Metabolic Conditioning: The Good, Bad and Ugly

Len Kravitz, Ph.D.
University of New Mexico
lkravitz@unm.edu
Recommended Readings


Kravitz, L. (2009). Too much sitting is hazardous to your health. IDEA Fitness Journal, 6(9), 14-17.


drlenkravitz.com
Publications LINK
What is Metabolic Conditioning?


Michael F. Bergeron, PhD, FACSM; Bradley C. Nindl, PhD, FACSM; Patricia A. Deuster, PhD, MPH, FACSM; Neal Baumgartner, PhD; Shawn F. Kane, MD, FACSM; William J. Kraemer, PhD, FACSM; Lisa R. Sexauer, BS, ATC; Walter R. Thompson, PhD, FACSM; and Francis G. O’Connor, MD, MPH, FACSM

Current Sports Medicine Reports 2011
What is Metabolic Conditioning?

“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.”

Anaerobic-Type Metabolic Cond.

- “Motor unit activity, substrate flux and force-speed production patterns such that anaerobic bioenergetics pathways are preferential.”
  - Peripheral in nature
  - ‘sprint-interval’ training example

Aerobic-Type Metabolic Cond.

- 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

Newest Form of Metabolic Cond.

Non-Exercise Activity Thermogenesis (NEAT)
James A. Levine, M.D.

NEAT-Type Metabolic Cond.

- Non-exercise activity thermogenesis (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”
  - Can burn 269 to 477 kilocalories/day

What is Metabolism?

Metabolism: sum total of a living cell’s energy-producing and energy-utilizing reactions
AT–Activity Thermogenesis

Structured (or planned) Exercise

Energy expenditure of standing, walking and moving during the day “Spontaneous physical activity”
Terms of Metabolism cont.

- **NEAT =** non-exercise activity thermogenesis (part of AT)
  - sitting, standing, leisure walking, toe-tapping, shopping, occupational moving
- **TEF =** thermic effect of food; digestion, absorption, transport, metabolism and storage of food
  - 10% of TDEE
- **Thermogenesis =** process body generates heat and/or energy
Research on NEAT

Interindividual Variation in Posture Allocation: Possible Role in Human Obesity

James A. Levine, Lorraine M. Lanningham-Foster, Shelly K. McCrady, Alisa C. Krizan, Leslie R. Olson, Paul H. Kane, Michael D. Jensen, Matthew M. Clark

NEAT Study Results

* Sleep time and diet very similar!

On average, lean individuals expend additional 352 kcals/day

Over course of a year, this is equivalent to ~16 kg (36 lbs)

Is There an Action Plan to Combat Sedentary Behavior?
Action Plan to Combat Sedentary Behavior

Too Little Exercise and Too Much Sitting: Inactivity Physiology and the Need for New Recommendations on Sedentary Behavior

Marc T. Hamilton, PhD, Genevieve N. Healy, PhD, David W. Dunstan, PhD, Theodore W. Zderic, PhD, and Neville Owen, PhD


Create a Metabolic Profile for Client
Create a Metabolic Profile for Patient

**Structured Workout**
60 min.
**WAKE-UP AT 7 AM**

**Eat Breakfast**
30 min.

**Drive to Work**
45 min.

**Work on Computer**
4 hours

**Eat Lunch**
45 min.

**Go TO SLEEP AT 11 PM**

**Watch TV/Read**
3.5 Hours

**Eat Dinner**
45 min.

**Drive Home**
45 min.

**Work on Computer**
4 hours
Create a Metabolic Profile for Patient

- Structured Workout 60 min.
  WAKE-UP AT 7 AM
- Eat Breakfast 30 min.
- Drive to Work 45 min.
- Work on Computer 4 hours
- Eat Lunch 45 min.
- Drive Home 45 min.
- Work on Computer 4 hours

GO TO SLEEP AT 11 PM
- Watch TV/Read 3.5 Hours
- Eat Dinner 45 min.
- Work on Computer 4 hours
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
Create a Metabolic Profile for Patient

Structured Workout
60 min.
WAKE-UP AT 7 AM

Eat Breakfast
30 min.

Drive to Work
45 min.

Work on Computer
4 hours

Eat Lunch
45 min.

Drive Home
45 min.

Work on Computer
4 hours

Watch TV/Read
3.5 Hours

Go to Sleep AT 11 PM
Interventions at Home to Combat Sedentary Lifestyle

1) Get up and move during every commercial

2) Stand up and move for the opening segment of each TV show

3) At the end of reading every 4, 6 or 8 pages, get up to walk around the room or house

Metabolic Profile Interventions
Source for Movement Ideas

America’s Move to Raise a Healthier Generation of Kids

Learn the Facts
About Let’s Move!

Eat Healthy
Food & Nutrition

Get Active
Physical Activity

Take Action
Simple Steps to Success

Join Us
Let’s Move Together

School Fitness Test Gets a Makeover

The new Presidential Youth Fitness Program will focus more on assessing health and less on athleticism. Learn more about the new personal fitness goals for students!

READ MORE
1. Walk to work
2. Walk during your lunch hour
3. Walk instead of drive whenever you can
4. Take a family walk after dinner
5. Skate to work instead of drive
6. Mow the lawn with a push mower
7. Walk to your place of worship instead of driving
8. Walk your dog
9. Replace the Sunday drive with a Sunday walk
10. Park safely in the back of the parking lot
11. Work and walk around the house
12. Take your dog to the park
13. Wash the car by hand
14. Run or walk fast when doing errands
15. Pace the sidelines at your kids' athletic games
16. Walk the airport while awaiting your flight  
17. Walk to a coworker's desk instead of emailing or calling  
18. Make time in your day for moving  
19. Bike with family and friends  
20. If you find it difficult to be active after work, try it before work  
21. Take a walk break with a coffee break  
22. Perform gardening and/or home repair activities  
23. Avoid sitting for more than 30 minutes at a time  
24. Move around more at the grocery market  
25. Play with your kids 30 minutes a day  
26. Dance to music  
27. Walk briskly in the mall  
28. Take the long way to the water cooler  
29. Take the stairs instead of the escalator  
30. Go for a hike
Recruiting the anaerobic bioenergetics pathways

What are the Anaerobic Energy Systems that Supply ATP?

- CrP-ATP or phosphagen system
- Glycolysis
Long-term (Mitochondrial Respiration)

Short-term system (glycolysis)

Immediate system (ATP-CP)

Percent capacity of energy systems

Exercise duration

10 Sec

30 Sec

2 Min

5 Min

100%
The phosphagen system

Let’s REVIEW some basic chemistry & biology!
Adenosine Triphosphate (ATP)

Adenine

Phosphates

Potential energy!

Ribose
Hydrolysis of ATP

\[ \text{ATP} + \text{H}_2\text{O} \rightarrow \text{ADP} + \text{Pi} + \text{energy} \]

ATPase

Energy
Synthesis of ATP

ATP + H₂O \xrightarrow{ATP Synthetase} ADP + Pi + Energy
Phosphocreatine

- CrP, PCR, creatine phosphate, phosphocreatine
Phosphocreatine

Phosphocreatine

Creatine

Creatine Kinase

ADP  ATP
Why is There Such a Drop in PCr?

40%-60% Depletion in ATP
Much Greater Depletion PCr

Phosphagen Recovery from Exercise

Occurs oxidatively: Thus aerobic training improves recovery for anaerobic exercise

Let’s Turn our Focus on Glycolysis
Long-term (Mitochondrial Respiration)

Short-term system (glycolysis)

Immediate system (ATP-CP)

Percent capacity of energy systems

Exercise duration

100%

10 Sec 30 Sec 2 Min 5 Min
Glucose & Glycolysis Names

- ‘Glyc’ is Greek for glucose
- Glycolysis is the splitting of sugar
- Gluc is Greek for sweet
- ‘ose’ means sugar
- Glucose means ‘Sweet Sugar’
- Glycolysis kicks in within 3-5 seconds of exercise

\[ \text{C}_6\text{H}_{12}\text{O}_6 \]
Glycolysis
Training Implications of the Hexokinase reaction

Step 1.

Glucose $\rightarrow$ ATP $\rightarrow$ ADP $\rightarrow$ Glucose-6-phosphate

-1 ATP
Glucose

-1 ATP

Fructose-1,6-bisphosphate

PFK is an **allosteric enzyme**. What does that mean?
Glycolysis Summary NET Yield!

2 H₂O

2 ATP

2 Pyruvate

2 NADH + H⁺

H shuttled to 2 FAD

(in ETC)
Please Explain Lactate Accumulation!
Lactate Accumulation
At End of Glycolysis

Strenuous exercise, energy demands exceed oxygen supply
Two pyruvate converted to two lactate molecules

Temporarily
The Lactate Formation Story

NADH + H⁺ → NAD⁺

NADH + H⁺ → NAD⁺

Two pyruvate molecules

Two lactate molecules
NAD$^+$ returns to Step 6 of glycolysis to get more H & glycolysis continues
Research on Lactate!
Lactate is not the cause of burn (acidosis)!
It is the $H^+$ that create the acidic environment

Where do the $H^+$ come from?

[Diagram of hydrogen ion transfer and ATP hydrolysis]
Best Way to Clear Acidosis

Increased capillary density

Increased mitochondria density

Exercise Science sure is Fun!

What is the BEST Way to Train The Anaerobic System
Anaerobic-Type Metabolic Cond. Design

- In sets or repetitions
- Intervals or sprints performed intermittently
- Multiple-sequence exercises (circuits)
- Moderate to Near maximal to Supramaximal (above VO\textsubscript{2}Max) intensities
- Usually 15 to 90-second bouts
- Can last as long as 120 seconds
- Relief of 2 to 3 minutes (active or passive)
- Two to three times per week for fit persons

🌟 Based on timeline for glycogen repletion

Anaerobic-Type Metabolic Cond. Design

- Anaerobic-Type conditioning is best trained by increasing intensity or speed (not duration)
- Extending duration of bouts leads to poor exercise technique and longer recovery
- Exercise relief by heart rate (HR): allow HR to recover to 120 to 140 bpm
- Initially, 1:4 work-to-relief intervals recommended; may gradually taper ratio to 1:2, 1:1.5 and 1:1; **IMPORTANCE of progression**

<table>
<thead>
<tr>
<th>Circuit A: 2x: 30 second on, 40 second off</th>
</tr>
</thead>
<tbody>
<tr>
<td>◆ Jump lunge (TRX)</td>
</tr>
<tr>
<td>◆ Kettlebell single arm farmers walk</td>
</tr>
<tr>
<td>◆ Medicine ball 1/2 kneel side rotation throw</td>
</tr>
<tr>
<td>◆ Front plank with band row (low row)</td>
</tr>
<tr>
<td>◆ Plate push</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circuit B: 2x 30 second on, 40 second off</th>
</tr>
</thead>
<tbody>
<tr>
<td>◆ Bear crawls</td>
</tr>
<tr>
<td>◆ 1/2 knee bottom up with kettlebell</td>
</tr>
<tr>
<td>◆ Medicine ball rollover floor slams</td>
</tr>
<tr>
<td>◆ Single arm row standing</td>
</tr>
<tr>
<td>◆ Kettlebell swings</td>
</tr>
<tr>
<td>Circuit C: 3x: 20 second on, 30 second off</td>
</tr>
<tr>
<td>------------------------------------------</td>
</tr>
<tr>
<td>◆ Kettle bell swings</td>
</tr>
<tr>
<td>◆ Side plan with band row</td>
</tr>
<tr>
<td>◆ TRX shoulder elevated low curls</td>
</tr>
<tr>
<td>◆ Spiderman pushups</td>
</tr>
<tr>
<td>◆ Mountain climbers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circuit D: 3x 20 second on, 30 second off</th>
</tr>
</thead>
<tbody>
<tr>
<td>◆ Broad jump</td>
</tr>
<tr>
<td>◆ Medicine scoop throw (forward)</td>
</tr>
<tr>
<td>◆ TRX inverted row</td>
</tr>
<tr>
<td>◆ Kettlebell single leg deadlift</td>
</tr>
<tr>
<td>◆ Single arm overhead press with dumbbell</td>
</tr>
</tbody>
</table>
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)
Aerobic-Type Metabolic Cond. Optimizing the cardiorespiratory, metabolic and bioenergetic pathways
Key Terms

- Maximal Oxygen Consumption (VO₂max)
  - Max rate of consumption, distribution and utilization of O₂ (ml O₂/kg·min)
- Heart Rate Max (HRmax), Maximal HR
  - The highest heart rate one can achieve during graded exercise
- Stroke volume
  - Blood pumped by ventricle per beat
- Cardiac output (CO): HR x SV = CO
  - Resting: 75 b/min x 70 ml/beat = 5.2 L/min
  - Exercise: 180 b/min x 120 ml/beat = 22 L/min
### Key Terms

- **Peak power**
  - The maximal maximal power output measured in watts.
  - Typically performed on a cycle ergometer

- **Exercise intensity in HIIT**
  - A percentage of maximal effort
  - 95% VO$_{2\text{max}}$ = VO$_{2\text{max}}$ x .95
  - 85% Peak Power = Peak Power x .85
  - 75% HR$_{\text{max}}$ = HR$_{\text{max}}$ x .75

- **HIIT Intervals**
  - Exercise Interval: work bouts of exercise that range from 5 sec to 8 min
  - Rest Interval: Recovery between exercise intervals
Key Terms

- **Work/Relief ratio**
  - Exercise 1 min and rest 2 min
    - 1 min to 2 min relationship: Work/rest ratio: 1/2
  - Exercise 5 min and rest 5 min
    - 90 sec. to 60 sec relationship: Work/rest ratio: 1.5/1
Where is Fat Completely Oxidized in Cells?

Mitochondrion
Where is Fat Completely Oxidized in Cells?

Mitochondrion
Increase in Mitochondrial Density

35% bigger
15-50% more
Five Programs Compared

- 8 subjects (2 men, 6 women) aged 20-30
- Average VO$_2$ max = 48.5 ml/kg/min
- Randomly assigned one of 5 aerobic protocols: one continuous bout and 4 intervals
- Compared the oxygen consumption, caloric expenditure, blood lactate, heart rate and blood pressure

1) Metabolic Base Training

Warm-up: 5-10 min of light intensity exercise
Continuous submaximal aerobic exercise at 70% VO₂ peak
(Somewhat Hard Intensity)
Mode: Treadmill with no grade
Can be preformed on any mode

Why is it called Metabolic Base Training?
Mitochondrion is the base of all fat and carbohydrate metabolism
Because mitochondria have their 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$_2$max (RPE = Very Hard)

**Relief Interval:** 30 seconds at 35-40% VO$_2$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$_2$max (RPE =Very Hard)

Relief Interval: 30 seconds at 35-40% VO$_2$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 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% VO$_2$max (RPE =Very Hard)

Relief Interval: 60 seconds at 35-40% VO$_2$max (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 ever 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% VO₂ max (RPE = Very Hard)

Relief Interval: 30 seconds at 35-40% VO₂ max (Walk, RPE=Light)

Work/Rest Ratio: 1 to 1 ratio.

Modification: Step-Wise Interval Training
1) After each interval increase treadmill grade 3% and keep for work and relief interval
2) Can complete on any mode increasing work with each interval
Special Findings of Study

- 90/30 protocol had the highest VO\textsubscript{2}, heart rate, rating of perceived exertion and lactate levels
- 30/30 protocol the lowest VO\textsubscript{2}, heart rate, rating of perceived exertion and lactate levels
- Blood pressure was similar in all protocols
- 30/30, 60/60 and metabolic base training slightly higher (150 kilocalories) caloric values (than 90/30 and 60/30 protocols)

How Safe Are these Extreme Conditioning Programs?

“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”

What is Exertional Rhabdomyolysis?

“Breakdown of striated muscle tissue”

Reports date back thousands of years

Elevated proteins in blood (notably myoglobin) can lead to acute renal failure, blood clotting, heart arrhythmias

Response to excessive, prolonged or repetitive exercise (hot climate exacerbates) in persons with low fitness level and/or too early introduction to the demands of the exercise program

Excessive, prolonged or repetitive exercise may overstretch the sarcoplasmic reticulum

Skeletal muscle protein fibers

Sarcoplasmic Reticulum

Increase in Ca^{2+} leakage into muscle cell

Activation of sarcolemma (cell membrane): release degrading enzymes

Increase in sarcolemma permeability

Release of harmful proteins in blood that may cause renal failure, blood clotting, heart arrhythmias

Exertional Rhabdomyolysis Triad?

- Reddish brown (cola colored) urine
- Muscular pain
- Muscular weakness
- (Symptoms of muscular stiffness and swelling may occur with rhabomyolysis)

Trainer Prevention Recommendations

- Ensure suitable rest periods between sets and workouts
- Vary workouts so all are not to exhaustive fatigue
- Discourage clients from using caffeine and other stimulants which mask fatigue
- Monitor clients for signs of overtraining
- Track client records to note signs of performance decrements
- Be cautious of training at high intensities in hot environments
Thank You!

Any Questions
References


References


