BEFORE WE START

- **Questions** during the webinar?
- **CEC Credit –** will be emailed in 1-2 days
- **#ACSMwebinar** – join the conversation on Twitter about today's webinar using this hashtag
- ACSM moderator- **Dr. Lynn Cialdella-Kam,** Assistant Professor, Case Western Reserve University
- Presenter **– Dr. Glenn Gaesser,** Professor of Exercise and Wellness in the School of Nutrition and Health Promotion; director of the Healthy Lifestyles Research Center, Arizona State University

Carbohydrates, Performance & Weight Loss: Is low the way to go, or the way to bonk?

ACSM Webinar
February 15, 2017

Glenn Gaesser, PhD
School of Nutrition and Health Promotion
Arizona State University
glenn.gaesser@asu.edu

Disclosure

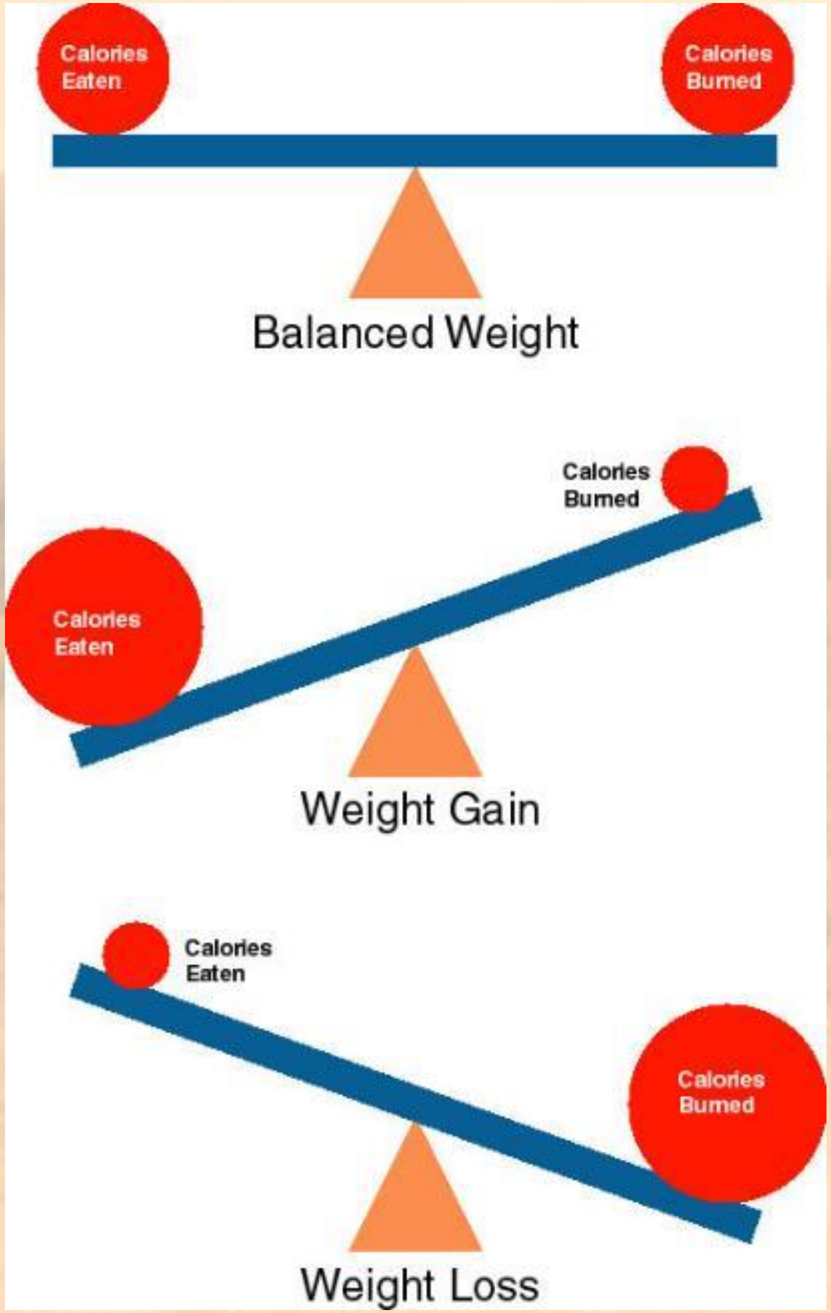
Glenn Gaesser is a member of the Scientific Advisory Board of the Wheat Foods Council, which is sponsoring this presentation

Learning Objectives

Participants will be able to:

- **Advise clients on the optimal amount of carbohydrates to recommend for performance or weight loss**
- **Accurately explain why or why not a low-carbohydrate approach is appropriate for athletes or others**
- **Discuss the research on carbohydrate metabolism and health, weight, and chronic disease and its impact on public health recommendations for carbohydrate intake**

Is a low-carbohydrate diet better for weight loss?

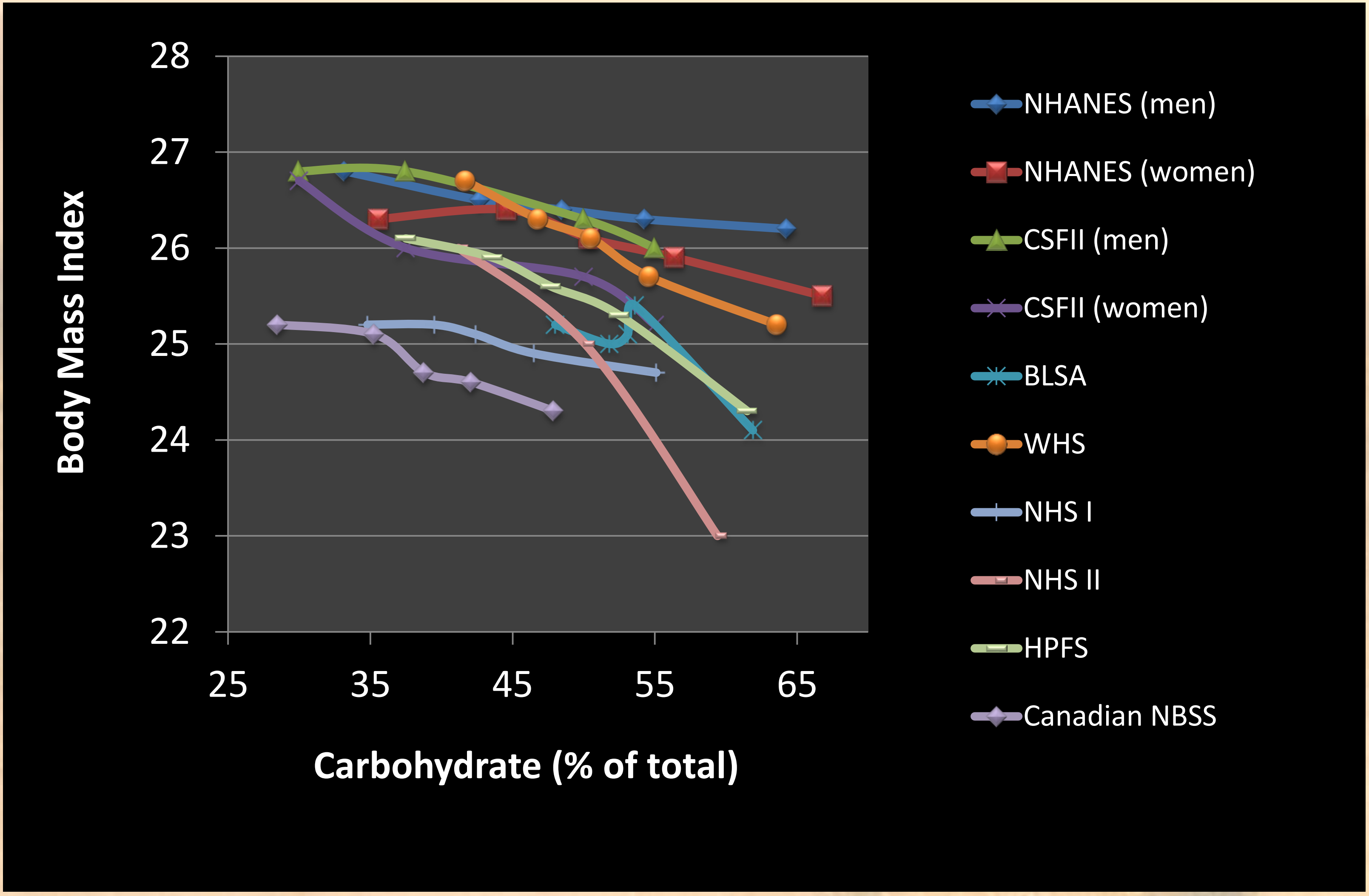


Energy <u>im</u>balance is necessary for weight loss

Calories expended must exceed calories eaten

For <u>*fat*</u> loss, fat calories expended must exceed fat calories eaten

Relationship Between Carbohydrate Intake and Body Mass Index – Cohort Studies



Gaesser. *JADA* 2007; 107:1768-1780

Virtually all prospective cohort studies show an *inverse* relationship between carbohydrate intake and body mass index

Body weight difference between high- and low-carbohydrate intake groups is approximately 5-7 pounds

Gaesser, *JADA*, 2007; 107: 1768-1780

Original Investigation

Comparison of Weight Loss Among Named Diet Programs in Overweight and Obese Adults
A Meta-analysis

Bradley C. Johnston, PhD; Steve Kanters, MSc; Kristofer Bandayrel, MPH; Ping Wu, MBBS, MSc; Faysal Naji, BHSc; Reed A. Siemieniuk, MD; Geoff D. C. Ball, RD, PhD; Jason W. Busse, DC, PhD; Kristian Thorlund, PhD; Gordon Guyatt, MD, MSc; Jeroen P. Jansen, PhD; Edward J. Mills, PhD, MSc

***JAMA*, 2014;312(9):923-933**

CONCLUSIONS AND RELEVANCE Significant weight loss was observed with any low-carbohydrate or low-fat diet. Weight loss differences between individual named diets were small. This supports the practice of recommending any diet that a patient will adhere to in order to lose weight.

Low Carb vs. Low Fat: No Difference in Weight Loss at 6 and 12 Months

Figure 1. Difference in Mean Weight Loss at 6- and 12-Month Follow-up Across All Diet Classes With 95% Credible Intervals

6-mo Weight Loss, kg \ 12-mo Weight Loss, kg					
	No diet (6 mo: 0; 12 mo: 0)[a]	5.16 (2.68 to 7.63)	5.70 (4.14 to 7.35)	7.25 (5.33 to 9.25)	7.27 (5.26 to 9.34)
	6.07 (4.23 to 7.84)	LEARN (6 mo: 0; 12 mo: 0.02)[a]	0.55 (−1.71 to 2.87)	2.10 (−0.20 to 4.47)	2.12 (−0.33 to 4.59)
	6.78 (5.50 to 8.05)	0.71 (−0.97 to 2.44)	Moderate macronutrients (6 mo: 0; 12 mo: 0)[a]	1.55 (0.13 to 2.95)	1.56 (−0.17 to 3.30)
	8.73 (7.27 to 10.20)	2.66 (0.93 to 4.44)	1.95 (1.13 to 2.79)	Low carbohydrate (6 mo: 0.83; 12 mo: 0.48)[a]	0.02 (−1.78 to 1.79)
	7.99 (6.01 to 9.92)	1.92 (−0.19 to 4.06)	1.20 (−0.42 to 2.79)	−0.74 (−2.31 to 0.78)	Low fat (6 mo: 0.17; 12 mo: 0.50)[a]

The values above the diet classes (blue boxes) correspond to the difference in mean weight lost between the columns and row at 12 months (eg, the difference in average weight lost between moderate macronutrients and no diet at 12 months is 5.70 kg). The values below the diet classes correspond to the difference in mean weight lost between the row and the column at 6 months (eg, the difference in average weight lost between moderate macronutrients and no diet at 6 months is 6.78 kg). LEARN indicates Lifestyle, Exercise, Attitudes, Relationships, and Nutrition.

[a] The values in parentheses represent the estimated probability of that treatment being the best.

Net difference, Low-carb vs. Low-fat, at 12 months = 0.02 kg!!

Johnston et al, *JAMA*, 2014;312(9):923-933

Low Carbohydrate versus Isoenergetic Balanced Diets for Reducing Weight and Cardiovascular Risk: A Systematic Review and Meta-Analysis

Celeste E. Naude[1*], Anel Schoonees[1], Marjanne Senekal[2], Taryn Young[1,3], Paul Garner[4], Jimmy Volmink[1,3]

1 Centre for Evidence-based Health Care, Faculty of Medicine and Health Sciences, Stellenbosch University, Cape Town, South Africa, 2 Division of Human Nutrition, Department of Human Biology, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa, 3 South African Cochrane Centre, South African Medical Research Council, Cape Town, South Africa, 4 Effective Health Care Research Consortium, Department of Clinical Sciences, Liverpool School of Tropical Medicine, Liverpool, United Kingdom

PlosOne 2014; 9(7): e100652

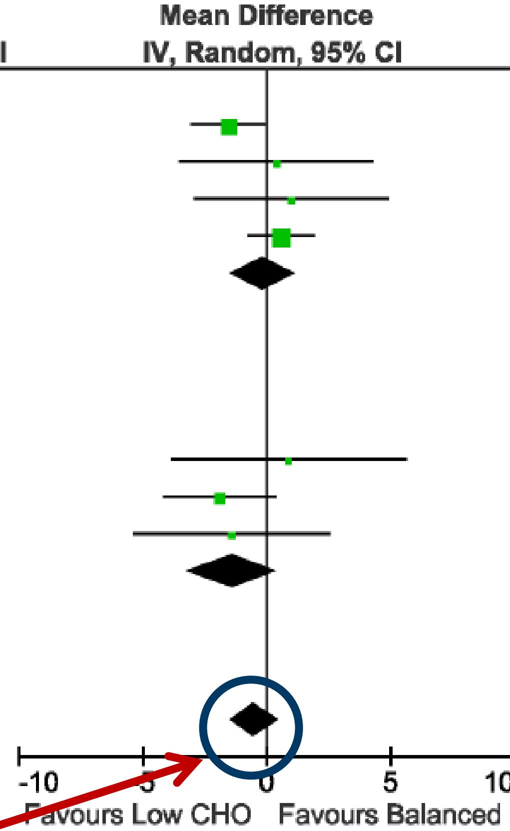
Major Points:

- **Trials show weight loss in the short-term irrespective of whether the diet is low-carb or balanced.**
- **There is probably little or no difference in weight loss and changes in cardiovascular risk factors up to two years of follow-up when overweight and obese adults, with or without type 2 diabetes, are randomized to low-carb diets or balanced weight loss diets, both having the same calorie levels.**

Weight Loss Differences, Low-carb vs. Balanced Diets

Overweight and Obese Adults at 1-2 Years

Study or Subgroup	Low CHO Mean	Low CHO SD	Low CHO Total	Balanced Mean	Balanced SD	Balanced Total	Weight	Mean Difference IV, Random, 95% CI
1.2.1 High fat variant vs Recommended diet								
Frisch 2009	-5.8	6.1	100	-4.3	5.1	100	28.7%	-1.50 [-3.06, 0.06]
Klemsdal 2010	-3.9	14.23	100	-4.3	14.23	102	5.7%	0.40 [-3.52, 4.32]
Lim 2010	-2.9	4.9	17	-3.9	6.3	15	5.7%	1.00 [-2.95, 4.95]
Sacks 2009	-2.9	7.3	201	-3.5	6.7	207	35.0%	0.60 [-0.76, 1.96]
Subtotal (95% CI)			**418**			**424**	**75.1%**	**-0.17 [-1.49, 1.15]**
Heterogeneity: Tau² = 0.58; Chi² = 4.45, df = 3 (P = 0.22); I² = 33%								
Test for overall effect: Z = 0.25 (P = 0.80)								
1.2.2 High protein variant vs Recommended diet								
Keogh 2007	-4.6	5.6	7	-5.5	2.9	6	4.0%	0.90 [-3.85, 5.65]
Layman 2009	-9.3	7.2	52	-7.4	4.3	51	15.4%	-1.90 [-4.19, 0.39]
Wycherley 2012	-12.3	8	33	-10.9	8.6	34	5.6%	-1.40 [-5.38, 2.58]
Subtotal (95% CI)			**92**			**91**	**24.9%**	**-1.38 [-3.21, 0.45]**
Heterogeneity: Tau² = 0.00; Chi² = 1.08, df = 2 (P = 0.58); I² = 0%								
Test for overall effect: Z = 1.48 (P = 0.14)								
Total (95% CI)			**510**			**515**	**100.0%**	**-0.48 [-1.44, 0.49]**
Heterogeneity: Tau² = 0.21; Chi² = 6.81, df = 6 (P = 0.34); I² = 12%								
Test for overall effect: Z = 0.97 (P = 0.33)								
Test for subgroup differences: Chi² = 1.11, df = 1 (P = 0.29), I² = 9.7%								



Non-significant 0.48 kg difference at 1-2 years

Naude et al, *PlosOne* 2014; 9(7): e100652

Diet and Health

- Low-fat diets that are high in fiber-rich foods tend to be associated with higher overall diet quality
- Whole-grain consumption is associated with lower risk of type 2 diabetes, cardiovascular disease and all-cause mortality

Recent meta-analyses

- **Aune et al, *BMJ* 2016; 353:i2716**
- **Chen et al, *Am J Clin Nutr* 2016; 104:164-172**
- **Wei et al, *BMJ* 2016;116:514-525**
- **Zong et al, *Circulation* 2016;133:2370-2380**

Diet and Exercise Performance:
Is Carbohydrate Necessary?

Hitting the "Wall"

- Most people have about 2 hours worth of glycogen they can use when racing
- Once glycogen stores are depleted, or severely reduced, fatigue and discomfort sets in and pace must slow down

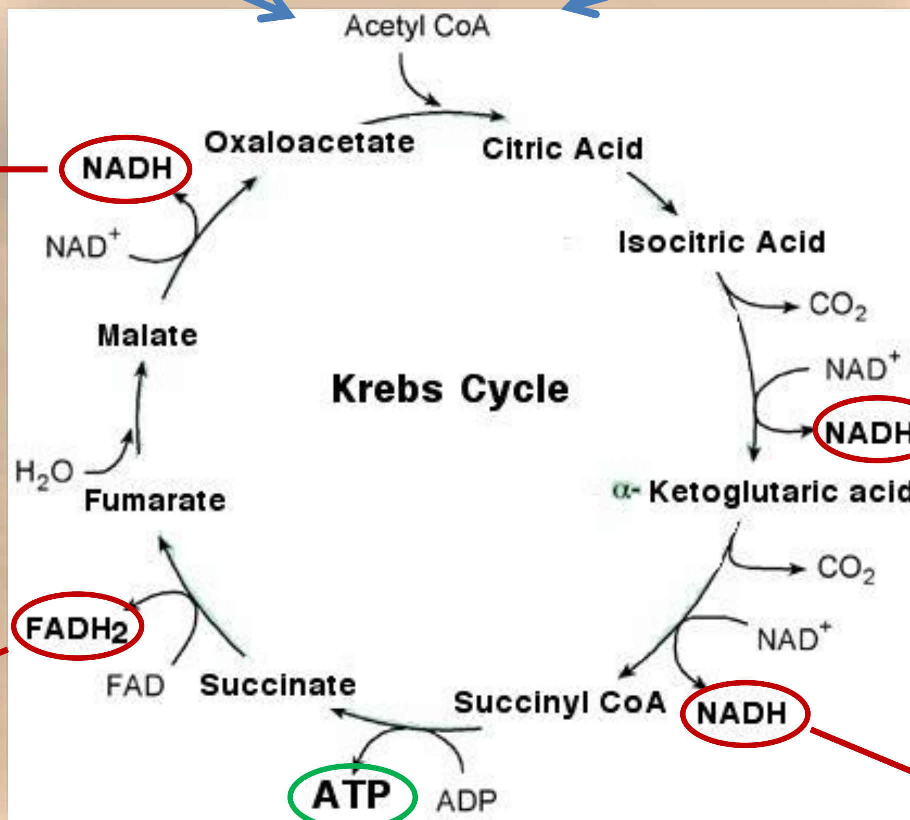
Energy Production 101

Carbohydrates

Fast

Slow

Fats



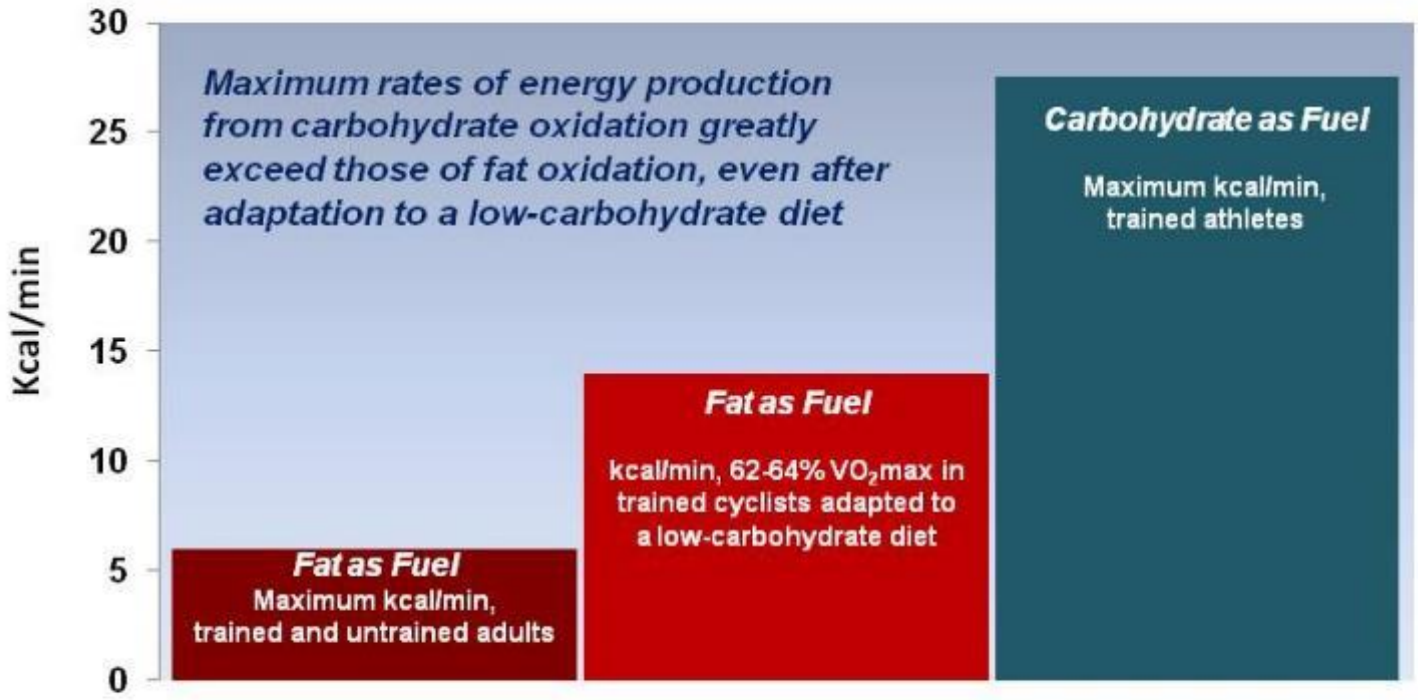
ATP synthesis via oxidative phoshorylation

ATP synthesis via oxidative phoshorylation

ATP synthesis via oxidative phoshorylation

ATP synthesis via oxidative phoshorylation

Maximum Rates of Energy Production from Carbohydrates and Fats



Gaesser, *Agro FOOD Industry Hi-Tech*, 2015;26:35-38

Muscle Glycogen Use Increases Dramatically as Exercise Intensity Increases

Because fat burns more slowly than carbohydrates, muscle glycogen use is essential to sustain high-intensity exercise.

Especially important for:

- Sudden increases in pace
- The sprint at the end of the race

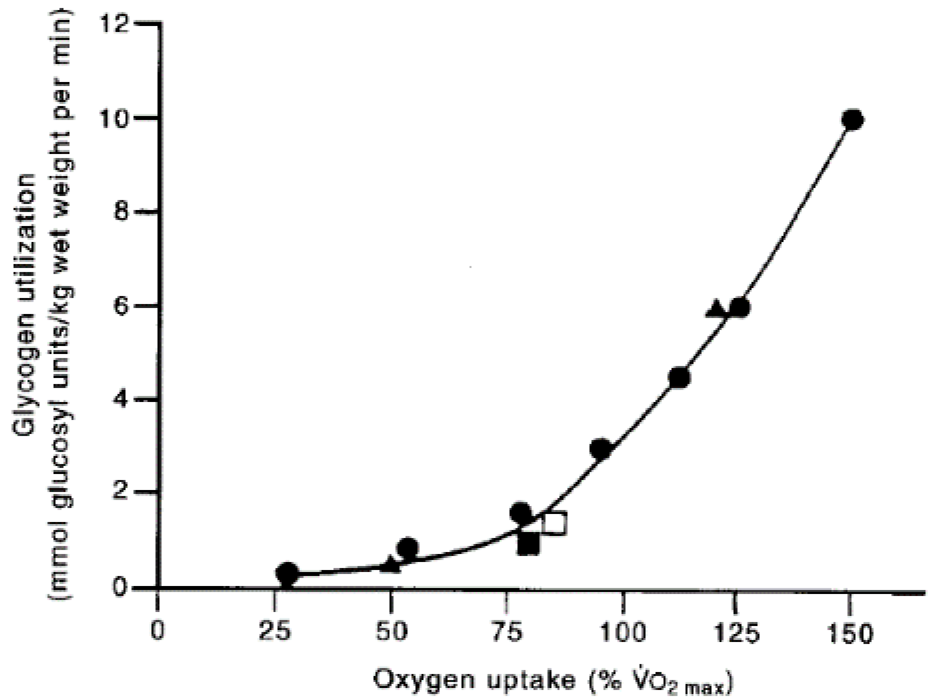


Fig. 2. Muscle glycogen utilization rates at various work intensities during different types of exercise. (●), cycling (vastus lateralis); (■), running (soleus); (□), running (gastrocnemius muscle); (▲), ice skating (vastus lateralis). (Reproduced from Hultman and Spriet[18] with permission.)

Hultman and Spriet, In: *Exercise, Nutrition and Energy Metabolism*, Horton and Terjung (eds), Macmillan: New York, 1988, 132-149

Muscle Glycogen Use is High Even in Intermittent Efforts

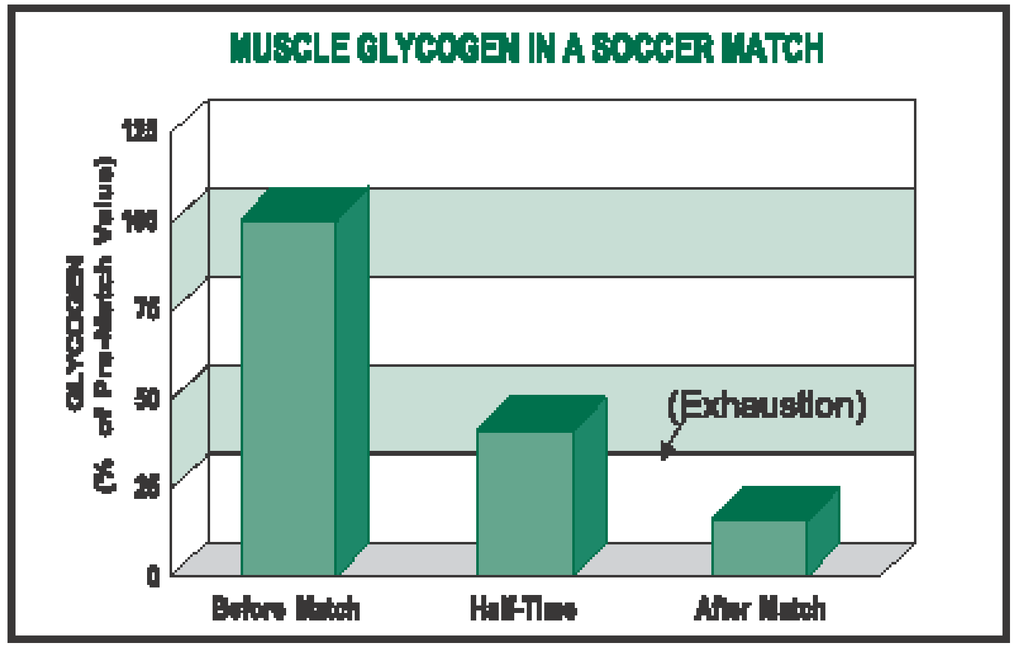
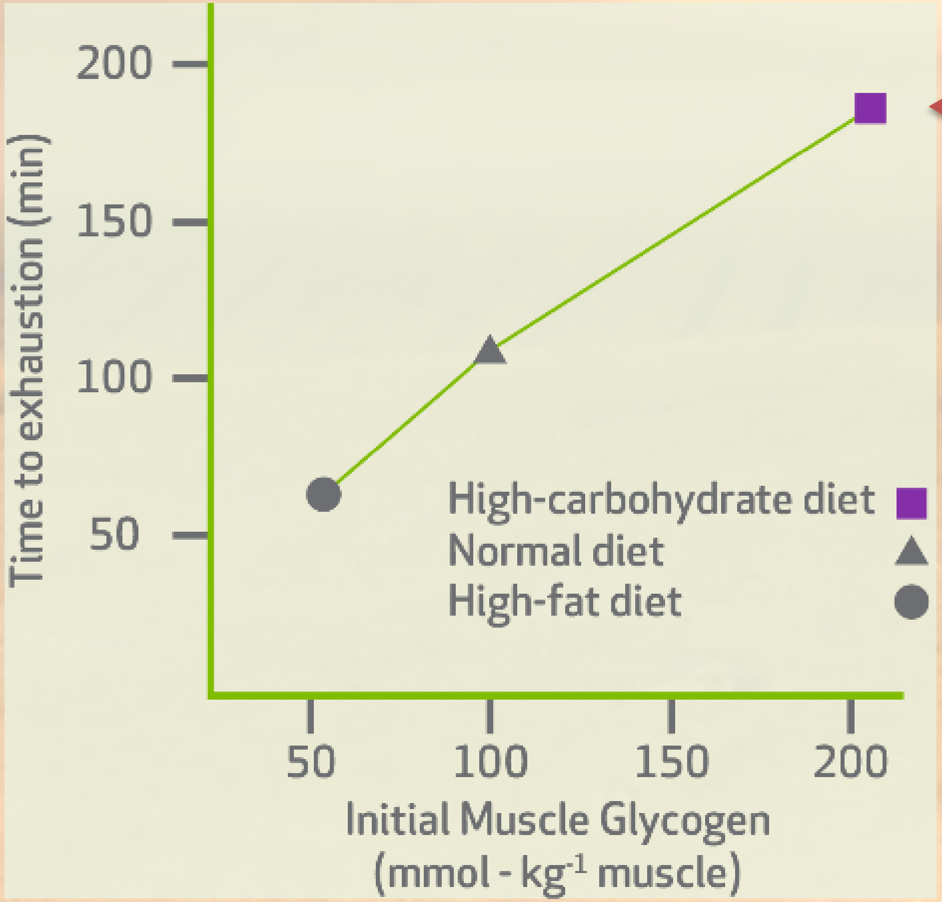


FIGURE 1. Effect of match play in soccer on stores of glycogen in leg muscles. Modified from Agnevik (1970).

Soccer, football, lacrosse and other "team" sports are not steady state athletic efforts. Still, athletes use a great deal of stored glycogen.

Agnevik, *Sport Physiol Report Number 7* (Swedish) Trygg-Hansa, Stockholm, 1970

Muscle Glycogen and Time to Exhaustion

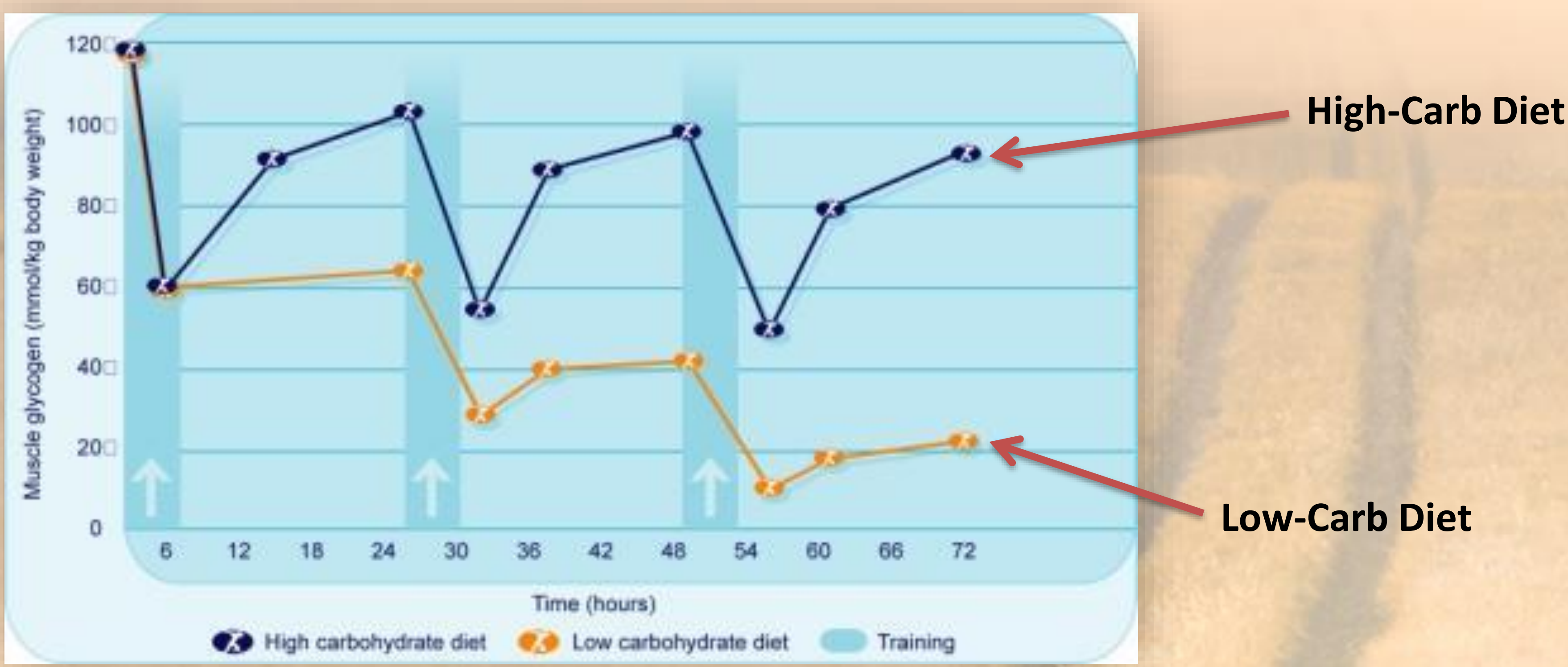


Athletes on high- carb diets store more muscle glycogen.

The greater the amount of muscle glycogen the longer the time to exhaustion when exercising.

Bergstrom et al. *Acta Physiol Scand*, 1967;71:140-150

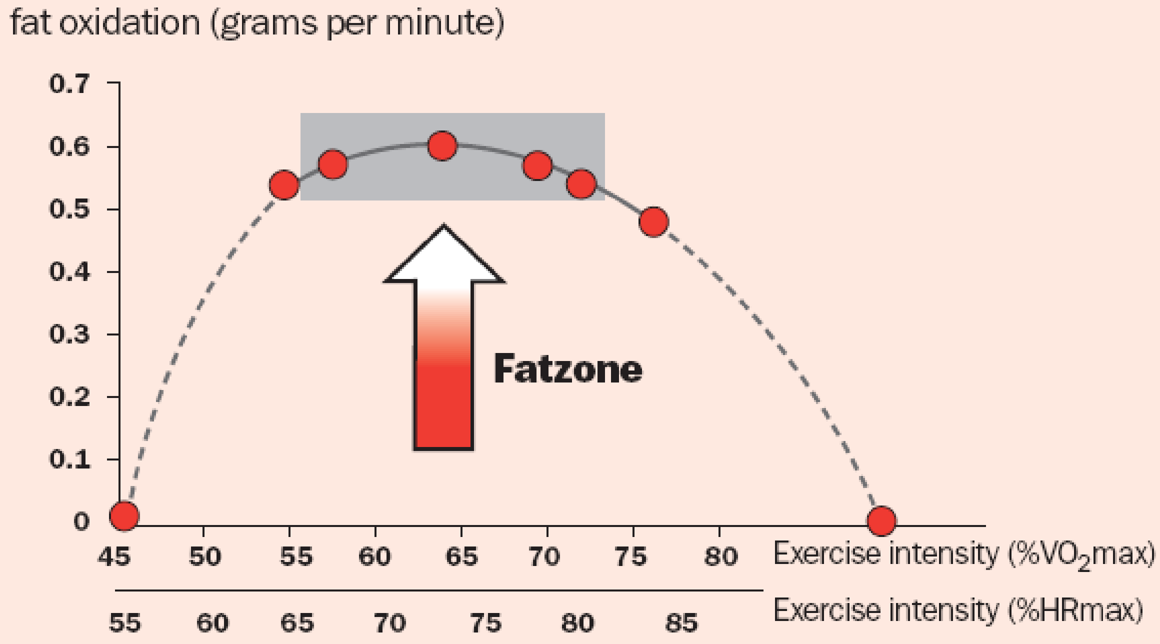
Muscle Glycogen Replenishment During Consecutive Days of Hard Exercise High-Carb Diet vs. Low-Carb Diet



Costill, *Inside Running*, Benchmark Press, Indianapolis, 1986, p. 63

Endurance "Race" Intensities are Well Above the "Fat Burning" Zone

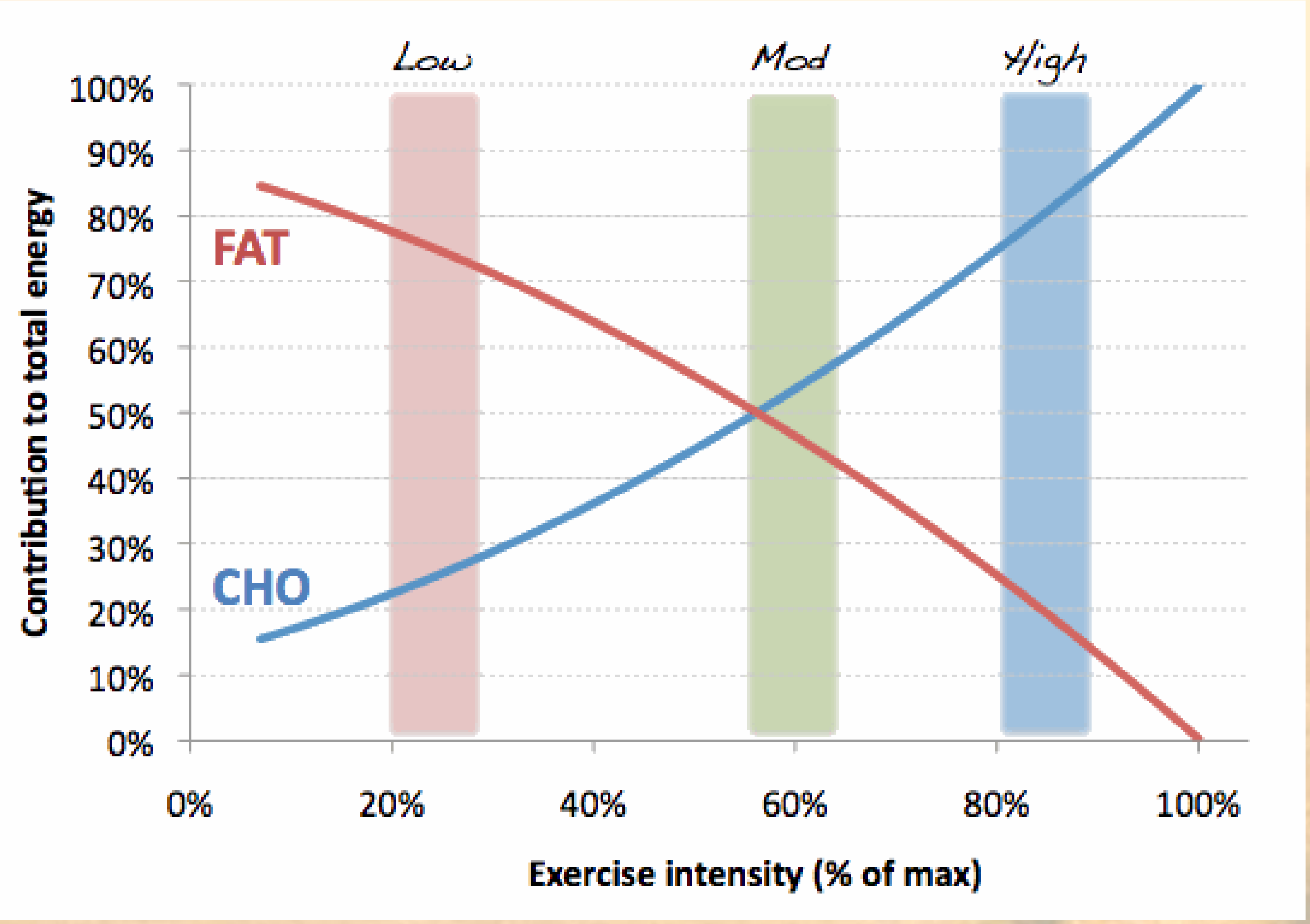
Figure 1: Exercise intensity and fat oxidation



Exercise intensity (expressed as %HRmax and $\%VO_2max$) and fat oxidation. Fat oxidation increases from low to moderate exercise intensities, peaks at *Fatmax*, and decreases as the exercise intensity increases further. The grey area represents the Fatzone: a range of exercise intensities where fat oxidation is high.

Achten and Jeukendrup, *Nutrition*, 2004;20:716-727

Crossover Concept in Fuel Utilization



Most competitive endurance athletes are at >70% VO_{2max} during high-intensity training and during competitive races *carbohydrate is the dominant fuel*

Brooks and Mercier, *J Appl Physiol*, 1994;76:2253-2261.

Summary: Carbohydrates & Exercise

Carbohydrate:

- Preferred fuel during high-intensity exercise
- "FAST" fuel (produces energy faster); fat is a "SLOW" fuel
- Allows for greater endurance during high-intensity exercise
- Replaces glycogen stores much faster after exercise (= faster recovery)

Low Carbohydrate Intake and Exercise:

What's the rationale?

Does it work?

Origins of “low-carb” strategy

Why all the hype?

- Anecdotal testimonials
- Popularity of the Paleo Diet
- Recent scientific evidence
- “Classic” study by Phinney et al (1983)

Closer Examination of the Study by Phinney et al

The Human Metabolic Response to Chronic Ketosis Without Caloric Restriction: Preservation of Submaximal Exercise Capability with Reduced Carbohydrate Oxidation

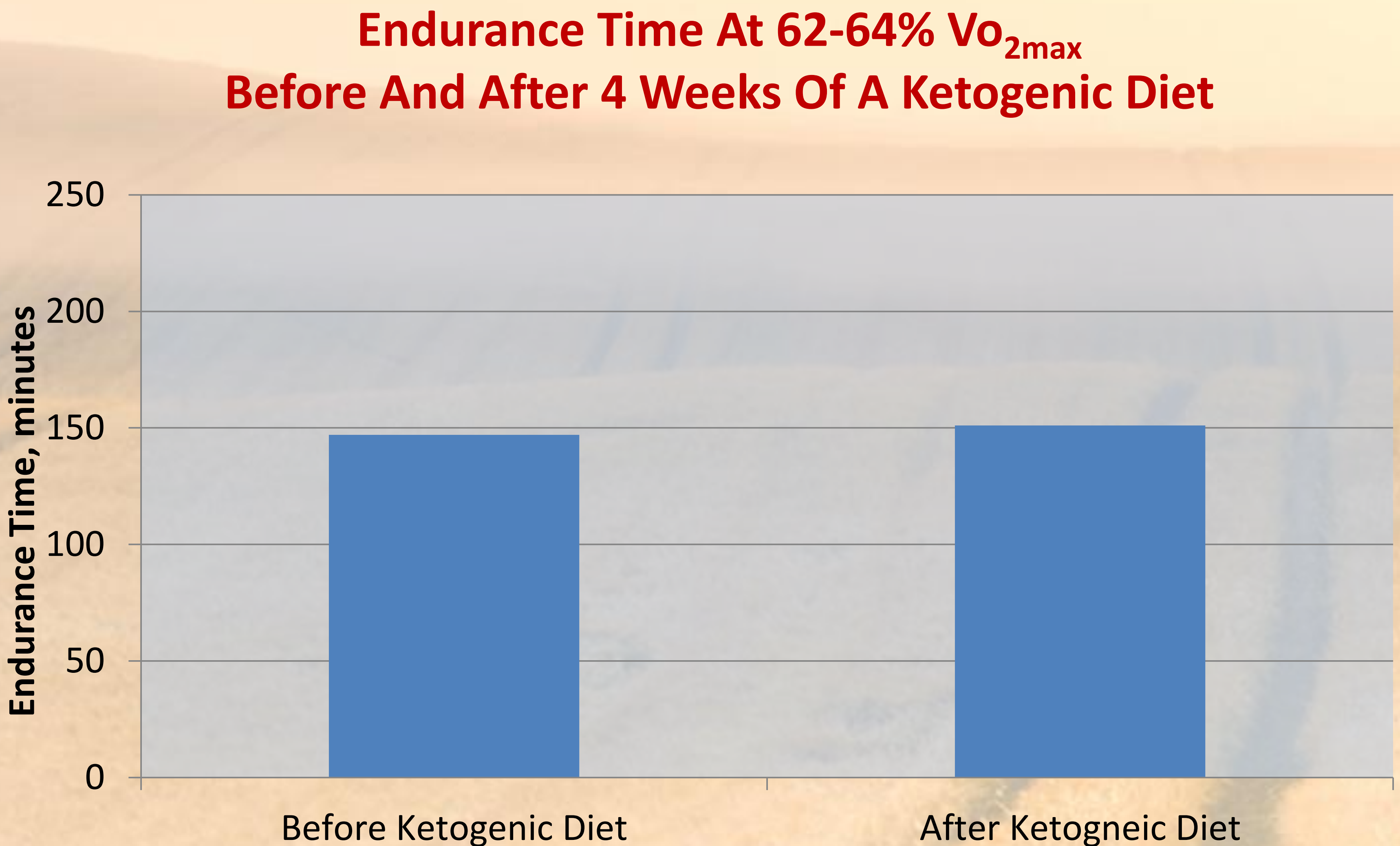
S. D. Phinney, B. R. Bistrian, W. J. Evans, E. Gervino, and G. L. Blackburn

Metabolism, 1983, 32: 769-776

Five well-trained male cyclists consumed a ketogenic diet (very low-carb) for four weeks

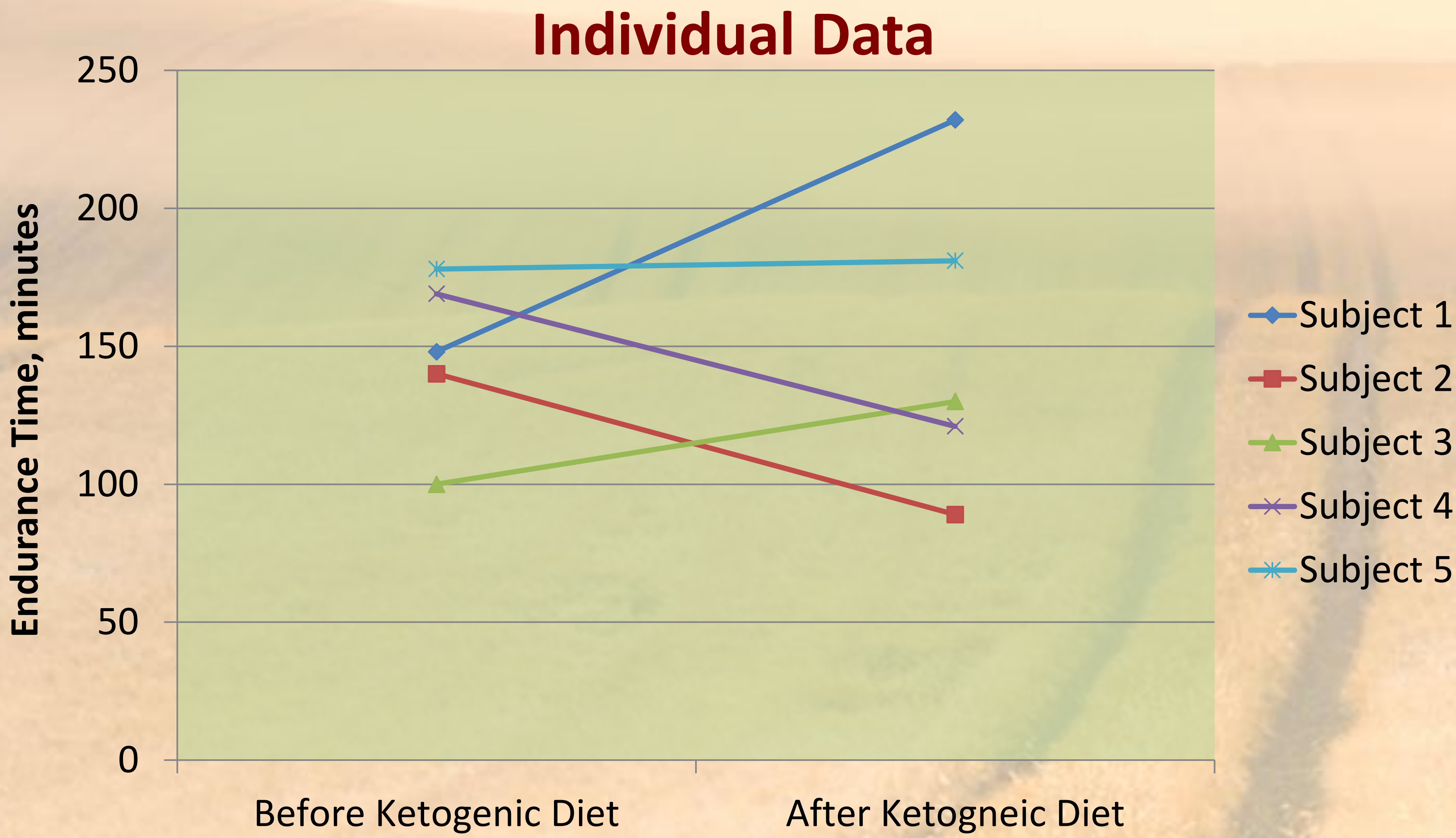
<u>Authors' conclusion:</u>
"These results indicate that aerobic endurance exercise by well-trained cyclists was not compromised by four weeks of ketosis"

Low-Carbohydrate Did Not Improve Endurance Time



Phinney et al, *Metabolism*, 1983, 32: 769-776

Endurance time at 62-64% VO_{2max} before and after 4 weeks of a ketogenic diet



Phinney et al, *Metabolism*, 1983, 32: 769-776

- *Yes, two subjects performed **better***
- *But two subjects performed **worse*****
- *And one subject performed **the same***

***Ironically, these two subjects increased fat oxidation the most on the ketogenic diet*

And this is the most cited study as an endorsement of a ketogenic diet for endurance performance!?

Phinney et al, *Metabolism*, 1983, 32: 769-776

Furthermore, very few endurance contests are performed at an intensity of only ~63% of VO_{2max}

There is no published evidence that a low-carbohydrate diet will improve endurance performance at high (race competitive) exercise intensities

Metabolic characteristics of keto-adapted ultra-endurance runners

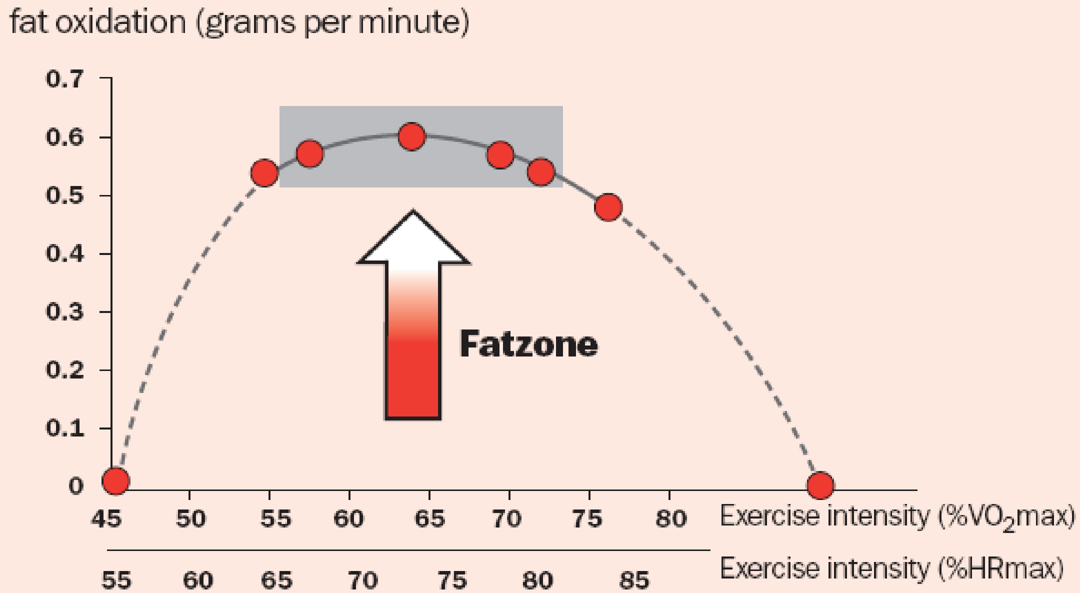
Jeff S. Volek[a,b,*], Daniel J. Freidenreich[a,b], Catherine Saenz[a,b], Laura J. Kunces[a], Brent C. Creighton[a], Jenna M. Bartley[a], Patrick M. Davitt[a], Colleen X. Munoz[a], Jeffrey M. Anderson[a], Carl M. Maresh[a,b], Elaine C. Lee[a], Mark D. Schuenke[c], Giselle Aerni[a], William J. Kraemer[a,b], Stephen D. Phinney[d]

- Twenty elite ultra-marathoners and ironman distance triathletes
  - 10 habitually consumed a high-carb diet
    - 59% carb, 14% protein, 25% fat
  - 10 habitually consumed a low-carb diet
    - 10% carb, 19% protein, 70% fat
- Max and submax testing

Metabolism, 2016;65:100-110

"Fat Burning" Zone is in the SUBMAXIMAL intensity domain

Figure 1: Exercise intensity and fat oxidation

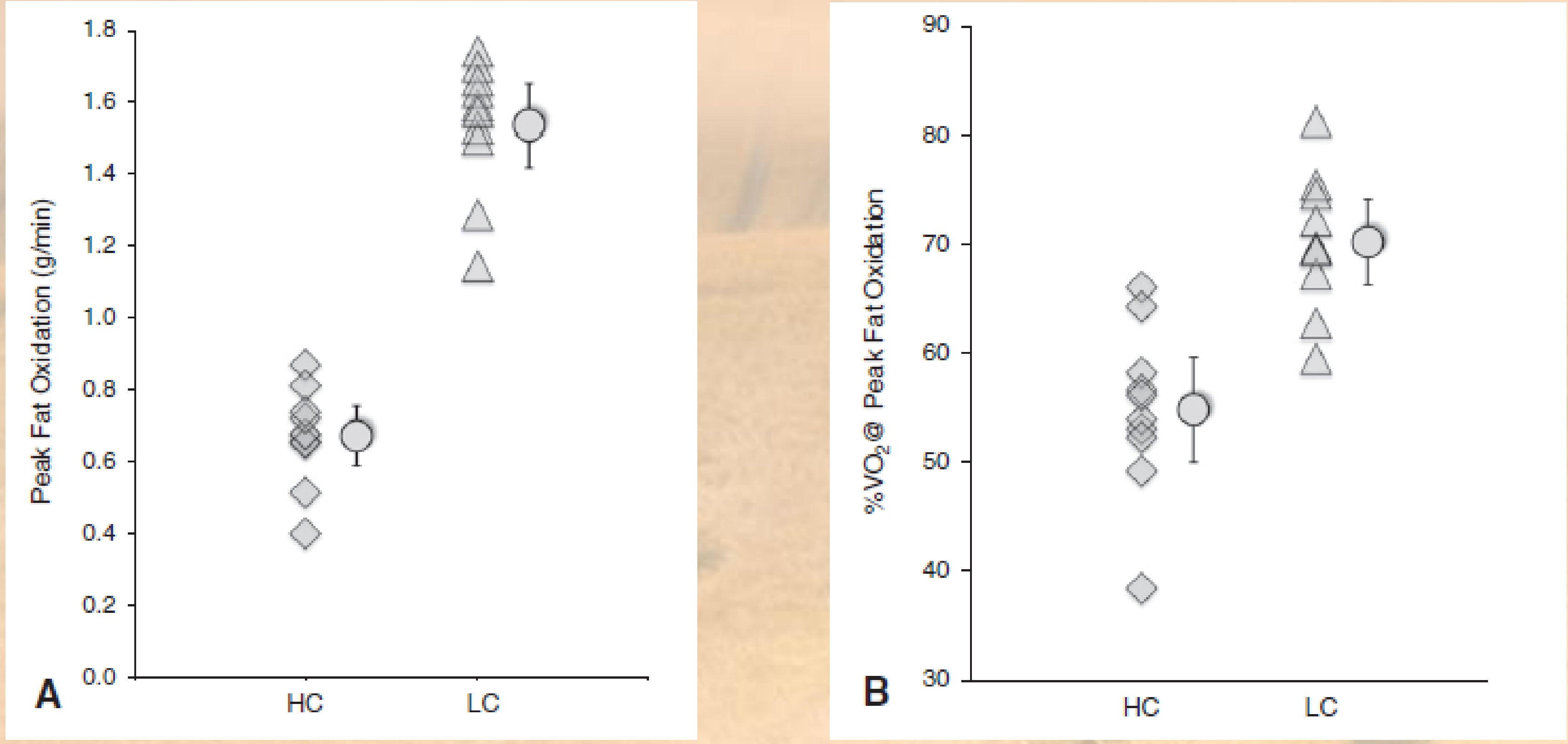


Exercise intensity (expressed as %HRmax and %VO_2max) and fat oxidation. Fat oxidation increases from low to moderate exercise intensities, peaks at *Fatmax*, and decreases as the exercise intensity increases further. The grey area represents the Fatzone: a range of exercise intensities where fat oxidation is high.

Achten and Jeukendrup, *Nutrition*, 2004;20:716-727

Individual peak fat oxidation rates (A) and the exercise intensity eliciting peak oxidation (B) during a maximal graded treadmill test

[Habitual low-carb consumers had higher fat oxidation]



Volek et al, Metabolism, 2016;65:100-110

Experimental design of submaximal exercise test

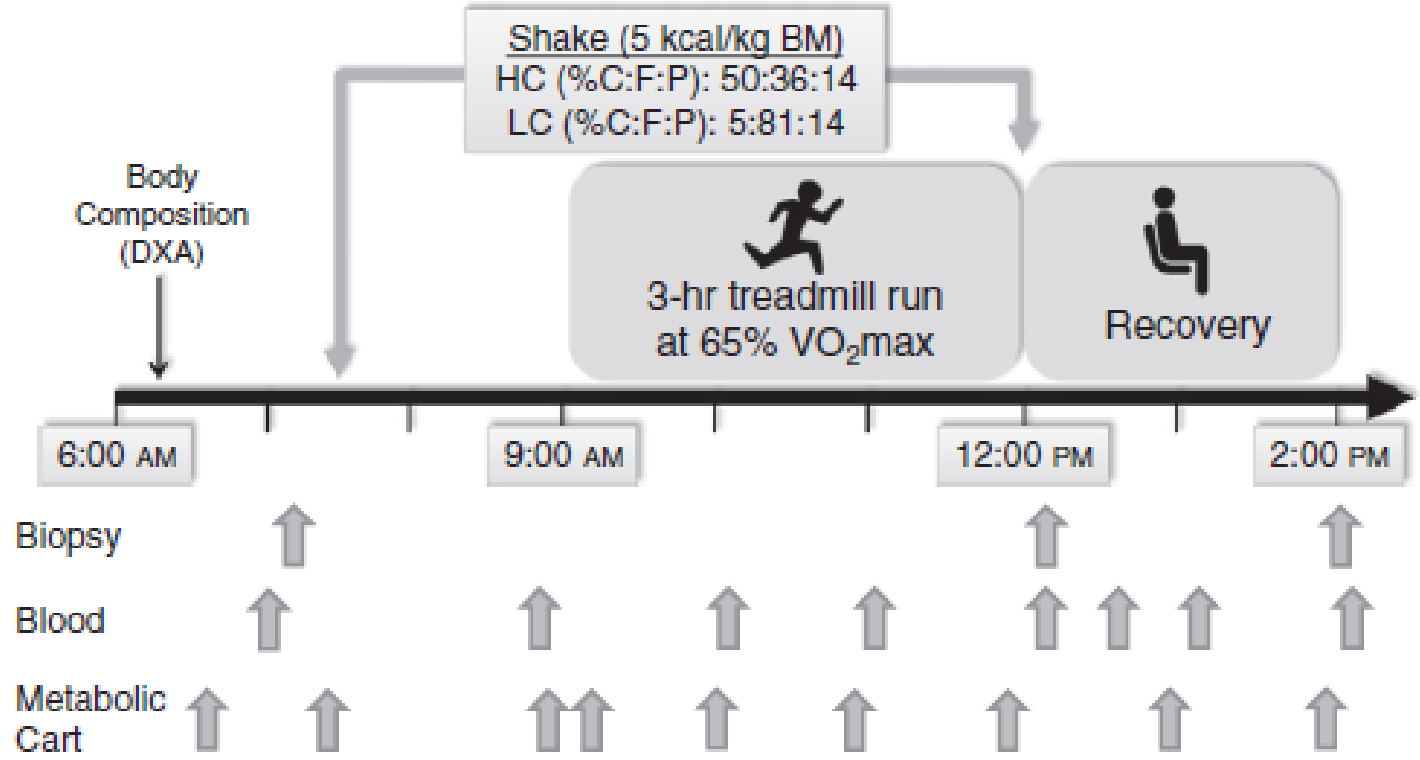
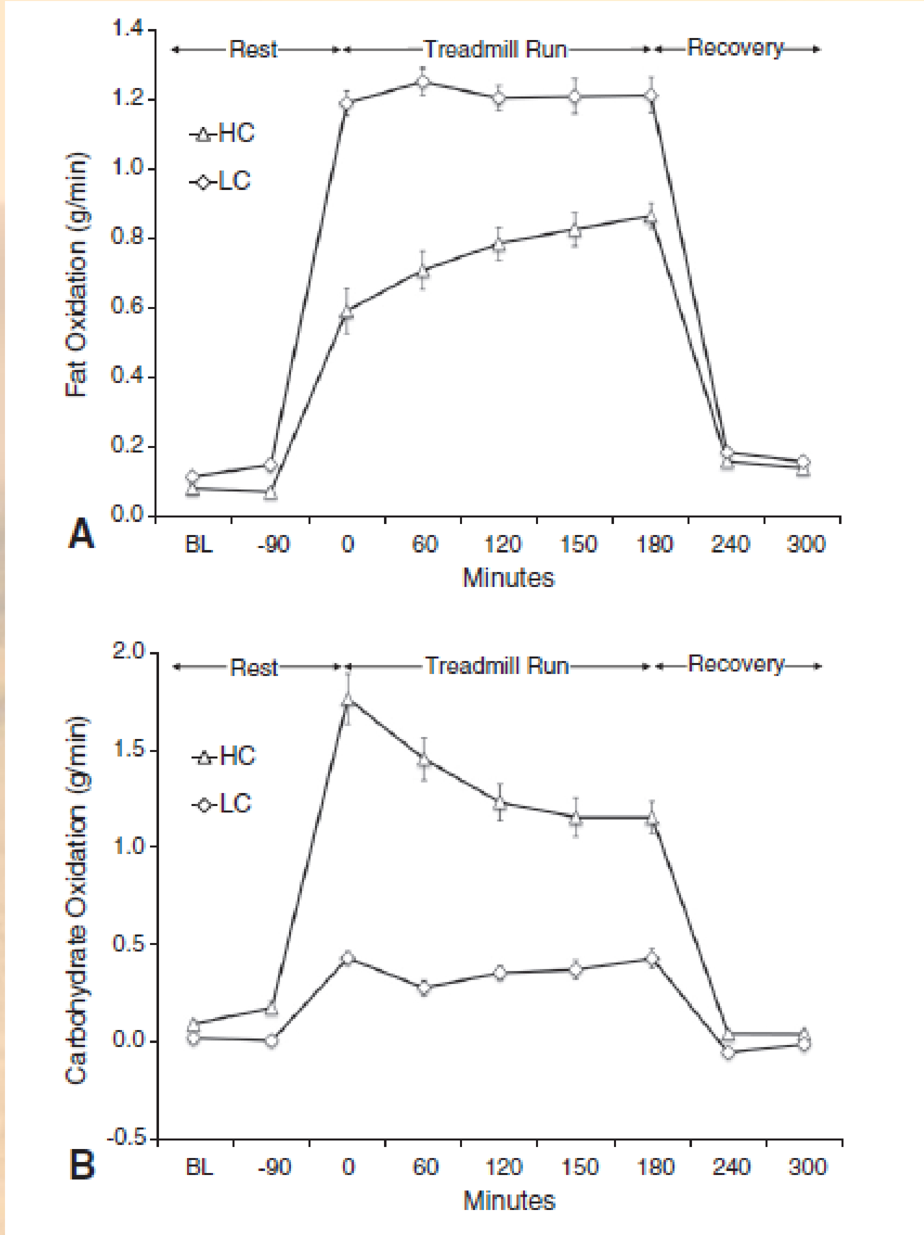


Fig. 1 – Experimental protocol to determine metabolic responses to submaximal exercise.

***Volek et al, Metabolism*, 2016;65:100-110**



Fat (A) and carbohydrate (B) oxidation rate during 180 min of running at 64% VO_{2max} and 120 min of recovery

Habitual low-carb consumers burned more fat and less carbohydrate

Volek et al, Metabolism, 2016;65:100-110

Authors' Conclusion

These results provide the first documentation of the metabolic adaptations associated with long-term consumption of a very low carbohydrate, high-fat diet in highly trained keto-adapted ultra-endurance athletes.

Caveats:

- **Performance was not assessed**
- **Prolonged submaximal exercise test was at 64% VO_{2max}**

Volek et al, Metabolism, 2016;65:100-110

Low Carbohydrate, High Fat diet impairs exercise economy and negates the performance benefit from intensified training in elite race walkers

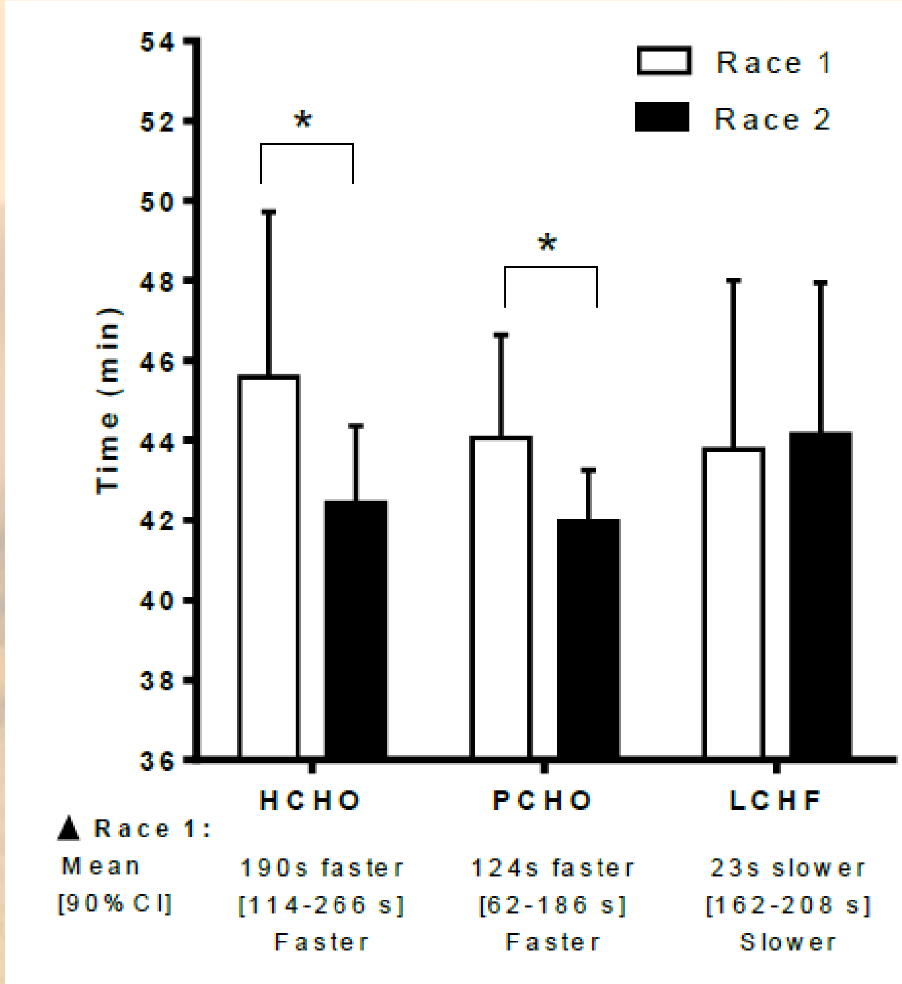
- Male race walkers (Australia Institute of Sport)
- Three weeks of intensified training, along with:
  - Three dietary interventions (all meals provided)
    - High carb availability (HCHO)
      - 60-65% CHO, 15-20% protein, 20% fat
    - Periodized carb availability (PCHO)
      - Same as HCHO but spread differently between and within days
    - Low-carb, high-fat (LCHF)
      - 75-80% fat, 15-20% protein, <50g/day CHO
- Physiological <u>and</u> performance testing

Burke et al, *J Physiol*, epub online, December 23, 2016

Results

- Total energy and protein intake was the same across dietary conditions
- Training volume similar in groups (low-carb, high-fat group experienced higher perception of effort and had difficulty completing training sessions)
- VO_{2peak} increased in all groups
- Low-carb, high-fat diet (LCHF) increased fat oxidation during exercise but <u>did not improve performance</u> <u>despite an increase in VO_{2peak}</u>
- Race walking performance was improved in both high-carb groups

Burke et al, *J Physiol*, epub online, December 23, 2016



Endurance performance improved with high carbohydrate availability but not during training while consuming a low-carbohydrate diet

Race times for IAAF sanctioned 10 km race walk events in elite race walkers undertaken pre- (Race 1) and post- (Race 2) 3 weeks of intensified training and high carbohydrate availability (HCHO, n = 9); periodized carbohydrate availability (PCHO, n = 8) or ketogenic low-carbohydrate high fat (LCHF, n = 9) diets.

Burke et al, *J Physiol*, epub online, December 23, 2016

Major take-home message

In contrast to training with diets providing chronic or periodized high carbohydrate availability, adaptation to low-carb, high-fat diet impairs performance in elite endurance athletes *despite a significant improvement in peak aerobic capacity*

Burke et al, *J Physiol*, epub online, December 23, 2016

Does the High-Carb Approach Work?

95 of the top 100 marathon performances ever recorded are by Kenyans and Ethiopians

Macronutrient Intake of the World's Best Marathoners

	Carbohydrate (%)	Fat (%)	Protein (%)
Kenyans	**76.5**	**13.4**	**10.1**
Ethiopians	**64.3**	**23.3**	**12.4**

Onywera et al, *Int J Sport Nutr Exerc Metab*, 2004;14:709-719
Beis et al, J *Int Soc Sports Nutr*, 2011;8:1-7 (Open Access)

Can a modified strategy, using both "low-carb" and "normal/high-carb" dietary practices, enhance performance?

Train "Low" – Race "High"
The Science

Scientific evidence is limited to a handful of short-term studies with this design:

Two groups of athletes, randomized to two training conditions, both receiving the same daily carbohydrate intake:

- **"Train high": 1 training session per day**
- **"Train low": 2 trainings sessions per day, alternating days, with <u>no carbohydrate repletion between sessions on the same day</u> (i.e., the second training session is performed under "low-carb" conditions)**

Train “Low” – Race “High”
The Results

- Better skeletal muscle adaptations under the “train low” condition
- Higher exercise tolerance and greater work performed under “train high” condition
- *NO DIFFERENCE IN PERFORMANCE MEASURES*

Potential Pitfalls of "Training Low"

- Chronic low-carb diet may compromise ability to maintain desired training intensity
- High amounts of exercise performed in a low-carb state may increase susceptibility to illness and infection (Carbs play an important role in offsetting exercise-induced immunosuppression)
- Exercising under conditions of low-carbohydrate availability may increase protein breakdown (could impair maintenance of muscle mass)
- Exercising while limiting carbohydrate intake may impair capacity to utilize carbohydrate consumed during competition

Bartlett et al, *Eur J Sport Sci*, 2015;1:3-12

High Carb Day

Low Carb Day

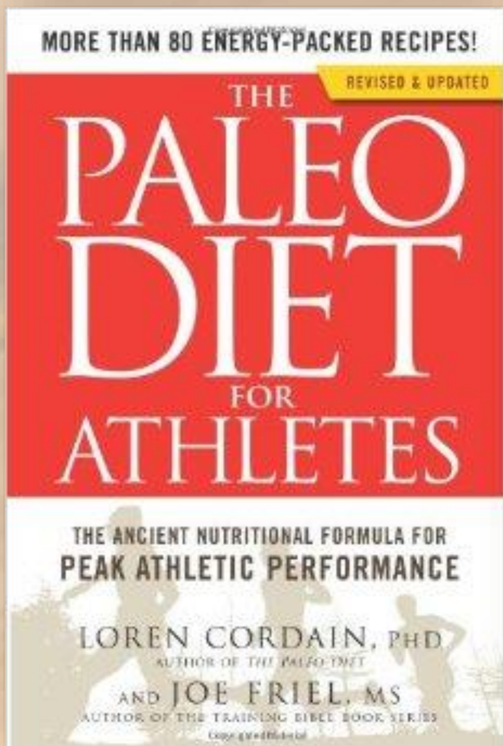
No Carb Day

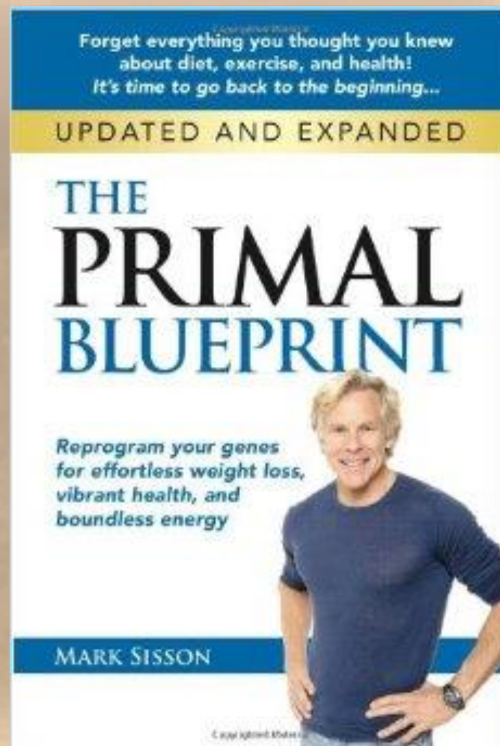
Practical Applications for Train "Low" – Race "High"

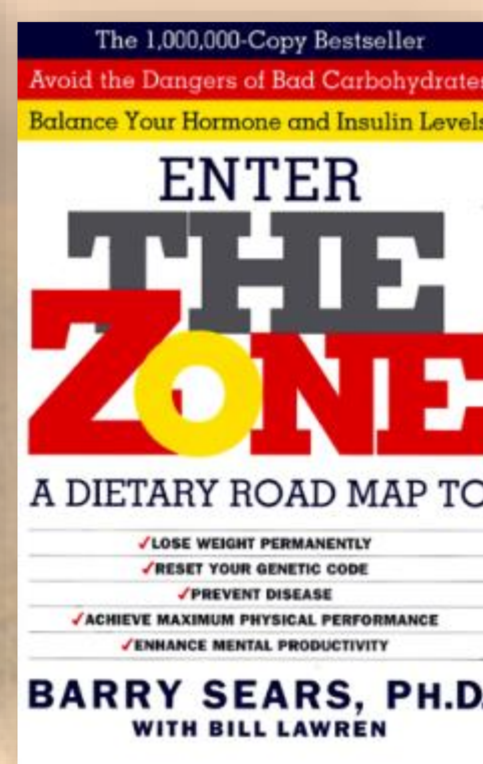
- Train in a fasted state
  - Morning exercise before eating
  - Two training sessions per day (no CHO replenishment after first session)
- Train "low" workouts should not be intense
- Athletes should consider caffeine ingestion and/or CHO mouth rinse on train "low" days
- Protein ingestion (20-25 grams) should be ingested before, during and/or right after a train "low" exercise session
- Training program should include sessions of training "high" that simulate competition fueling schedule

Bartlett et al, *Eur J Sport Sci*, 2015;1:3-12

So Why Does The Train Low/Race High Concept Persist?







Potential Pitfalls of Too Much Protein in the Diet (which may occur on a Paleo diet)

A number of studies published in the past 35 years have shown that high protein intake impairs the capacity for very high-intensity exercise

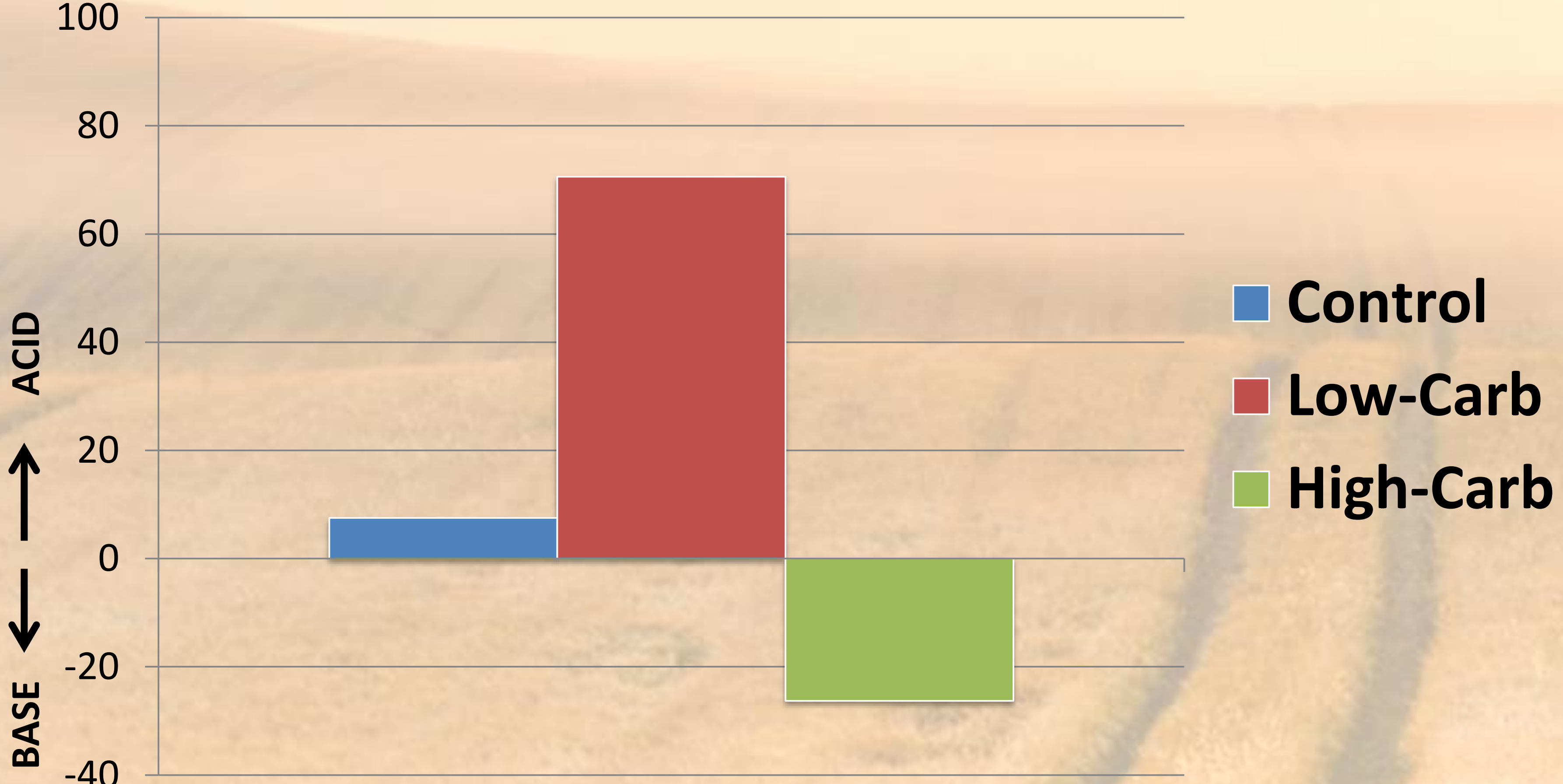
The Effects of Dietary Manipulation on Blood Acid-Base Status and the Performance of High-Intensity Exercise

Eleven healthy men performed exercise to exhaustion under three dietary conditions:

- Control (46.2 % CHO; 39.2 % Fat; 14.1 % Protein)
- Low-Carb (10.1 % CHO; 64.5 % Fat; 25.3 % Protein)
- High-Carb (65.5 % CHO; 24.7 % Fat; 9.4 % Protein)

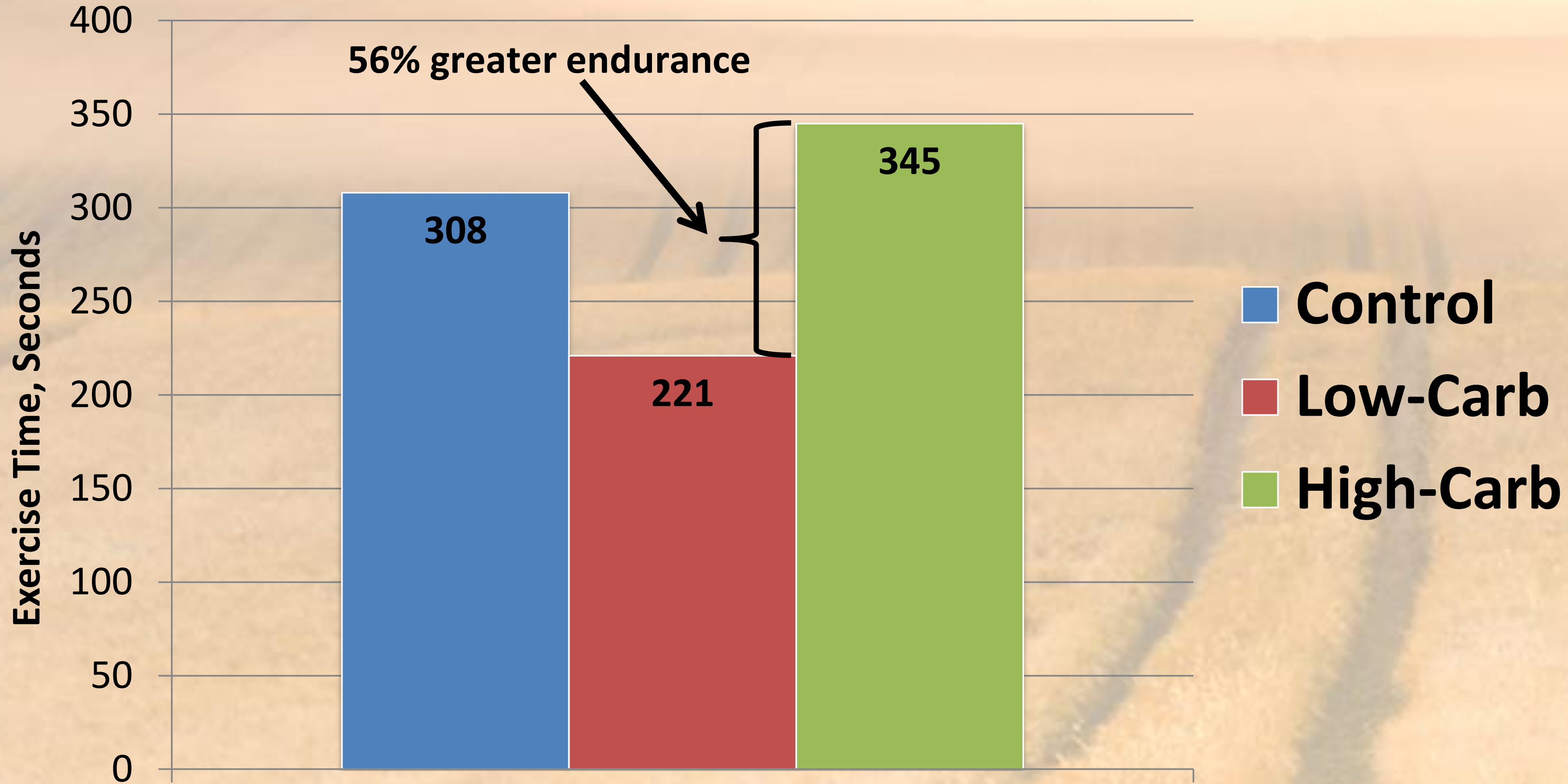
Greenhaff et al, *Eur J Appl Physiol*, 1987;56:331-337

Dietary Acid-Base Intake (meq/day)



Greenhaff et al, *Eur J Appl Physiol*, 1987;56:331-337

Exercise Time at a Fixed Workload (~100% VO_{2max})



Greenhaff et al, *Eur J Appl Physiol*, 1987;56:331-337

Results of this study have been replicated a number of times

Take-home message:

Exercise performance at very high intensities is reduced by a low-carb diet that is relatively high in protein (> ~2 grams/kg/day)

The adverse effects of high protein intakes is likely due to increasing acid load and reducing buffering capacity of the blood <u>(blood bicarbonate levels are 11% lower on the low-carb diet compared to the high-carb diet)</u>

Guidelines For Fueling Before, During and After Exercise

Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: *Nutrition and Athletic Performance*

Journal of the Academy of Nutrition and Dietetics, 2016;116:501-528

Daily Needs for Fuel and Recovery

Intensity	Situation	Daily CHO targets (grams per kg body weight)
Light	Low-intensity or skill-based activities	3-5
Moderate	Moderate exercise program (~1 h/day)	5-7
High	Endurance program (1-3 h/day of moderate-to-vigorous activity)	6-10
Very High	Extreme commitment (>4-5 h/day of moderate-to-vigorous activity)	8-12

Journal of the Academy of Nutrition and Dietetics, 2016;116:501-528

Acute fueling Strategies

Intensity	Situation	CHO targets
General fueling up	Preparation for events < 90 min	7-12 g/kg per 24 h (as for daily needs)
Carbohydrate loading	Preparation for events > 90 min (sustained or intermittent)	10-12 g/kg per 24 h for 36-48 h
Speedy refueling	< 8 h recovery between two fuel-demanding sessions	1.0-1.2 g/kg/h for first 4 h, then resume daily fuel needs

Journal of the Academy of Nutrition and Dietetics, 2016;116:501-528

Acute fueling Strategies (continued)

Intensity	Situation	CHO targets
Pre-event fueling	Before exercise > 60 min	1-4 g/kg consumed 1-4 h before exercise
During brief exercise	< 45 min	Not necessary
During sustained high-intensity exercise	45 – 75 min	Small amounts including mouth rinse

Journal of the Academy of Nutrition and Dietetics, 2016;116:501-528

Acute fueling Strategies (continued)

Intensity	Situation	CHO targets
During endurance exercise (including "stop and start" sports)	1.0 – 2.5 h	30-60 g/hour
During ultra-endurance exercise	> 2.5 – 3.0 h	Up to 90 g/hour

Journal of the Academy of Nutrition and Dietetics, 2016;116:501-528

Summary Points and Comments
Weight Loss

- For weight loss, low-carb diets are no more effective than low-fat or "balanced" diets
- It's the calories, not the carbs

Summary Points and Comments
Endurance Performance

- Carbohydrate is a “faster” fuel than fat
  - Faster rate of breakdown
  - More energy (ATP) can be produced in a given amount of time (i.e., per minute)
- Carbohydrates are essential for high-intensity exercise
  - Carbohydrates provide more energy (ATP) per liter of oxygen consumed
  - <u>Maximum rate of energy production is ~3-5 times higher for carbohydrate compared to fat</u>

Summary Points and Comments *Endurance Performance*

- Initial muscle glycogen levels are important for endurance sports lasting >90 minutes
- There is no evidence to show that a low-carbohydrate diet will improve competitive endurance sport performance by more than a moderate-to-high carb diet
- Low-carb diets may impair an athlete's capacity for performing and completing high-intensity workouts
- High-protein content of some low-carb diets may reduce tolerance for high-intensity and maximal exercise

Summary Points and Comments
Endurance Performance

- Train “low” – race “high” method
  - Skeletal muscle adaptations are enhanced
  - But actual endurance performance has not been shown to be improved
- Even with train “low” – race “high” there is a need for adequate carbohydrate
- The world’s best marathoners consume high-carbohydrate diets (>60%)

Thank You!

ACSM CEC Certificate

Participant Name

ACSM/Wheat Foods Council Webinar – February 15, 2017

Carbohydrates, Performance & Weight Loss: Is Low the Way to Go or the Way to Bonk?

Course Title

792731
Approved Provider Number

1.0 CEC
CECs Awarded

Michele Tuttle, Wheat Foods Council
Lead Program Administrator Signature

One (1) CEC Credit – emailed within 1-2 days