SP.235 / ESG.SP235 Chemistry of Sports
Spring 2009

SP.235 - Chemistry of Sports

Week 3-Wednesday February 18th, 2009

Topics to cover:

- Newton Running shoe study
- Workouts
- Training your body - focusing on lungs, and muscle
- Repair and maintenance of body

Newton Running Shoe Study

- Has been approved!
- If you are interested please send email to Patti. If you know of any friends who are interested, have them send email to Patti as well
- To do the study, you need to sign the consent form, and fill in the questionnaire.
- Workouts will get started this week

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Weekly workouts

- Thursday swims are out. Potential swim workouts
  - Option 1: Fridays from 3:30 to 4:30 pm - starting February 26th
  - Option 2: Swim with MIT masters swimming, either Monday through Friday at 6:15 am, M, W and F at noon, Monday through Friday at 7 pm, Sunday from 10:30 am to 11:45 am. Check out the club's website (http://web.mit.edu/swim-masters/) for more info
- Saturday am Workouts - we had fun this past week - didn't we? Oz?Adam?
  - We will be there this Saturday at 8:30 am for more fun

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Weekly workouts

- How are things going?
- Starting slow?
- Anyone injured?

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Readings for you to have done before class (from our website)

- Physiologic consequences of training
- Limitations to Maximinal Oxygen uptake
- Optional readings
  - Muscle Fatigue
  - Applied Physiology of Triathlon
  - Recovery from prolonged exercise: restoration of water and electrolyte balance
  - Weight changes, sodium levels, and performance in the south African ironman triathlon
  - Lactic Acid and Exercise Performance

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Patti's new favorite book

- Exercise physiology: Human bioenergetics and its applications, 4th edition (2005)
  - By George A. Brooks, Thomas D. Fahey and Kenneth M. Baldwin

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Cardiovascular Responses to Exercise

1. Increased cardiac output (by increasing heart rate and stroke volume)
2. Increase skin blood flow (helps remove heat)
3. Decreased blood flow to the kidneys (reduces urinary output and maintains blood volume)
4. Decreased visceral blood flow (especially in gastrointestinal tract)
5. Vasoconstriction in the spleen (increased blood volume)
6. Maintenance or slight increase in brain blood flow
7. Increased flood flow to the coronary arteries
8. Increased muscle blood flow (limited by the blood pressure)

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VO_2 Max

- This is a reflection on the efficiency of your cardio respiratory system.
- This is the maximum volume of oxygen that can be delivered to the working muscles
- The higher the VO_2 max, the more fit you are and the easier you find physical work and exercise. It is easier for you body to deliver oxygen to your muscles

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VO_2 Max

- The ability to supply energy for activities lasting more than 30 seconds depends on the consumptio and use of oxygen.
- The rate of consumption of a given volume of O_2 (VO_2) increase as activities progress from rest to easy, to difficult and finally to maximal
- The maximum rate at which an individual can consume oxygen (VO_2 max) is an importan determinant of the peak power output and the maximal sustained power output, or physical work capacity of which an individual is capable
- From Exercise Physiology, 4th edition Brooks et al.

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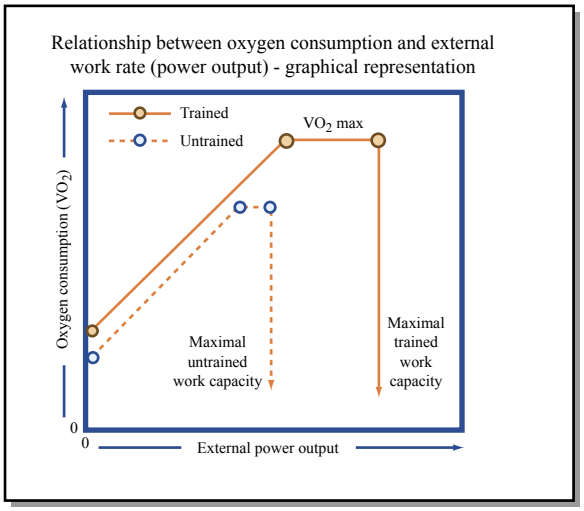

Image by MIT OpenCourseWare.

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VO_2 Max

- When the VO_2 test was done in your fitness assessment, the following information was incorporated in the data:
  - Workload (kg m/min)
  - Heart rate at the two workloads
  - Plotted HR (y-axis) vs. Heart rate (x axis), then where the line intercepted at predicted max heart rate, is the Max O_2 (L/min)
  - Divide this number by your body weight in kg (convert L to ml), then you get Max O_2 in ml/kg/min

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How can we improve our VO_2

- Manipulate the heart rate
  - Heart is a muscle and if it gets regularly exercised, it will be more efficient.
  - How can you improve your heart muscle?

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Improve your heart muscle

- Work out at your targeted heart rate.
- First you need to calculate your maximum heart rate;
- The easiest way to do this is to use the following formula: 220 - age
- Now to improve your heart muscle, you need to work on in your target heart rate which is 55 to 85 % of your maximum heart rate

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Target Heart Rate

Age	Target HR Zone 50-85 %	Maximum Heart Rate 100 %
20 years	100-170 beats per minute	200 beats per minute
25 years	98-166 beats per minute	195 beats per minute
30 years	95-162 beats per minute	190 beats per minute
35 years	93-157 beats per minute	185 beats per minute
40 years	90-153 beats per minute	180 beats per minute
45 years	88-149 beats per minute	175 beats per minute
50 years	85-145 beats per minute	170 beats per minute
55 years	83-140 beats per minute	165 beats per minute

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How should I pace myself? (from the American Heart Association website)

When starting an exercise program, aim at the lowest part of your target zone (50 percent) during the first few weeks. Gradually build up to the higher part of your target zone (75 percent). After six months or more of regular exercise, you may be able to exercise comfortably at up to 85 percent of your maximum heart rate. However, you don't have to exercise that hard to stay in shape.

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Workload

- The Maximum workload is measured in Watts (joules per second).
- It is a measure of power
- Think it as the maximum amount of work that you can do in a second. This is sometimes referred to as critical power

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Cycling Test

The purpose of these tests is to calculate the VO_2 max.

This is accomplished by having the subject work out at 60 to 70 % of VO_2 and use this value to calculate VO_2 max

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Dark-side Cycling Test

"*Maximal Incremental Exercise*
Each subject performed an incremental cycling exercise to volitional exhaustion. Pedaling frequency was set at 70 rpm. The incremental test began with a 5-min warm-up at 60 W. The work rate then increased by 30 W every minute until the subjects reached volitional exhaustion. A value of heart rate close to the theoretical maximal heart rate, a respiratory exchange ration higher than 1.1, and a plateau for VO2 were considered as criteria for VO2 max."

Excerpted from: Keslacy, S., S. Matecki, J. Carra, F. Borrani, R. Candau, C. Prefaut, and M. Ramonatxo. "Effect of inspiratory threshold loading on ventilatory kinetics during constant-load exercise." American Journal of Physiology - Regulatory Integrrative, and Comparative Physiology 289 (2005): R1618-R1624.

Volitional: The act or an instance of making a conscious choice or decision. Therefore the subjects decided that they were tired.

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Maximum Acceptable work duration

Wu, Hsin-Chieh, and Mao-Jiun J. Wang. "Determining the maximum acceptable workduration for high-intensity work." *European Journal of Applied Physiology* 85 (2001):339-344.

- Concern about high-intensity jobs (i.e.. Mining, construction, forestry and fishing)
- Prolonged high-intensity work frequently causes fatigue and over exhaustion and possibly leads to occupational disorders and accidents
- Workload associated with a heart rate over 150 beats/min^{-1} is an extremely heavy workload

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Conclusions from the paper

- Workers should take a break after 18.8 minutes of work when the average workload is about 65 % relative VO_2 (for 85 % it is 4.1 minutes, and for 70 % it is 12.3 minutes)
- Keep this is mind when you are training - you need to listen to your body and do not overtrain to exhaustion, this could lead to a physical mishap

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Back to training

- So you need to get your VO_2 up, so that you can increase your maximum workload

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Limitations to Maximal oxygen uptake

- There is a very good review paper published in 1992:

Sutton, John R. "Limitations to maximal oxygen uptake." *Sports Medicine* 12, no. 2 (1992): 127-133.

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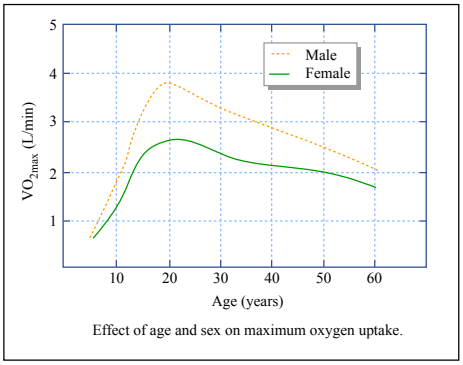
There is a correlation between Age and Sex on VO_2 max



Effect of age and sex on maximum oxygen uptake.

Figure by MIT OpenCourseWare.

Based on averages, as you age, your VO_2 decreases but training can increase your VO_2 up 2-3 fold

From Sutton (1992)

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Limits to maximal oxygen uptake

Image removed due to copyright restrictions.
See Fig. 2 in Sutton, J. R. "Limitations to Maximal Oxygen Uptake." *Sports Medicine* 12, no. 2 (1992): 127-133.
Diagram shows individual components of the oxygen transport chain:

- Ventilation
- Hemoglobin
- Cardiac output
- Peripheral circulation
- Metabolism□□

From Sutton, 1992

Physical limits to improving your max O_2

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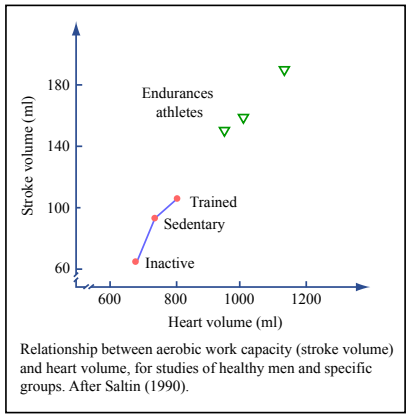
Aerobic work capacity and heart volume



Relationship between aerobic work capacity (stroke volume) and heart volume, for studies of healthy men and specific groups. After Saltin (1990).

Figure by MIT OpenCourseWare.

- Look at the relationship between heart volume/stroke volume and work capacity
- Compare inactive, sedentary, trained and endurance athletes.

From Sutton, 1992

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Conclusions from Sutton's paper

"Maximal oxygen uptake depends on the optimal linkage between all components of the oxygen transporting system from the lungs to the capillary network. Of all the determinants of maximal oxygen uptake which change with physical training the cardiovascular system is most adaptable and within that system it is the maximum increases in stroke volume which are most important."

From Sutton, 1992

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Another predictor of VO_2 - weight

In the fitness test - Max O_2 was in ml/kg/min

One way to improve this number is to decrease the weight of your body (this will be discussed next week - Nutrition)

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A word about training

- Physiologically the purpose of an training session is to stress the body so that adaptation results.
- Training is beneficial only as long as it forces the body to adapt to the stress of physical effort
- If the stress is not sufficient to overload the body, then no adaptation occurs (hence no improvement in physical fitness)

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A word about training

- Now if the stress is so great that it cannot be tolerated, then injury or overtraining results
- Make sure that when you are working out that you are making sure that you are not overstressing your body - listen to your body!
- The greatest improvements in performance occur when appropriate exercise stresses are introduced into an individual's training program.

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Hans Selye

- Hans Selye was born in Vienna in 1907. As early as his second year of medical school (1926), he began developing his now-famous theory of the influence of stress on people's ability to cope with and adapt to the pressures of injury and disease. He discovered that patients with a variety of ailments manifested many similar symptoms, which he ultimately attributed to their bodies' efforts to respond to the stresses of being ill. He called this collection of symptoms--this separate stress disease--stress syndrome, or the general adaptation syndrome (GAS).
- There are three stages involved in response to a stressor: alarm reaction, resistance development and exhaustion

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The Alarm reaction

- Initial response to the stressor involves the mobilization of systems and processes within the organism
- IE. During exercise the stress of running is supported by the strain of increasing oxygen transport through an augmentation of cardiac output and a redistribution of blood flow to active muscle
- Remember that that body has a limited capacity to adjust to various stressors - homeostasis must not be affected long-term

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Resistance Development

- The body improves its capacity or builds its reserves during the resistance stage of GAS
- This stage represents the goal of physical conditioning.
- You need to make sure that you are at the critical threshold to achieve this state (not above or below)
- Remember that if you are sick, that your ability to effectively workout may be diminished. You might end up hurting yourself instead of improving

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Exhaustion (or distress)

- This occurs when stress becomes intolerable, and can either be acute or chronic
- Acute exhaustion can be fractures, sprains or strains
- Chronic exhaustion (overtraining) examples include stress fractures, emotional problems, and soft tissue injuries

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Overload principle

- Application of an appropriate stressor will cause the body to respond and adapt
- Overload is a positive stressor that can be quantified according to load (intensity and duration), repetition, rest and frequency

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Load

- This refers to the intensity of the exercise stressor
- For strength training - load refers to the amount of resistance
- For running and swimming - it refers to speed
- In general, the greater the load, the greater the fatigue and recovery time required

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Repetition

- This is the number of times the load is applied
- More favorable adaptation tends to occur (up to a point) when the load is administered more than once.
- There is no agreement on the number of repetitions you should do

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Rest

- This is the time interval between repetitions as well as the interval between training sessions
- Vitally important for obtaining an adaptation and should be applied according to the nature of the desired physiological outcome.
- Resting is a necessary part of training because adaptations occur during recovery

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Frequency

- This is the number of training sessions per week
- You need to listen to your body to decide on the total number of times you work out.
- For triathlon training - you rotate through the different sports on different days generally starting with one a day workouts and building up to twice a day workouts.
- Then once a week you do a brick workout (bike followed by a run)

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Other Training strategies

- Specificity -
  - don't over train specific part of your body - think of the body as a whole
  - Also, the close the training routine to the requirements of competition, the better the outcome
- Reversibility
  - Inactivity will lead to performance decrement
- Individuality
  - You need to listen to your body and adapt your training regime to fit your body

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Repair and Maintenance of your body

- What happens when you work out?

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Repair and Maintenance of your body

When you exercise you affect the muscle protein turnover

This can be described as the protein synthesis minus protein degradation

One paper (During exercise, the metabolic activity is accelerated due to an increased blood flow through muscle under circumstances of normal amino acid concentrations.

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Repair and Maintenance of your body

Blomstrand, E., J. Eliasson, H. K. R. Karlsson, and R. Köhnke. "Branched-chain amino acids activate key enzymes in protein synthesis after physical exercise." *Journal of Nutrition* 136 (2006): 269S-273S.

During exercise, the metabolic activity is accelerated due to an increased blood flow through muscle under circumstances of normal amino acid concentrations.

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Repair and Maintenance of your body

Blomstrand et al state that regular exercise increases muscle mass due to a higher rate of protein synthesis in relation to protein breakdown.

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From their abstract:

ABSTRACT BCAAs (leucine, isoleucine, and valine), particularly leucine, have anabolic effects on protein metabolism by increasing the rate of protein synthesis and decreasing the rate of protein degradation in resting human muscle. Also, during recovery from endurance exercise, BCAAs were found to have anabolic effects in human muscle. These effects are likely to be mediated through changes in signaling pathways controlling protein synthesis. This involves phosphorylation of the mammalian target of rapamycin (mTOR) and sequential activation of 70-kD S6 protein kinase (p70 S6 kinase) and the eukaryotic initiation factor 4E-binding protein 1. Activation of p70 S6 kinase, and subsequent phopsphorylation of the ribosomal protein S6, is associated with enhanced translation of specific mRNAs. When BCAAs were supplied to subjects during and after one session of quadriceps muscle resistance exercise, an increase in mTOR, p70 S6 kinase, and S6 phosphorylation was found in the recovery period after the exercise with no effect of BCAAs on Akt or glycogen synthase kinase 3 (GSK-3) phosphorylation. Exercise without BCAA intake led to a partial phosphorylation of p70 S6 kinase without activating the enzyme, a decrease in Akt phosphorylation, and no change in GSK-3. It has previously been shown that leucine infusion increases p70 S6 kinase phosphorylation in an Akt-independent manner in resting subjects; however, a relation between mTOR and p70 S6 kinase has not been reported previously. The results suggest that BCAAs activate mTOR and p70 S6 kinase in human muscle in the recovery period after exercise and that GSK-3 is not involved in the anabolic action of BCAAs on human muscle. J. Nutr. 136: 269S–273S, 2006.

Anabolic - synthesis

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Please see: Wackerhage, Henning, and Michael J. Rennie. "How nutrition and exercise maintain the human musculoskeletal mass." *Journal of Anatomy* 208 (2006): 451-458.

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Please see: Borsheim, Elisabet, Melanie G. Cree, Kevin D. Tipton, Tabatha A. Elliott, Asle Aarsland, and Robert R. Wolfe. "Effect of carboyhydrate intake on net muscle protein synthesis during recovery from resistance exercise." *Journal of Applied Physiology* 96 (2004): 674-678.

46

Material removed due to copyright restrictions.

Please see: Tipton, Kevin D., Blake R. Rasmussen, Sharon L. Miller, Steven E. Wolf, Sharla K. Owens-Stovall, Bart E. Petrini, and Robert R. Wolfe. "Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise." *American Journal of Physiology - Endrocrinology and Metabolism* 281, no. 2 (2001): E197-E206.

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Conclusions from the paper:

"The ingestion of a relatively small amount of essential amino acids, combined with carbohydrates, is an effective stimulator of net muscle protein synthesis."

"The combination of incrased amino acid levels at a time when blood flow is increased appears to offer the maximum stimulation of muscle protein synthesis by increasing amino acid delivery to the muscle and thus amino acid availability."

Excerpted from: Tipton, Kevin D., Blake R. Rasmussen, Sharon L. Miller, Steven E. Wolf, Sharla K. Owens-Stovall, Bart E. Petrini, and Robert R. Wolfe. "Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise." *American Journal of Physiology - Endrocrinology and Metabolism* 281 (2001): E197-E206.

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Comments?

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