46 (13-23)	20.03± 3.851 (12-29)	5.278* NW-OB*, OW-OB*
0	26.1±2.5 (20-30)	25.5±3.85 (21-37)	31.8±3.04 (24-40)	23.331* NW-OW*, NW-OB*, OW-OB*
5	23.30±3.4 (16-29)	23.81±3.17 (18-32)	25.7±3.68 (19-32)	3.74* NW-OB*
10	19±3.7 (12-26)	20±2.9 (18-32)	22±3.6 (12-29)	5.233* NW-OB*, OW-OB*
20	17±3.5 (11-24)	17±0.0 (12-22)	20±3.6 (11-28)	7.263* NW-OB*, OW-OB*
30	16.26±3.1 (11-24)	16.4±2.55 (12-22)	18.90±3.35 (11-25)	7.26* NW-OB*, OW-OB*
Within Group (*p*-value)	0.000*	0.000*	0.000*	-

Notes. RR = respiratory rate. NW = normal weight. OW = overweight. OB = obese.
** = sig at p < 0.05*

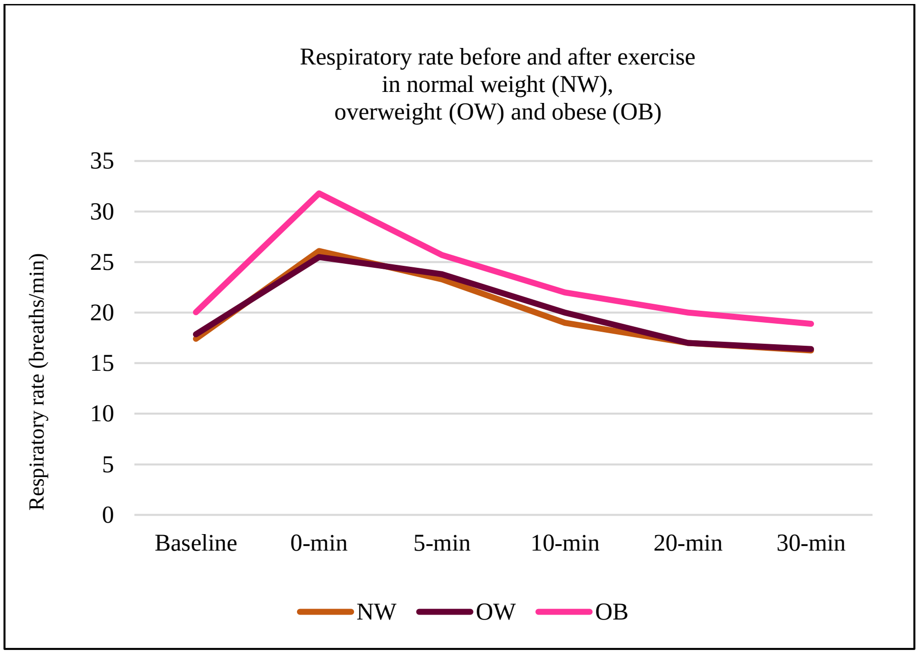

Figure 1. Respiratory rate in NW, OW and OB.

The finding of this study indicates that individuals with obesity may have a higher metabolic demand to move a heavier body. Thus, they increased their work of breathing which in turn lead to a longer recovery time to return to the pre-exercise level. This demand is reflected in the fact that OB's oxygen consumption is higher at rest and during exercise. A previous study by Littleton (2012) suggested that individuals with obesity have a higher basal metabolic rate at rest, thus they tend to have a higher oxygen consumption during exercise.

Based on the current finding, it is also suggested that NW, OW and OB have different rate of breathing at pre-training (baseline) and post training. This is because RR and tidal volume vary in response to the metabolic demand and an increase in physical activity. This finding is supported by a very classical study (Weber, Kinasewitz, Janicki & Fishman, 1982) that reported an increase in minute ventilation and rate of air flow on individuals at a given workload. It can be further explained that OB and OW have a higher work of breathing and hyperventilation to complete the submaximal exercise because of the requirement for more cardiorespiratory effort to move their larger body mass through space (Norman et al., 2005). However, in our study, all three groups required about 20-min to return to their pre-exercise RR level, which can be explained that all participants were physically inactive. Therefore, we can suggest that all physically inactive individuals should participate in exercise, however, their exercise prescription should be individualized due to their different timing of responses to exercise.

Effects on work output

For WO, immediately after the exercise, the analysis showed significant differences between groups (*F*-test = 28.07, p = 0.000). OB showed the highest WO (mean = 612.3 Joules, SD = 147.4) followed by OW (mean = 530.6 Joules, SD = 91.28) and NW (mean = 406.6 Joules, SD = 72.88). Further analysis using post-hoc tests showed significant differences between NW and OB (p = 0.01), as well as OW and OB (p = 0.029). No significant difference was found between NW and OW (p=0.930). Figure 2 shows the WO among NW, OW and OB.

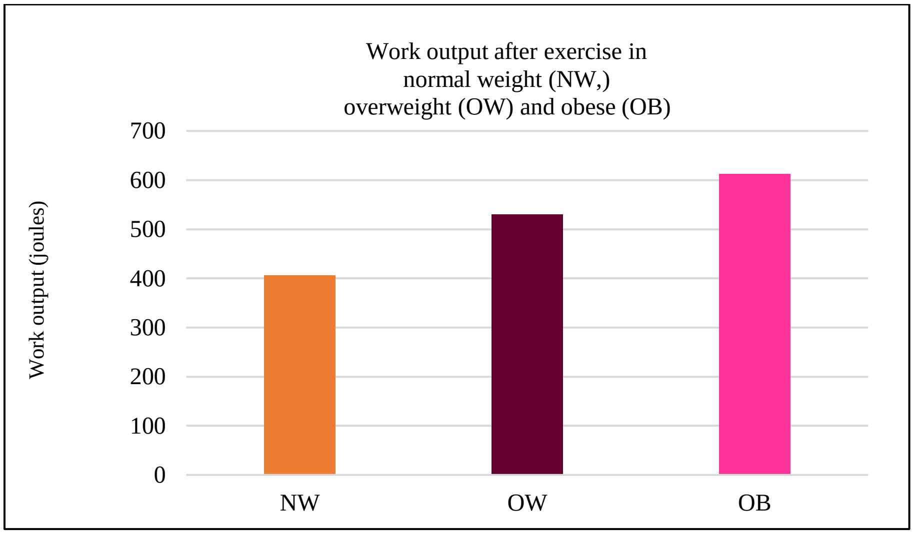

Figure 2. Work output in NW, OW and OB.

In this study, OB exerted the highest WO followed by OW and NW. It is probably due to the excess body weight that explains the need for a metabolic demand imposed by the expanded adipose tissue and extra body fat. In addition, as the finding of the study showed that the obese group performed more work which could be due to their higher body mass that explained their higher RR, hence the WO may be accounted as influencing their performance. Our finding is supported by a previous study (Norman et al., 2005), in which excess adipose tissue influences exercise performance. In addition, according to a previous study (Isacco, Thivel, Duclos, Aucouturier & Boisseau, 2014) a predominantly higher abdominal fat mass distribution is associated with a lower capacity to maximize lipid oxidation during exercise. A previous study (Pataky, Armand, Miller-Pinget, Golay & Allet, 2014) suggested that obesity influences functional capacity performance by exhibiting lower gait speed, shorter strides and increase step width that cost them a higher metabolic energy. This is further explained due to fat mass distribution over the abdomen and in the hip region that limit the degree of hip flexion. Thus, this will create more energy expended during exercise due to altered mechanical efficiency. In our study, as seen in Table 1, OW and OB participants also presented with a higher fat %, waist and hip circumferences.

CONCLUSION

We noted that a major limitation of this study is that we did not record the treadmill speed and grade in accordance with its respiratory rate. Furthermore, the exercise testing employed was walking or running on a treadmill as participants were free from any physical limitations. The walking pattern on a treadmill follows the Modified Bruce protocol in which the speed is controlled by the machine, thus running freely on a flat ground may not produce similar results, as the participant may be able to control his or her own walking or running phase to overcome fatigue.

As a conclusion, individuals with different BMI classification may respond differently to submaximal exercise with regards to their RR recovery and WO. This finding indicated that individuals with different BMI, may require different designs of exercise intervention, to prevent the early onset of fatigue that may discourage them from engaging in a recommended time for exercising. Most importantly, an exercise program should be individualized to individuals according to their BMI and current level of fitness and physical activity.

ACKNOWLEDGEMENTS

The authors wish to thank the Ministry of Education, Malaysia for funding the research project through the Fundamental Research Grant Scheme (Ref. No. 600-RMI /FRGS/5/3(54/2015)) and, the Research Management Centre (RMC), Universiti Teknologi MARA (UiTM) Selangor for administrative support.

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