LA'84 Foundation High School Cross-Country Coaches Clinic: *July 22nd, 2017*

- Endurance Training: *Current Science & Application to Training Program Design*

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- Endurance Training: *Current Science & Application to Training Program Design*

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Part I

Speaker Background

Speaker Background

- **Education – Ph.D. in exercise physiology w/ concentration in exercise biochemistry (*Arizona State University, 2004*)**
  - **M.S. Exercise Science (*Arizona State University, 1995*)**
  - **M.B.A. (*Duke University, 1992*)**
  - **B.A. Economics (*Wesleyan University, 1984*)**

- **Experience – Darien High School (*2 Years*), Desert Vista High School (*2.5 Years*), Queen Creek High School (*1.5 Years*), Xavier College Preparatory (*6.5 Years*), & Desert Vista High School (*2013 / 2014 / 2015 / 2016 / 2017*)**

Speaker Background

- **Coaching Influences**
  - **Chris Hanson / Ellie Hardt / Dave Van Sickle**
  - ***Dan Beeks, Michael Bucci, Renato Canova, Dana Castoro, Robert Chapman, Steve Chavez, Liam Clemons, Bob Davis, Erin Dawson, Marty Dugard, Jason Dunn, John Hayes, Brad Hudson, Jay Johnson, Tana Jones, Arthur Lydiard, Steve Magness, Joe Newton, Dan Noble, Jim O' Brien, Tim O'Rourke, Rene Paragas, Haley Paul, Louie Quintana, Ken Reeves Alberto Salazar, Jerry Schumacher, Brian Shapiro, Scott Simmons, Mando Siquieros, Renee Smith-Williams, Doug Soles, Danna Swenson, Bill Vice, Joe Vigil, Mark Wetmore, & Chuck Woolridge***

Speaker Background

- **Tara Erdmann, 2:14 / 4:54**
- **Kari Hardt, 2:11 / 10:26**
- **Baylee Jones 2:16 / 4:55 / 10:36**
- **Danielle Jones, 2:09 / 4:39 / 10:09**
- **Haley Paul, 2:13 / 4:51**

- **Desert Vista High School: 2016, 2014, & 2013 Arizona State High School Girls' Cross-Country Team Champions**
- **Xavier College Preparatory: 2012, 2011, 2010, 2009, 2008, and 2007 Arizona State High School Girls' Cross-Country Team Champions**
- **Two (*2*) Foot Locker National (*FLN*) Championship qualifiers**

Speaker Background

- Sarah Penney, 2:11 / 10:39
- Mason Swenson, 2:16 / 4:59 / 10:56
- Jessica Tonn, 2:13 / 4:50 / 10:21
- Sherod Hardt, 4:10 / 8:59
- Garrett Kelly, 4:17 / 9:18
- 4 x 1,600-m Relay (20:14 / 20:52 / 21:37) & 4 x 800-meter Relay (8:57)

- Desert Vista High School: 2002 Arizona State High School Boys' Cross-Country Team Champions
- 2012 Mt. SAC Relays 4 x 1,600-m Event – 3 teams / 12 student-athletes averaged 5:13 per split
- Three (*3*) time NXN team participant across two schools (*XCP, DVHS*) and one (*1*) time NXN individual qualifier

Part II

What This Presentation Is Not

“What this presentation is *not*”

Xavier College Preparatory or Desert Vista High School Training Philosophies or Training Programs

https://www.highschoolrunningcoach.com/

Part III

Pre-Training Static Stretching & Muscle Performance

Pre-Training Static Stretching

Perspective: ***"Aren't we told that we are not supposed to static stretch?"***

…

Comment by an exceptionally accomplished California high school coach providing his rationale for warm-up in response to a question at a 2007 LA '84 Foundation X-C Clinic

Pre-Training Static Stretching

Perspective: ***"Anyone have a suggestion for how to warm-up?"***

…

Request for assistance by an exceptionally accomplished Midwest high school coach and United States Olympic Training Center (*USOTC*) camp director in response to a question at the 2008 USOTC Emerging Elite Coaches Camp

Pre-Training Static Stretching

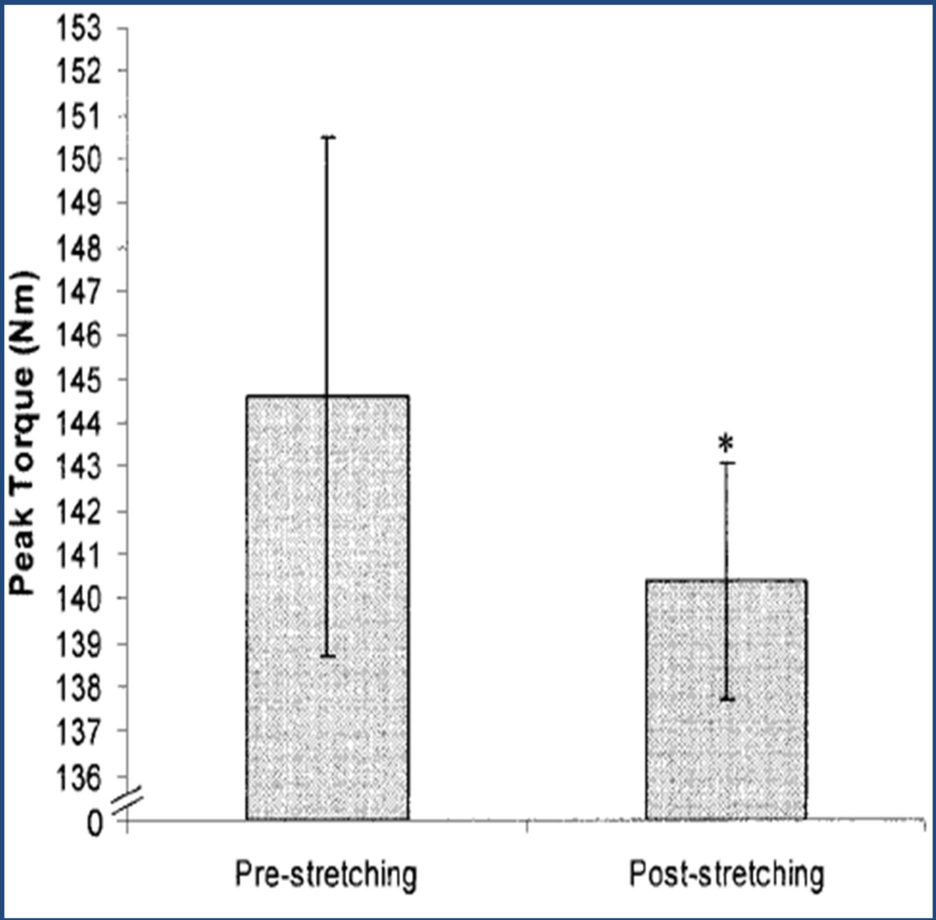
- **Simic, I., Sarabon, N. & Markovic, G. (*2013*). Does Pre-Exercise Static Stretching Inhibit Maximal Muscular Performance? A Meta-Analytical Review, Scandinavian Journal of Medicine & Science in Sports & Exercise, 23, 131 – 148.**

Simic, Sarabon, & Markovic (*2013*)

- **Recognition of the various data sets relating pre-exercise / pre-training muscle stretching to decrements in muscle force and / or power production**

Systematic literature review

Kay & Blazevich (*2011*)



- ***http://www.telegraph.co.uk/sport/othersports/athletics/6782321/Great-Britains-new-coaching-guru-Dan-Pfaff-orders-shake-up-of-training-methods.html***
- **http://www.youtube.com/watch?v=sDDSm1Utz7s**

Simic, Sarabon, & Markovic (*2013*)

- PubMed
- SCOPUS
- Web of Science

- Crossover, randomized, and nonrandomized controlled trials
- Studies that evaluated acute effects of static stretching on human muscular performance
- Peer-reviewed publications
- Studies in which static stretching lasted not longer than thirty (30) minutes

Simic, Sarabon, & Markovic (*2013*)

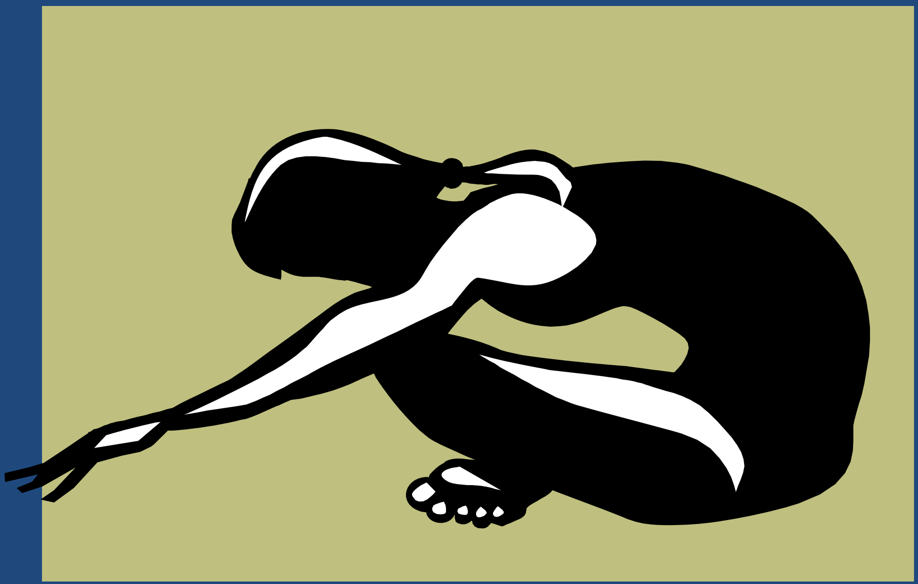
- **Identification of 1,699 articles for potential inclusion in review**
- **104 studies met the multiple inclusion criteria**

Simic, Sarabon, & Markovic (*2013*)

- **Meta-analytic results indicated that acute static stretch (≤ *45-seconds*) has a "most likely trivial effect" on maximal muscle strength**

Simic, Sarabon, & Markovic (*2013*)

- **Meta-analytic results indicated that acute static stretch (*46- to 90-seconds or > 90-seconds*) has a "likely negative effect" or "almost certainly negative effect" on maximal muscle strength**



Simic, Sarabon, & Markovic (*2013*)

- **Meta-analytic results indicated that acute static stretch is associated with an "unclear acute effect" on muscle power**

Simic, Sarabon, & Markovic (*2013*)

- **Meta-analytic results indicated that acute static stretch is associated with an "very likely negative acute effect" on explosive muscular performance tests**

Simic, Sarabon, & Markovic (*2013*)

Potential Interpretation: Pre-training static stretching has significant, practically relevant negative acute effects on maximal muscular strength and explosive muscular performance

Simic, Sarabon, & Markovic (*2013*)

- **Practical Application**
  - **Execute a dynamic (*i.e. movement-based*) warm-up prior to training in order to engender the general systematic (*i.e. whole-body*) transitions (*elevated heart rate, elevated cardiac output, elevated sweat rate*) that support aerobic power training**

Simic, Sarabon, & Markovic (*2013*)

- **Practical Application**
  - **Execute a dynamic (*i.e. movement-based*) warm-up prior to training in order to engender the specific muscular movement patterns and specific movement velocities that support aerobic power training**

Simic, Sarabon, & Markovic (*2013*)

- **Practical Application**
  - **Execute a static (*i.e. movement-based*) post-training range-of-motion routine in order to engender both the maintenance of existing range-of-motion and an immediate post-training diagnostic assessment**

Simic, Sarabon, & Markovic (*2013*)

- **Practical Application**
  - **Part XXIV**
  - **Appendices A - D**

Part IV

Post-Training Macronutrient Intake

Post-Training Macronutrient Intake

- **Ferguson-Stegall, L., McCleave, E., Zhenping, D., Doerner III, P.G., Liu, Y., Wang, B., Healy, M., Kleinert, M., Dessard, B., Lassiter, D.G., Kammer, L., & Ivy, J.I. (*2011*). Aerobic Exercise Training Adaptations Are Increased By Postexercise Carbohydrate-Protein Supplementation, Journal of Nutrition and Metabolism, 2011, 1 – 11.**

Post-Training Macronutrient Intake

- **Lunn, W.R., Pasiakos, S.M., Colletto, M.R., Karfonta, K.E., Carbone, J.W., Anderson, J.M., & Rodriguez, N.R. (*2012*). Chocolate Milk And Endurance Exercise Recovery: Protein Balance, Glycogen, And Performance, Medicine & Science in Sports & Exercise, 44(*4*), 682 – 691.**

Ferguson-Stegall et al. (*2011*)

- **Purpose: To investigate training adaptations subsequent to a 4.5-week aerobic endurance training program when daily, post-training nutrient provision was provided in the form of a carbohydrate-protein containing supplement, an isoenergetic carbohydrate containing supplement, or a placebo**
  - **0.94 g CHO / kg BM plus 0.31 g PRO / kg BM immediately and 1-hour post-training (*Chocolate Milk Supplement*)**
  - **1.25 g CHO / kg BM plus 0.17 g FAT / kg BM immediately and 1-hour post-training (*Carbohydrate Supplement*)**
  - **0.00 g CHO / kg BM plus 0.00 g PRO / kg BM immediately and 1-hour post-training (*Placebo*)**

Ferguson-Stegall et al. (*2011*)

- **Experimental design**
  - **Randomized, double-blinded, placebo-controlled design**
  - **Thirty-two (*32*) healthy, recreationally-active females and males**
  - **VO_2-max 35.9 $\pm$ 1.9 ml $O_2 * kg^{-1} * min^{-1}$**
  - **Macronutrient intake subsequent to five (5) weekly 60-minute bouts of cycle endurance exercise @ 60% (*for the initial 10-minutes*) and 75% (*for the final 50-minutes*) of VO_2-max**

Ferguson-Stegall et al. (*2011*)

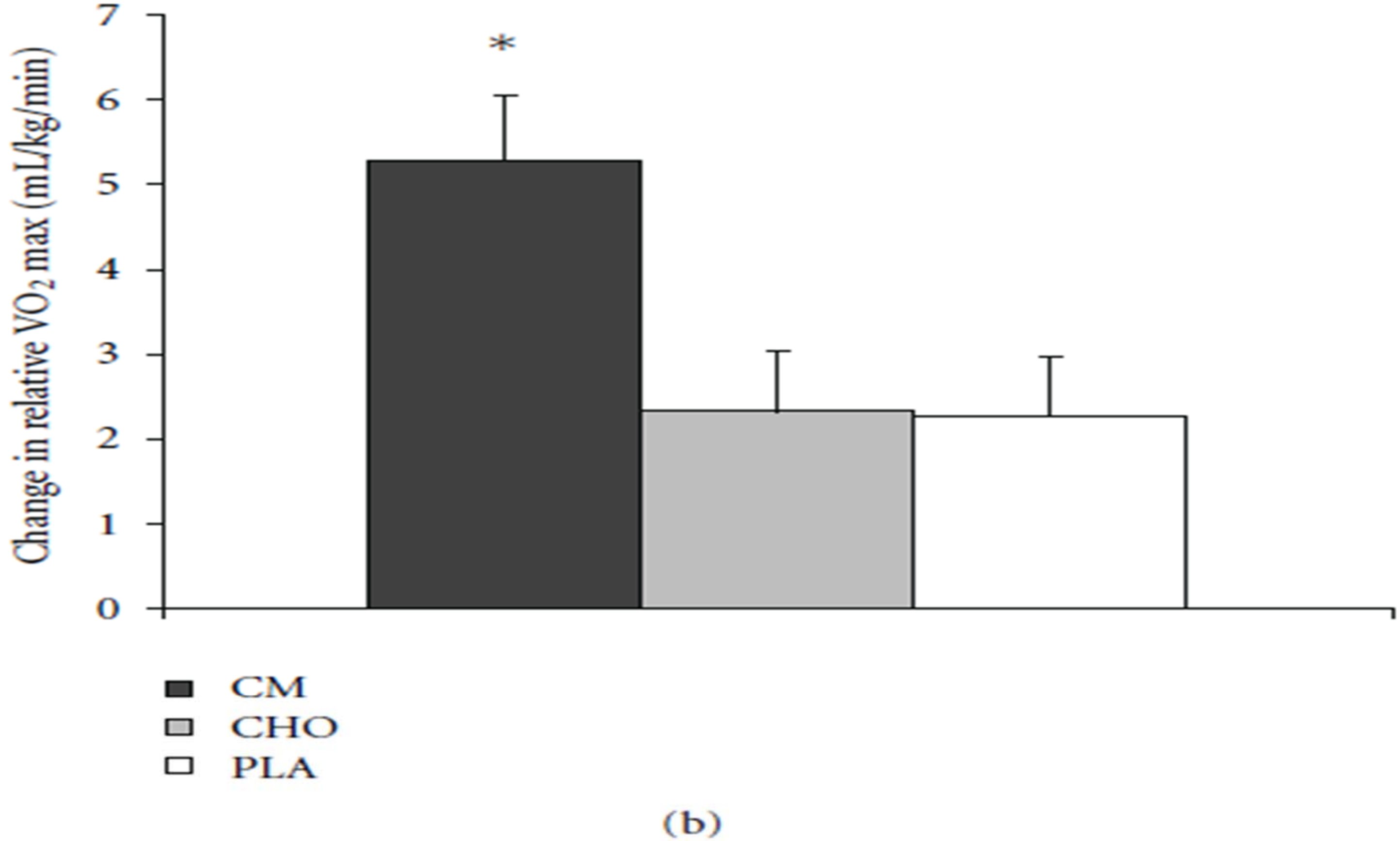
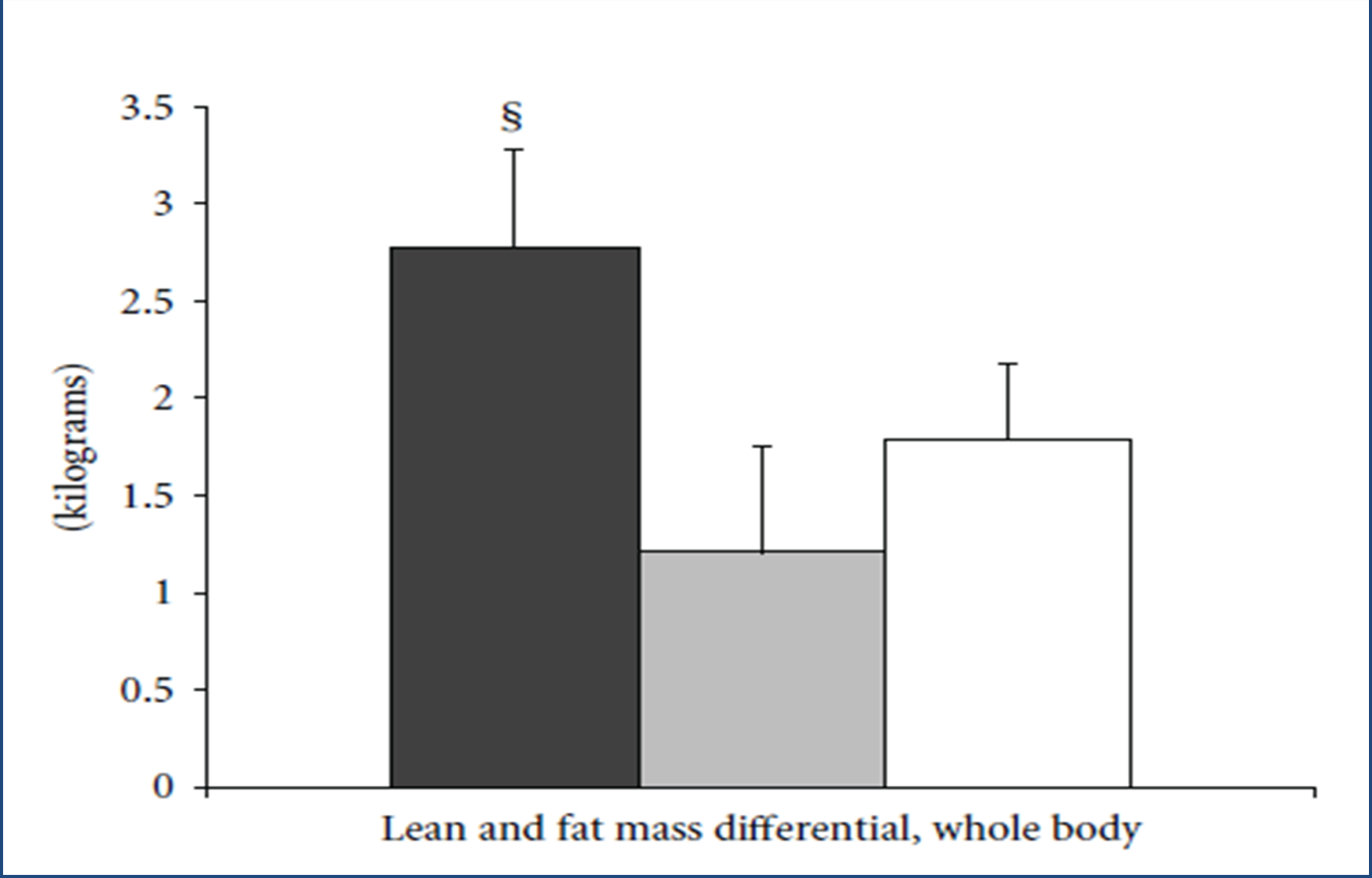


FIGURE 1: VO_2 max changes after 4.5 wks of aerobic endurance training. (a) Change from baseline in absolute VO_2 max. (b) Change from baseline in relative VO_2 max. Values are mean ± SE. Significant treatment differences: *, CM versus PLA and CHO ($P < .05$).

Ferguson-Stegall et al. (*2011*)



Ferguson-Stegall et al. (*2011*)

- **Data Interpretation**
  - **Consumption of a daily, post-training chocolate milk supplement relative to either a carbohydrate-only supplement or a placebo is associated with an approximate two-fold (*2-fold*) greater (*i.e. 100%*) percentage increase in relative VO_2-max**
  - **Body composition improvements, quantified by a lean and fat mass differential, were significantly greater in the chocolate milk supplement group relative to the carbohydrate supplement group**

Ferguson-Stegall et al. (*2011*)

- **Practical Application**

  - **Consume an individualized, mass-specific combination of carbohydrate and protein in the immediate post-training period including approximately 1.00 to 1.25 grams of <u>carbohydrate</u> per kilogram body mass and approximately 0.30 grams of <u>protein</u> per kilogram body mass**

Ferguson-Stegall et al. (*2011*)

Body Weight (lbs.)	Body Mass (kilograms)	Post-Training CHO Intake (grams)	Post-Training CHO Intake (calories)	Post-Training PRO Intake (grams)	Post-Training PRO Intake (calories)	Post-Training Caloric Intake (calories)	Post-Training Chocolate Milk (ounces)
96	43.5	52	199	13	52	251	13.2
98	44.4	53	203	13	53	256	13.5
100	45.4	54	207	14	54	261	13.7
105	47.6	57	217	14	57	274	14.4
107	48.5	58	221	15	58	280	14.7
108	49.0	59	223	15	59	282	14.8
110	49.9	60	227	15	60	287	15.1
112	50.8	61	232	15	61	293	15.4
115	52.2	63	238	16	63	300	15.8
117	53.1	64	242	16	64	306	16.1
120	54.4	65	248	16	65	313	16.5
122	55.3	66	252	17	66	319	16.8
125	56.7	68	259	17	68	327	17.2
126	57.1	69	261	17	69	329	17.3
130	59.0	71	269	18	71	340	17.9
132	59.9	72	273	18	72	345	18.1
134	60.8	73	277	18	73	350	18.4
135	61.2	73	279	18	73	353	18.6
136	61.7	74	281	19	74	355	18.7
138	62.6	75	285	19	75	360	19.0
139	63.0	76	287	19	76	363	19.1
140	63.5	76	290	19	76	366	19.2
142	64.4	77	294	19	77	371	19.5
145	65.8	79	300	20	79	379	19.9
146	66.2	79	302	20	79	381	20.1
150	68.0	82	310	20	82	392	20.6

Part V

Cold-Water Immersion & Recovery

Cold-Water Immersion & Recovery

- **Bleakley, C.M. & Davison, G.W. (*2010*). What Is The Biochemical And Physiological Rationale For Using Cold-Water Immersion In Sports Recovery?: A Systematic Review, British Journal of Sports Medicine, 44: 179 – 187.**

Cold-Water Immersion & Recovery

- **Perspective: "There is good research support to the efficacy of … cryotherapy (*ice baths*) (*French et al., 2008, Kuligowski et al. 1998, Burke et al., 2001,2003*)"**
- ***http://www.endurancecorner.com/Serious_Recovery_for_Serious_Athletes***

Table 2 Performance time, maximum oxygen uptake ($\dot{V}O_{2max}$) and ventilatory threshold (VT) before and after leg training by ergometer cycling in series 1, as assessed by one-leg exercise. Comparison of control legs with cooled legs ($n=6$)

	Performance time (s)	$\dot{V}O_{2\,max}$ (ml/kg/min)	VT (ml/kg/min)
Control leg			
Pre-training	758 ± 120	34.7 ± 4.6	19.6 ± 5.0
Post-training	866 ± 80*,**	37.1 ± 1.8**	21.7 ± 4.6
Cooled leg			
Pre-training	797 ± 86	36.9 ± 5.5	21.8 ± 3.5
Post-training	863 ± 99**	35.8 ± 3.4**	23.0 ± 4.2

Data are presented as means ± SD
Difference between pre- and post-training: $*P<0.05$
Difference between changes induced in the control and the cooled legs: $**P<0.05$

Cold-Water Immersion & Recovery

Question: **Does cryotherapy enhance adaptation and / or recovery?**

Bleakley & Davison (*2010*)

- British Nursing Index
- Cumulative Index to Nursing and Allied Health
- EMBASE
- MEDLINE
- Sports Discus

- Researchers screened 3,971 titles
- Researcher s read 440 abstracts
- Researchers retrieved 109 full-text articles
- Review included 16 studies

Bleakley & Davison (*2010*)

- British Nursing Index
- Cumulative Index to Nursing and Allied Health
- EMBASE
- MEDLINE
- Sports Discus

- All study participants had to be healthy human participants
- No restrictions placed on subject experience with cold-water immersion (CWI)
- Interventions of 5-minutes or less with water temperatures of less than 15º C
- Study participants must be attired in swimming shorts / trunks or wear no attire

Bleakley & Davison (*2010*)

- "Cold shock response"
- "Extreme activation of the sympathetic nervous system"
- "Oxidative stress"
- "Increase in free-radical species formation"

Cold-Water Immersion & Recovery

- **Yamane, M., Teruya, H., Nakano, N., Ogai, R., Ohnishi, N., & Kosaka, M. (*2006*). Post-exercise leg and forearm flexor muscle cooling in humans attenuates endurance and resistance training effects on muscle performance and on circulatory adaptation, European Journal of Applied Physiology, 96, 572-680.**

Table 2 Performance time, maximum oxygen uptake ($\dot{V}O_{2max}$) and ventilatory threshold (VT) before and after leg training by ergometer cycling in series 1, as assessed by one-leg exercise. Comparison of control legs with cooled legs ($n = 6$)

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Data are presented as means ± SD
Difference between pre- and post-training: *$P < 0.05$
Difference between changes induced in the control and the cooled legs: **$P < 0.05$

Yamane et al. (*2006*)

Potential Interpretation: "Myofiber microdamages, and cellular and humoral events induced by endurance and strength training within skeletal muscles must be considered as … preconditions … for the adaptive processes leading to improved muscular performances … cryotherapy will interfere with these regenerative processes and … will retard rather than support the desired improvement of muscular performance."

Cold-Water Immersion & Recovery

- **Practical Applications:**
  - **Nike's Oregon Project athletes no longer do routine ice baths**
  - **new approach is based on the realization that training is designed to stimulate molecular biological 'signaling pathways' for fitness adaptations**
  - **What's new is the realization that inflammation is one of the 'signaling pathways'--and probably an important one**

Cold-Water Immersion & Recovery

- **Perspective: "Apart from the physiological benefits conferred by cold-water immersion (CWI) in promoting post-exercise recovery, CWI may be a potential strategy to enhance exercise-induced mitochondrial adaptations"**
- **Ihsan et al. (*2015*). Regular Post-Exercise Cooling Enhances Mitochondrial Biogenesis through AMPK and p38 MAPK in Human Skeletal Muscle, American Journal of Physiology, Article in Press.**

Ihsan et al. (2015)

- **Subjects**
  - Eight (8) physically-active, healthy males
  - VO_2-peak = 46.7 mL O_2 * kg^{-1} * min^{-1}
  - Recreationally-active for at least one (1) year prior to study
  - No lower limb musculoskeletal injuries
- **Methods**
  - Three (3) repetition training sessions / week for four (4) weeks
  - Long (6- to 8-min), moderate (2-min), and short (30-sec) repetition sessions @ 80 – 110 percent of maximal aerobic velocity
  - One legged post-training cooling for 15-minutes @ ~ 10^o C

Ihsan et al. (2015)

- **Methods**
  - **Pre- and Post-training muscle biopsies from both legs**
  - **Biopsies analyzed for multiple regulators of mitochondrial biogenesis, multiple mitochondrial enzyme activities, and multiple mitochondrial protein contents**
- **Results**
  - **Certain biogenic signaling proteins were up-regulated (*total AMPK, for example*)**
  - **Several mitochondrial enzyme activities were not different between conditions**
  - **Select mitochondrial proteins were increased with CWI**

Ihsan et al. (*2015*)

Potential Interpretation: "Despite CWI being a popular post-exercise recovery modality, there was little evidence for how this intervention might influence muscle adaptations to training."

Ihsan et al. (*2015*)

Potential Interpretation: "Regardless, we advocate caution with regards to regular use of this intervention as some preliminary evidence suggests that *cold-induced mitochondrial biogenesis may concomitantly decrease mitochondrial efficiency*."

Yamane et al. (*2006*) & Ihsan et al. (*2015*)

Integrative, summary interpretation:
Cryotherapy involving cold-water immersion (*CWI*) may provide a stimulus for enhanced mitochondrial biogenesis yet simultaneously yield compromised mitochondrial function

i.e. more mitochondria that do not work as well

Part VI

Training Intensity Distribution

Training Intensity Distribution

- Neal, C.M., Hunter, A.M., Brennan, L., O'Sullivan, A., Hamilton, D.L., DeVito, G., & Galloway, D.R. (2013). **Six Weeks Of A Polarized Training-Intensity Distribution Leads To Greater Physiological And Performance Adaptations Than A Threshold Model In Trained Cyclists**, Journal of Applied Physiology, 114, 461-471.

Neal et al. (*2013*)

- **Experimental design**
  - **Randomized, crossover design**
  - **Twelve (*12*) well-trained male cyclists**
  - **Two six-week training periods separated by four weeks of detraining**
  - **All participants completed a 40-kilometer, pre-study time trial at an average power output $\geq$ 240 Watts**
  - **Three training sessions per week for six weeks**

Neal et al. (*2013*)

- **Polarized Training Model**

  6.4 ± 1.4 hours / week

  80% of training in low-intensity zone

  0% of training in moderate-intensity zone

  20% of training in high-intensity zone

- **Threshold Training Model**

  7.5 ± 2.0 hours / week

  57% of training in low-intensity zone

  43% of training in moderate-intensity zone

  0% of training in high-intensity zone

Data Summary: Neal et al. (*2013*)

	Polarized	Threshold
Δ In Peak Power Output (%)	8 ± 2	3 ± 1
Δ in Lactate Threshold (%)	9 ± 3	2 ± 4
Δ in High-Intensity Exercise Capacity (%)	85 ± 14	37 ± 14

Neal et al. (*2013*)

- **Data Interpretation**
  - **Six weeks of cycling endurance training with a polarized intensity distribution leads to greater performance adaptations than a threshold intensity distribution in well-trained cyclists**

Neal et al. (*2013*)

- **Practical Application(*s*)**
  - **A critical focus for both promoting ongoing adaptation and, ideally, optimizing adaptation may be the incorporation of significant high-intensity interval training, perhaps at the expense of moderate-intensity, continuous threshold training sessions**

Part VII

Training Intensity Distribution Among Well-Trained & Elite Endurance Athletes

Training Intensity Distribution Among Well-Trained & Elite Endurance Athletes

- **Stoggl, T.L. & Sperlich (*2015*), The Training Intensity Distribution among Well-Trained and Elite Endurance Athletes, Frontiers in Physiology, 6(*295*), 1 – 14.**

Training Intensity Distribution Among Well-Trained & Elite Endurance Athletes

- **Objectives:**
  - **Provide a Systematic Review of Training Intensity Distributions (*TID's*) during Preparation, Pre-Competition, and Competition Phases in Distinct Endurance Disciplines**
  - **Address whether one TID has demonstrated greater efficacy than other TID's**

Training Intensity Distribution Among Well-Trained & Elite Endurance Athletes

- Training Intensity Distribution (*TID*)
- High-Intensity Training (*HIT or HIIT*)
- High-volume, low-intensity training (*HVLIT*)
- Threshold Training (*THR*)
- Polarized Training
- Pyramidal Training

Stoggl, T.L. & Sperlich (*2015*): Preparation Phase

- **Vast majority of training conducted in the HVLIT range; 84% to 95%**
- **Small relative volume of training conducted in the THR range; 2% – 11%**
- **Small relative volume of training conducted in the HIT range; 2% – 9%**

Stoggl, T.L. & Sperlich (*2015*): Pre-competition Phase

- Vast majority of training conducted in the HVLIT range; 78%

- Small relative volume of training conducted in the THR range; 4%

- Small relative volume of training conducted in the HIT range; 18%

Stoggl, T.L. & Sperlich (*2015*): Competition Phase (*data are more sparse*)

- **Vast majority of training conducted in the HVLIT range; 77%**
- **Small relative volume of training conducted in the THR range; 15%**
- **Small relative volume of training conducted in the HIT range; 8%**

Stoggl, T.L. & Sperlich (*2015*): Seasonal (*across a six-month period*) TID

- **Vast majority of training conducted in the HVLIT range; 71%**

- **Small relative volume of training conducted in the THR range; 21%**

- **Small relative volume of training conducted in the HIT range; 8%**

Stoggl, T.L. & Sperlich (*2015*): Randomized, controlled studies

- **Esteve-Lanao et al. (*2007*)**
- **Group I: *80% / 12% / 8%***
- **Group II: *67% / 25% / 8%***
- **Group I retrospectively evaluated and quantified as a *74% / 11% / 15%* group**
- **Group I demonstrated superior improvement in 10.4K TT performance (*-157 seconds vs. -122 seconds*)**

Stoggl, T.L. & Sperlich (*2015*): Randomized, controlled studies

- **Stoggl & Sperlich (*2014*)**
- **Group I (*HVLIT*): *83% / 16% / 1%***
- **Group II (*THR*): *46% / 54% / 0%***
- **Group III (*HIT*): 43% / 0% / 57%**
- **Group IV (*P*): 68% / 6% / 26%**
- **ALL groups increased Time-to-Exhaustion (*TTE*)**
- **Polarized (*P*) TID increased maximal aerobic capacity (*11.7%*), time-to-exhaustion (*17.4%*), and and peak performance (*5.1%*) to the greatest extent**
- ***"experimental studies lasting 6 weeks to 5 months demonstrate superior responses to polarized TID"***

Stoggl, T.L. & Sperlich (*2015*)

- **Potential Practical Application(*s*)**
  - **Periodically review training intensity distribution (*TID*)**
  - **Do not neglect (*or eliminate*) threshold training (*particularly for high school student-athletes*)**
  - **Progress systematically (*95 / 5 {frosh.}, 90 / 10 {soph.}, 85 / 15 {junior}, 80 /20 {senior}*) toward increased incorporation of HIT?**

Part VIII

High-Intensity Interval Training

High-Intensity Interval Training (*HIIT*)

Question: Is there a tenable role for and / or value of high-intensity interval training in the broader training programs of endurance athletes?

High-Intensity Interval Training (*HIIT*)

- Gibala, M.J., Little, J.P., van Essen, M., Wilkin, G.P., Burgomaster, K.A., Safdar, A., Raha, S., & Tarnopolsky, M.A. (*2006*). Short-term Sprint Interval versus Traditional Endurance Training: Similar Initial Adaptations in Human Skeletal Muscle and Exercise Performance, Journal of Physiology, 575(*3*), 901-911.

Gibala et al. (*2006*)

- Sprint Interval Training (*SIT*) Group
  - 30-second intervals
  - 15-minutes of total training time over a 2-week period

- Endurance Training (*ET*) Group
  - 90-minute to 120-minute continuous runs
  - 630-minutes of total training time over a 2-week period

Data Summary: Gibala et al. (*2006*)

	SIT	ET
Δ in Muscle Gly. [ ]	28.0%	17.0%
Δ in Muscle Buffering Capacity	7.6%	4.2%
Δ in Endurance Time Trial Performance	10.1%	7.5%

Gibala et al. (*2006*)

Potential Interpretation: Periodic sprint interval training may not only enhance aerobic capacity but also promote multiple, complementary muscular adaptations that support improved endurance performance

High-Intensity Interval Training (*HIIT*)

- **Denadai, B.S., Ortiz, M.J., Greco, C.C., & de Mello, M.T. (*2006*). Interval training at 95% and 100% of the velocity at VO_{2}-$_{max}$: Effects on Aerobic Physiological Indexes and Running Performance, Applied Physiology, Nutrition, and Metabolism, 31, 737-743.**

Denadai et al. (*2006*)

Experimental Objective: To analyze the effect of two different high-intensity interval training (*HIIT*) programs on selected physiological indices in addition to potential effects on 1,500-m and 5,000-m running performance in well-trained runners

Denadai et al. (*2006*)

- **Experimental design**
  - **Randomized design**
  - **Seventeen (*17*) well-trained male runners**
  - **All participants completed both pre- and post-training 1,500-m and 5,000-m time trials on a 400-meter track**

Denadai et al. (*2006*)

- **Experimental design**
  - One four-week training period incorporating two weekly HIIT training sessions and four weekly submaximal training sessions
  - One group completed two weekly HIIT sessions at 95% vVO_2-max while the other group completed two weekly HIIT sessions at 100% vVO_2-max

Denadai et al. (*2006*)

Table 2. Maximal oxygen uptake ($VO_{2\,max}$), velocity at $VO_{2\,max}$ ($vVO_{2\,max}$), and velocity at onset of blood lactate accumulation (vOBLA) of 95%$vVO_{2\,max}$ and 100%$vVO_{2\,max}$ groups, before (pre) and after (post) training.

	$vVO_{2\,max}$ (km/h)		$VO_{2\,max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)		vOBLA (km/h)	
Group	Pre	Post	Pre	Post	Pre	Post
95% $vVO_{2\,max}$ ($n = 9$)	19.00±1.0	19.22±0.9	59.05±6.0	58.97±5.7	17.3±1.3	18.0±1.0*
100% $vVO_{2\,max}$ ($n = 8$)	18.30±0.5	19.06±1.0*	59.98±6.0	58.35±5.4	17.3±0.8	18.1±0.6*

Note: Values are mean ± SD.
*$p < 0.05$ compared with before training.

Denadai et al. (*2006*)

Table 1. Example of weekly programs for 95% $vVO_{2\,max}$ and 100% $vVO_{2\,max}$ groups.

Days	Groups 95% $vVO_{2\,max}$	100% $vVO_{2\,max}$
Mon	Warm-up: 4 km Interval training: 4×60% $t_{lim}95\%vVO_{2\,max}$ at 95% $vVO_{2\,max}$ Active recovery: 30% $t_{lim}95\%vVO_{2\,max}$ at 50% $vVO_{2\,max}$ Cool-down: 2 km	Warm-up: 4 km Interval training: 5×60% $t_{lim}100\%vVO_{2\,max}$ at 100% $vVO_{2\,max}$ Active recovery: 60% $t_{lim}100\%vVO_{2\,max}$ at 50% $vVO_{2\,max}$ Cool-down: 2 km
Tue	45 min at 70% $vVO_{2\,max}$	45 min at 70% $vVO_{2\,max}$
Wed	Interval training as on Monday	Interval training as on Monday
Thu	60 min at 60% $vVO_{2\,max}$	60 min at 60% $vVO_{2\,max}$
Fri	Warm-up: 3 km 2×20 min at OBLA velocity with 5 min of active recovery at 60% $vVO_{2\,max}$ between bouts Cool-down: 2 km	Warm-up: 3 km 2×20 min at OBLA velocity with 5 min of active recovery at 60% $vVO_{2\,max}$ between bouts Cool-down: 2 km
Sat	Rest	Rest
Sun	60 min at 60% $vVO_{2\,max}$	60 min at 60% $vVO_{2\,max}$
Total volume	75–80 km	75–80 km

Denadai et al. (*2006*)

Table 4. The 1500 and 5000-m time trial data from the 95% $vVO_{2\,max}$ and 100% $vVO_{2\,max}$ groups, before (pre) and after (post) training.

	1500 m (s)		5000 m (s)	
Group	Pre	Post	Pre	Post
95% $vVO_{2\,max}$ (n = 9)	271.1±13.5	269.0±13.4	1001.0±61.8	986.0±56.9*
100% $vVO_{2\,max}$ (n = 8)	270.7±8.7	265.5±8.4*	994.7±44.8	981.0±39.6*

Note: Values are mean ± SD.
*$p < 0.05$ compared with before training.

Denadai et al. (*2006*)

- **Conclusion**
  - **5,000-m run performance can be significantly improved in well-trained runners using a 4-week program consisting of 2 HIIT sessions (*at 95% or 100% of $_{v}VO_2$-max*) and 4 submaximal sessions per week**

- **Conclusion**
  - **However, improvement in 1,500-m run performance appears to be dependent upon incorporation of training at 100% of $_{v}VO_2$-max**

High-Intensity Interval Training (*HIIT*)

- **Esfarjani, F. & Laursen, P.B. (*2007*). Manipulating high-intensity interval training: Effects on VO2-max, the lactate threshold, and 3000-m running performance in moderately-trained males, Journal of Science and Medicine in Sport, 10, 27-35.**

Esfarjani & Laursen (*2007*)

- **Subjects**
  - Seventeen (17) moderately-trained male runners
  - Pre-intervention VO_2-max = 51.6 $\pm$ 2.7 mL O_2 * kg^{-1} * min^{-1}
  - No HIIT training for at least three (3) months prior to the study
- **Methods**
  - Ten-week (10) treadmill training program
  - Group I: 2 HIIT sessions & 2 distance runs (60-minutes at 75% of $_vVO_2$-max) each week
  - Group II: 2 HIIT sessions & 2 distance runs (60-minutes at 75% of $_vVO_2$-max) each week
  - Group III: 4 distance runs (60-minutes at 75% of $_vVO_2$-max) each week

Esfarjani & Laursen (*2007*)

- **Methods**
  - **Group I: 2 HIIT sessions (*5 to 8 repetitions @ 100% $_{v}VO_2$-max for 60% T_{max} w/ 1:1 work:rest ratio*) each week**
  - **Group II: 2 HIIT sessions (*7 to 12 x 30-second repetitions @ 130% $_{v}VO_2$-max w/ 1:9 work:rest ratio*) each week**
  - **Group III: No HIIT sessions throughout the training intervention**

- **Outcome Measures**
  - **VO_2-max (*mL O_2 * kg^{-1} * min^{-1}*)**
  - **$_{v}VO_2$ (*kilometers * $hour^{-1}$*)**
  - **T_{max} (*seconds*)**
  - **V_{LT} (*kilometers * $hour^{-1}$*)**

Esfarjani & Laursen (*2007*)

Δ(%)	Group I	Group II	Control Group
VO_2-max	+9.1	+6.2	+2.1
$_vVO_2$	+6.4	+7.8	+1.3
T_{max}	+35.0	+32.0	+3.5
V_{LT}	+11.7	+4.7	+1.9

Esfarjani & Laursen (*2007*)

Potential Interpretation: Periodic repetition training at approximately $_{v}VO_2$-max pace / intensity appears to correlate robustly (*yet again*) with multiple, performance-enhancing adaptations such as *IMPROVED* velocity at VO_2-max ($_{v}VO_2$*-max*) and *ENHANCED* velocity at lactate threshold (V_{LT})

Part IX

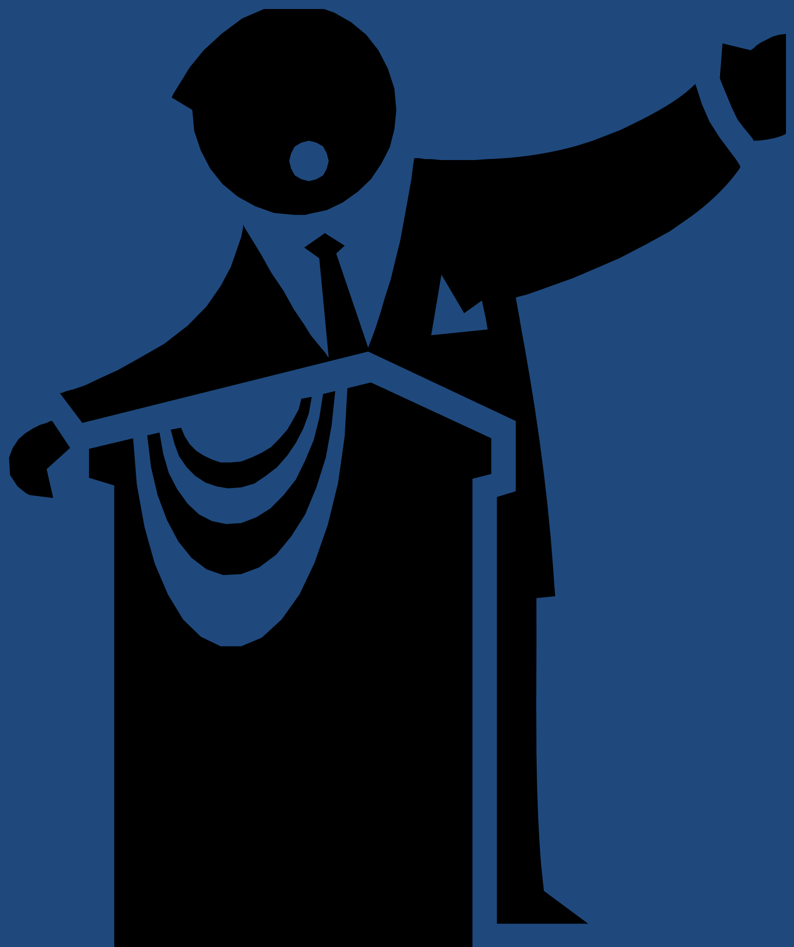
Uphill Interval Training

Uphill Interval Training

- **Barnes, K.R., Kilding, A.E., Hopkins, W.G., Mcguigan, M.R., & Laursen (*2012*). Effects of Different Uphill Interval-Training Programs on Running Economy and Performance, Journal of Science and Medicine in Sport, 15, S33.**

Barnes et al. (*2012*)

- Introduction
  - Uphill running is a form of running-specific resistance training
  - Optimal parameters for prescribing uphill interval training are unknown
  - Dose-response approach might yield specific insight as to program design

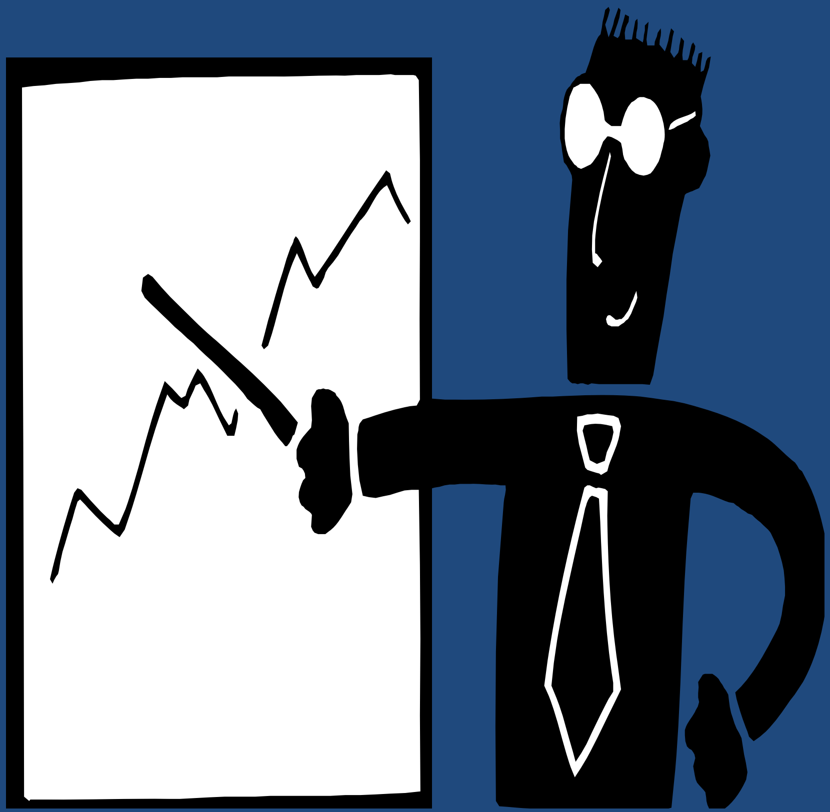


Barnes et al. (*2012*)

- **Methods**
  - **Twenty well-trained runners performed VO_2-max, running economy and 5-k time trial assessments**
  - **Subsequent random assignment to one of five intensities of uphill interval training**
  - **20 x 10-sec. intervals at 120% of $_vVO_2$-max w 18% grade / 2 x 20-min. intervals at 80% of $_vVO_2$-max w 4% grade**

Barnes et al. (*2012*)

- Results
  - Improvement in running economy was greatest at the highest intensity of hill interval training
  - There was no clear optimum for improvement of 5-K time trial performance



Barnes et al. (*2012*)

- **Discussion**
  - Uphill interval training @ 95% $_{v}VO_2$-max (*8 x 2-min intervals*) produced greatest improvements in most physiological measures related to performance
  - However, running economy improved most dramatically at the greatest (*120% $_{v}VO_2$-max*) intensity

Barnes et al. (*2012*)

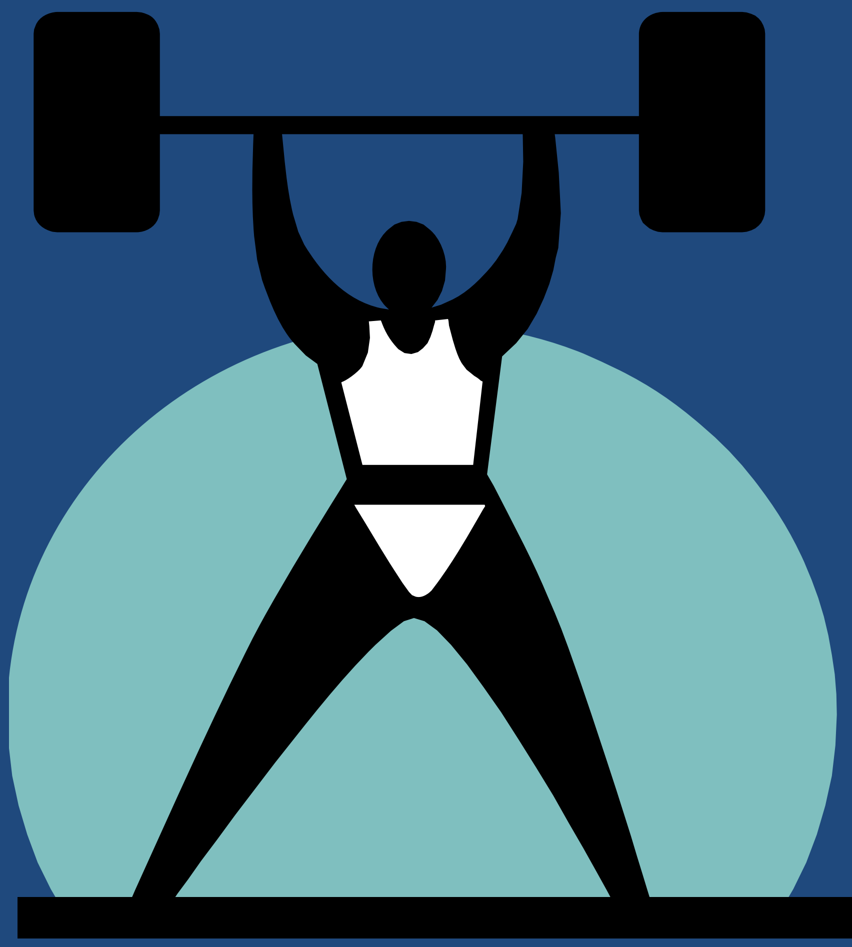
- **Conclusion(s)**
  - **"Until more data are obtained, runners can assume that <u>any</u> <u>form</u> of high-intensity uphill interval training will benefit 5-k time trial performance"**
  - **<u>Integrate</u> short- <u>and</u> intermediate- / long-hill repetitions into hill training workouts**

Part X

Concurrent Training

Concurrent Training

- Chtara, M., Chamari, K., Chaouachi, M., Chaouachi, A., Koubaa, D., Feki, G., Millet, P., & Amri, M. (*2005*). Effects of Intra-session Concurrent Endurance and Strength Training Sequence on Aerobic Performance and Capacity, British Journal of Sports Medicine, 39: 555-560.



Concurrent Training

- **Purpose:** **To not only examine the effects of concurrent strength and endurance training on aerobic performance but also determine if the order of training within a training session differentially impacts endurance performance**
  - **Endurance training group (*E*)**
  - **Strength training group (*S*)**
  - **Endurance / strength training group (*E* + *S*)**
  - **Strength / endurance training group (*S* + *E*)**

Concurrent Training

- **Experimental design**
  - **Five (*5*) group (*E*, *S*, *E* + *S*, *S* + *E*, & *C*) design**
  - **Forty-eight (*48*) physically-active subjects (*engaged in approximately fifteen {15} hours per week of activities specific to their sport studies academic program*)**
  - **VO_2-max = 50.6 ml O_2 * kg^{-1} * min^{-1}**

Concurrent Training

Table 1 Strength training programme

	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Duration of cycle (weeks)	3	3	3	3
Main objective	Strength endurance	Strength endurance	Explosivity	Explosivity
Number of exercises per circuit	6	6	6	6
Number of circuit revolutions (series)	4	4	4	4
Work/rest (s)	30/30	40/20	30/30	40/20
Inter-series recovery (min)	2	2	2	2
Total duration of the session (min)	30	30	30	30

Concurrent Training

Table 2 Physical and physiological characteristics before and after 12 weeks of training

				$\dot{V}O_2MAX$			$Th2_{vent}$		
	4 km time trial (s)	$v\dot{V}O_2MAX$ (km/h)	t_{lim} (s)	l/min	ml/kg/min	$ml/kg^{0.75}/min$	ml/kg/min	$\%\dot{V}O_2MAX$	HR_{max} (beats/min)
E (n = 10)									
Before	934.2 (47.0)	16.17 (1.06)	312.20 (68.01)	3.80 (0.53)	49.84 (3.06)	147.13 (10.29)	38.90 (2.60)	78.05 (1.87)	187.50 (6.26)
After	881.0 (39.2)**	17.52 (0.72)**	394.2 (53.9)**	4.22 (0.53)**	54.73 (3.42)**	162.03 (10.46)**	44.71 (2.40)**	81.78 (2.96)**	187.88 (6.06)
S (n = 9)									
Before	931.1 (32.8)	16.12 (0.50)	280.89 (55.58)	3.41 (0.35)	50.08 (4.89)	143.82 (14.18)	39.08 (3.26)	78.15 (2.22)	190.38 (9.10)
After	908.1 (29.4)*	16.38 (0.41)*	326.67 (57.88)**	3.69 (0.30)**	53.00 (4.05)**	153.09 (11.77)**	42.33 (2.86)**	79.92 (1.77)*	191.25 (7.55)
S+E (n = 10)									
Before	929.3 (30.4)	16.16 (1.02)	274.90 (63.30)	3.75 (0.24)	51.15 (3.45)	149.58 (8.20)	39.63 (2.34)	77.51 (1.23)	187.75 (9.02)
After	886.0 (11.3)*	17.48 (0.79)**	346.00 (39.50)**	4.20 (0.20)**	56.61 (2.03)**	166.05 (3.54)**	45.96 (1.67)**	81.19 (0.88)**	188.75 (7.92)
E+S (n = 10)									
Before	932.3 (17.1)	16.18 (0.91)	312.70 (57.01)	3.65 (0.42)	51.29 (1.60)	148.83 (6.53)	40.25 (0.93)	78.50 (1.94)	187.13 (7.61)
After	852.3 (29.5)**	17.86 (0.45)**	417.01 (38.02)**	4.16 (0.38)**	58.27 (1.90)**	169.24 (4.54)**	48.92 (1.77)**	83.97 (1.89)**	188.25 (5.78)
C (n = 9)									
Before	920.8 (42.3)	16.14 (0.78)	253.89 (51.01)	3.67 (0.34)	50.65 (6.34)	147.73 (17.22)	38.66 (4.06)	76.49 (2.25)	191.25 (9.59)
After	923.83 (35.2)	16.18 (0.75)	247.56 (50.52)	3.68 (0.28)	50.51 (4.71)	147.51 (12.96)	38.70 (3.68)	76.63 (1.86)	191.63 (8.72)

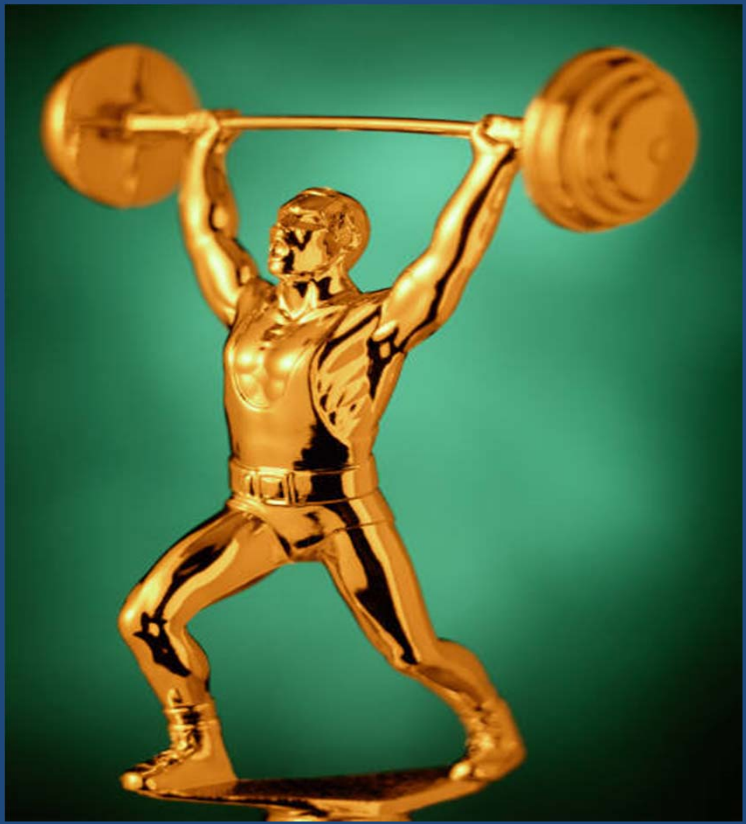
*$p<0.05$, **$p<0.01$, significantly different from before training.
$v\dot{V}O_2MAX$, Lowest velocity associated with $\dot{V}O_2MAX$; t_{lim}, time to exhaustion at $v\dot{V}O_2MAX$; $\dot{V}O_2MAX$, maximal oxygen uptake; $Th2_{vent}$, second ventilatory threshold or respiratory compensation threshold; HR_{max}, maximal heart rate.

Concurrent Training

- **Data Interpretation**
  - **4-kilometer time trial running performance improved in the E + S group (*8.57%*), the E group (*5.69%*), the S + E group (*4.66%*), and the S group (*2.47%*)**
    - **E + S group improvement superior to S + E group improvement**
    - **E group improvement superior to S + E group improvement**

Concurrent Training

- **Wang, L., Mascher, H., Psilander, N., Blomstrand, E., & Sahlin, K. (*2011*). Resistance Exercise Enhances the Molecular Signaling of Mitochondrial Biogenesis Induced by Endurance Exercise in Human Skeletal Muscle, Journal of Applied Physiology, 111: 1335 – 1344.**



Concurrent Training

- **Purpose: To investigate if resistance exercise can alter the molecular signaling response to endurance exercise in skeletal muscle**

- **Hypothesis: Molecular signaling of mitochondrial biogenesis subsequent to endurance exercise is impaired by resistance exercise**

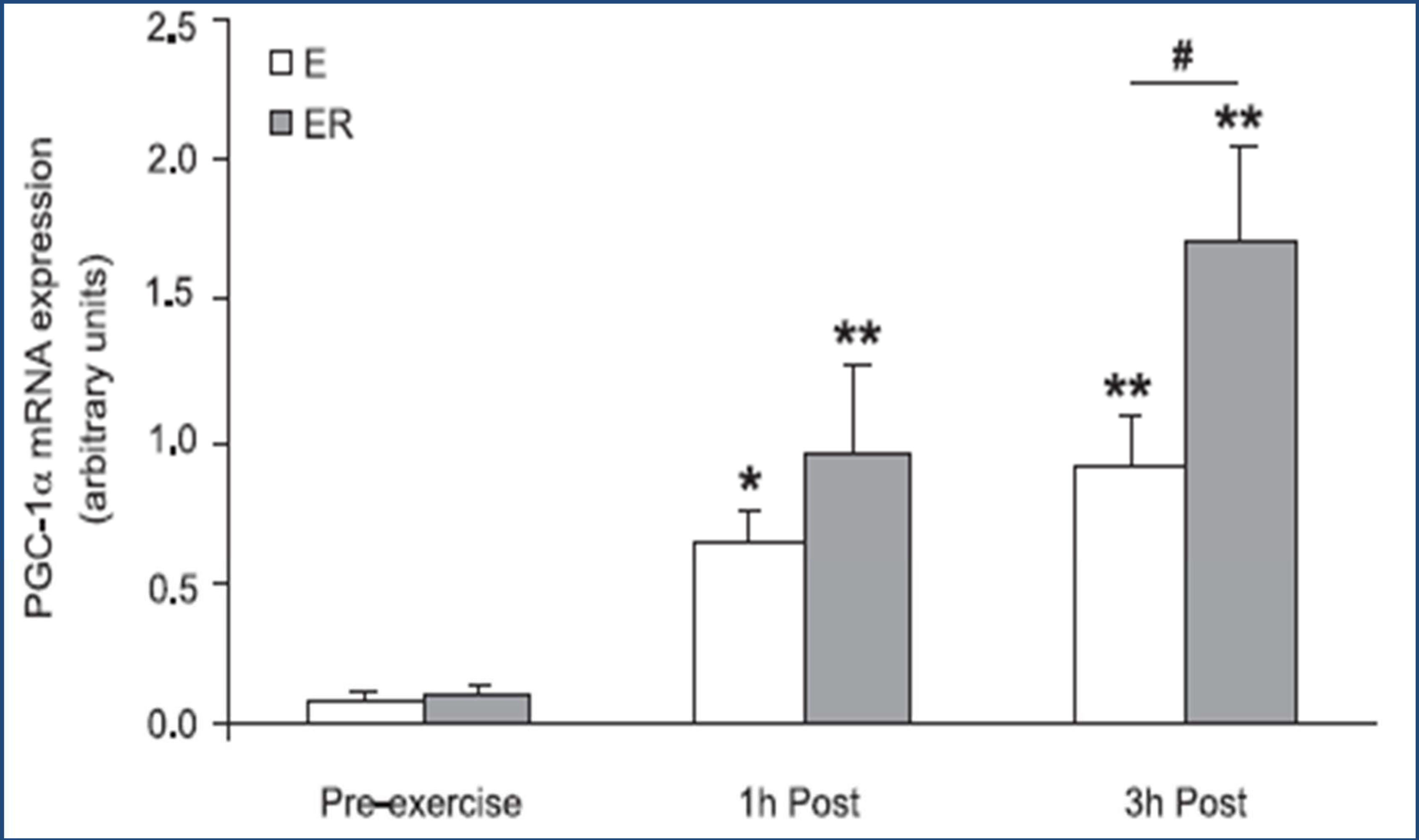
  - **60-minutes of cycling exercise @ 65% of VO_2-max (*E*)**

  - **60-minutes of cycling exercise @ 65% of VO_2-max followed by 6 sets of leg press @ 70-80% of 1-repetition maximum (*1-RM*) (*ER*)**

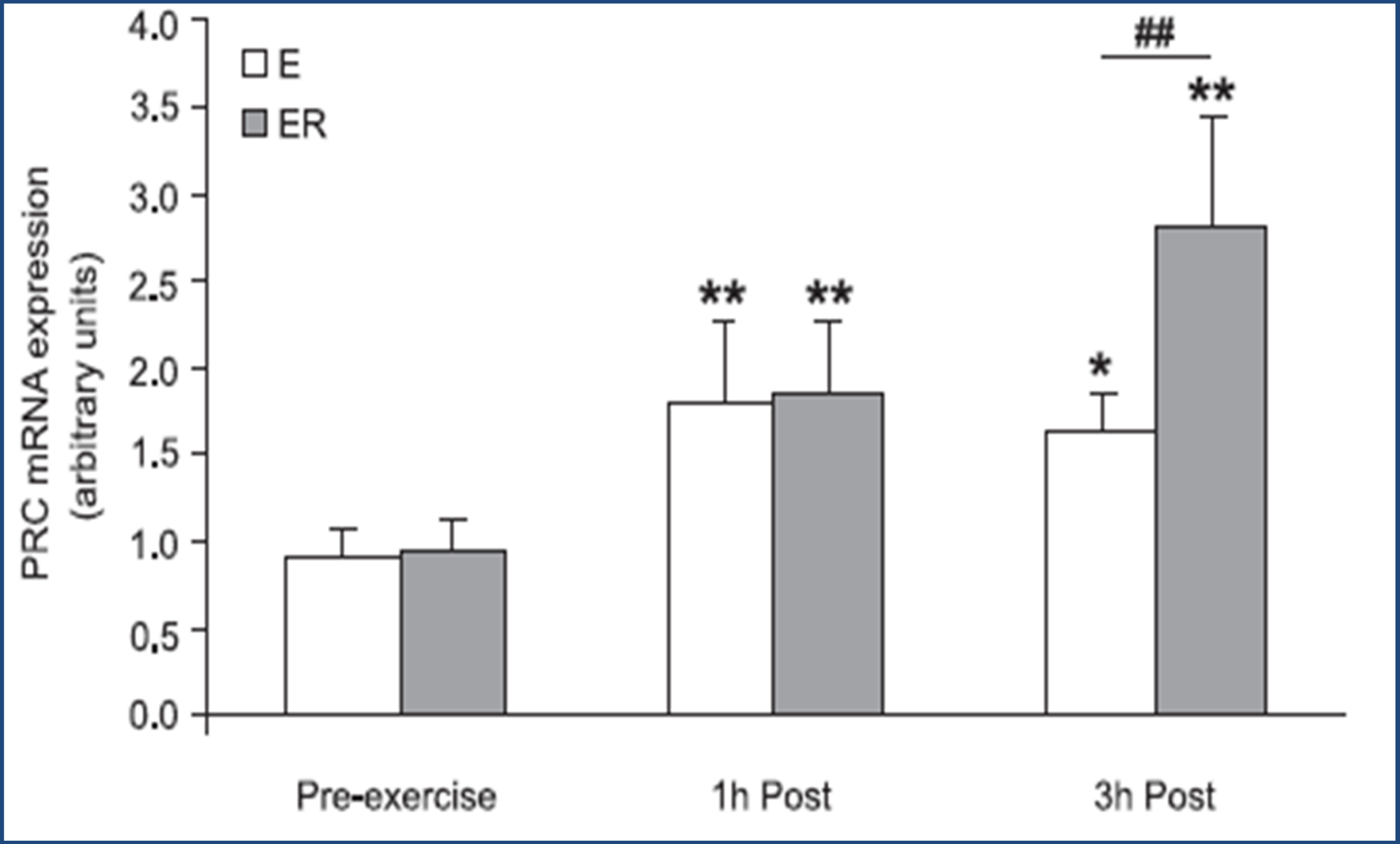
Concurrent Training

- **Experimental design**
  - **Randomized, crossover design**
  - **Ten (*10*) recreationally-active subjects (*not engaged in programmed endurance or resistance exercise during the six months prior to the study*)**
  - **VO_2-peak = 50.0 ml O_2 * kg^{-1} * min^{-1} $\pm$ 1.9 ml O_2 * kg^{-1} * min^{-1}**
  - **1-RM leg press = 336 $\pm$ 22.3 kg**

Concurrent Training



Concurrent Training



Concurrent Training

- **Data Interpretation**
  - **The messenger RNA (*mRNA*) of multiple "*master regulators*" of mitochondrial biogenesis are almost 50% (*PGC-1α*) and 90% (*PGC-1α & PRC*) higher, respectively, in the post-training period when resistance training is performed subsequent to endurance exercise as compared to single-mode endurance exercise**

Concurrent Training

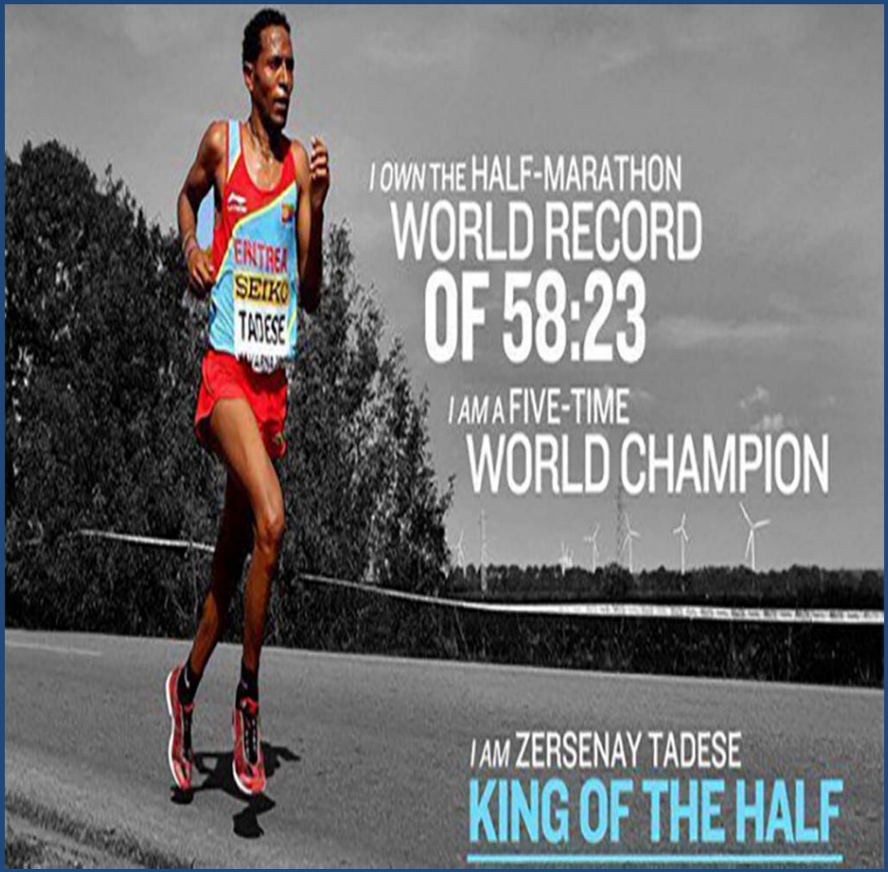
- **Practical Application**
  - **Perform a brief bout of (*lower body*) resistance exercise immediately <u>subsequent</u> <u>to</u> an endurance training session in order to <u>amplify</u> the training-induced <u>stimulation</u> of <u>mitochondrial biogenesis</u>**
  - **Bouts of General Strength (*GS*) training (*Appendices E, F, & G*)?**

Part XI

Explosive Training, Heavy Weight Training, & Running Economy

Explosive Training, Heavy Weight Training, & Running Economy

- **Denadai, B.S., de Aguiar, R.A., de Lima, L.C.R., Greco, C.C., & Caputo, F. (*2016*), Explosive Training and Heavy Weight Training are Effective for Improving Running Economy in Endurance Athletes: A Systematic Review and Meta-Analysis, Sports Medicine.**



Denadai et al. (*2016*)

<u>Objective:</u> To Evaluate the Effect of Concurrent Training on Running Economy (*RE*) in Endurance Athletes

Denadai et al. (*2016*)

- Searched PubMed database
- Searched Web of Science database
- Reviewed reference lists from selected studies
- Searched studies published up to August 15th, 2015
- Incorporated Inclusion / Exclusion Criteria
- One-hundred and nineteen (*119*) relevant studies were identified

Denadai et al. (*2016*)

Ultimately, sixteen (*16*) studies were formally assessed to meet all requisite criteria and thus be sufficiently rigorous to be included in the quantitative analysis

Denadai et al. (*2016*)

- **Percentage (%) change in RE ranged from -12.52 to +0.72**
- **Overall, concurrent training had a positive effect: *-3.93%***
- **Millet et al. (*2012*): -*12.52%* change in RE consequent to HWT emphasizing half-squat and heel raises**
- **Only heavy weight training (*HWT*) and explosive training (*EXP*) presented a % change significantly lower than zero**
- **Saunders et al. (*2006*): -3.63% change in RE consequent to EXP emphasizing foundational plyometric movements**

Denadai et al. (*2016*)

- **Short- and medium-term training periods (*6- to 14-weeks*) of concurrent training were sufficient to enhance RE in recreationally-trained endurance runners**

- **Relatively longer training periods (*14- to 20-weeks*) in combination with relatively high weekly training volumes of endurance running were requisite to enhancing RE in highly-trained individuals**

Denadai et al. (*2016*)

- **Practical applications:**
  - **Consistently incorporate age-appropriate, beginning- and intermediate-level plyometric training throughout the season for both novice and experienced endurance athletes in order to duly emphasize foundational RE enhancement**
  - **Consider the eventual, selective incorporation of specific, lower-limb, heavy resistance exercises in order to further amplify foundational improvements in RE**

Part XII

“Popular” Literature – Running Economy

Running Economy

The presenter's incorporation of the term "*popular literature*" refers to non-data-based, non-peer reviewed information / literature sources

Running Economy

Question: Can running economy be enhanced through incorporation of resistance training?

Running Economy

Perspective: "… a 2008 review article by Linda Yamamoto and colleagues indicates a trend toward improved RE when plyometric exercises are added to an endurance training program."

Running Economy

- Yamamoto, L.M., Lopez, R.M., Klau, J.F., Casa, D.J., Kraemer, W.J., & Maresh, C.M. (*2008*). The Effects of Resistance Training on Endurance Distance Running Performance among Highly Trained Runners: A Systematic Review, Journal of Strength and Conditioning Research, 22(*6*): 2036 – 2044.

Running Economy

- **The prior data-based resource as referenced in a popular literature source purportedly addresses "*highly trained runners*" in a systematic review of applicable scientific literature**

- **Definition of "*highly trained runners*"**
  - **Run greater than or equal to thirty (*30*) miles per week <u>or</u>**
  - **Run greater than or equal to five (*5*) days per week**

Running Economy

Question: How does one define a *"highly trained runner?"*

Running Economy

Question: Is the aforementioned review of literature as cited in a popular magazine applicable to high school cross-country student-athletes?

Running Economy

Interpretation: Simple acceptance and application of the summary statements and corresponding recommendations offered through non-data-based literature sources may be suboptimal

Running Economy

- **Practical Application**
  - **Coaches would likely benefit from personally reading select data-based literature**
  - **Consequent, associated, select application of data-based literature (*Saunders et al., 2006*) is likely preferable to passive acceptance of popular literature recommendations**

Saunders et al. (*2006*)

Table 2. Nine-week plyometric training program.

	1		2–5			6–9		
Week session	1	2	1	2	3	1	2	3
Back extension	1 × 15		2 × 15	2 × 15		2 × 15		
Leg press	2 × 6		5 × 8	5 × 8		5 × 8		
Countermovement jumps	1 × 6		3 × 6	3 × 6		3 × 6		
Knee lifts (technical)	1 × 20		3 × 20			3 × 20		
Ankle jumps	1 × 10		3 × 10	3 × 10		3 × 10		
Hamstring curls	1 × 10		3 × 10	3 × 10		3 × 10		
Alternate-leg bounds		1 × 10			6 × 10 m		6 × 10 m	4 × 10 m
Skip for height		1 × 30 m			4 × 30 m		4 × 30 m	5 × 20 m
Single-leg ankle jumps		1 × 20 m			4 × 20 m		4 × 20 m	
Continuous hurdle jumps								5 × 5
Scissor jumps for height								5 × 8

Part XIII

"Popular" Literature – Long-run duration

Long-Run Duration

The presenter's incorporation of the term "*popular literature*" refers to non-data-based, non-peer reviewed information / literature sources

Long-Run Duration

Question: Is there a specific long-run duration and / or minimal requirement for long-run duration necessary to support desired physiological adaptation(*s*)?

Long-Run Duration

Perspective: "… '*the magic number to hit in a single run is 80 minutes*. A lot of the science shows that once you reach the 80-minute mark, there is a bigger benefit in endurance enzymes made.' _______ notes that studies have shown that the differences of enzymatic production from 60 to 80 minutes are enormous."

Long-Run Duration

- **The previous quotation and subsequent summary statement reflect the perspective of a <u>highly</u> <u>recognized</u>, so-called "*elite*" US marathon coach**

- **Immediately subsequent to reading these statements, J.I. Messer contacted the coach directly and requested specific, scientific references**

Long-Run Duration

- **The presenter's initial request for specific references was addressed through an electronic mail response indicating that the author of the comment would promptly respond subsequent to an ongoing geographical relocation**

- **Presenter never received a follow-up response to the initial request**

Long-Run Duration

- **The presenter's second and final request for specific references was addressed through an electronic mail response in which the** ***author of the comment conceded that he could not cite a single scientific reference***

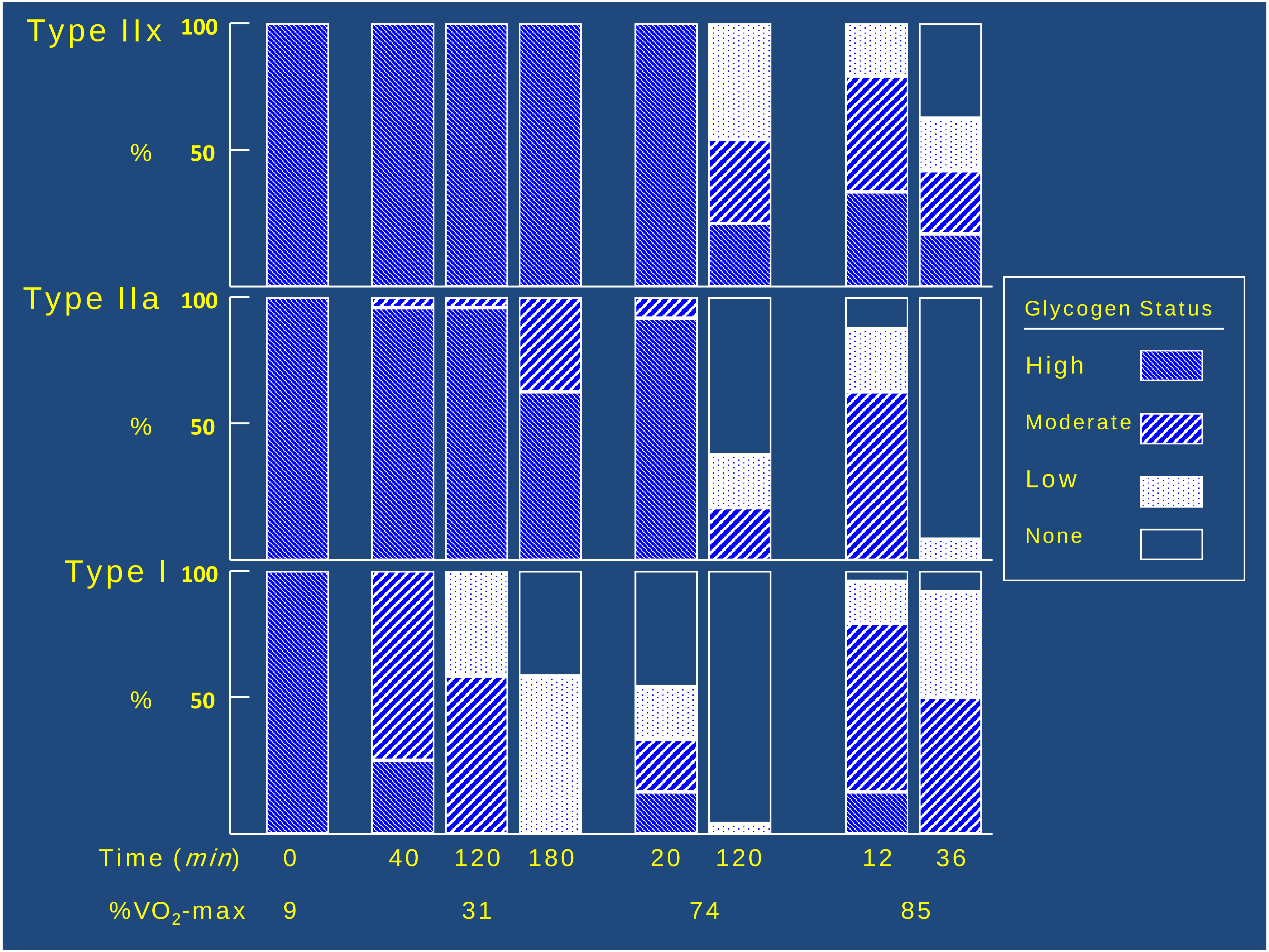
- **His most telling comment to the presenter was …** ***"I think I saw a similar statement in an issue of Running Research News"***

Long-Run Duration

Perspective: Training programs need not (*and likely cannot and should not*) always be data-based but statements offered by widely-recognized, widely-written "*expert*" coaches should reflect an honest, information-based approach

Long-Run Duration

Question: Is there a viable data-based perspective that we can offer with regard to appropriate long-run duration?



Type IIx
100
%
50
Type IIa
100
%
50
Type I
100
%
50
Glycogen Status
High
Moderate
Low
None
Time (*min*)
0
40
120
180
20
120
12
36
%VO2-max
9
31
74
85

Long-Run Duration

Interpretation: The previous data set robustly reminds us that specific adaptive "*signals*" in skeletal muscle (*glycogen depletion, for example,*) accumulate progressively through distinct combinations of duration and intensity

Long-Run Duration

- **Practical Application**
  - **Existing scientific literature has yet to identify a critical / optimal long run duration**
  - **It is highly likely that no such duration exists as muscle physiology and attendant adaptation appear to respond <u>progressively</u> to training stress / stimuli**

Long-Run Duration

- **Practical Application**
  - **Simply maintain a principled approach to the development and incorporation of a long-run in a broader training program**
    - **Consistency**
    - **Progression**
    - **Goal-specificity**

Part XIV

Protein Ingestion Prior to Sleep: Potential for Optimizing Post-Exercise Recovery

Protein Ingestion Prior to Sleep

- **Protein Ingestion Prior to Sleep: Potential for Optimizing Post-Exercise Recovery, 2013, GSSI Sports Science Exchange, Volume 26, Number 117, 1 – 5.**

Protein Ingestion Prior to Sleep

- **In addition to the amount and source(*s*) of protein ingested subsequent to an acute bout of training, associated timing of protein ingestion has been identified and accepted as a key factor in modulating post-exercise muscle anabolism (*Beelen, Burke, Gibala, & van Loon, 2011*)**

Protein Ingestion Prior to Sleep

- **While immediate post-training protein ingestion does support enhanced muscle protein synthesis in the acute stages / period of post-training recovery, such a strategy does not support a sustained increase in muscle protein synthetic rate during subsequent overnight recovery (*Beelen, Tieland, Gijsen, Vandereyt, Kies, Kuipers, Saris, Koopman, & van Loon, 2008*)**

Protein Ingestion Prior to Sleep

- Res, P.T., Groen, B., Pennings, B., Beelen, M., Wallis, G.A., Gijsen, A.P., Senden, J.M., & van Loon, L.J. (2012). Protein Ingestion prior to Sleep Improves Post-Exercise Overnight Recovery, Medicine and Science in Sports and Exercise, 44: 1560 – 1569.

- Recreational athletes
- Single bout of evening resistance exercise
- All participants were provided standardized post-exercise recovery nutrition
- 30-minutes prior to sleep, participants ingested either a placebo or 40 grams of casein protein

Protein Ingestion Prior to Sleep

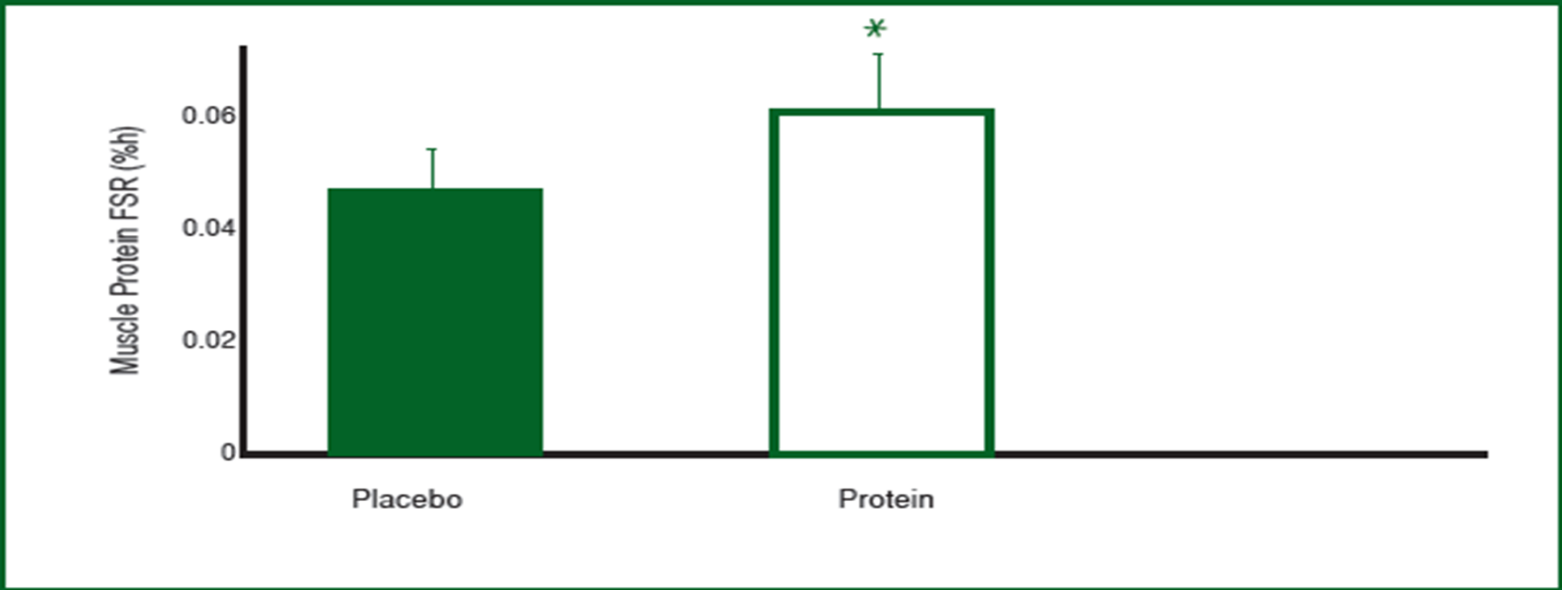


Figure 3. Dietary protein ingestion prior to sleep stimulates muscle protein synthesis during overnight recovery. Fractional synthesis rate (FSR) of mixed muscle protein during overnight recovery from a single bout of resistance type exercise. In the protein trial, 40 g of casein protein were ingested prior to sleep. Values represent means ± SEM. *Significantly different from placebo (P=0.05). Figure redrawn from Res et al. (2012) Med. Sci. Sports Exerc. 44:1560-1569, American College of Sports Medicine.

Protein Ingestion Prior to Sleep

Nutritional Recommendations for the Athlete

Provide sufficient protein (20-25 g) with each main meal

Consider coingesting some protein with carbohydrate during exercise (to optimize protein synthesis. However, protein has also been linked with slowing of delivery of carbohydrate and fluid as well as GI distress, and thus individuals need to determine their own strategy)

Ingest 20-25 g of protein immediately after exercise

Consume 20-40 g of protein prior to sleep

Part XV

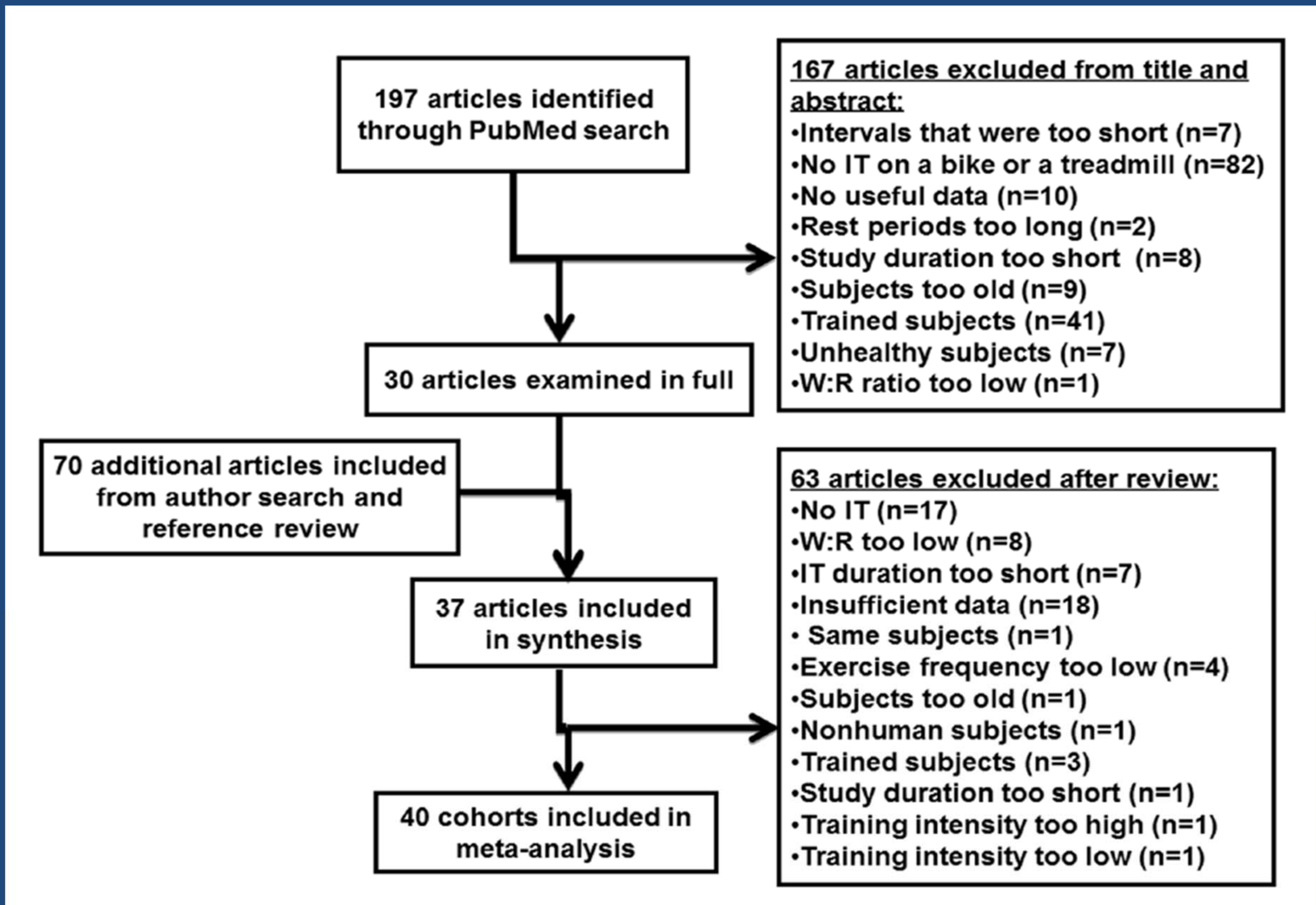
VO_2-max Trainability and High Intensity Interval Training (*HIIT*) in Humans

VO_2-max and HIIT

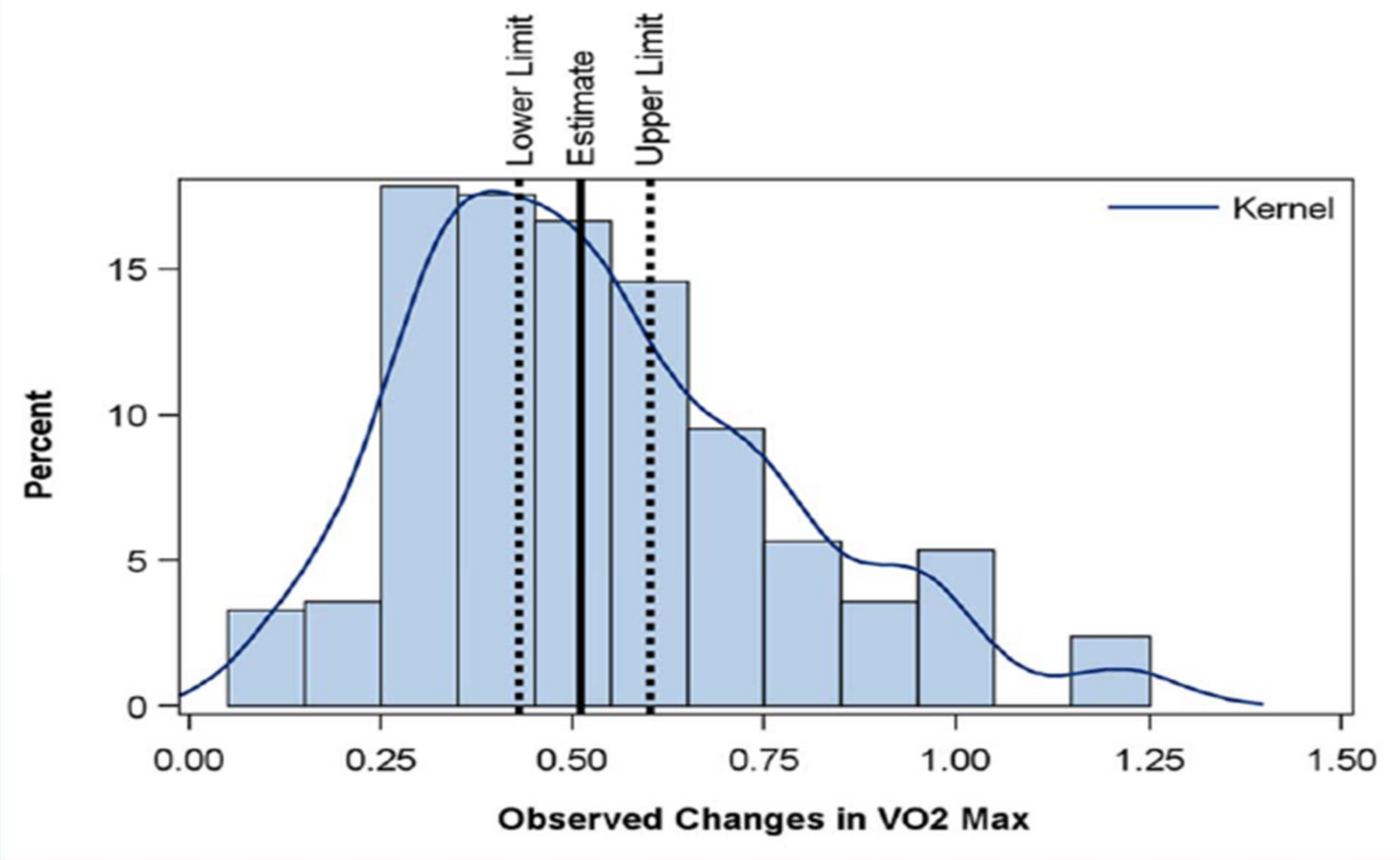
- Bacon, A.P., Carter, R.E., Ogle, E.A., & Joyner, M.J. (2013). VO_2-max Trainability and High Intensity Interval Training in Humans: A Meta-Analysis, PLOS, September, 8:9, e73182.

- Analysis reviewed studies published in English from 1965 – 2012
- Study inclusion criteria involved 6- to 13-week training periods, $\geq$ 10-minutes of HIIT in a representative training session (*i.e.workout*), and a $\geq$ 1:1 work:rest ratio

VO_2-max and HIIT



VO_2-max and HIIT



VO_2-max and HIIT

- **Authors note "*conventional wisdom*" that repetitions of 3- to 5-minutes are thought to be particularly effective in invoking enhanced aerobic capacity**

- **Current analysis strongly supports this perspective; the nine (*9*) studies that associate with the greatest increases in maximal aerobic capacity (*VO_2-max*) involve 3- to 5-minute intervals and relatively high intensities *($\geq$ 85% of VO_2-max*)**

VO_2-max and HIIT

Potential Interpretation: **Emphasize repetitions of, for example, 800-m, 1,000-m, and 1,200-m in order to provide a robust stimulus for enhancement of maximal aerobic capacity (*and include very brief, for instance, repetitions of 150-m and 200-m to provide a complementary stimulus for enhancement of both maximal aerobic capacity and running economy, Gibala et al., 2012*)**

Part XVI

Plyometric Training & Endurance Performance

Plyometric Training & Endurance Performance

- Ramirez-Campillo, R., Alvarez, C., Henriquez-Olguin, C., Baez, E.B., Martinez, C., Andrade, D.C., & Izquierdo, M. (*2014*). Effects of Plyometric Training on Endurance and Explosive Strength Performance in Competitive Middle- and Long-Distance Runners, Journal of Strength and Conditioning Research, 28(*1*), 97 – 104.

- Primary study objective was to assess the effect(*s*) of concurrent endurance and plyometric training on both endurance time trial performance and explosive strength in competitive middle- and long-distance runners

Plyometric Training & Endurance Performance

- **36 participants (*14 women, 22 men*)**
- **Mean age of 22.7 ± 2.7 years**
- **Minimum of 2-years of competitive national and / or international experience**
- **Personal best performances ranging from 3:50 to 4:27 (*min:sec, 1,500-m*) and 2:32 to 2:52 (*hours:min, marathon*)**

Plyometric Training & Endurance Performance

- **Mean weekly endurance training volume of 67.2 ± 18.9 kilometers**

- **Mean pre-study 2.4-km time trial performance of approximately 7.8-minutes (*i.e. 5-minute, 13-second per mile pace for approximately 1.5-miles*)**

Plyometric Training & Endurance Performance

- **Six (*6*) week plyometric training intervention**
- **Two (*2*) plyometric training sessions per week**
- **Less than thirty (*30*) minutes per session**
- **All plyometric training involved depth jumps (*2 x 10 jumps from a 20 cm box, 2 x 10 jumps from a 40 cm box, and 2 x 10 jumps from a 60 cm box*)**
- **Fifteen (15) second rest intervals between repetitions and two (2) minute rest intervals between sets**

Plyometric Training & Endurance Performance

Plyometric	Control	Plyometric	Control	Plyometric	Control
2.4-km TT	2.4 km TT	20-m Sprint	20-m Sprint	CMJA	CMJA
7.6 to 7.3-minutes 3.9% faster	8.0- to 7.9-minutes 1.3% faster	3.92 to 3.83 seconds 2.3% faster	3.97 to 3.94 seconds 0.8% faster	36.1 to 39.3 cm 8.9% higher	34.1 to 36.3 cm 6.5% higher

Plyometric Training & Endurance Performance

Potential Interpretation: **Incorporate plyometric training into the ongoing endurance training of student-athletes in order to both enhance muscular strength / power and improve endurance performance**

Part XVII

Adaptations to Aerobic Interval Training: Interactive Effects of Exercise Intensity and Duration

Adaptations to Aerobic Interval Training

- **Seiler, S., Joranson, K., Olesen, B.V., & Hetlelid, K.J. (2013). Adaptations to Aerobic Interval Training: Interactive Effects of Exercise Intensity and Total Work Duration, Scandinavian Journal of Medicine and Science in Sports, 23, 74 – 83.**

- **Experimental Objective: To compare the effects of three distinct 7-week interval training programs varying in duration but matched for effort in trained cyclists**

Adaptations to Aerobic Interval Training

- **Experimental design**
  - **Thirty-five (*35*) well-trained (*pre-training VO_2-peak = 52 $\pm$ 6 ml O_2 * kg^{-1} * min^{-1}*) cyclists**
  - **Four distinct seven-week training protocols**
  - **Average of approximately five (*5*) training sessions per week for the seven-week training period**
  - **All participants completed pre- and post- maximal aerobic capacity testing and time trial evaluation**

Adaptations to Aerobic Interval Training

- **Experimental design**
  - **One group (*six males, two females*) engaged strictly in low-intensity, continuous training four to six times per week {*"long, slow distance"*}**
  - **One group (*seven males, two females*) executed two two weekly sessions of 4 x 16-minutes (*w/ a three-minute recovery*) in addition to two-to-three weekly, low-intensity, continuous training sessions {*"threshold training"*}**

Adaptations to Aerobic Interval Training

- **Experimental design**

  - **One group (*nine males*) executed two weekly sessions of 4 x 8-minutes (*w/ a two-minute recovery*) in addition to two-to-three weekly, low-intensity, continuous training sessions {*"Supra-threshold, sub-VO_2-max training"*}**

  - **One group (*seven males, two females*) executed two weekly sessions of 4 x 4-minutes (*w/ a two-minute recovery*) in addition to two-to-three weekly, low-intensity, continuous training sessions {*"VO_2-max training"*}**

Adaptations to Aerobic Interval Training

Table 3. Physiological test results before and after training

	Low ($n=8$)		4 × 16 min ($n=9$)		4 × 8 min ($n=9$)		4 × 4 min ($n=9$)	
	PRE mean (SD)	POST	PRE	POST	PRE	POST	PRE	POST
Weight (kg)	80.4 (12.5)	79.5* (12.2)	83.8 (10.8)	81.6* (11.0)	89.7 (11.3)	88.1* (10.9)	79.9 (13.3)	78.7 (12.9)
Body fat (%)	20.8 (7.2)	20.0* (7.2)	22.2 (5.4)	20.7 (5.2)	20.5 (5.3)	19.5* (6.1)	18.4 (2.9)	17.7 (3.9)
HF_{peak}	182 (12)	182 (9)	183 (9)	178* (8)	185 (7)	180* (8)	179 (7)	177 (8)
$V_{E\ Peak}$(L/min)	157 (35)	159 (40)	155 (35)	158 (39)	168 (19)	180* (21)	149 (35)	159 (37)
Lactate $_{peak}$ (mmol/L)	14.9 (1.6)	13.7* (1.0)	14.8 (1.6)	13.9 (1.5)	14.1 (2.0)	13.4 (1.4)	13.8 (1.5)	14.0 (2.1)
RPE $_{peak}$	19.4 (0.5)	19.5 (0.5)	19.3 (0.7)	19.6 (0.5)	19 (0.7)	19.2 (0.7)	19.4 (0.5)	19.8 (0.3)
VO_{2peak} (L/min)	4.2 (0.7)	4.3 (0.7)	4.3 (0.5)	4.5* (0.7)	4.7 (0.5)	5.1* (0.5)	4.0 (0.8)	4.2 (0.9)
(ml kg/min)	52.7 (8.0)	54.5 (6.9)	51.1 (5.8)	54.4* (5.2)	52.8 (4.8)	58.3* (5.8)	50.4 (5.8)	53.2 (7.6)
Power $_{VO2peak}$ (W)	349 (44)	358 (48)	361 (51)	372* (50)	378 (52)	410* (27)	343 (68)	361* (72)
(W/kg)	4.5 (0.6)	4.6 (0.6)	4.3 (0.4)	4.6* (0.4)	4.2 (0.5)	4.7* (0.5)	4.3 (0.4)	4.6* (0.5)
$Power_{4\,mM}$ (W)	222 (42)	239* (38)	228 (51)	249* (45)	241 (41)	280* (33)	220 (49)	238* (55)
TTE80% (min)	10.86 (2.6)	12.14 (3.2)	8.52 (1.8)	13.83* (4)	11.88 (4.1)	22.7* (12)	9.7 (2.8)	15.84* (7.1)

*$P<0.05$ vs the pre-test value.

Adaptations to Aerobic Interval Training

The 4 x 8-minute group realized superior improvement in maximal aerobic capacity, peak power output, and endurance time trial performance

Adaptations to Aerobic Interval Training

<u>Potential Interpretation:</u> By slightly reducing training intensity below near-VO_2-max intensity and extending total training volume (*32-minutes relative to 16-minutes*), participants training at approximately 90% of maximal heart rate achieved greater overall adaptive effects than participants training at a higher, relative intensity

Adaptations to Aerobic Interval Training

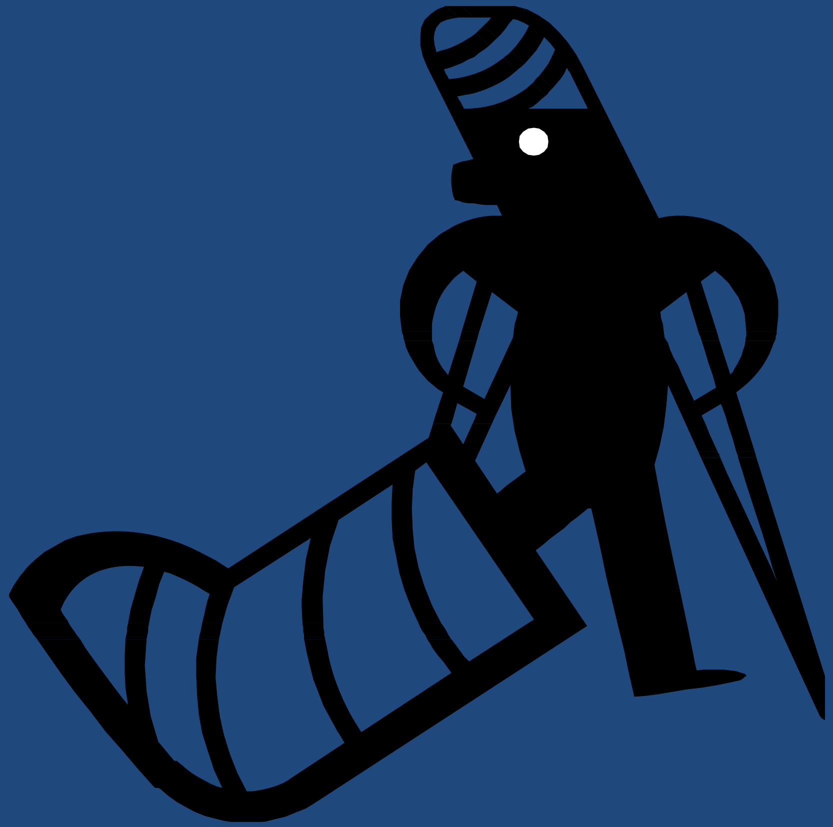
Potential Application: **Emphasize "*combination workouts*" that incorporate a spectrum of repetitions (*for example, 2 x 1,200-m, 4 x 800-m, & 6 x 400-m*) and thus provide a complementary, aggregate stimulus for the improvement of both physiological characteristics (*VO_2-max*) and assessment measures (*time trial performance*)**

Part XVIII

Exercise Interventions and Sports Injury Prevention

Exercise Interventions and Sports Injury Prevention

- **Lauersen, J.B., Bertelsen, D.M., & Anderson, L.B. (*2014*). The Effectiveness of Exercise Interventions to Prevent Sports Injuries: A Systematic Review and Meta-analysis of Randomised Controlled Trials, British Journal of Sports Medicine, 48, 871 – 877.**



Exercise Interventions and Sports Injury Prevention

Objective: To assess whether physical activity interventions such as stretching, proprioception, and strength training can reduce sports injuries

Exercise Interventions and Sports Injury Prevention

- **PubMed, EMBASE, Web of Science, and SPORTDiscus databases were searched through October 2012**
- **Later updated to January 2013**
- **Search results yielded 3,462 "*hits*"**
- **"*Hits*" were screened by title to yield ninety (*90*) titles**
- **Abstract exclusion (*based on inclusion / exclusion criteria*) yielded forty (*40*) studies**
- **Full reading of the forty studies yielded twenty-two (*22*) studies**
- **Three (*3*) studies were added through the updated search**

Exercise Interventions and Sports Injury Prevention

Thus, twenty-five (*25*) studies were evaluated and judged as appropriately rigorous and specific for inclusion in the meta-analysis

Exercise Interventions and Sports Injury Prevention

- **Results / Conclusions**
  - **Stretching did not evidence any protective effect against sports injuries**
  - **Proprioception training was somewhat effective in protecting against sports injuries**
  - **Strength training demonstrated a highly significant protective effect against sports injuries**

Exercise Interventions and Sports Injury Prevention

- **Interpretations / Applications**

  - **The meta-analysis <u>does</u> <u>not</u> <u>support</u> the use of stretching for injury prevention either before or after training**

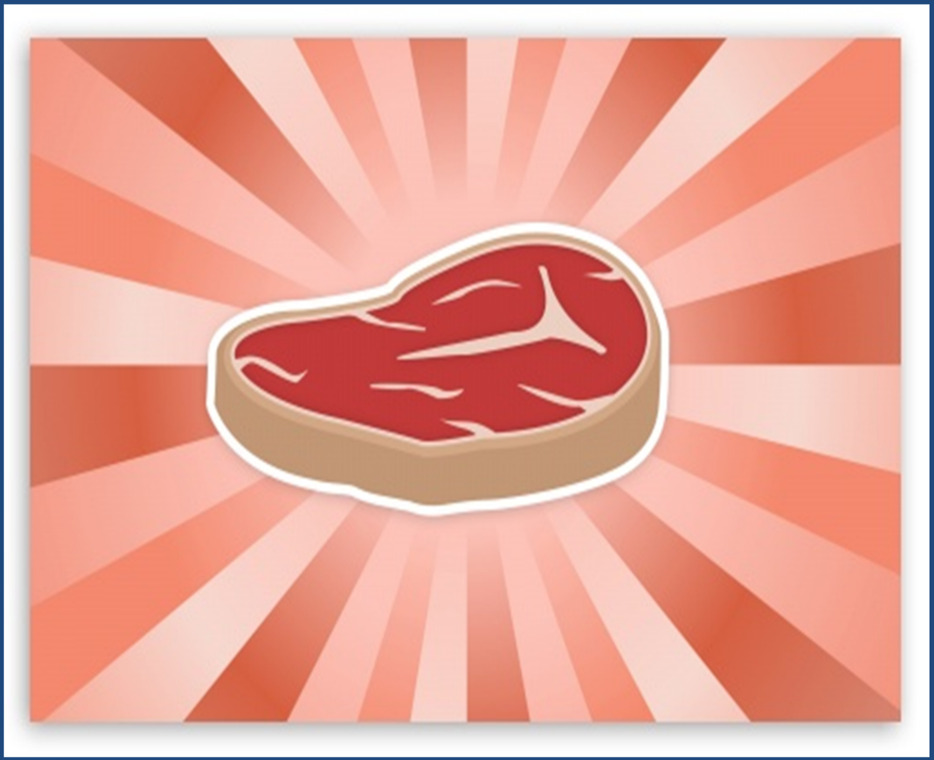
  - **The analysis <u>strongly</u> <u>supports</u> the incorporation of a <u>strength</u> <u>training</u> component into a physical training regimen in order to reduce the potential for development of a sports injury**

Part XIX

Protein Requirements in Endurance Athletes

Protein Requirements in Endurance Athletes

- **Kato, H., Suzuki, K., Bannal, M., & Moore, D. (*2016*). Protein Requirements Are Elevated after Exercise as Determined by the Indicator Amino Acid Oxidation Method, PLoS One, 11(6), 1-15.**



Protein Requirements in Endurance Athletes

Objective: To quantify the recommended protein intake in endurance athletes during an acute, three-day training period using the indicator amino acid oxidation (*IAAO*) method

Protein Requirements in Endurance Athletes

- Six male, endurance-trained adults
- Mean VO_2-peak = 60.3 ± 6.7 ml $*kg^{-1} * min^{-1}$
- Acute training session (*20-km treadmill run*)
- Post-training consumption of variable protein mass
- Utilize labeled phenylalanine method in order to quantify both estimated average protein requirement and recommended protein intake

Protein Requirements in Endurance Athletes

- **Current Recommended Dietary Allowance (*RDA*) is 0.8 grams PRO * kg^{-1} body mass * day^{-1}**
- **Current recommendations for endurance athletes are 1.2 – 1.4 grams PRO * kg^{-1} body mass * day^{-1}**

Protein Requirements in Endurance Athletes

- **Experimental results yield an estimated, average, post-training protein requirement of 1.65 grams PRO * kg^{-1} body mass * day^{-1}**
- **Experimental results yield an estimated, average, post-training recommended protein intake of 1.83 grams PRO * kg^{-1} body mass * day^{-1}**

Protein Requirements in Endurance Athletes

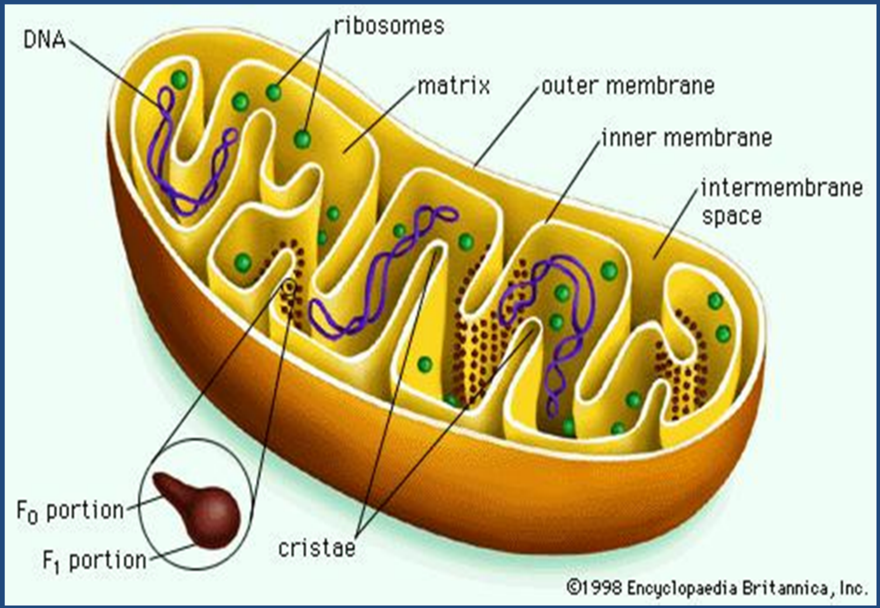
<u>Potential Interpretation:</u> The metabolic demand for protein intake (*1.83 grams PRO * kg^{-1} body mass * day^{-1}*) in trained endurance athletes engaged in high-volume and / or high-intensity training is not only greater than their sedentary counterparts but also greater than current recommendations for endurance athletes (*1.2 – 1.4 grams PRO * kg^{-1} body mass * day^{-1}*)

Part XX

Mitochondrial Quality versus Mitochondrial Quantity

Mitochondrial Quality versus Mitochondrial Quantity

- **Bishop, D., Granata, C., & Eynon, N. (*2014*). Can We Optimise the Exercise Training Prescription to Maximise Improvements in Mitochondrial Function and Content, Biochimica et Biophysica Acta, 1840, 1266-1275.**



Mitochondrial Quality versus Mitochondrial Quantity

Objective: To review relevant literature focused primarily on the effects of exercise / training on both mitochondrial function (quality) and mitochondrial content (quantity)

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

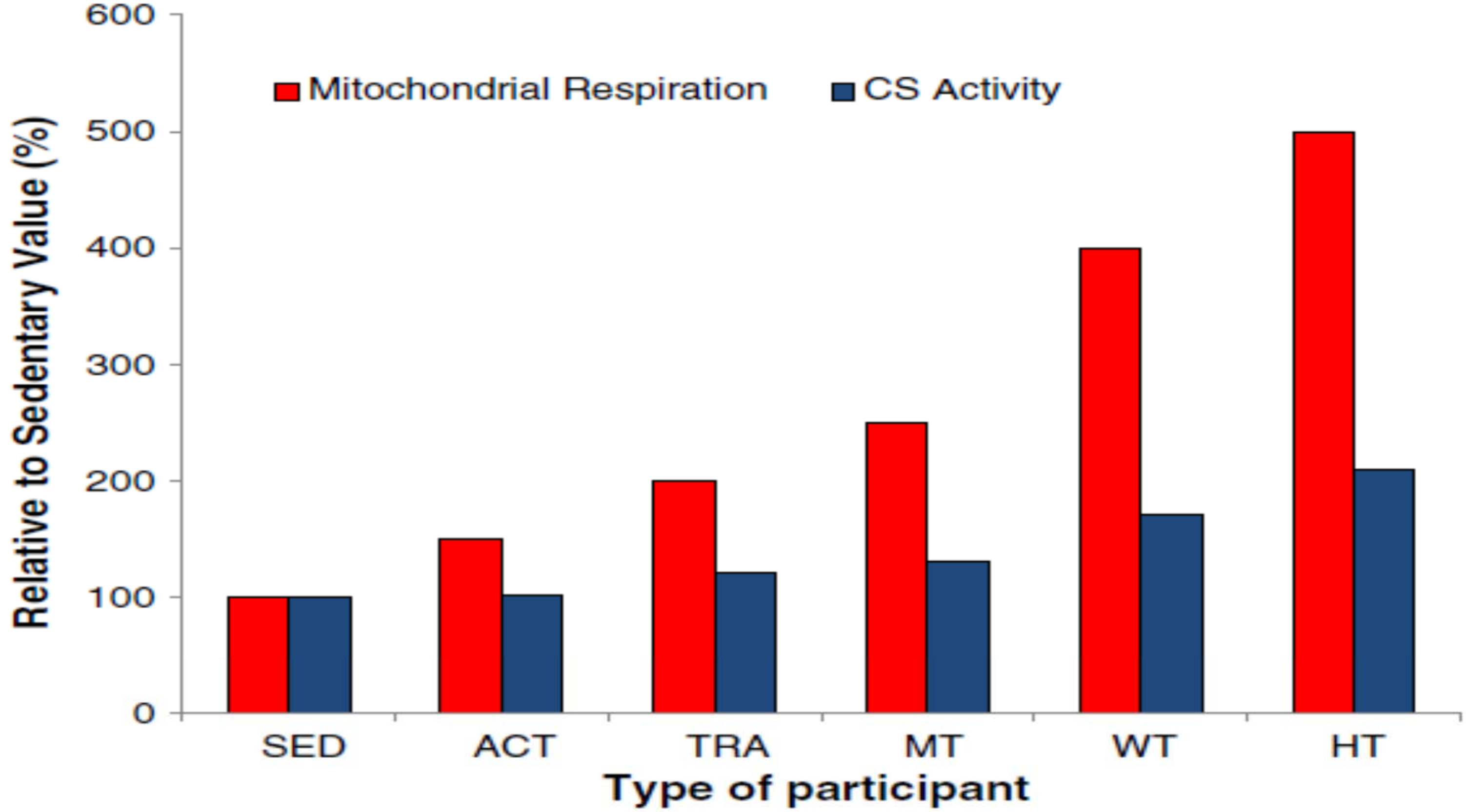


Fig. 1. Mitochondrial respiration and citrate synthase activity in humans of differing training status [32–39]. SED = sedentary, ACT = active, TRA = trained, MT = moderately-trained, WT = well-trained, and HT = highly-trained.

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

Potential Interpretation: **There is a disconnect across various sub-groups (*sedentary, active, well-trained, highly-trained, etc.*) between mitochondrial content (*as assessed by maximal citrate synthase activity*) and mitochondrial function (*as assessed by maximal rate of respiration*)**

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

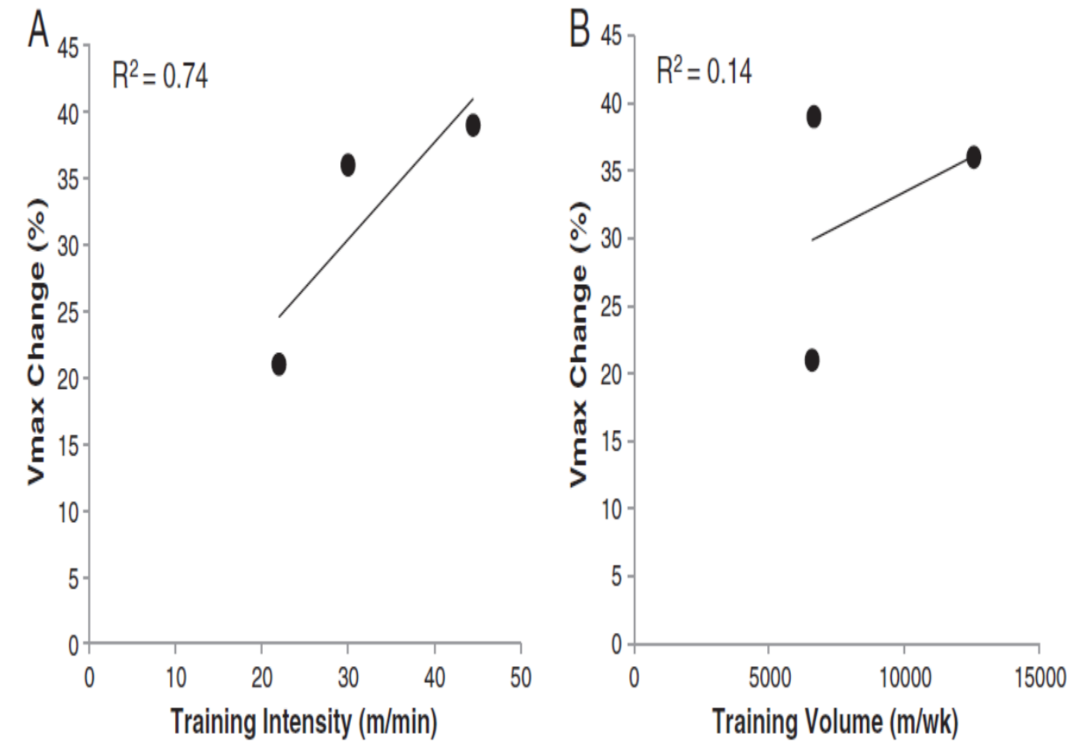


Fig. 2. The relationship between A) training intensity and B) training volume and training-induced changes in mitochondrial respiration in rats [58–60]. Studies were excluded if they did not provide precise information about the training prescription or if they used "mixed training" (i.e., a combination of continuous, moderate-intensity training, and high-intensity interval training).

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

Potential Interpretation: **Training intensity exerts a relatively more profound impact on maximal mitochondrial function (*as assessed by maximal rate of respiration, or* V_{MAX}*,) than training volume (*$R^2 = 0.74$ *versus* $R^2 = 0.14$*)***

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

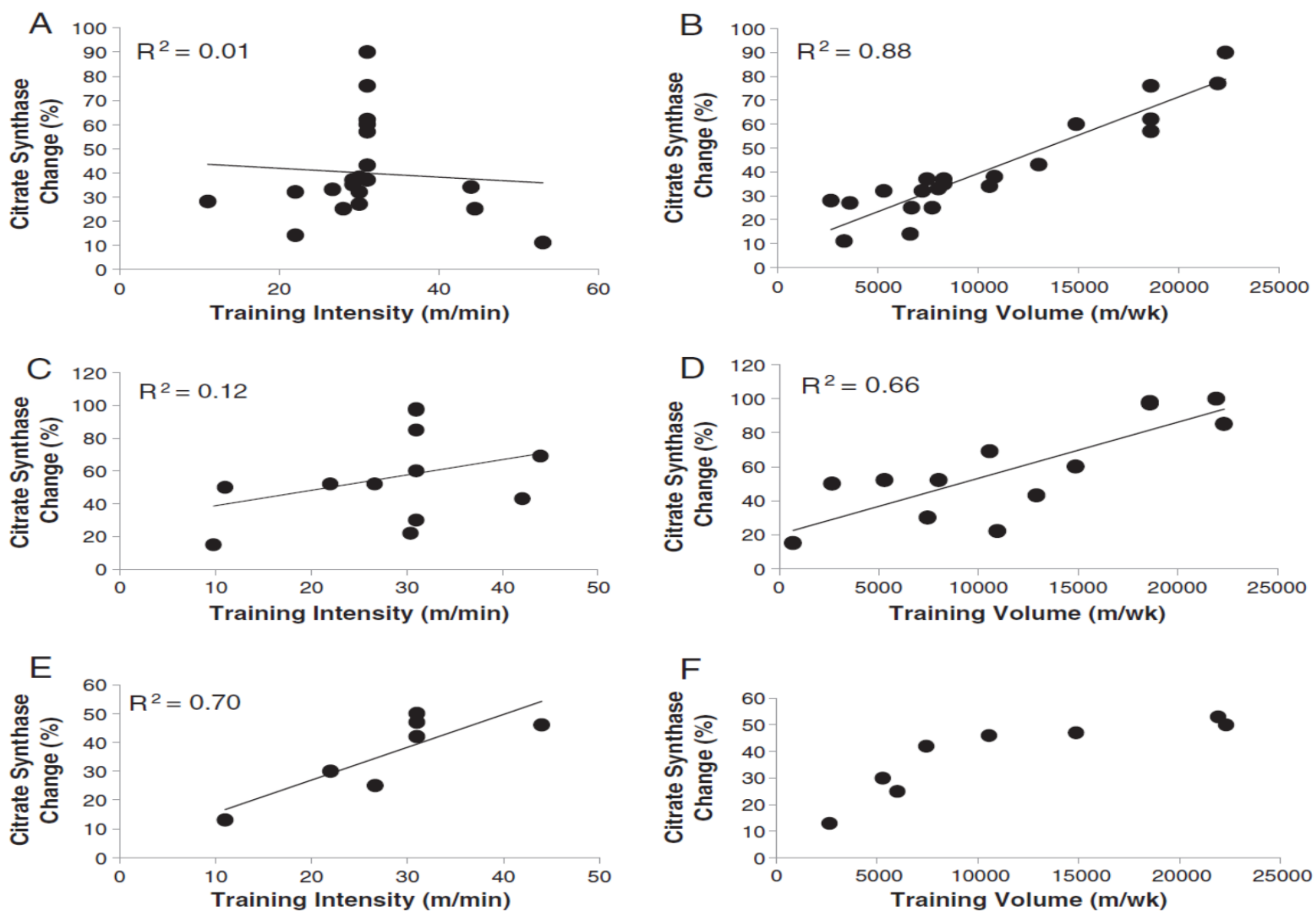
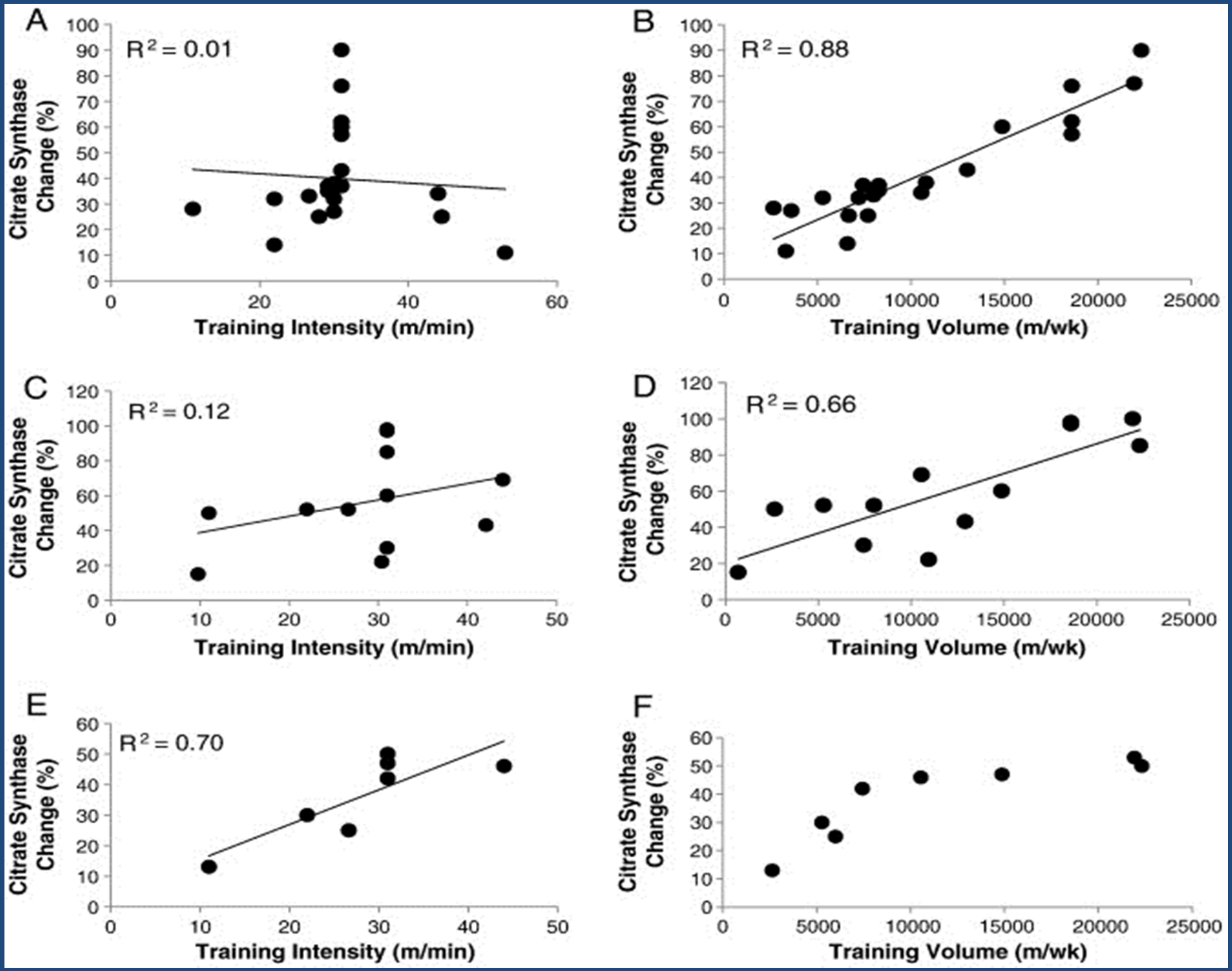


Fig. 4. The relationship between training intensity and training volume and training-induced changes in citrate synthase activity of rats in the red soleus (A and B respectively), the red vastus (C and D respectively), and the white vastus (E and F respectively) [54,58,60,63,93–103]. Studies were excluded if they did not provide precise information about the training prescription or if they used "mixed training" (i.e., a combination of continuous, moderate-intensity training, and high-intensity interval training).

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

Potential Interpretation: **Training volume exerts a relatively more profound impact on mitochondrial content (*as assessed by percentage {%} change {Δ} in citrate synthase content) than training intensity (R^2 = 0.88 & 0.66 versus R^2 = 0.12 & 0.01)***

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)



Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

Potential Interpretation: **There is a strong relationship between training volume and skeletal muscle mitochondrial content (*as assessed by percentage {%} increase in citrate synthase*) across multiple muscle fiber types (*red soleus, red vastus, and white vastus*)**

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

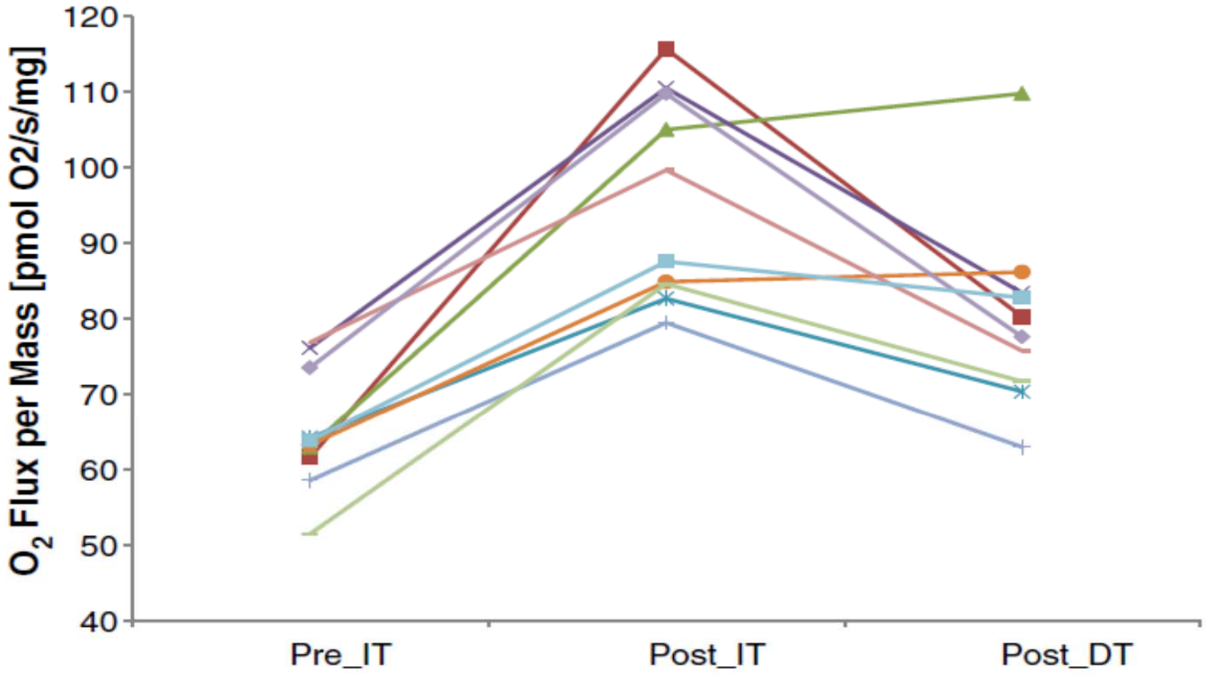


Fig. 5. Individual changes in mitochondrial respiration during training and de-training [56]. Pre_IT = pre interval training, Post_IT = post interval training, Post_DT = post de-training.

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

Potential Interpretation: **An interval training-induced increase in maximal mitochondrial function is reversed over one (*1*) to three (*3*) weeks with the cessation of interval training**

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

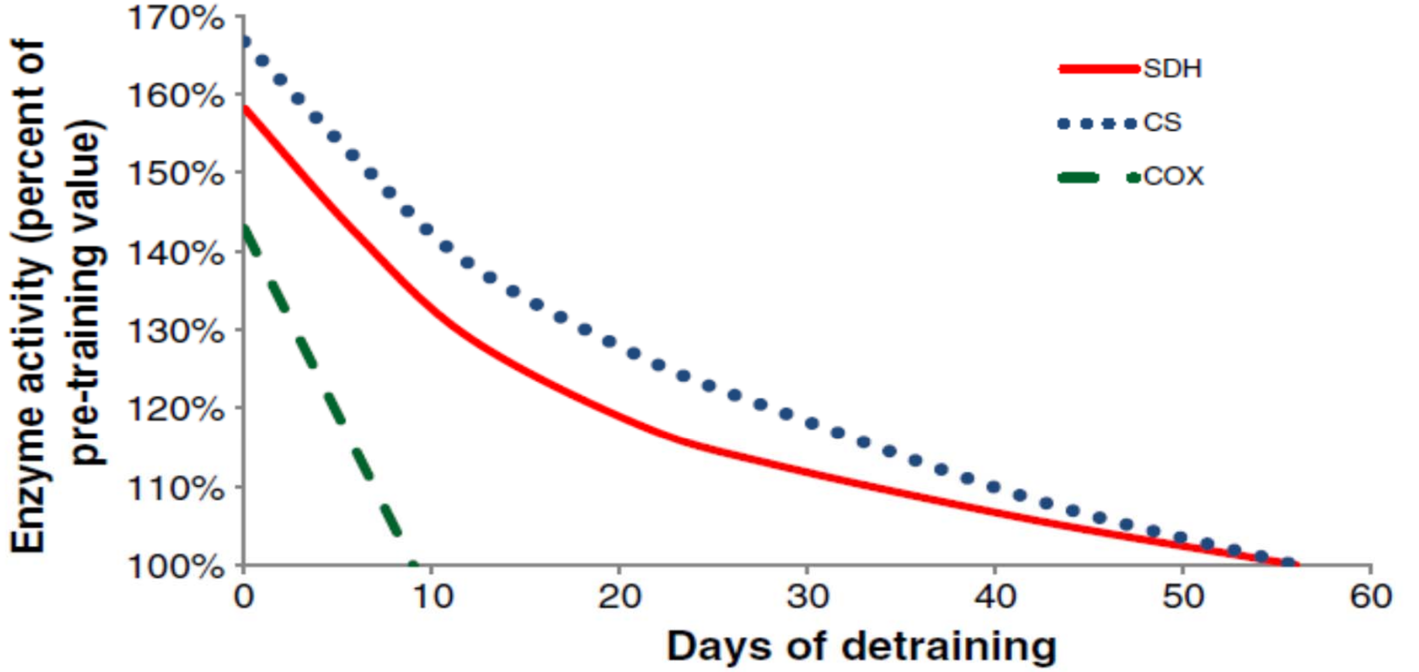


Fig. 6. Changes in the activities of cytochrome c oxidase (COX), citrate synthase (CS) and succinate dehydrogenase (SDH) during training cessation in humans. Values are based on results from the few studies that have measured changes in enzyme activity during the cessation of training [66,67,69,70]. Values on the y-axis are percent of pre-training values.

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

Potential Interpretation: **However, rates of regression in distinct components of maximal mitochondrial function appear to differ both across mitochondrial enzymes and across different fiber types**

Mitochondrial Quality versus Mitochondrial Quantity (*Bishop et al.*)

Current, Summary Interpretation: Training intensity appears to appears to be an important determinant of maximal mitochondrial function albeit not mitochondrial content; by contrast, training volume appears to be an important determinant of training-induced adaptation in muscle mitochondrial content albeit not function (*caveat: training intensity & mitochondrial content in type IIx fibers?*)

Mitochondrial Quality

- Hypothesis that training intensity may be a critical determinant of improvements in maximal rate of mitochondrial respiration (*MAPR*)
- Multiple studies evidence a trend toward greater MAPR with higher training intensities
- Absence of evidence correlating training intensity with enhanced mitochondrial content

Mitochondrial Quantity

- Hypothesis that training volume may be a critical determinant of enhanced mitochondrial content
- Recent research suggests that improvements in MAPR are not proportional to training volume in humans
- Multiple studies evidence a strong correlation between training volume and improvements in mitochondrial content

Mitochondrial Quality and Quantity

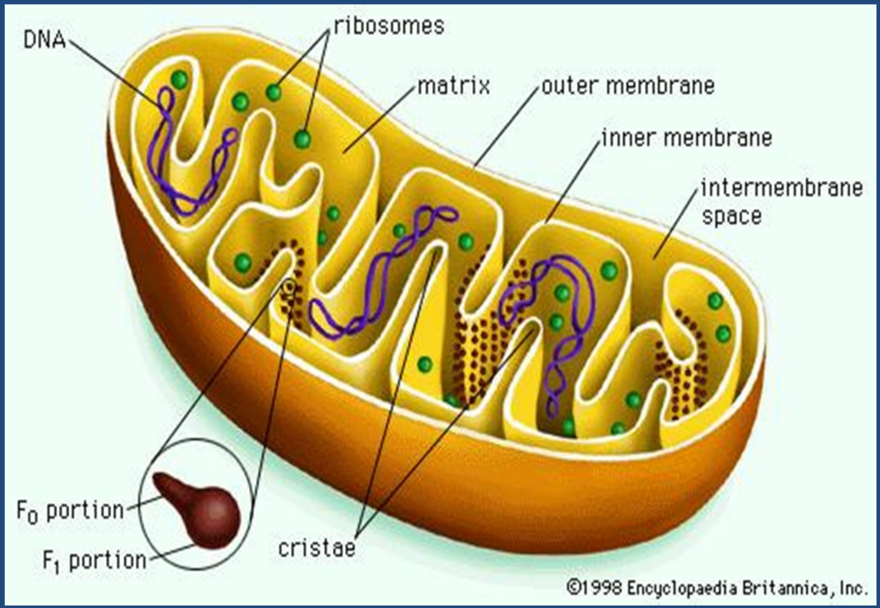
<u>Potential Interpretation:</u> **Training intensity appears to be an important determinant of improvements in mitochondrial function (*quality*) but not mitochondrial content; by contrast, training volume appears to be a similarly important determinant of improvements in mitochondrial content (*quantity*) albeit not mitochondrial function**

Part XXI

Carbohydrate (*CHO*) Manipulation & Adaptation

Carbohydrate Manipulation & Adaptation

- Hawley, J.A. & Morton, J.P. (*2013*). Ramping up the Signal: Promoting Endurance Training Adaptation in Skeletal Muscle by Nutritional Manipulation, Proceedings of the Australian Physiological Society, 44, 109-115.



Carbohydrate Manipulation & Adaptation

- ***"You need to teach your body to operate with low glucose stores because that's what you'll be facing in the later miles of a marathon."***

- ***"By not taking in carbs or energy gels during the run, you're giving your body no choice but to go to fat-burning. You will feel fatigued near the end, but that's necessary if you want to get stronger."***

Carbohydrate Manipulation & Adaptation

- **The essential premise is that the combination of 1) contractile activity (*i.e. training*) and 2) intentionally compromised muscle glycogen availability combine to amplify the training-induced up-regulation of multiple proteins that underlie mitochondrial biogenesis**

Carbohydrate Manipulation & Adaptation

- Prior slide … stated more succinctly …

- Training with diminished carbohydrate availability allows for enhanced skeletal muscle mitochondrial content and, ultimately, greater aerobic capacity

Carbohydrate Manipulation & Adaptation

Has such a hypothesis been strongly, experimentally supported?

NO

Carbohydrate Manipulation & Adaptation

- **What does existing scientific literature reveal?**
  - **Multiple protein precursors (*specifically, mRNA's*) associated with mitochondrial biogenesis can indeed be further up-regulated through the juxtapositioning of compromised carbohydrate status with, for example, endurance training**

Carbohydrate Manipulation & Adaptation

- **The mRNA → protein synthesis relationship has yet to be compellingly demonstrated**
  - **Increased mRNA content is necessary albeit not necessarily sufficient for increased protein expression**

- **Enhanced endurance performance has yet to be quantified**

Carbohydrate Manipulation & Adaptation

- Potential application for high school endurance (*student-*)athletes
  - – Undertake and complete periodic, two-a-day training sessions with the second session performed with compromised carbohydrate status

Part XXII

Acknowledgments

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- Savannah Gaffney (*XCP, '14*)
- Sophi Johnson (*DVHS, '15*)
- Baylee Jones (*DVHS, '17*)
- Danielle Jones (*DVHS, '15*)
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- Laura Orlie (*XCP, '12*)
- Caroline Pass (*DVHS, '16*)
- Tessa Reinhart (*DVHS, '15*)
- Elise Richardson (*DVHS, '14*)
- Emily Smith (*DVHS, '16*)
- Mason Swenson (*DVHS, '16*)
- Brittany Tretbar (*DVHS, '13*)
- Julianne Vice (*XCP, '14*)
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- Haley Wolf (*DVHS, '18*)
- Kate Yanish (*XCP, '12*)
- Aubrey Worthen (*DVHS, '16*)

Part XXIII

Questions & Discussion

Questions & Discussion

Part XXIV

Appendices

Appendix A: Warm-up A

- **1,000-meter jog**
- **Step-Outs with Torso Rotations (*4 Step-Outs with 6 Rotations per Step*)**
- **Forward Lunge with Right / Left Torso Rotation (*6 repetitions*)**
- **Forward Lunge with Rotating Twist & Reach (*6 repetitions*)**
- **Forward Lunge with Two-Arm Vertical Reach (*6 repetitions*)**
- **Modified Power Walks (*20 Repetitions*)**
- **Carioca (*2 x 8 repetitions*)**
- **Progressive Speed A-Skips (*24 Repetitions*)**
- **B-Skips (*24 repetitions*)**
- **Progressive Turnover High Knees (*50 repetitions*)**
- **Two (*2*) to Four (*4*) x 100-meter Strides**
- **WORKOUT or RUN**

Appendix B: Warm-up B

- **1,000-meter jog**
- **Hip-Twist with Ankle Hops (*20 hop repetitions & 30 hop / twist repetitions*)**
- **Progressive Speed Base Rotations (*50 repetitions*)**
- **Lateral Lunge with Rotation (*6 repetitions / 3 per side*)**
- **Backward Lunge with Vertical Reach (*6 repetitions*)**
- **Forward Lunge with Hamstrings Group Stretch (*6 repetitions*)**
- **Modified Power Walks (*20 Repetitions*)**
- **Carioca (*2 x 8 repetitions*)**
- **Hamstrings Group Kicks (*Fifteen {15 }"touches" per leg*)**
- **B-Skips (*24 repetitions*)**
- **Progressive Turnover High Knees (*50 repetitions*)**
- **Two (*2*) to Four (*4*) x 100-meter Strides**
- **WORKOUT or RUN**

Appendix C: Warm-up C

- **1,000-meter jog**
- **Ten (*10*) Alternating Knee Hugs with Heel Raise**
- **Ankling (*approximately 25- to 35-meters*)**
- **Hamstring Kicks (*Fifteen {15 }"touches" per leg*)**
- **Side Walking Lunge (*Eight {8} Rightward / Eight {8} Leftward Lunges*)**
- **Side Shuffle with Arm Swing (*Eight {8} Rightward / Eight {8} Leftward Shuffles*)**
- **Lateral A-Skips (*Twelve {12} Rightward / Twelve {12} Leftward Skips*)**
- **Backward Run (*approximately 30- to 50-meters*)**
- **Single Leg Skip (*approximately 20- to 40-meters; alternate lead leg*)**
- **Two (*2*) to Four (*4*) x 100-meter Strides**
- **WORKOUT or RUN**

Appendix D: Warmdown A

- **Nick Swings (*4 right circles, 4 left circles*)**
- **Arm Swings (*4 forward circles, 4 backward circles*)**
- **Chest Stretch**
- **Trunk Rotation (*4 right circles, 4 left circles*)**
- **Rock Squat (*10 repetitions*)**
- **Quadriceps Group Stretch (*10 count per quadriceps group*)**
- **Piriformis Stretch (*10 count per quadriceps group*)**
- **Hamstrings Group Stretch (*10 count per hamstrings group*)**
- **Lunge Stretch (*10 count per lunge*)**
- **Gastrocnemius / Soleus Stretch (*10 count per leg*)**

Appendix E: General Strength (*GS*) / Plyometric Routine I

- *"Runner's"* Push-ups (*30-seconds of continuous repetitions = 1 set*)
- *"Russian"* Twists (*30-seconds of continuous repetitions = 1 set*)
- Hyperextensions (*30-seconds of continuous repetitions = 1 set*)
- *"Prisoner"* Squats (*30-seconds of continuous repetitions = 1 set*)
- Ankle Hoops (*30-seconds of continuous repetitions = 1 set*)
- Split Squat Jumps (*30-seconds of continuous repetitions = 1 set*)

- 1 set of every GS / Plyometric movement = 1 circuit

- Perform continuous circuits utilizing a 30-second *"on"* / 20-second *"off"* work / recovery combination for a total of 10- to 20-minutes

Appendix F: General Strength (*GS*) / Plyometric Routine II

- **Abdominal Crunches (*30-seconds of continuous repetitions = 1 set*)**
- **Rocket Jumps (*30-seconds of continuous repetitions = 1 set*)**
- **"*V*" Sit-Ups (*30-seconds of continuous repetitions = 1 set*)**
- **Supine Bridge with Alternating Leg Raises (*30-seconds of continuous repetitions = 1 set*)**
- **Right "*Plank*" with Left Leg Raises (*30-seconds of continuous repetitions = 1 set*)**
- **Left "*Plank*" with Right Leg Raises (*30-seconds of continuous repetitions = 1 set*)**

- **1 set of every GS / Plyometric movement = 1 circuit**

- **Perform continuous circuits utilizing a 30-second "*on*" / 20-second "*off*" work / recovery combination for a total of 10- to 20-minutes**

Appendix G: General Strength (*GS*) / Plyometric Routine III

- Prone "*Plank*" with Alternating Leg Raises (*30-seconds of continuous repetitions = 1 set*)
- Continuous Hurdle Jumps (*30-seconds of continuous repetitions = 1 set*)
- Supine "*Plank*" with Alternating Leg Raises(*30-seconds of continuous repetitions = 1 set*)
- Scissor Jumps for Height (*30-seconds of continuous repetitions = 1 set*)
- Side-Ups (*30-seconds of continuous repetitions = 1 set*)
- Skips for Vertical Displacement (*30-seconds of continuous repetitions = 1 set*)

- 1 set of every GS / Plyometric movement = 1 circuit

- Perform continuous circuits utilizing a 30-second "*on*" / 20-second "*off*" work / recovery combination for a total of 10- to 20-minutes

Appendix H: General Strength (*GS*) / Plyometric Routine IV

- **Donkey Kicks (*30-seconds of continuous repetitions = 1 set*)**
- **Straight-Arm Prone Plank w/ Single Leg Stride (*30-seconds of continuous repetitions = 1 set*)**
- **Push-up to Prone Plank w/ Bilateral Hip / Knee / Ankle Flexion & Extension (*30-seconds of continuous repetitions = 1 set*)**
- **Donkey Whips (*30-seconds of continuous repetitions = 1 set*)**
- **Lateral Plank w/ Straight Leg Raise (*30-seconds of continuous repetitions = 1 set*)**
- **Modified Russian Twist (*30-seconds of continuous repetitions = 1 set*)**

- **1 set of every GS / Plyometric movement = 1 circuit**

- **Perform continuous circuits utilizing a 30-second *"on"* / 20-second *"off"* work / recovery combination for a total of 10- to 20-minutes**

Appendix H: General Strength (*GS*) / Plyometric Routine V

- **Lateral Lunge Walks w/ Runner's Arms (*30-seconds of continuous repetitions = 1 set*)**
- **Lateral Shuffle w/ Runner's Arms (*30-seconds of continuous repetitions = 1 set*)**
- **Lateral A-Skips (*30-seconds of continuous repetitions = 1 set*)**
- **Lateral Plank w/ Lower Limb Ankle / Knee / Hip Flexion & Extension (*30-seconds of continuous repetitions = 1 set*)**
- **Lateral Plank w/ Straight Leg Raise (*30-seconds of continuous repetitions = 1 set*)**
- **Lateral Leg Swings (*30-seconds of continuous repetitions = 1 set*)**

- **1 set of every GS / Plyometric movement = 1 circuit**

- **Perform continuous circuits utilizing a 30-second *"on"* / 20-second *"off"* work / recovery combination for a total of 10- to 20-minutes**