Optimizing Nutrient Intake During Recovery from Aerobic Exercise

John L. Ivy, PhD
Teresa Lozano Long Endowed Chair Emeritus
Department of Kinesiology and Health Education
University of Texas at Austin

1

Post Exercise Nutrition for Aerobic Exercise

- Post exercise the body is highly responsive to nutrient intervention.
- Consuming the appropriate types and amounts of nutrients immediately to 45 minutes after an acute bout of exercise can:

increase rate of rehydration
increase the rate of muscle glycogen storage
reduce muscle damage and soreness
increase rate of recovery
increase protein accretion
increase training adaptation

2

Rehydration Post Exercise

3

3

Retention of Fluid Replacement

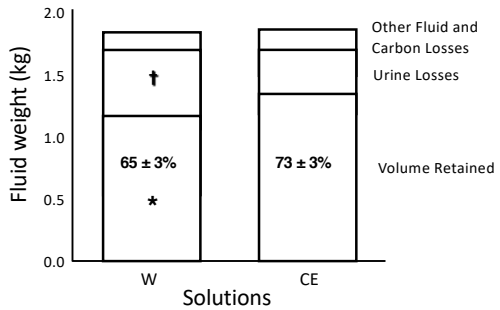
Experimental Protocol

- Exercised subjects in heat until 1.8 L of fluid loss (~ 2.5% of body mass)
- 30 min of passive recovery
- Replaced 0.9 L of fluid with water or a carbohydrate-electrolyte solution (Glucose, NaCl, KCl)
- 45 minutes later replaced final 0.9 L of fluid
- Fluid recovery was followed for the next 2 hours

González-Alonso, Heaps & Coyle, Int. J. Sports Med 13 (1992).

4

Fate of the Ingested Volume (n=19)



González-Alonso, Heaps & Coyle, Int. J. Sports Med 13 (1992).

5

Effect of a Carbohydrate/Protein Supplement on Rehydration

6

Experimental Design

Subjects exercised to dehydrate by 2.5% of body weight.

Immediately after exercise subjects consumed one of three liquid supplements equivalent to weight loss:

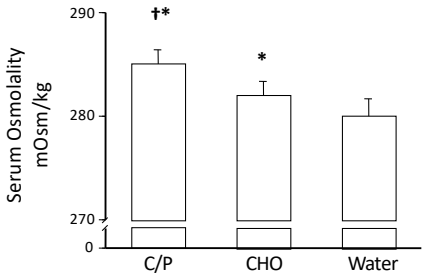
1. Carbohydrate/protein 6g CHO, 1.75g PRO, 45.8 mg Na
2. Carbohydrate 6g CHO, 45.8 mg Na
3. Water

Monitored recover for 3 hours.

Seifert J et al. IJSNEM 16: 420-429, 2006

7

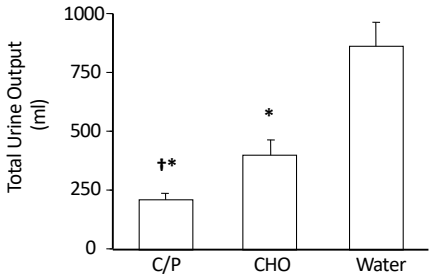
Serum Osmolality



Seifert J et al. IJSNEM 16: 420-429, 2006

8

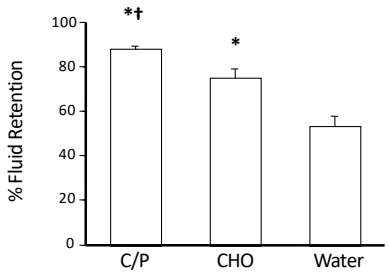
Total Urine Output



Seifert J et al. IJSNEM 16: 420-429, 2006

9

Fluid Retention



Seifert J et al. IJSNEM 16: 420-429, 2006

10

Experimental Design

Subjects exercised to dehydrate by 1.8% of body weight.

Immediately after exercise subjects consumed one of four liquid supplements equivalent to 150% sweat rate:

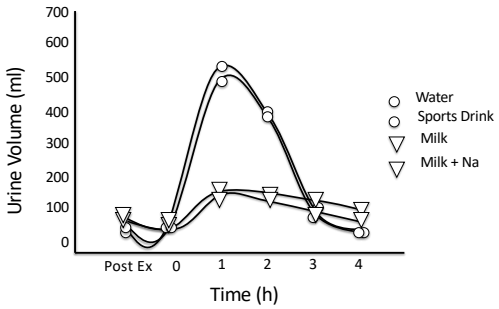
1. Low-fat milk, 50g CHO/L, 36g PRO/L, 38 mmol/L Na
2. Low-fat milk, 50g CHO/L, 36g PRO/L with 20 mmol/L Na added (total 58 mmol/L)
3. Sports Drink, 60g CHO/L, 23 mmol/L Na
4. Water

Monitored recover for 4 hours.

Shirreff SM et al. Bri J Nutr 98:173-180, 2007

11

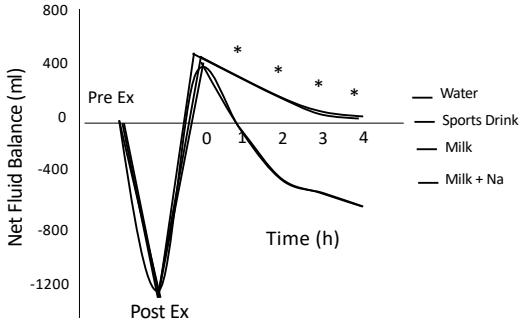
Urine Volume During Recovery



Shirreff SM et al. Bri J Nutr 98:173-180, 2007

12

Net Fluid Balance



Shirreff SM et al. Bri J Nutr 98:173-180, 2007

13

Summary

- Rehydration post exercise requires consuming about 1.5 times the volume of fluid loss
- The addition of electrolytes with fluid consumption helps with fluid retention
- The added addition of protein or amino acids to an electrolyte replacement drink will increase fluid retention.
- Fat free milk, which contains CHO, PRO, and electrolytes, is actually an appropriate rehydration drink and also has additional benefits for recovery over that of a traditional sports drink.

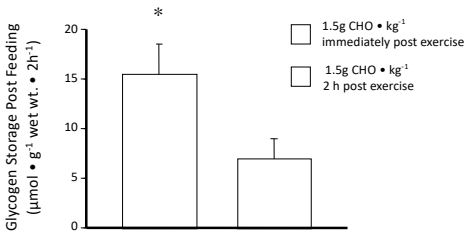
14

Rapid Muscle Glycogen Replenishment

15

Timing of Supplementation for Rapid Glycogen Synthesis

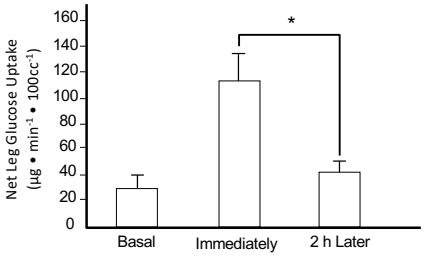
16



Ivy et al. J Appl Physiol 64:1480-1485, 1988.

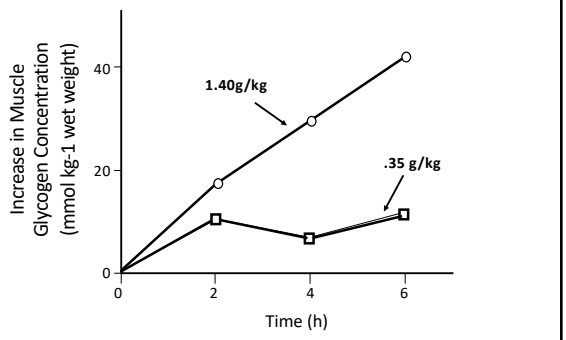
17

Muscle Glucose Uptake



Levenhagen et al. Am J Physiol Endocrinol Metab 280:E982-E993, 2001

18

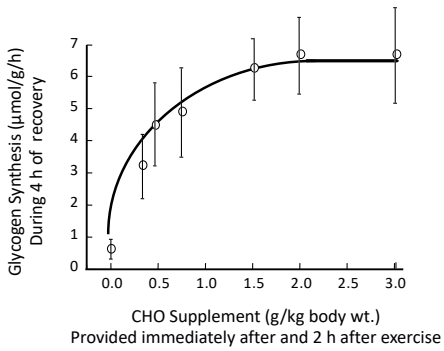


Blom PCS et al. MSSE 19:491-496, 1987.

19

Amount of Carbohydrate Supplementation

20

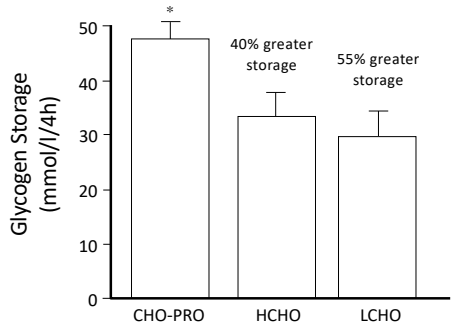


Ivy JL. J Sports Med 19:S142-S145, 1998.

21

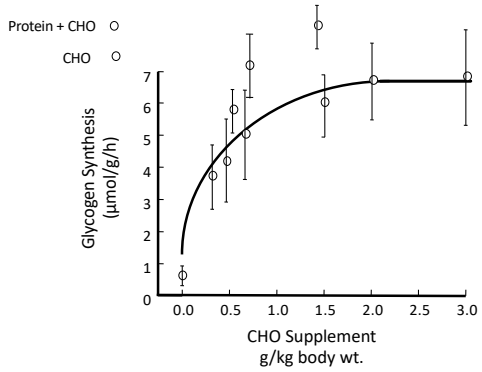
Increase Glycogen Storage with Added Protein

22



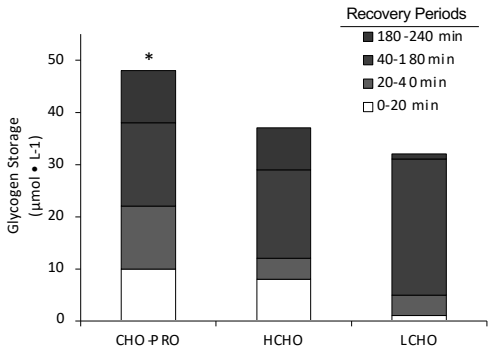
Ivy JL et al. J Appl Physiol 93:1337-1344, 2002

23



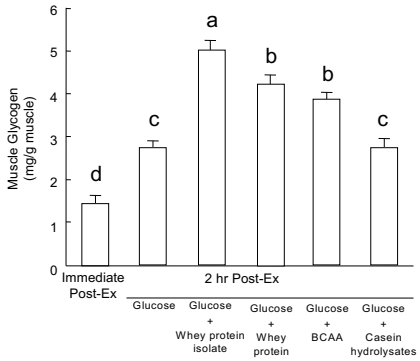
Ivy JL. J Sports Med 19:S142-S145, 1998.

24



Ivy et al. J Appl Physiol 93:1337-1344, 2002

25



Morifuji M. et al. Amino Acids 38:1109-1115, 2010.

26

SuperStarch and Muscle Glycogen Synthesis

27

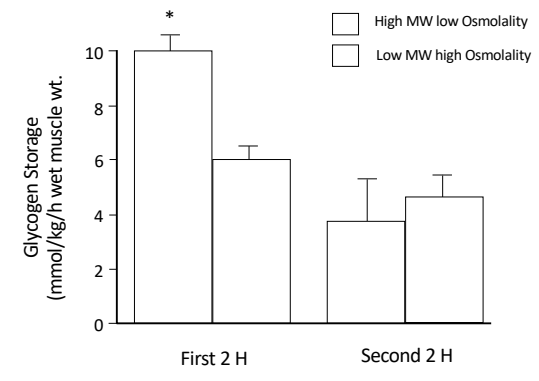
Experimental Protocol

- The rate of muscle glycogen synthesis during 2 and 4 h of recovery after depletion by exercise was studied in 13 trained volunteers.
- Treatments: energy equivalent carbohydrate drinks

  polyglucoside – High molecular weight/low osmolarity - mean molecular mass of 500,000 (84 mosmol/L)

  monomers and oligomers of glucose – Low molecular weight/high osmolarity - molecular mass of approximately 500 (350 mosmol/L)
- The total amount of carbohydrates consumed was 300 g (4.2 g/kg) body mass given as 75 g in 500 ml water immediately after exercise and again 30, 60 ad 90-min post exercise.

28



Aulin K, et al. Eur J Appl Physiol 81:346-351, 2000.

29

Muscle Glycogen Storage with Caffeine and Carbohydrate Supplementation

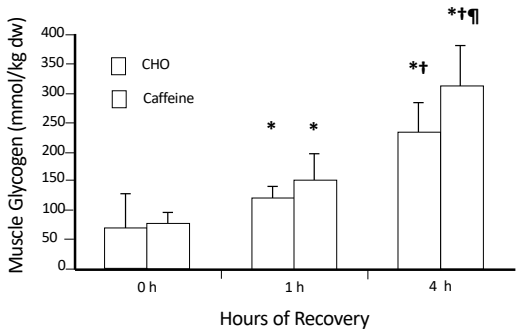
30

Experimental Protocol

- The effect of co-ingestion of caffeine with carbohydrate on rates of muscle glycogen resynthesis during recovery from exhaustive exercise was investigated.
- Subjects cycled to exhaustion to deplete muscle glycogen stores.
- Subjects then consumed either CHO (4 g/kg body mass) or the same amount of CHO plus Caffeine (8 mg/kg body mass) during 4 h of passive recovery.
- CHO was consumed within 5 min of the cessation of exercise and again after 60, 120, and 180 min.
- Caffeine was administered in two equal doses immediately after exercise and after 2 h of recovery.

Pedersen DJ et al. J Appl. Physiol. 105:7-13,2008.

31



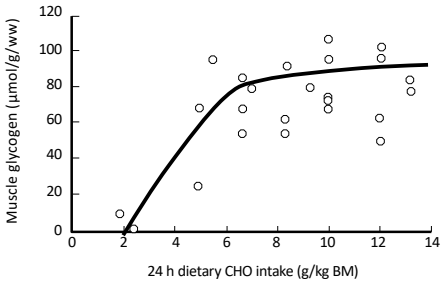
Pedersen DJ et al. J Appl. Physiol. 105:7-13,2008.

32

Replenishing Glycogen Stores Over 24 Hours

33

Glycogen Recovery in 24 Hours



Ivy JL. The Encyclopedia of Sports Medicine Vol XIX, Sports Nutrition. 2013, pg 113-125.

34

Summary

For rapid muscle glycogen replenishment after exercise:

- Carbohydrate consumption should start as soon as possible.
- About 1.5g/kg body wt. of carbohydrate should be provided at 2 h intervals for the first 4 h of recovery.
- The addition of protein (2.5:1 up to a 3.5:1 ratio of CHO to PRO) will help increase the rate of glycogen storage.
- The protein should be rapidly digestible such as whey isolate. Slow digestible proteins such as casein do not work as well.
- The addition of caffeine to a post exercise CHO supplement may also increase the rate of muscle glycogen recovery.
- To maximize muscle glycogen storage over a 24 h period, one must consume between 7 to 8 g of CHO/kg body wt. over the first 18 hours of recovery.

35

CHO/PRO Supplementation Reduces Muscle Damage

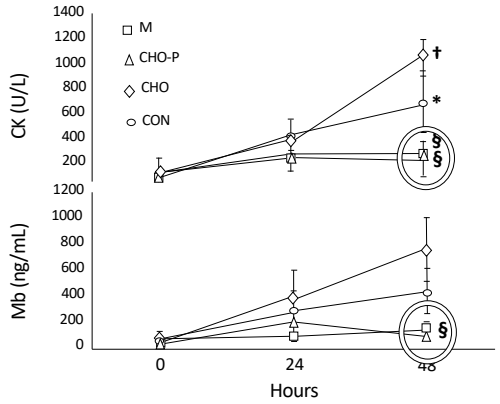
36

Experimental Protocol

- Subjects (n = 24) were 21 ± 3 yr old and randomly assigned to 1 of 4 treatment groups: CHO/PRO, Milk, CHO or Water.
- Exercise to induce muscle damage was 6 sets of 10 repetitions concentric/eccentric contractions on a Cybex Dynamometer.
- Within 10 min after the completion of exercise the subjects consumed 500 ml of their supplement and another 500 ml at 2 h post exercise.

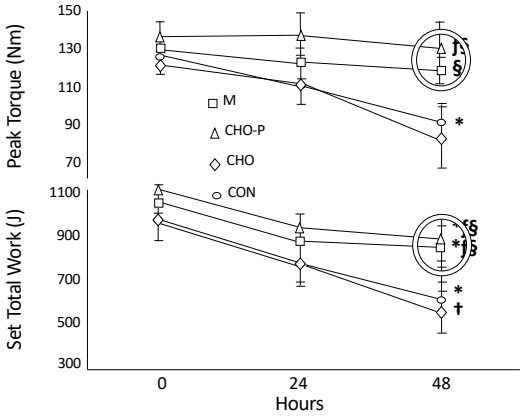
Cockburn E., et al. Appl Physiol Nutr Metab 33: 775-783, 2008

37



Cockburn E., et al. Appl Physiol Nutr Metab 33: 775-783, 2008

38



Cockburn E., et al. Appl Physiol Nutr Metab 33: 775-783, 2008

39

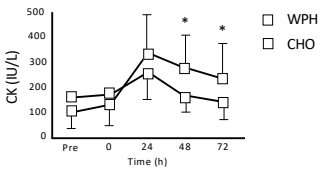
Experimental Protocol

- This study sought to determine if whey protein can reduce muscle damage and increase the rate of recovery in females following aerobic exercise along with repeated-sprint exercise.
- Twenty physically active females were assigned to consume 1 dose of 70 mL whey protein hydrolysate (WPH – 20 g) or isoenergetic carbohydrate supplement (CHO – 20 g) post exercise, and one dose 2 hours after exercise. Then one dose of each supplement was consumed each day of recovery.
- Measures of muscle soreness, flexibility, muscle function, and creatine kinase were collected before, immediately after, and 24, 48, and 72 h postexercise.

Brown MA et al. Appl Physiol Nutr Metab 43:324-330, 2018.

40

Results



- WPH attenuated the rise in blood CK during recovery.
- Delayed onset muscle soreness tended to be lower with the WPH treatment vs. the CHO treatment.
- By the 4th day of recovery muscle flexibility of the legs had returned to normal with the WPH treatment but remained significantly suppressed during the CHO treatment.
- Relative to the CHO treatment, the WPH treatment significantly suppressed the loss of muscle strength during recovery.

Brown MA et al. Appl Physiol Nutr Metab 43:324-330, 2018.

41

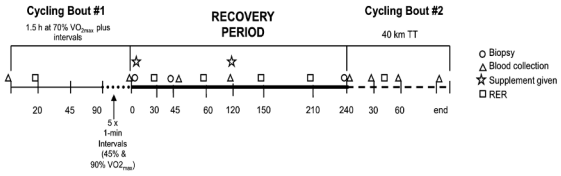
Effect of CHO/PRO on Exercise Recovery Performance

42

Experimental Design

Treatments:	CHO (g)	PRO (g)	FAT (g)	Energy (kcals)
Chocolate milk	11.5	3.7	2.0	79.1
Carbohydrate	15.2	0	2.0	79.1
Placebo	0	0	0	0

*Values are per 100 ml of fluid



Ferguson-Stegall L E et al. J Strength Cond Res 25:1210-1224, 2011.

43

Energy and macronutrient composition of the recovery beverages.

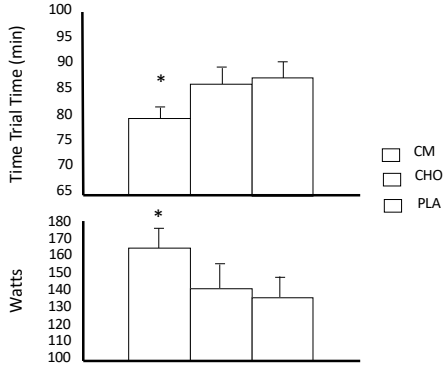
	CM	CHO	PLA
CHO, g/100 mL	11.48	15.15	0
PRO, g/100 mL	3.67	0	0
Fat, g/100 mL	2.05	2.05	0
Kcals/100 mL	79.05	79.05	0
Ratio of CHO:PRO	3.12:1	--	--

Per 100 ml: CM, chocolate milk; CHO, carbohydrate + fat; PLA, placebo.

Ferguson-Stegall L E et al. J Strength Cond Res 25:1210-1224, 2011.

44

Time Trial Performance



Ferguson-Stegall L E et al. J Strength Cond Res 25:1210-1224, 2011.

45

Oslo Study on Recovery of Performance - I

Effect of dietary intake of carbohydrate and protein during the first 2 h after exhaustive cycling on performance 18 h later.

Diet-controlled, randomised, cross-over design

Isocaloric diets:

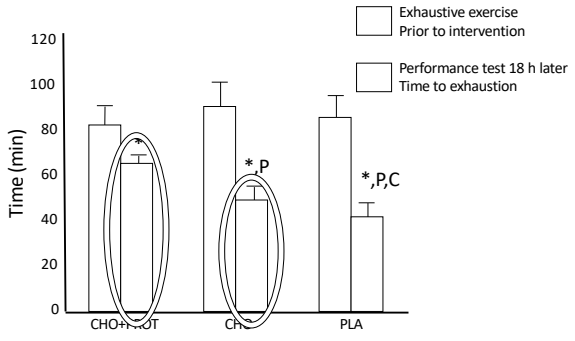
1) Carbohydrate (CHO):
   1.2 g CHO $kg^{-1} \cdot h^{-1}$
   (*0.6 g CHO $kg^{-1} \cdot 30\ min^{-1}$*)
2) Carbohydrate-protein (CHO+PROT):
   0.8 g CHO + 0.4 g PROT $kg^{-1} \cdot h^{-1}$
   (0.4 g CHO + 0.2 g PROT $kg^{-1} \cdot 30\ min^{-1}$)
3) Low caloric diet:
   No energy intake the first 2 h after exhaustive exercise (65 % reduction in caloric intake: 3,124 versus 2,017 kcal during 18 h).

Subjects (Cycling was part of their training): Age (24±0.4 y); height (182±2); weight (75±3 kg); VO_{2max} (69.6±1.3 ml·kg^{-1}·min^{-1}). N=8

Rustad PI et al. PLoS ONE 2016 Apr 14;11(4):e0153229

46

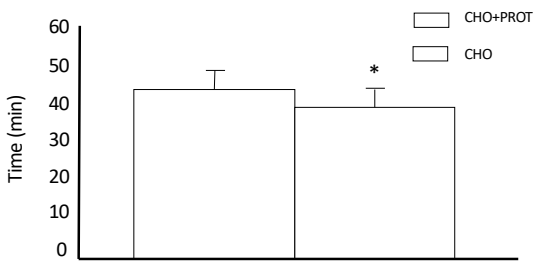
Performance 18 h After Exhaustive Exercise



Rustad PI et al. PLoS ONE 2016 Apr 14;11(4):e0153229

47

Whey intake immediately after exhaustive exercise improves TT performance 18 h later – Study 2



Sollie et al. J Appl Physiol 2018 Sep 13. doi: 10.1152.

48

Summary

- CHO/PRO recovery drinks consumed over the first 2 h of recovery are more effective in reducing muscle damage than consuming CHO recovery drinks.
- CHO/PRO recovery drinks consumed during the first 2 h of recovery enhance the rate of recovery more effectively in the short term and over a 24 h period than CHO recovery drinks.
- Recovery drinks can be spaced 30 min, 60 min or 120 min apart but should start as soon after exercise as possible.
- Over the first 2 hours of recovery CHO intake should be ~0.8 g/kg body wt./h and PRO ~0.3 g/kg body wt./h.
- Fat free chocolate milk makes an excellent post exercise recovery drink.

49

CHO/Protein Supplementation on Aerobic Training Adaptation

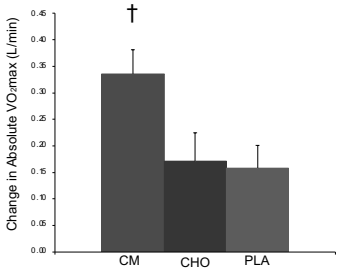
50

Experimental Protocol

- N = 32 untrained subjects
- Cycled 60 min/d, 5 d/wk. for 5 wks. at 75–80% of maximal oxygen consumption (VO_2max)
- Treatments
  - Carbohydrate/protein supplement in the form of chocolate milk (CM)
  - Isocaloric carbohydrate (CHO) supplement
  - Placebo
- Supplements were ingested immediately and 1 h after each exercise session

51

Maximal Oxygen Consumption



% increase, absolute:

- All: 8.3%
- CM: 12.5%
- CHO: 6.5%
- PLA: 6.0%

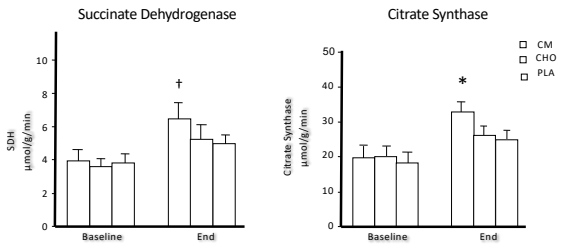
% increase, relative:

- All: 9.1%
- CM: 14.3%
- CHO: 6.4%
- PLA: 6.5%

Ferguson-Stegall et al. J Nutr Metab 2011:623182. doi:10.1155/2011/623182.

52

Muscle Oxidative Capacity

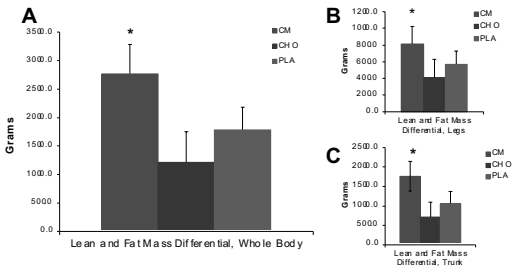


Ferguson-Stegall et al. J Nutr Metab 2011:623182. doi:10.1155/2011/623182.

53

Body Composition Changes

+ 1121 g lean mass - (- 1135 g fat mass) = 2256 g whole body differential



Ferguson-Stegall et al. J Nutr Metab 2011:623182. doi:10.1155/2011/623182.

54

Experimental Protocol

- N = 14 (mean age 68 ± 5 yr) randomly assigned to a CHO/PRO (N=7) or Control (N=7) treatment group
- Workouts were cycling 60 min per day (4 X 15 min sessions with 5 min rest between sessions) 3 days per week for 8 weeks
- CHO/PRO supplementation was provided within 10 min post exercise. Control received a low carbohydrate supplement

Okazaki, K et al. J Appl Physiol 107:725-733, 2009.

55

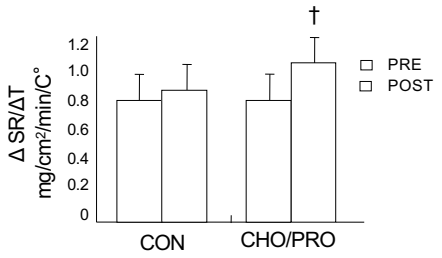
RESULTS

PHYSIOLOGICAL CHANGES	CONTROL	CHO/PRO
VO2peak	3.3%	6.8%
Blood Volume	0%	3.6%
Plasma Volume	0%	5.8%
Total Protein	0%	6.6%
Total Albumin	<1%	6.4%
Osmolality	<1%	4.9%

Okazaki, K et al. J Appl Physiol 107:725-733, 2009.

56

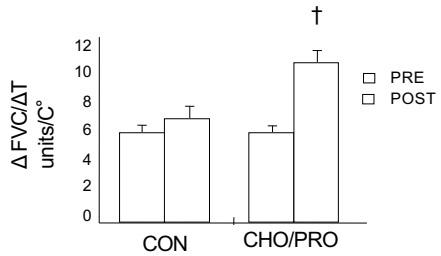
Sweat Rate per Change in Temperature At 60% VO_2max



Okazaki, K et al. J Appl Physiol 107:725-733, 2009.

57

Vascular Conductance per Change in Temperature At 60% VO_2max



Resulted in a greater sweat rate and lower rise in core temperature

Okazaki, K. et al. J Appl Physiol 107:725-733, 2009.

58

Summary

- Post exercise the body is highly responsive to nutrient intervention.
- Rehydration should start soon after exercise and the drink should be composed of water as a base, and contain an appropriate amount of electrolytes (Na, Cl, K, Mg).
- The addition of protein will help with fluid retention and improve the rate of rehydration.
- For rapid muscle glycogen resynthesis CHO consumption should start as soon as possible after exercise (~1.5g/kg body wt.) and be provided at 2 h intervals for the first 4 h of recovery.
- To maximize muscle glycogen storage over a 24 h period, one must consume between 7 to 8 g of CHO/kg body wt. over the first 18 hours of recovery. It may be helpful to start the supplementation at 2 hour intervals for the first 2 to 4 hours of recovery.
- A CHO/PRO recovery (0.8 g CHO – 0.4 g PRO/kg body wt./h) drink consumed during the first 2 h of recovery is more effective in reducing muscle damage and accelerating exercise recovery in the short term and over a 24 h period than consuming a CHO recovery drink.
- A CHO/PRO recovery drink promotes muscle protein synthesis faster than a CHO recovery drink, thus accelerating aerobic training adaptation and improving body composition.

59