S.A. Journal for Research in Sport, Physical Education and Recreation, 2001, 23(1):1-7.
S.A. Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2001, 23(1):1-7.
ISSN: 0379-9069

EFFECT OF EXERCISE INTENSITY ON EXERCISE AND POST EXERCISE ENERGY EXPENDITURE IN MODERATELY OBESE WOMEN

Marius F. COETSEE
Department of Human Movement Science, University of Zululand, KwaDlangezwa, Republic of South Africa

ABSTRACT

Walking and/or jogging has become a popular activity especially for moderate obese women who aim to maintain acceptable body fat levels. The question whether it is more beneficial to walk/jog at a moderate pace for a longer duration or at a fast pace for a shorter duration is often asked. Research literature fails to answer this question conclusively. The aim of this study was to determine if exercise and post exercise energy expenditure are affected by the intensity of exercise during a set distance of 4km walking and/or jogging. Subjects for this study were 12 moderately obese females with mean fat percentage of 31.7±6.3% and mean age of 38.2±4.6 years. For the low intensity protocol (LI) continuous indirect calorimetry, using the Cortex Metamax portable system, was performed for a 30 minute pre-exercise period of sedentary sitting, for a 4km walk/jog on a motorised treadmill at 57% of maximum heart rate, as well as for 4 hours post exercise. The high intensity protocol (HI) consisted of continuous indirect calorimetry for a 30-minute pre-exercise period of sedentary sitting, for a 4km walk/jog on a motorised treadmill at the highest voluntary pace of the subject, as well as for 4 hours post exercise. A minimum period of one week separated the HI and LI evaluations. Oxygen consumption and substrate utilisation during and 4 hours following LI and HI were analysed. The main findings were: 1) oxygen consumption (ℓO_2) was significantly higher ($p<0.05$) during HI (54.5±9.8) than during LI (44.1±16.7); 2) post exercise oxygen consumption (ℓO_2) did not differ significantly ($p>0.05$) between HI (79.9±13.2) and LI (82.4±15.2); 3) total (exercise plus 4-hour recovery) oxygen consumption (ℓO_2) did not differ significantly ($p>0.05$) between HI (134.4±16.1) and LI (126.5±28.3); 4) post exercise fat utilisation (gm) was slightly lower after HI (18±18.7) than after LI (22.2±13.7), but the difference was not significant ($p>0.05$); 5) post exercise carbohydrate utilisation (gm) was slightly higher after HI (53.7±19.9) than after LI (46.5±21.0), but the difference was not significant ($p>0.05$); 6) total carbohydrate utilisation (gm) was significantly ($p<0.05$) higher with HI (100.7±33.7) than LI (73.8±30.2); and 7) total fat utilisation (gm) was lower with HI (26.1±17.1) than with LI (33.1±22.8), but it was not significant ($p>0.05$). This study did not find any significant advantage for mildly obese females to walk/jog for 4km at a very high intensity compared to a moderate intensity, in order to increase energy expenditure as well as enhance the oxidation of fat and thereby accelerate fat loss.

Key words: Recovery metabolism; Energy metabolism; Women; Walking.

INTRODUCTION

Walking and/or jogging has become a popular activity especially for women who aim to maintain acceptable body fat levels. The question whether it is more beneficial to walk/jog at a moderate pace for a longer duration than at a faster pace for a shorter duration, is often asked. The research literature remains unequivocal in this regard.

The relationship between oxygen uptake and running speed is linear; therefore, the total energy cost of running a given distance at a steady rate is about the same regardless of whether the pace is fast or slow (McArdle *et al.,* 1996). The same is true for walking at speeds of approximately 3 to 5 $km.hr^{-1}$, where after walking economy decreases and the relationship curves upward (McArdle *et al.,* 1996). It seems, therefore, that if the magnitude of energy expenditure is of importance, it is more beneficial to walk at a faster pace for a given distance. However, there are other factors that play a role in total energy expenditure resulting from a bout of exercise. If the magnitude of post exercise energy expenditure following exercise of low to moderate intensity differs significantly from that following high intensity exercise, it could play an important role in the maintenance of acceptable body fat levels. Research literature addresses this fact substantially but fails to reach an unopposed conclusion. Some researchers (Gore & Withers, 1990; Bahr & Sejersted 1991; Broeder *et al.,* 1991; Dawson *et al.,* 1996; Phelain *et al.,* 1997; Laforgia *et al.,* 1997) found a higher post exercise energy expenditure following more intensive exercise while others (Sedlock 1991; Thompson *et al.,* 1998) did not. It seems that the protocols employed by these researchers differed significantly and this can partly explain the controversial findings. Most studies concentrated on changing intensity but keeping duration constant. Total work done during exercise, and therefore energy expenditure, differed between the different protocols. Another factor that might explain the controversial findings, is the exercise duration that differed between different studies. Quinn *et al.* (1994) pointed out that duration of exercise could significantly affect the magnitude of post exercise oxygen consumption.

In addition to energy expenditure during and after exercise the contribution of carbohydrate and fat should be considered. Some researchers (Broeder *et al*., 1991) found a higher fat contribution to post exercise energy expenditure after higher intensity exercise when compared to lower intensity exercise, while others (Phelain *et al.,* 1997, Thompson *et al.,* 1998) did not. During exercise, fat contribution to energy expenditure is highest at approximately 57% of maximum heart rate (Coetsee & Teubes, 1993). As exercise intensity increases further, carbohydrate contribution increases and fat contribution decreases (McArdle *et al.,* 1996). This is due to the fact that a carbohydrate molecule contains many more oxygen atoms in its structure than a fat molecule, and therefore, requires less oxygen from the respiratory system. At higher intensities, when there is a relative shortage of respiratory derived oxygen at mitochondria level, carbohydrate will be the preferred fuel for the metabolic pathways.

The research described in this paper investigates the above issues as it applies to common exercise practice. The aim was to determine if exercise and post exercise energy expenditure were affected by the intensity of exercise during a set distance of 4km walking and/or jogging. The total workload was kept constant by standardising the distance covered. Only the intensity at which the standardised total amount of work was done (57% of heart rate maximum vs. voluntary fastest pace), differed. Necessarily the duration of exercise became shorter as the intensity increased.

These are common exercise modalities used by individuals wishing to lose fat. The results are therefore very relevant to a large group of women who utilise exercise to reduce body fat.

METHODS AND PROCEDURES

Subjects for this study were 12 moderately obese females with a fat percentage (mean ± standard deviation) of 31.7±6.3%, age of 38.2±4.6 years, mass of 71.9±12.8 kg and stature of 167.3±5.2 cm. All subjects were medically fit, free from any metabolic disorders, had no history of cardiovascular conditions and were not on any medication. Subjects all signed an informed consent form. Fat percentage was determined from measurements of the triceps, iliac crest and thigh skin folds, as per the method described by Jackson *et al.* (1980). Subjects were randomly assigned to perform either the low intensity protocol (LI) or the high intensity protocol (HI) first.

A standardised nutritional protocol was followed for three days prior to testing, which included a 12 hours fast, followed by a standardised light meal of cereal and one cup of coffee at 06h00, before reporting to the laboratory at 08h00. No exercise was allowed for 24 hours prior to testing. All possible factors that could affect the resting metabolic rate were avoided or standardised. The laboratory temperature was strictly controlled (mean for LI was 20.9±0.9°C and for HI 20.9±1.4°C) and humidity did not differ significantly (LI=74.7±5.7% and HI=73.1±4.6%). For the low intensity protocol (LI) continuous indirect calorimetry, using the Cortex Metamax portable system, was performed for a 30 minute pre-exercise period of sedentary sitting, for a 4km walk/jog on a motorised treadmill at 57% of maximum heart rate, as well as for 4 hours post exercise. The high intensity protocol (HI) consisted of continuous indirect calorimetry for a 30-minute pre-exercise period of sedentary sitting, for a 4km walk/jog on a motorised treadmill at the highest voluntary pace of the subject, as well as for 4 hours post exercise. A minimum period of one week separated the testing of the same subject. Data for all respiratory parameters, as well as heart rate, were recorded on-line. Rating of perceived exertion (RPE) using the Borg Scale (Borg, 1982) was recorded at 5 minute intervals during the 4km walk/jog. The 4 hours post-exercise period was spent in a secluded room, sitting and watching videos or reading. Subjects had free access to water but were not allowed any other nutrients. The following blood concentrations were measured using a Boehringer Reflotron and making use of an arterialized sample of blood from the finger: glucose 15 minutes before exercise, triglyceride 10 minutes before exercise, lactate 2 minutes after exercise, glucose 10 minutes after exercise and triglyceride 15 minutes after exercise. Energy consumption (kcal) and the contribution of carbohydrate and fat to energy consumption was calculated from oxygen consumption and respiratory quotient (RQ) according to the procedure described by McArdle *et al.*, (1996).

Statistical analyses were done using the dependent paired two-tailed t-test (Thomas & Nelson, 1996). Alpha was set at $p \leq 0.05$ for all analyses.

RESULTS

TABLE 1. **VARIABLES MEASURED DURING THE LOW INTENSITY (LI) AND HIGH INTENSITY (HI) EXERCISE PROTOCOLS (MEAN±STANDARD DEVIATION)**

Variable	**LI**	**HI**	**% Difference**
Resting metabolic rate (mlO_2/min)	271±39	276±37	+1.5
Exercise oxygen consumption (ℓO_2)	44.1±16.7	54.5±9.8	+23.4*
Post exercise oxygen consumption (ℓO_2)	82.4±15.2	79.9±13.2	-3.1
Total oxygen consumption (ℓO_2)	126.5±28.3	134.4±16.1	+6.8
Post exercise energy expenditure (kcal)	400.2±70.9	390.4±62.7	-2.4
Post exercise carbohydrate utilization (gm)	46.5±21.0	53.7±19.9	+15.6
Post exercise fat utilization (gm)	22.2±13.7	18±9.7	-18.8
Total carbohydrate utilization (gm)	73.8±30.2	100.7±33.7	+36.5*
Total fat utilization (gm)	33.1±22.8	26.1±17.1	-21.2
Exercise heart rate (bpm)	103.5±3.4	155.7±14.5	+50.3*
Post exercise heart rate (bpm)	66.2±6.1	71.3±5.7	+7.7
Exercise RPE	9.9±1.3	12.1±1.7	+22.7*
Blood lactate after exercise (mmol/l)	1.71±0.51	5.36±1.85	+213.5*

* = Statistically significant difference ($p<0.05$)

TABLE 2. **BLOOD TRIGLYCERIDE AND BLOOD GLUCOSE CONCENTRATIONS BEFORE AND AFTER LOW INTENSITY (LI) AND HIGH INTENSITY (HI) EXERCISE (MEAN±STANDARD DEVIATION)**

Variable	**Before exercise**	**After exercise**	**% Difference**
Blood triglyceride (mmol/l) for LI	0.98±0.27	1.14±0.42	16.3
Blood triglyceride (mmol/l) for HI	1.07±0.45	1.33±0.63	24.3*
Blood glucose (mmol/l) for LI	5.52±0.42	5.17±0.40	-6.3*
Blood glucose (mmol/l) for HI	6.02±0.82	6.14±0.84	2.0

* = Statistically significant difference (p<0.05)

In the present study exercise and post exercise oxygen consumption and substrate utilisation, during and 4 hours following a low and high intensity walk/jog of 4km, were compared. The results as shown in tables 1 and 2, (exercise heart rate, exercise RPE and blood lactate) clearly indicate that exercise intensity of HI was significantly ($p<0.05$) higher than for LI. Even though the distance of the walk/run was standardised at 4km, the oxygen consumption of LI and HI differed significantly ($p<0.05$). Post exercise oxygen consumption and total oxygen consumption, however, did not. Total carbohydrate utilisation differed significantly ($p<0.05$) due to the higher contribution of carbohydrate to energy consumption during HI. None of the other substrate values showed significant differences.

The main findings (mean ± standard deviation) were:

1) oxygen consumption (ℓO_2); was significantly higher ($p<0.05$) during high intensity exercise (54.5±8) than during low intensity exercise (44.1±16.7);

2) Post exercise oxygen consumption (ℓO_2); did not differ significantly ($p>0.05$) between high (79.9±13.2) and low (82.4±15.2) intensity exercise;

3) Total (exercise plus 4-hour recovery) oxygen consumption (ℓO_2); did not differ significantly ($p>0.05$) between high (134.4±16.1) and low (126.5±28.3) intensity exercise;

4) Post exercise fat utilisation (gm) was slightly lower after high intensity exercise *(18±18.7)* than after low intensity exercise *(22.2±13.7)*, but the difference was not significant ($p>0.05$);

5) Post exercise carbohydrate utilisation (gm) was slightly higher after high intensity exercise (53.7±19.9) than after low intensity exercise (46.5±21.0), but the difference was not significant ($p>0.05$);

6) Total carbohydrate utilisation (gm) was significantly ($p<0.05$) higher with high intensity exercise (100.7±33.7) than with low intensity exercise (73.8±30.2); and

7) Total fat utilisation (gm) was lower with high intensity exercise (26.1±17.1) than with low intensity exercise (33.1±22.8), but it was not significant ($p>0.05$).

DISCUSSION

This study does not support the findings of Phelain *et al*. (1997), Laforgia *et al*. (1997), Bahr and Sejersted (1991), Broeder *et al*. (1991), Gore and Withers, (1990) and Dawson *et al*. (1996) that higher intensity exercise induce a greater excess post exercise oxygen consumption. This discrepancy could partly be explained by the threshold phenomenon, described by Bahr and Sejersted (1991), who found that an exercise intensity above 40-50% of VO2max is required in order to trigger the metabolic processes responsible for prolonged excess post exercise O2 consumption. All the above researchers except Laforgia *et al*, (1997) compared an exercise intensity of 50% VO2max or lower with a higher intensity. However, both Thompson *et al*. (1998) and Sedlock (1991), who did not show a difference in excess post exercise oxygen consumption between low and high intensity exercise, used a low intensity of below 50% VO2max (33 vs. 66% and 40 vs. 60% respectively). The present study did not find a significant difference ($p>0.05$) in post exercise oxygen consumption following exercise of 57% of heart rate max versus 90% of heart rate max. Research further indicate that the duration of exercise may influence the magnitude of post exercise oxygen consumption (Sedlock 1991). A minimum of 1 hour seems to be required to effect prolonged excess post exercise oxygen consumption. The mean exercise time for low as well as high intensity exercise in the present study was below 1 hour (58.04 minutes and 35.04 minutes respectively).

The resting values for blood glucose and triglycerides were within normal range (see Table 2). HI resulted in a significant ($p<0.05$) increase in blood triglyceride level. This is consistent with what is expected, as lipids are the preferred substrate during moderate intensity exercise at a steady rate. LI resulted in a significant ($p<0.05$) increase in blood glucose level. Again this is consistent with the fact that, because of the relative shortage of cellular oxygen, glucose is preferred in the metabolism of energy for muscle contraction. The significant ($p<0.05$) higher total carbohydrate use of HI compared to LI supports this finding. Although 21% less total fat was utilised in HI than LI the difference was not significant ($p>0.05$).

CONCLUSION

This study did not find any significant advantage for moderate obese females to walk/jog at a very high intensity, relative to a moderate intensity, for a distance of 4km, in order to increase energy expenditure as well as enhance the oxidation of fat and thereby accelerate fat loss.

ACKNOWLEDGMENT

The Research Committee of the University of Zululand financially supported this research project.

REFERENCES

Bahr, R. & Sejersted, O.M. (1991). Effect of intensity of exercise on excess postexercise O_2 consumption. *Metabolism*, 40(8): 836-841.

Borg, G.A. (1982). Psychological basis of physical exertion. *Medicine Science in Sports and Exercise,* 14: *377.*

Broeder, C.E.; Brenner, M.; Hofman, Z.; Paijmans, U.; Thomas, E.L. & Wilmore, J.H. (1991). The metabolic consequences of low and moderate intensity exercise with or without feeding in lean and borderline obese males. *International Journal of Obesity*, 15(2): 95-104.

Coetsee, M.F. & Teubes, N.W. (1993). Effect of aerobic training on metabolism with special reference to obese individuals. In J. Parizkova & P. Douglas (Eds.), *Human growth, dietary intake, and other environmental factors (*78-82). Proceedings of 13th International Congress of Anthropological and Ethnological Sciences, Mexico City, 1993.

Dawson, B.; Straton, S. & Randal, N. (1996). Oxygen consumption during recovery from prolonged submaximal cycling below the anaerobic threshold. *Journal of Sports Medicine and Physical Fitness,* 36(2): 77-84.

Gore, C.J. & Withers, R.T. (1990). The effect of exercise intensity and duration on the oxygen deficit and excess post-exercise oxygen consumption. *European Journal of Applied Physiology,* 60(3): 169-174.

Jackson, A.S.; Pollock, M.L. & Ward, A. (1980). Generalized equations for predicting body density of women. *Medicine and Science in Sports and Exercise*, 12:175-182.

Laforgia, J.; Withers, R.T.; Shipp, N.I. & Gore, C.J. (1997). Comparison of energy expenditure elevations after submaximal and supramaximal running. *Journal of Applied Physiology*, 82(2): 661-666.

McArdle, W.D.; Katch, F.I. & Katch, V.L. (1996). *Exercise Physiology* (4th ed.). Baltimore, MD: Williams & Wilkins.

Phelain, J.F.; Reinke, E.; Harris, M.A. & Melby, C.L. (1997). Postexercise energy expenditure and substrate oxidation in young women resulting from exercise bouts of different intensity. *Journal of the American College of Nutrition*, 16(2): 140-146.

Quinn, T.J.; Vroman, N.B. & Kertzer, R. (1994). Postexercise oxygen consumption in trained females: Effect of exercise duration. *Medicine and Science of Sport and Exercise*, 26(7): 908-913.

Sedlock, D.A. (1991). Effect of exercise intensity on postexercise energy expenditure in women. *British Journal of Sports Medicine*, 25(1): 38-40.

Thomas, J.R. & Nelson, J.K. (1996). *Research methods in physical activity* (3rd ed.). Champaign, IL: Human Kinetics.

Thompson, D.L.; Townsend, K.M.; Boughey, R.; Patterson, K. & Bassett, D.R. (1998). Substrate use during and following moderate- and low-intensity exercise: Implications for weight control. *European Journal of Applied Physiology*, 78(1): 43-49.

Prof. Marius F. Coetsee, Dept. of Human Movement Science, University of Zululand, Private Bag X 1001, KwaDlangezwa 3886, Republic of South Africa. Tel: +27 (0)35 902-6648 (w), +27 (0)35 772-6639 (h), Fax: +27(0)35 93 916, E-mail: mcoetsee@pan.uzulu.ac.za

(Review editor: Dr. H.J. van Heerden)