

The effects of swimming and running on energy intake during 2 hours of recovery

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Objective. To determine energy intake in the 2 hrs after swimming (S) and running (R) at the same relative exercise intensity and duration ($71.8 \pm 2.5\%$ $\dot{V}O_2$ max; 45 min) to evaluate whether a difference in recovery energy intake could explain the greater body fat observed in swimmers relative to runners.

Methods. Experimental design: this was a randomized crossover design. Setting: running exercise was conducted on a motorized treadmill (Quinton) while swimming was conducted in a 45.7 m pool. Participants: eight well-trained competitive male triathletes participated in this investigation. Interventions: subjects were blinded to the purpose of the study and swam and ran on separate occasions for 45 min at $71.8 \pm 2.5\%$ of $\dot{V}O_2$ max. Subjects were then placed in a room with a variety of foods and beverages for 2 hrs after R and S. Measures: energy intake (kJ/2 hrs and kcal/2 hrs) was determined by weighing and measuring the food remaining in the room after 2 hrs of postexercise recovery. Expired gases, heart rates, and Ratings of Perceived Exertion were obtained at 15 min intervals throughout exercise. Blood samples for serum glucose and lactate were obtained preexercise and immediately, 15 min, and 135 min postexercise. Perceived hunger and thirst ratings were obtained after the subjects were seated in the room containing the food.

Results. Serum glucose was significantly ($p \leq 0.05$) higher after R compared to S immediately after exercise (5.4 ± 0.3 mmol/L for R and 4.2 ± 0.1 mmol/L for S) but no significant differences were observed for hunger using a five point Likert scale (3.3 ± 0.3 for R and 3.4 ± 0.3 for S), energy intake (4584 ± 611 kJ/2 hrs; 1095 ± 146 kcal/2 hrs for R and 4383 ± 484 kJ/2 hrs; 1047 ± 116 kcal for S) or blood lactate.

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Conclusion. The type of exercise, swimming or running, did not significantly influence energy intake during 2 hours of post-exercise recovery.

KEY WORDS: Body fat - Hunger - Blood glucose.

Competitive swimmers are frequently reported to have a significantly greater body fat percentage than competitive runners of the same caliber.¹⁻⁴ However, the energy expenditure resulting from training appears to be similar for these two groups.¹ With regard to energy intake, Jang *et al.*³ reported that energy intake assessed from a three-day diet recall was similar for collegiate swimmers and runners. Likewise, Flohr *et al.*⁵ reported that perceived hunger and energy intake assessed from a 24-hr diet recall was similar after 600 kcal swimming and running bouts. Thus, the mechanism for the greater body fat percentage of swimmers when compared to runners has been elusive.

Flynn *et al.*¹ reported that the blood glucose concentration was significantly lower after swimming when compared to running. The blood glucose concentration has been proposed to be one of the potential regulators of hunger.⁶ A decline in the blood glucose con-

centration correlates well with increases in perceived hunger in humans.⁷ In addition, attenuation of the decline in blood glucose by glucose infusion has been shown to significantly delay feeding in rats suggesting a causal relationship between the blood glucose concentration and feeding behavior.⁸ Because the blood glucose concentration is a potential regulator of hunger and feeding behavior,⁷⁻⁹ the lower blood glucose concentration after swimming could result in an increased energy intake during the postexercise period and could ultimately result in a greater relative body fat content for swimmers compared to runners. In addition to attempting to explain the discrepancy in body fat between swimmers and runners, we were also interested in adding to the available literature comparing the influence of different modes of exercise on energy intake in the hours after exercise as there are very little data available. Recently, King and Blundell¹⁰ reported no difference in energy intake in the hours after exercise when comparing cycling to running.

The purpose of this investigation was to determine the physiological responses and energy intake in the 2 hours of recovery after swimming and running at the same relative exercise intensity and same duration in male triathletes.

Materials and methods

Subjects

Eight well trained male triathletes participated in this investigation after signing an informed consent and completing a medical history form. The descriptive data for these subjects can be found in Table I. This study was approved by the University of Toledo Human Subjects Research Review Board prior to its initiation.

Preliminary testing

Subject's maximal oxygen consumption ($\dot{V}O_2\text{max}$) was determined for running and their peak oxygen consumption ($\dot{V}O_2\text{ peak}$) was determined for swimming. Running $\dot{V}O_2\text{max}$ was determined using an incremental treadmill test to exhaustion. The treadmill speed was initially set at 53.64 m/min (2 miles per hour) below the subject's self reported 10-kilometer race pace for 3 min. The treadmill velocity was increased by 26.8 m/min every three minutes for three

stages. Thereafter, the grade was increased by 2% every two minutes until fatigue. A 12-lead EKG was used to determine heart rate and to determine if the subject had any detectable cardiovascular abnormalities. Expired gases were continuously analyzed for oxygen using an Applied Electrochemistry SA-3 O_2 analyzer (Applied Electrochemistry, Sunnyvale, CA) and carbon dioxide using an Applied Electrochemistry CD-3A CO_2 analyzer (Ametek, Thermomax Instruments Division, Pittsburgh, PA). Inspired gas volumes were determined using a Rayfield flow meter (Rayfield Equipment, Waitsfield, VT). Expired gas volumes, oxygen consumption, ventilation, and the respiratory exchange ratio were determined at 30-second intervals using a computer based system (Rayfield Equipment, Waitsfield, VT). $\dot{V}O_2\text{ peak}$ for swimming was determined using four 365.8-m swims of increasing velocity. Velocity was controlled by providing underwater hand signals to the subjects every 50 meters from which they increased, decreased, or maintained their velocity the same. The subjects were asked to make the final 182.9-m of the last 365.8-m swim a maximal effort. Expired gases were obtained using a Douglas bag during 40 seconds of recovery from each swim and $\dot{V}O_2$ was determined using a backward extrapolation of the recovery oxygen consumption.¹¹⁻¹³ $\dot{V}O_2\text{ peak}$ measured directly was found to be 0.53% greater than when using the backward extrapolation, 3.81 L/min measured compared with 3.79 L/min with the backward extrapolation¹³. Percent body fat was determined using the seven site skinfold formula of Jackson and Pollock.¹⁴

Experimental testing

Subjects were asked to abstain from heavy physical exercise for 48 hours prior to the experimental trials and arrived at the laboratory after a 10 hour fast. Both trials (swimming and running) were conducted in the early morning at the same time. Upon arrival at the laboratory, subjects were weighed and after 10 min of rest in the seated position a 5-ml blood sample was obtained from an antecubital vein. The triathletes either ran on a treadmill (20.5°C) for 45 min at 0% grade at $71.4 \pm 2.0\%$ of $\dot{V}O_2\text{max}$ (R) or swam in a pool (29.5°C) for 45 min at $72.1 \pm 3.1\%$ of $\dot{V}O_2\text{max}$ (S). The order of trials was counterbalanced. Heart rate via telemetry, the rating of perceived exertion (RPE; 15), and respiratory gases were obtained at 15-min intervals during these trials. Immediately following the exercise bout subjects were seated and a blood sample was obtained

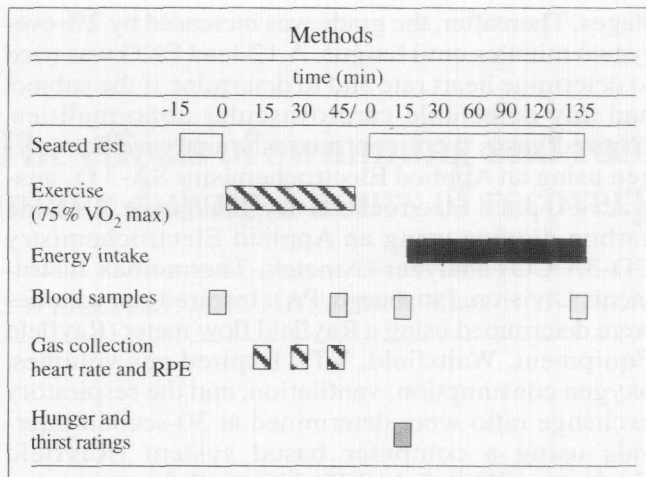


Fig. 1.—Schematic representation of the experimental trials.

from an antecubital vein. A second recovery blood sample was obtained after 15 min of recovery. Perceived hunger and thirst ratings were obtained using a five-point Likert scale after the subjects were seated in the room containing food. These questions on hunger and thirst were within a survey that contained other questions related to exercise effort, muscle soreness, mood, fatigue level etc. The subjects were then weighed and taken to a separate room which contained approximately 20,930 kJ (5000 kcal) of food and beverages. Subjects were kept in the room containing the food and beverages for 2 hours after which a final blood sample was obtained. The food ranged from high-fat selections such as chocolate and potato chips to low-fat selections such as fat-free cereal bars and pretzels. Beverages ranged from water, to cola, and a commercially available rehydration solution. The subjects were blinded to the purpose of the study. The heart rate monitor was kept on the subjects and they were informed that physiological variables would be monitored during the recovery period. The subjects were also told that money was not available to pay them and so the food in the room was their "reward" for participating in the study and that they should "help themselves". After the 2 hrs blood sample, subjects were dismissed and the food and beverages were carefully measured. Energy intake (kJ and kcal) was calculated using the Nutritionist IV software package. A schematic representation of the experimental trials is provided in Figure 1.

TABLE I.—Descriptive statistics ($n=8$).

Parameters	Values
Age (yrs)	31±8
Height (cm)	177.1±7.1
Weight (kg)	73.1±7.0
Swimming $\dot{V}O_2$ max (l/min)	3.8±0.6*
Running $\dot{V}O_2$ max (l/min)	4.7±0.6
% body fat	9.5±2.8

$\bar{X}\pm SD$; * $p<0.05$.

TABLE II.—Selected physiological and perceptual responses during the experimental trials.

Parameters	Values
Percent of $\dot{V}O_2$ max during exercise	
Swim	72.1±3.1
Run	71.4±2.0
Absolute $\dot{V}O_2$ during exercise (l/min)	
Swim	2.69±0.11*
Run	3.33±0.16*
Rating of perceived exertion (RPE)	
Swim	12.0±0.4
Run	13.2±0.6
Heart rate (bpm)	
Swim	134±6*
Run	158±4*

*) $p<0.05$.

Blood analyses

Blood was analyzed for lactate and serum glucose concentrations. Immediately after obtaining the blood sample, blood for lactate determination was deproteinated in chilled 8% perchloric acid (HClO₄). Serum glucose concentration was determined using the glucose oxidase method (YSI 23L; Yellow Springs Instruments; Yellow Springs OH) while the lactate concentration was determined using a method obtained from a commercially available kit (Sigma procedure 826-UV).

Statistics

Statistical analysis was by one-way repeated measures ANOVA on the energy intake data, swimming $\dot{V}O_2$ peak and running $\dot{V}O_2$ max (Table I) the Physiological and Perceptual Responses (Table II), the perceived hunger, and perceived thirst. A two-way ANOVA with repeated measures on both the exercise type (swim or run) and time (Pre, Post, 15 min Post, 2 hrs Post) factors was performed on the blood lactate (Fig. 2) and blood

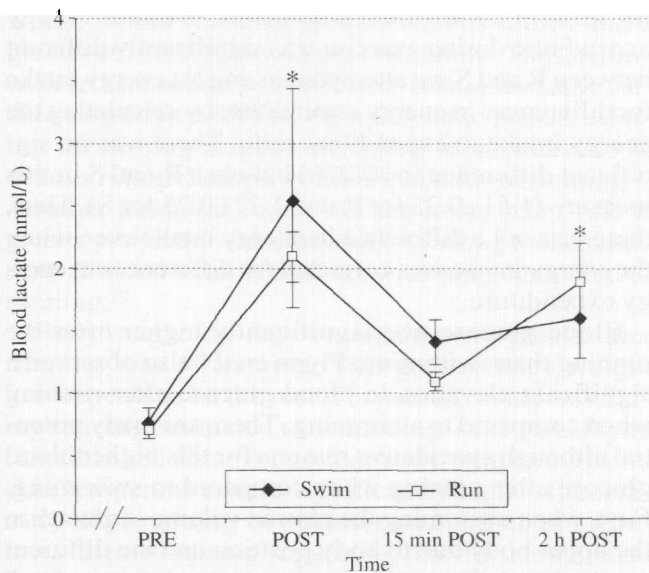


Fig. 2.—The blood lactate concentration (mmol/L). A significant ($p < 0.05$;*) time effect was observed with the POST value being significantly higher than the PRE value. In addition, the 2H POST value was significantly higher than the PRE value.

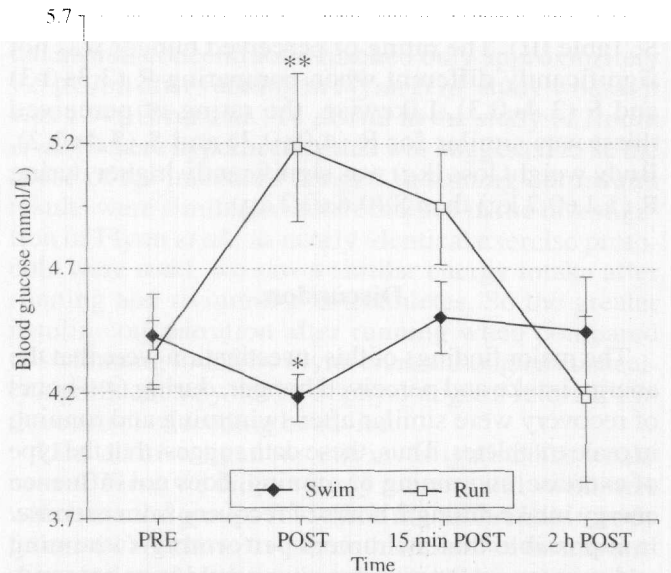


Fig. 3.—The blood glucose concentration (mmol/L). A significantly lower (*) blood glucose concentration was observed when comparing the POST value for the Swim to the POST value for the Run. In addition, there was a significantly greater (**) blood glucose concentration for POST for the Run than PRE for the Run.

glucose (Fig. 3) data. When a significant F ratio was found, and where appropriate, a Newman-Keuls posthoc test was used. The probability level was set at 0.05.

Results

The percentage of maximal oxygen uptake (l/min) was similar during S and R (72.1 ± 3.1 and $71.4 \pm 2.0\%$ for S and R, respectively; Table II). The absolute $\dot{V}O_2$ was significantly higher during R than S (3.33 ± 0.16 l/min for R and 2.69 ± 0.11 l/min for S; Table II). In addition, the energy expenditure was significantly greater on the R trial than the S trial (3056 ± 143 kJ; 730 ± 34 kcal for R and 2548 ± 102 kJ; 609 ± 24 kcal for S; Table III). The heart rate during exercise (mean of the 15-min, 30-min, and 45-min samples) was significantly higher during R (158 ± 4 beats/min; bpm; Table II) than during S (134 ± 6 bpm). The ratings of perceived exertion (RPE) were similar for S (12.0 ± 0.4 ; Table II) and R (13.2 ± 0.6).

The blood lactate concentration increased as a result of exercise (time effect) but was not different between the groups at any time (Fig. 2). The difference in blood glucose concentration between R and S was not statistically significant pre-exercise (PRE; Fig. 3), 15 min

TABLE III.—Energy intake, energy expenditure, and energy intake/energy expenditure ratio.

Mode	Energy intake (kJ/kcal)	Energy expenditure (kJ/kcal)	Energy intake/ Energy expenditure
Run	$4584 \pm 611 / 1095 \pm 146$	$3056 \pm 143 / 730 \pm 34$	1.51 ± 0.22
Swim	$4383 \pm 484 / 1047 \pm 116$	$2548 \pm 102 / 609 \pm 24$	1.77 ± 0.25

after exercise (15 min POST), and 2 hours after exercise (2H POST). However, blood glucose was significantly higher for R than S immediately after exercise (POST). In addition, the value obtained immediately after exercise (Post) for R was significantly higher than the Pre value for R.

Total energy intake during 2 hours of recovery was not significantly different when comparing R to S trials (4584 ± 611 kJ/2 hrs; 1095 ± 146 kcal/2 hrs for R and 4383 ± 484 kJ/2 hrs; 1047 ± 116 kcal/2 hrs for S, respectively; Table III). Because energy expenditure during exercise was significantly different between R and S we attempted to correct energy intake for differences in energy expenditure by calculating the energy intake to energy expenditure ratio. There was no significant difference ($p = 0.226$) between R and S

in this measure (1.51 ± 0.22 for R and 1.77 ± 0.25 for S; Table III). The rating of perceived hunger was not significantly different when comparing R (3.3 ± 0.3) and S (3.4 ± 0.3). Likewise, the rating of perceived thirst was similar for R (4.0 ± 0.3) and S (3.4 ± 0.2). Body weight loss (kg) was significantly higher during R (1.1 ± 0.2 kg) than S (0.6 ± 0.2 kg).

Discussion

The major findings of this investigation were that the energy intake and perceived hunger, during two hours of recovery were similar after swimming and running in male triathletes. Thus, these data suggest that the type of exercise, swimming or running, does not influence energy intake during 2 hours of recovery from exercise. It is possible that swimmers performing swimming and runners performing running would have responded differently. However, Flohr *et al.*⁵ found no difference in perceived hunger or energy intake (24-hr diet recall) after 600 kcal energy expenditure as a result of running in trained runners and swimming in trained swimmers. In addition, Flynn *et al.*¹ found glucose and other responses of swimmers to be similar to triathletes while swimming and runners responded similarly to triathletes while running. The absolute $\dot{V}O_2$ (l/min) was significantly different when comparing running (3.33 ± 0.16 l/min) to swimming (2.69 ± 0.11 l/min) trials (Table II) as was energy expenditure (3056 ± 143 kJ; 730 ± 34 kcal for R and 2548 ± 102 kJ; 609 ± 24 kcal for S). However, the purpose of this study was to compare the energy intake after swimming and running at the same relative exercise intensity (72.1% for S and 71.4% for R) for the same duration. To equate the energy expenditure between R and S, subjects would have to have had to exercise 20% longer (~9 min) during S. It is unclear what this large difference in exercise duration would have done to energy intake. A comparison of energy intake between swimming and running after equivalent energy expenditure is a potential topic for a different investigation. It could be argued that with a greater energy expenditure in the running trial there would be a greater energy intake during recovery. However, Kisseleff *et al.*¹⁶ reported that when subjects exercised on a cycle ergometer at 90 watts for 40 min energy intake was significantly lower than when subjects exercised at 30 watts for 40 min despite the much greater energy expenditure for the 90 watts

for 40 min condition. In addition, because energy expenditure during exercise was significantly different between R and S we attempted to correct energy intake for differences in energy expenditure by calculating the energy intake to expenditure ratio. There was no significant difference ($p=0.226$) between R and S in this measure (1.51 ± 0.22 for R and 1.77 ± 0.25 for S). Thus, there was not a difference in energy intake even when the energy intake was corrected for differences in energy expenditure.

Blood glucose was significantly higher after the running than swimming. Flynn *et al.*¹ also observed a significant elevation in blood glucose after running when compared to swimming. There are many potential although speculative reasons for this higher blood glucose after running when compared to swimming. First, when swimming the plasma volume is greater in the upper body due to body position and the different gravitational effects of being in water vs being on land. This will dilute the blood with plasma and thus reduce the glucose concentration while the subject is in water relative to being on land. In addition, the forearm is actively pulling against the water during swimming. The forearm is extracting glucose from the blood to provide energy for muscular contraction. This would likely reduce the blood glucose in swimming relative to running when blood is sampled from an antecubital vein.

As expected there was a time effect with regard to blood lactate. Thus, both modes of exercise at a similar relative exercise intensity resulted in a similar elevation in blood lactate. Interestingly, the blood lactate concentration was approximately ~1.3 fold greater 2H POST relative to the pre-exercise value. It appears this was an effect of feeding. Likewise, Kerckhoffs *et al.*²¹ found large elevations in arterialized blood lactate (~140%), adipose tissue lactate, and muscle lactate after 75 min after ingestion of 75 g of glucose. In addition, Hagstrom *et al.*²² observed an ~82% increase in plasma lactate 90 min after the ingestion of 75 g of glucose. Thus, it appears that glucose feeding results in an elevation in lactate presumably from muscle tissue, adipose tissue and possibly other tissues.

The heart rate during swimming (134 ± 6 bpm) was significantly lower than the heart rate during running (158 ± 4 bpm). Similar results have been found by others^{1,18} and there are a number of plausible explanations for this phenomenon. First, swimmers while performing the front crawl stroke are in the prone position

which would result in greater venous return and a greater stroke volume during swimming. Thus, a lower heart rate would be required to obtain the same cardiac output. In addition, the hydrostatic pressure during swimming might also result in an increase in venous return during swimming relative to running.¹⁷ Another potential source for the lower heart rate is greater peripheral vasoconstriction leading to increased central blood volume during swimming compared to running.¹⁹

Body weight loss (kg) was significantly greater after running than swimming. This greater body weight loss appears to be the result of greater sweat loss during running compared to swimming. Likewise, Flynn (unpublished data) found that body temperature and skin temperature were significantly higher immediately after running in trained runners than in swimmers after swimming suggesting that the thermal load is greater after running than swimming.

It has been hypothesized since the early 1950s that the blood glucose concentration is one of the potential regulators of hunger.⁶ It has been reported that the decline in blood glucose correlates well with the increase in perceived hunger in humans⁷ and with an increase in feeding behavior in rats.^{8,9} In addition, attenuation of the decline in blood glucose by glucose infusion has been shown to significantly delay feeding in rats suggesting a causal relationship between the blood glucose concentration and feeding behavior.⁸ Chapman *et al.*²³ found when blood glucose was elevated (~9.3 mmol/l) relative to controls (~5.25 mmol/l) there was a significant (~15%) reduction in feeding behavior in humans. We did not observe a decline in blood glucose following the swim trial. We did, however, see a significantly lower blood glucose concentration for the swim when compared to the run immediately after exercise (Post). It does not appear, from our perceived hunger and energy intake results that the lower blood glucose concentration in the swim trial post exercise (Post), relative to that attained in the run trial, resulted in greater hunger or energy intake. Evidence provided by Rodin *et al.*²⁰ suggests that hyperinsulinemia, in addition to, or rather than hypoglycemia, may be a primary factor responsible for increased hunger. We do not have insulin data for the present study; however, Flynn *et al.* (unpublished data) found that the insulin concentration was significantly higher for triathletes after running than swimming at 15 and 30 minutes using an exercise protocol similar

to the one used in the present investigation. However, the insulin concentration reached only approximately 9.5 μ U/ml after running in Flynn *et al.* study whereas it was 134 μ U/ml and 114 μ U/ml in the study of Rodin *et al.*²⁰ where hyperinsulinemia was suggested to be the cause of the increased hunger. Assuming our insulin results were similar to those obtained in the investigation of Flynn *et al.*, as nearly identical exercise protocols were used, we saw a similar energy intake after running and swimming in triathletes. So the greater insulin concentration after running when compared to swimming found by Flynn *et al.* although statistically significant may not be of physiological relevance in the control of feeding behavior.

Like all investigations this investigation has weaknesses. First, we did not study runners and swimmers which are the groups for which the difference in body fat exists. We chose to use triathletes rather than swimmers and runners because we wanted to examine the effect of mode of exercise on energy intake. In addition, the repeated measures design used in this investigation is very statistically precise (ability to locate a significant difference if one is present) way of examining the effect of mode of exercise on energy intake.

A second weakness of this study was that we only examined short term food intake. We chose to measure only short term food intake because providing them with food and actually measuring food intake is likely more accurate than having subjects perform dietary recalls. Food intake from dietary recalls is usually underreported. Also, we were interested in short term food intake as we thought a difference might exist in the short term which was not observed over longer periods of time.^{3,5}

It could also be argued that a weakness of the study was that the "help yourself" situation with regard to the subjects' feeding is artificial. However, we thought that this was the best way to answer our question of interest. Dietary recalls are not accurate and we wanted to assess *ad libitum* food intake. We believed the best way to do this was to provide the subjects with food as it is probable that many of the subjects would not have ate/drank in an *ad libitum* manner due to time constraints or limited access to food.

Conclusions

In conclusion, under the conditions of this investigation, there was no difference in energy intake in the

two hours of recovery from swimming when compared to running which lends evidence suggesting that a difference in energy intake in the two hours after swimming and running is not the operative mechanism for the greater body fat percentage in swimmers compared to runners.

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