Metabolic Conditioning: The Good, Bad and Ugly
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Recommended Readings from Len Kravitz’s WEB site:
Kravitz, L. (2009). Too much sitting is hazardous to your health. IDEA Fitness Journal, 6(9), 14-17.

I. What is metabolic conditioning? (from Bergeron et al., 2011)
A. “Exercises that impose a moderate to high demand on the cardiovascular system and energy metabolism of the active muscle fibers to meet with the muscles’ repeated high energy requirement.”
B. Anaerobic-type metabolic conditioning: “Motor unit activity, substrate flux and force-speed production patterns such that anaerobic bioenergetics pathways are preferential.” (Plisk, 1991) Peripheral in nature
C. Aerobic-type metabolic conditioning: Dynamic exercise integrating cardiorespiratory parameters, including heart rate, cardiac output, blood flow distribution, left ventricular stroke volume, arterial pressures, total peripheral resistance, and arterial and venous blood oxygen content. Central in nature
D. Newest form of metabolic conditioning. Non-exercise activity thermogenesis (NEAT). NEAT is the energy expended for everything we do that is not sleeping, eating or sports-like exercise. Central and peripheral in nature. “Changes in NEAT accompany experimentally induced changes in energy balance and may be important in the physiology of weight change.” (Levine, 2004). Can burn 269 to 477 kilocalories/day with NEAT

II. Metabolism 101: Basics and terms
A. Metabolism: sum total of living cell’s energy producing and utilizing reactions
B. TDEE=Total daily energy expenditure
C. RMR=Resting metabolic rate (60%-70% or up to 75% of energy)
D. AT=Activity thermogenesis; Structured exercise vs spontaneous physical activity (15%-30% TDEE)
E. NEAT=Non-exercise activity thermogenesis, part of AT; sitting, standing moving, shopping, etc.
F. TEF=Thermic effect of food: digestion, absorption, transport, metabolism, and storage
G. Thermogenesis=process body generates heat or energy
H. New research on NEAT: Fidgeters expend 352 additional kcals/day (16 kg/yr)
I. Reading source for NEAT: Move a Little, Lose a Lot by James A. Levine, MD, PHD

A. Too much sitting is hazardous to health; even if you get your 30 min/day of moderate intensity ex.
B. Mechanisms: sitting results in dramatic drops in lipoprotein lipase (captures fat from blood for fuel); leads to soaring levels of triglycerides; also lowers HDL-C; elevates risk to CVD
C. “Technology’s sedentary seduction” (Franklin, 2008).
D. Creating a Metabolic Profile for a Client: Action Plan to Combat Sedentary Behavior
E. Case study: Interventions at work to combat sedentary lifestyle: 1) stand up and walk around the office every 30 minutes, 2) stand up and move every time the client needs to get some water, 3) walk to the farthest bathroom in the worksite facility, 4) take a walk break with every coffee and tea break,
F. Source for ideas for moving: letsmove.gov (walk to work, walk during your lunch hr, walk instead of drive whenever you can, take a family walk after dinner, skate to work instead of drive, mow the lawn with a push mower, walk to your place of worship instead of driving, walk your dog, replace Sunday drive with a Sunday walk, park safely in the back of the parking lot, work and walk around the house, etc.)
take your dog to the park, wash the car by hand, run or walk fast when doing errands, pace the sidelines at your kid’s games, walk the airport while awaiting your flight, walk to a coworkers desk instead of emailing or calling, make time in your day for moving, bike with family and friends, if you find it difficult to be active after work, try it before work, take a walk break with a coffee break, perform gardening and/or home repairs, avoid sitting for more than 30 min at a time, move around more at the grocery market, play with your kids 30 minutes a day, dance to music, walk briskly in the mall, take the long way to the water cooler, take the stairs instead of the escalator, go for a hike.

G. Metabolic facts:
1. Lean individuals store 2-3 months of energy in the form of fat
2. Obese individuals can store a year’s worth of energy in fat
3. Neat is the most variable component of energy expenditure: ranges from 15% of total energy expenditure in very sedentary individuals to 50% or more in highly active individuals
4. Glycolysis kicks in within 3-5 seconds of exercise

   Men: 9.99xWt(kg)+6.25xHt(cm)-4.92xage+5
   Women: 9.99xWt(kg)+6.25xHt(cm)-4.92xage-161
   RMR is solved in Kcal/day

K. Issues with energy balance: very complex interaction of diet, exercise, NEAT, TEF, RMR

IV. Anaerobic metabolic conditioning: Recruiting the anaerobic bioenergetics pathways
A. What are the anaerobic energy systems that supply ATP: CrP-ATP or phosphagen and glycolysis
B. Review of the phosphagen system; observing the 3 high energy phosphates attached to the ribose
C. Hydrolysis of ATP: Splitting of ATP occurs by water: One proton (H+) is released from reaction
D. Phophocreative CrP or PCr is high energy molecule which synthesizes ATP in cell
E. Why is there such a drop in PCr in sprint exercise? 40%-60% depletion of ATP; more for PCr. ATP is supplied by the phosphagen, glycolytic and mitochondria respiration; PCr just from phosphagen: phosphagen replenishment occurs in recovery by oxidative means: Thus aerobic training improves recovery for anaerobic exercise: important training implications
F. Turn our focus on glycolysis: ‘glyc’ is Greek for glucose; glycolysis is the splitting of sugar; gluc is Greek for sweet; ose means sugar; glucose means ‘sweet sugar’; kicks in within 3-5 seconds of exercise
G. Training implications of first reaction of glycolysis (hexokinase reaction)
H. In reaction 3 of glycolysis the enzyme is PFK. It is an allosteric enzyme. Means it is rate limiting.
I. Net yield of glycolysis: 2 water, 2 ATP, 2 pyruvate, 2 NADH+H+ (shuttled to 2 FAD in the ETC)
J. Lactate formation explanation:
   1. At end of glycolysis the two molecules of interest are two NADH+H+ (a vitamin carrying a proton with another loosely coupled proton) and two pyruvate molecules
   2. Under steady state conditions the two pyruvate go to the TCA cycle and the two NADH+H+ go to the Electron Transport Chain for use for energy synthesis
   3. However, in strenuous exercise, energy demands exceed oxygen supply (pyruvate and NADH+H+ are inhibited)
   4. To resolve this situation, pyruvate accepts 2 protons into its structure and temporary converts itself to lactate; so, lactate is actually a ‘buffer’ to acidosis and not the cause of acidosis; NAD+ returns to step 6
   5. Latest on lactate and burn. The cause of the burn (or acidosis) is the accumulation of protons at the muscle myofilaments (from the splitting of ATP); not lactate; aerobic exercise is best way clear acidosis

V. Anaerobic-type metabolic conditioning design
A. In sets or repetitions
B. Intervals or sprints
C. Multiple-sequence exercises (circuits)
D. Moderate to near maximal to supramaximal (above VO2max) intensities
E. Usually 15 to 90-second bouts; can last as long as 120 seconds
F. Relief of 2 to 3 minutes (active or passive)
G. Two to three times per week for fit persons (based on timeline for glycogen repletion)
H. Anaerobic-type conditioning is best trained by increasing intensity or speed; extending duration of bouts leads to poor exercise technique and longer recovery
I. Exercise relief by heart rate (HR): allow HR to recover to 120 to 140 bpm
J. Initially, 1:4 work-to-relief in intervals recommended; may gradually taper ratio to 1:2, 1:1.5, 1:1 with emphasis on the importance of gradual progression
K. Metabolic stress pathway: anaerobic exercise encourages a lot of anaerobic glycolysis; this leads to an increase in Pi, H+, lactate, anabolic products; these byproducts lead to activation of hypertrophy

### Anaerobic Programs

**Circuits A: 2x: 30 second on, 40 second off**
- Jump lunge (TRX)
- Kettlebell single arm farmers walk
- Medicine ball 1/2 kneel side rotation throw
- Front plank with band row (low row)
- Plate push

**Circuits B: 2x 30 second on, 40 second off**
- Bear crawls
- 1/2 knee bottom up with kettlebell
- Medicine ball rollover floor slams
- Single arm row standing
- Kettlebell swings

**Circuits C: 3x: 20 second on, 30 second off**
- Kettle bell swings
- Side plan with band row
- TRX shoulder elevated low curls
- Spiderman pushups
- Mountain climbers

**Circuits D: 3x: 20 second on, 30 second off**
- Broad jump
- Medicine scoop throw (forward)
- TRX inverted row
- Kettlebell single leg deadlift
- Single arm overhead press with dumbbell

**Combinations**
- Single leg Romanian dead lift + single arm row
- Good morning + reverse lunge
- Lateral lunge + single arm press
- Pull-up + inverted row + hip thrust combo
- Reverse lunge + landmine press

**Complex 1**
- Romanian deadlift {or regular} (6 reps)
- Hang clean (6 reps)
- Front squat (6 reps)
- Hang snatch and then Overhead press (6 reps)
- Barbell row (6 reps)

### VI. Aerobic-type metabolic conditioning

A. Maximal oxygen consumption (VO₂ max): The maximal rate of consumption, distribution and utilization of oxygen in ml oxygen/kg/min.
B. Heart rate max (HRmax), maximal HR. The highest heart rate one can achieve during graded exercise.
C. Stroke volume (SV): Blood pumped beat by each heart ventricle. Average at rest from 70ml-80ml each beat.
D. Cardiac output: (CO)=HRxSV. Resting CO: 75beat/min x 70ml/beat = 5.2L/min
   Exercise CO: 180beat/min x 120ml/beat = 22L/min
E. Peak power: The maximal power output measured in watts. Typically performed on a cycle ergometer.
F. Exercise intensity in HIIT: A percentage of maximal effort. Examples are 95% of VO₂ max (VO₂ max x .95); 85% Peak Power (Peak Power x .85); 75% HRmax (HRmax x .75)
G. HIIT Intervals: The exercise intervals are the work bouts of exercise that range from 5sec to 8min. The rest interval is the recovery between exercise intervals and can be quite variable.
H. Work/Rest Ratio. Scientists and coaches look at the relationship of the exercise interval and rest interval. An exercise interval of 1min and a rest interval of 4min is a Work/Rest ration of 1-to-4. An exercise interval of 5min and a rest interval of 5min is a Work/Rest ratio of 1-to-1.
I. Summary of benefits of CV responses and adaptations to HIIT and endurance training: increased heart size (thickening of cardiac muscle), increased heart contractility, increased cardiac output, enlarged ventricle volume, decreased resting heart rate, decrease submaximal exercise heart rate, increased venous blood return to the heart, improved aerobic capacity in healthy persons and those with cardiovascular disease, lowered resting blood pressure (when elevated), improved stroke volume, increased VO\textsubscript{2}max

VII. Metabolic adaptations

A. Where is fat completely oxidized in cells? Mitochondrion (think of it as a fat burning fireplace)

B. With cardiovascular and HIIT training mitochondrial density increases: the mitochondria get 35% bigger and can reproduce up to 15-50% more

C. Metabolic model diagram: In this model calcium–calmodulin kinase (CaMK) and adenosine monophosphate kinase (AMPK) are signaling pathways that activate peroxisome proliferator-activated receptor-γ coactivator-1α (PGC-1α). PGC-1α is like a “master switch” that is believed to be involved in promoting the development of the skeletal muscle function (increase in fat oxidation, increase in GLUT4 and glycogen, increase in mitochondrial density, increase in slow-twitch muscle fibers oxidative capacity. High-volume training appears more likely to operate through the CaMK pathway and HIIT appears more likely to signal via the AMPK pathway.

Cardiorespiratory programs compared; Gosselin, L.E. et al. (2012).

1) Metabolic Base Training

Warm-up: Light 5-10 min light intensity exercise
Continuous submaximal aerobic exercise at 70% of VO\textsubscript{2}peak; (RPE=Somewhat Hard intensity)

Why is it called Metabolic Base Training?
Mitochondrion is the base of all fat and carbohydrate metabolism
Because each mitochondrion has its own DNA they respond to stimuli,
In this case it is volume cardiovascular training
Mitochondria have been shown in get 35% bigger and produce 15-50% more with volume endurance training

2) 60/30 Interval Workout

Warm-up: 5-10 min of light intensity exercise
Mode: Treadmill with no grade
Work: 60 seconds at 90% VO\textsubscript{2}max (RPE=Very Hard)
Relief Interval: 30 seconds at 35-40% VO\textsubscript{2}max (Walk, RPE=Light)
Work/Rest Ratio: 2 to 1 ratio

Modification: Make this a hill training interval session
1) Incline up to 5 to 8% on Work Interval; no incline on relief
2) Vary the intensity of the relief interval
3) Protocol can be performed on any mode

3) 90/30 Interval Workout

Warm-up: 5-10 min of light intensity exercise
Mode: Treadmill with no grade
Work: 90 seconds at 90% VO\textsubscript{2}max (RPE=Very Hard)
Relief Interval: 30 seconds at 35-40% VO\textsubscript{2}max (Walk, RPE=Light)
Work/Rest Ratio: 3 to 1 ratio

Modification: Make this a hill training (work and relief)
1) Incline up to 5 to 8% for work and keep incline on relief interval
2) Protocol can be preformed on any mode
4) 60/60 Interval Workout  
Warm-up: 5-10 min of light intensity exercise  
Mode: Treadmill with no grade  
Work: 60 seconds at 90% VO2max (RPE =Very Hard)  
Relief Interval: 60 seconds at 35-40% VO2max (Walk, RPE=Light)  
Work/Rest Ratio: 1 to 1 ratio  
Modification: Alternate modes interval training training  
1) Compete two intervals on one mode and then just alternate modes every two intervals (cycle, elliptical, rowing)

5) 30/30 Interval Workout  
Warm-up: 5-10 min of light intensity exercise  
Mode: Treadmill with no grade  
Work: 30 seconds at 90% VO2max (RPE =Very Hard)  
Relief Interval: 30 seconds at 35-40% VO2max (Walk, RPE=Light)  
Work/Rest Ratio: 1 to 1 ratio.  
Modification: Step-Wise Interval Training  
After each interval increase treadmill grade 3% and keep for work and relief interval  
Can complete on any mode increasing work with each interval

Special Findings of Study  
90/30 protocol had the highest VO2, heart rate, rating of perceived exertion and lactate levels  
30/30 protocol the lowest VO2, heart rate, rating of perceived exertion and lactate levels  
Blood pressure was similar in all protocols  
30/30, 60/60 and metabolic base training had slightly higher (150 kilocalories) caloric values (than 90/30 and 60/30 protocols)

VIII. Wait, What About E.P.O.C.? Excess Postexercise oxygen consumption  
A. Mechanisms of EPOC include lactate removal, CrP replenishment, heart rate recovery, temperature recovery, ventilation recovery, glycogen re-synthesis, hormones recovery  
B. How long does it last? Most impact is 1-2 hours post exercise  
C. How many extra calories will a person burn? Depending on body wt: 65-150 calories for EPOC

IX. What safe are the extreme conditioning programs? From Bergeron 2011. “A potential emerging problem associated with increasingly popularized extreme conditioning programs has been identified by the military and civilian communities. That is, there is an apparent disproportionate musculoskeletal injury risk from these demanding programs, particularly for novice participants, resulting in lost duty time, medical treatment, and extensive rehabilitation….practical solutions to improve ECP prescription and implementation and reduce injury risk are of paramount importance”

X. What is exertional rhabdomyolysis?  
A. “Breakdown of striated muscle tissue”  
B. Reports date back thousands of years  
C. Elevated proteins in blood (notably myoglobin) can lead to acute renal failure, blood clotting, heart arrhythmias  
D. Response to excessive, prolonged or repetitive exercise (hot climate exacerbates) in persons with low fitness and/or too early of an introduction to the demands of the exercise program  
E. Exertional rhabdomyolysis triad: reddish brown (cola colored) urine, muscular pain, muscular weakness; symptoms of muscular stiffness and swelling may occur with rhabdomyolysis
F. Pathophysiology of exertional rhabdomyolysis: 1) Excessive, prolonged or repetitive exercise may overstretch the sarcoplasmic reticulum, 2) Leads to an increase in calcium ion leakage into the muscle cell, 3) This activates special receptors on sarcolemma (cell membrane) that begin releasing very powerful degrading enzymes, 4) This increases the sarcolemma permeability; 5) The sarcolemma releases harmful proteins in the blood that may cause renal failure, blood clotting, heart arrhythmias.

G. Trainer recommendations:
H. Ensure suitable rest periods between sets and workouts
I. Vary workouts so all are not to exhaustive fatigue
J. Discourage clients from using caffeine and other stimulants which mask fatigue
K. Monitor clients for signs of overtraining
L. Track client records to note signs of performance decrements
M. Be cautious of training at high intensities in hot environments

Selected Resources:


