EXERCISE AFTER-BURN:

A RESEARCH UPDATE

What effect do intensity, mode, duration and other factors have on calorie burning *after* exercise?

Just pick up a recent trade magazine and you are almost sure to read about a new exercise program that will accelerate the rate at which you burn fat after you complete a workout. Although this promise is enticing to the exerciser seeking optimal weight loss, rarely is there any scientific evidence validating a particular workout's postexercise capability to "incinerate fat." However, research does indicate that certain factors can lead to an increase in postexercise *caloric expenditure,* though little data exist on whether the calories burned are from fat or carbohydrates. The purpose of this article is to present an update on the research on exercise after-burn and all the factors that influence it.

By Chantal A. Vella, PhD, and
Len Kravitz, PhD

What Is Exercise After-Burn?

Exercise after-burn, also referred to as **excess postexercise oxygen consumption (EPOC),** is the number of calories expended (above resting values) after an exercise bout. EPOC represents the oxygen consumption the body uses to return to its pre-exercise state. The physiological mechanisms responsible for increased metabolism following exercise include oxygen replenishment; phosphagen (ATP-PC) resynthesis; lactate removal; and increased ventilation, blood circulation and body temperature (Børsheim & Bahr 2003). The body generally takes anywhere from 15 minutes to 48 hours to fully recover to a resting state. Studies have found that the magnitude and duration of EPOC depend on the intensity and duration of exercise. Other influencing factors include training status and gender. It should be noted that several methodological differences in study procedures (e.g., having subjects seated versus in a recumbent position, or using different techniques to obtain resting metabolic values) contribute to a wide variance in the research results.

EPOC and Cardiovascular Exercise

THE EFFECT OF INTENSITY

Research demonstrates that the intensity of a cardiovascular exercise bout has the greatest impact on EPOC. As exercise intensity increases, the magnitude and duration of EPOC increase.

In a study by Bahr and Sejersted (1991), subjects completed exercise bouts at intensities of 29%, 50% and 75% of VO_2max for a period of 80 minutes. The greatest EPOC was reported following the highest exercise intensity (75% VO_2max): 30.1 liters (L) of oxygen consumed, or 150.5 calories burned. (*Note:* Not all studies report actual caloric expenditure, but it is well understood in all exercise physiology and nutrition texts that for every liter of oxygen consumed, approximately 5 calories are burned.) Additionally, the *duration* of EPOC following the highest-intensity exercise was significantly longer when compared to the lower-intensity bouts (10.5 hours versus 0.3 and 3.3 hours).

Phelain and colleagues (1997) also investigated the effects of low-intensity (50% VO_2max) and high-intensity (75% VO_2max) exercise on the EPOC response. Although the energy expended during each exercise bout was 500 calories, the higher-intensity bout caused a significantly higher EPOC than the lower-intensity bout (9.0 L, or 45 calories, versus 4.8 L, or 24 calories). In yet another test, of both male and female subjects, Smith and McNaughton (1993) reported significant increases in EPOC following the highest exercise intensity. Subjects in this study exercised at 40%, 50% and 70% of VO_2max for 30 minutes. At the highest intensity, EPOC was 28.1 L (140.5 calories) for men and 24.3 L (121.5 calories) for women.

THE EFFECT OF DURATION

Research consistently reports that a direct relationship also exists between the duration of exercise and EPOC. Chad and Wenger (1988) investigated the effects on EPOC of exercise duration (30, 45 and 60 minutes) at 70% VO_2max. They reported EPOC values of 6.6 L (33 calories over 128 minutes), 14.9 L (74.5 calories over 204 minutes) and 33 L (165 calories over 455 minutes) for durations of 30, 45 and 60 minutes, respectively. The researchers concluded that increasing exercise duration significantly increased total EPOC. In another study Quinn and associates (1994) observed women who walked on a treadmill at 70% VO_2max for 20, 40 and 60 minutes. The authors reported a significantly higher and longer EPOC following the 60-minute duration. The values were 8.6 L (43 calories), 9.8 L (49 calories) and 15.2 L (76 calories) for 20-, 40- and 60-minute durations, respectively. In a similar study (Bahr et al. 1987), subjects exercised

selected studies on the effect of resistance training on EPOC

Study	Subjects	Exercise Mode	Intensity, Duration	EPOC
Elliot et al. 1992	5 F, 4 M	(a) cycle (b) circuit resistance training (c) heavy resistance training	(a) 40 minutes (min), 80% heart rate max (b) 4 sets, 8 exercises, 15 reps, 50% 1RM (c) 3 sets, 8 exercises, 3–8 reps, 80%–90% 1RM	(a) 6.7 liters (L) (b) 10.2 L (c) 10.6 L
Murphy & Schwarzkopf 1992	10 M	(a) standard resistance training (b) circuit resistance training	(a) 3 sets, 6 exercises, reps to exhaustion, 80% 1RM, 120-second [sec] rest (b) 3 circuit sets, 6 exercises, 10–12 reps, 50% 1RM, 30 sec rest	(a) 2.7 L (b) 5 L
Gilette et al. 1994	10 M	(a) cycle (b) resistance training	(a) 50% VO_2max, 60 min; (b) 5 sets, 10 exercises, 8–12 reps, 70% 1RM	(a) 5.6 L (b) 12.6 L
Thornton & Potteiger 2002	14 F	(a) high-intensity resistance training (b) low-intensity resistance training	(a) 2 sets, 9 exercises, 8 reps, 85% 8RM (b) 2 sets, 15 reps, 45% 8RM	(a) 2.3 L (b) 1.1 L

Key: F = females; M = males; % = intensity as a percentage of VO_2max; EPOC = excess postexercise oxygen consumption.
Source: Adapted from Borsheim & Bahr 2003.

selected studies on the effect of aerobic exercise on EPOC

Study	Subjects	Exercise Mode	Intensity, Duration	EPOC
Maehlum et al. 1986	4 F, 4 M	cycle	70%, 80 minutes (min)	26 liters (L)
Chad & Wenger 1988	3 F, 3 M	cycle	70%, 30 min, 45 min, 60 min	6.6 L, 14.9 L, 33 L
Sedlock et al. 1989	10 M	cycle	(a) 75%, 20 min (b) 50%, 30 min (c) 50%, 60 min	(a) 6.2 L (b) 3.0 L (c) 2.5 L
Kaminsky et al. 1990	6 F	TM	70%, 50 min, 2 x 25 min	1.4 L, 3.1 L
Withers et al. 1991	8 M	TM	70%, 164 min	32.4 L
Bahr & Sejersted 1991	6 M	cycle	80 min, 29%, 50%, 75%	1.3 L, 5.7 L, 30.1 L
Kaminsky & Whaley 1993	10 F	TM	(a) 36 min, (a) alternating 3 min bouts at 30% and 90% (b) continuous 36 min at 60%	(a) 3.6 L (b) 1.9 L
Smith & McNaughton 1993	8 F, 8 M	cycle	30 min at 40%, 50%, 70%	F: 12.1 L, 20.8 L, 24.3 L M: 16.3 L, 22.1 L, 28.1 L
Quinn et al. 1994	8 F	TM	70%, 20, 40, 60 min	8.6 L, 9.8 L, 15.2 L
Laforgia et al. 1997	8 M	TM	(a) 70%, 30 min (b) 105%, 20 x 1 min with 2 min break (equal work)	(a) 6.9 L (b) 15 L 5.3 L
Almuzaini et al. 1998	10 M	cycle	70%, 30 min, 2 x 15 min	5.3 L, 7.4 L

Key: F = females; M = males; TM = treadmill; % = intensity as a percentage of VO_2max; EPOC = excess postexercise oxygen consumption

Source: Adapted from Borsheim & Bahr 2003.

for 20, 40 and 80 minutes at 70% VO_2max and had EPOC values of 11.1 L (55.5 calories), 14.7 L (73.5 calories) and 31.9 L (159.5 calories) for each duration, respectively. These studies suggest that given sufficient aerobic exercise intensity, exercise duration is an important factor influencing EPOC.

Several studies have investigated the effects of combining high intensity with even longer duration. Maehlum and colleagues (1986) reported an EPOC of 26 L (130 calories) following 80 minutes of cycling at 70% VO_2max in eight men and women. In addition, the subjects' VO_2 was still elevated by an average of 5% 24 hours postexercise. Similarly, Withers and others (1991) investigated the effects of 164 minutes of treadmill training at 70% VO_2max in eight trained males. The average EPOC value was 32.4 L, or 162 calories—a notable contribution to overall energy expenditure.

Not all studies are consistent, however. Gore and Withers (1990) reported slightly lower EPOC values following 80 minutes of running at 70% VO_2max in nine male subjects (14.6 L, 73 calories). In studies investigating EPOC following shorter-duration exercise, Sedlock (1992) reported a very low EPOC average of 3.1 L (15.5 calories) following 30 minutes of cycling at 60%–65% VO_2max; and, in another study, Sedlock and colleagues (1989) found that the average EPOC following 20 minutes of exercise at 75%. VO_2max was only 6.2 L (31 calories).

So although most studies conclude that EPOC can contribute significantly to overall caloric expenditure, results do appear to vary somewhat among studies, possibly due to subjects' gender, the exercise modality employed, the sample size used for the study and so on.

THE EFFECT OF INTERMITTENT VERSUS SINGLE BOUTS OF EXERCISE

Several studies have concluded that intermittent aerobic exercise bouts elicit a greater EPOC response when compared to continuous exercise bouts. Laforgia and colleagues (1997) investigated the effects of a continuous run (30 minutes at 70% VO_2max) versus an interval run (20 bouts of 1-minute duration at 105% VO_2max, referred to as *supramaximal exercise*). The authors reported a significantly greater EPOC following the intermittent bouts of supramaximal exercise (15 L, 75 calories, versus 6.9 L, 34.5 calories).

Kaminsky and others (1990) also found that study subjects demonstrated a significantly greater EPOC following an intermittent bout of exercise (two 25-minute sessions at 70% VO_2max) when compared to a continuous bout (a 50-minute run at 75% VO_2max). The EPOC values for the split exercise sessions were combined, and averaged 3.1 L (15.5 calories) versus 1.4 L (7 calories) for the continuous exercise session. Similarly, Almuzaini and associates (1998) reported greater EPOC values following two 15-minute exercise bouts when compared to 30 minutes of continuous exercise at 70% VO_2max. The average EPOC following intermittent exercise was 7.4 L (37 calories) versus 5.3 L (26.5 calories) following continuous exercise. Interestingly, the EPOC values from the Kaminsky and Almuzaini studies were significantly lower than the values reported from similar studies, further supporting the hypothesis that the EPOC response may vary among individuals, and, in addition, study results may vary depending on the scientific methodologies employed.

Incorporating high-intensity intervals into continuous exercise has also been found to significantly increase EPOC (Kaminsky & Whaley 1993).

EPOC and Resistance Training

Few studies have investigated the effects of resistance training on EPOC, but the research that has been done suggests that resistance training elicits a valuable EPOC response for weight loss and/or weight management.

THE EFFECT OF RESISTANCE TRAINING VERSUS AEROBIC EXERCISE

Although it is difficult to equalize resistance training and aerobic exercise, Elliot and colleagues (1992) investigated the difference in EPOC between aerobic cycling (40 minutes at 80% heart rate max), circuit resistance training (4 sets, 8 exercises, 15 reps at 50% 1RM) and heavy resistance training (3 sets, 8 exercises, 3–8 reps at 80%–90% 1RM). Heavy resistance training produced the greatest EPOC (10.6 L, 53 calories) compared with circuit training (10.2 L, 51 calories) and cycling (6.7 L, 33.5 calories).

In a similar study by Gilette and others (1994), resistance training (5 sets, 10 exercises, 8–12 reps at 70% 1RM) elicited a significantly greater EPOC response than aerobic exercise (60 minutes at 50% VO_2max).

THE EFFECT OF INTENSITY AND TYPE OF PROGRAM

The data suggest that EPOC is distinctly influenced by the intensity of a resistance training program. A higher-intensity program has been found to elicit a greater EPOC response than a lower-intensity program when total work is kept constant. Thornton and Potteiger (2002) studied the effects on EPOC of a high-intensity workout (2 sets, 8 reps at 85% 8RM) versus a low-intensity workout (2 sets, 15 reps at 45% 8RM), keeping total work constant, and found a significantly greater EPOC with the high-intensity program (2.3 L, or 11.5 calories, versus 1.1 L, or 5.5 calories).

exercise program suggestions to maximize EPOC

Tempo Training: continuous aerobic exercise at a high intensity (70%–85% VO_2max) for 30–60 minutes (Smith & McNaughton 1993).

Long, Slow Distance Training: continuous aerobic exercise at a moderate intensity (60%–70% VO_2max) for 60–80 minutes (Gore & Withers 1990).

Split Training: two to four high-intensity exercise bouts (70%–85% VO_2max) for a period of 15–25 minutes, separated by at least 5 minutes or up to 6 hours (Kaminsky, Padjen & LaHam-Saeger 1990).

Continuous Interval Training: alternating 3-minute bouts of low-intensity (30%–40% VO_2max) and high-intensity (80–90% VO_2max) exercise for a period of 30–60 minutes (Kaminsky & Whaley 1993).

Supramaximal Interval Training: 15–20 supramaximal exercise bouts (105%–110% VO_2max) for a period of 1 minute, with 2- to 5-minute rest periods (Laforgia et al. 1997).

Heavy Resistance Training: 2–4 sets, 8–10 exercises, 3–8 reps at 80%–90% 1RM, 2- to 3-minute rest periods (Elliot et al. 1992).

Circuit Resistance Training: 2–3 circuits, 6–10 exercises, 10–12 reps at 50% 1RM, 30-second rest periods (Murphy & Schwarzkopf 1992).

The type of resistance training program is also important. In a study by Murphy and Schwarzkopf (1992), circuit resistance training (3 circuit sets, 6 exercises, 10–12 reps at 50% 1RM, 30-second rest) was compared to standard resistance training (3 sets, 6 exercises, reps to exhaustion at 80% 1RM, 120-second rest). Although the total work volume of both programs was similar, circuit resistance training elicited the greater EPOC response (5 L, 25 calories, versus 2.7 L, 13.5 calories).

EPOC and Training Status

The training status of an individual may also have an effect on EPOC. Studies are inconclusive but suggest that trained individuals recover from exercise faster than their untrained counterparts. One reason for the inconsistencies in the research is that it is difficult to match exercise intensity and total work performed for trained and untrained individuals. If matched relative to fitness level, the trained individual would be working at a higher intensity than the untrained individual. Several studies have reported a more rapid fall in EPOC (Short & Sedlock 1997) and a shorter duration of EPOC (Frey, Byrnes & Mazzeo 1993) in trained subjects. However, even though people with higher fitness levels appear to return more quickly to a pre-exercise state, the magnitude of their EPOC is still quite prominent due to their generally higher training intensities and longer exercise duration.

EPOC and Gender

Gender is another factor that may influence EPOC. Research shows that energy expenditure in women at rest and during exercise varies with the menstrual phase (Borsheim & Bahr 2003). Typically, resting energy expenditure is lowest 1 week before ovulation and highest during the 14-day luteal phase following ovulation, affecting EPOC accordingly.

Few controlled studies have been conducted to compare EPOC in men and women. Therefore the gender effect on EPOC is not completely clear at this time.

Practical Applications

Although individual responses to exercise appear to vary in terms of EPOC, the fact is that any additional caloric expenditure following exercise can add up over time and may contribute to long-term weight management. When working with clients who want to maximize energy expenditure through EPOC, focus on developing their training status so they can perform higher-intensity exercise for periods of 30 minutes or more. In addition, regularly incorporate interval training workouts, as this type of training positively enhances EPOC. Most of the current literature supports exercise intensities at or above 70% of VO_2max for optimal energy expenditure following exercise. Additionally, encourage clients to engage in resistance training at least twice a week. Not only will resistance training maintain or increase muscle mass in weight management interventions, but studies also report a meaningful EPOC effect following high-intensity and circuit resistance training.

Chantal A. Vella, PhD, recently earned her doctorate in exercise science from the University of New Mexico at Albuquerque (UNMA). She is certified as an ACSM Health Fitness Instructor and an American Red Cross Community Instructor. Vella has over 10 years' experience in the fitness industry as a fitness club manager, wellness coordinator, and university lecturer in exercise science and health promotion.

Len Kravitz, PhD, is senior exercise physiologist for IDEA, as well as the coordinator of exercise science and a researcher at UNMA, where he won the 2004 Outstanding Teacher of the Year Award.

References

Almuzaini, K.S., Potteiger, J.A., & Green, S.B. 1998. Effects of split exercise sessions on excess postexercise oxygen consumption and resting metabolic rate. *Canadian Journal of Applied Physiology, 23* (5), 433–43.

Bahr, R., & Sejersted, O.M. 1991. Effect of intensity of exercise on excess postexercise oxygen consumption. *Metabolism, 40* (8), 836–41.

Bahr, R., et al. 1987. Effect of duration of exercise on excess postexercise oxygen consumption. *Journal of Applied Physiology, 62* (2), 485–90.

Børsheim, E., & Bahr, R. 2003. Effect of exercise intensity, duration and mode on post-exercise oxygen consumption. *Sports Medicine, 33* (14), 1037–60.

Chad, K.E., & Wenger, H.A. 1988. The effect of exercise duration on the exercise and post-exercise oxygen consumption. *Canadian Journal of Sport Science, 13* (4), 204–7.

Elliot, D.L., Goldberg, L., & Kuehl, K.S. 1992. Effect of resistance training on excess post-exercise oxygen consumption. *Journal of Applied Sport Science Research, 6* (2), 77–81.

Frey, G.C., Byrnes, W.C., & Mazzeo, R.S. 1993. Factors influencing excess postexercise oxygen consumption in trained and untrained women. *Metabolism, 42* (7), 822–8.

Gilette, C.A., Bullough, R.C., & Melby, C. 1994. Postexercise energy expenditure in response to acute aerobic or resistive exercise. *International Journal of Sports Nutrition, 4,* 347–60.

Gore, C.J., & Withers, R.T. 1990. The effect of exercise intensity and duration on the oxygen deficit and excess postexercise oxygen consumption. *European Journal of Applied Physiology and Occupational Physiology, 60* (3), 169–74.

Kaminsky, L.A., Padjen, S., & LaHam-Saeger, J. 1990. Effect of split exercise sessions on excess postexercise oxygen consumption. *British Journal of Sports Medicine, 24* (2), 95–8.

Kaminsky, L.A., & Whaley, M.H. 1993. Effect of interval type exercise on excess post-exercise oxygen consumption (EPOC) in obese and normal-weight women. *Medicine in Exercise, Nutrition and Health, 2,* 106–11.

Laforgia, J., et al. 1997. Comparison of exercise expenditure elevations after submaximal and supramaximal running. *Journal of Applied Physiology, 82* (2), 661–6.

Maehlum, S., et al. 1986. Magnitude and duration of excess postexercise oxygen consumption in healthy young subjects. *Metabolism, 35* (5), 425–9.

Murphy, E., & Schwarzkopf, R. 1992. Effects of standard set and circuit weight training on excess postexercise oxygen consumption. *Journal of Applied Sport Science Research, 6* (2), 88–91.

Phelain, J.F., et al. 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), 140–6.

Quinn, T.J., Vroman, N.B., & Kertzer, R. 1994. Postexercise oxygen consumption in trained females: Effect of exercise duration. *Medicine & Science in Sports & Exercise, 26* (7), 908–13.

Sedlock, D.A. 1992. Postexercise energy expenditure after cycle ergometer and treadmill exercise. *Journal of Applied Sport Science Research, 6* (1), 19–23.

Sedlock, D.A., Fissinger, J.A., & Melby, C.L. 1989. Effect of exercise intensity and duration on postexercise energy expenditure. *Medicine & Science in Sports & Exercise, 21* (6), 662–6.

Short, K.R., & Sedlock, D.A. 1997. Excess postexercise oxygen consumption and recovery rate in trained and untrained subjects. *Journal of Applied Physiology, 83* (1), 153–9.

Smith, J., & McNaughton, L. 1993. The effects of intensity of exercise on excess post-exercise oxygen consumption and energy expenditure in moderately trained men and women. *European Journal of Applied Physiology, 67,* 420–5.

Thornton, M.K., & Potteiger, J.A. 2002. Effects of resistance exercise bouts of different intensities but equal work on EPOC. *Medicine & Science in Sports & Exercise, 34* (4), 715–22.

Withers, R.T., et al. 1991. Some aspects of metabolism following a 35 km road run. *European Journal of Applied Physiology and Occupational Physiology, 63* (6), 436–43.