Biochemical Adaptations to Training

Matt Van Dyke
Covered in this Presentation

- Basics of stress and adaptation
  - Homeostasis
- Requirements of sport
- Immediate adaptations
  - Stress response systems
- Stable adaptations
- Systematic training
- Testing for desired adaptations
Definition of “Adaptation”

• Goal is always maintain homeostasis
  – Any external influence to some extent, changes the organism
  – Body will increase survival odds by any means
    • Even though inefficiency may result when being exposed to new stimuli

• All stress leads to some adaptation within the athlete
  • Dependent on intensity, duration, and type
  • Must determine which stressors are optimal for desired adaptations
Homeostasis

• Regulation - cellular, autonomic, hormonal, and/or neural
• Rigid vs. plastic variables
  – Rigid
    • Great change means organism failure and death
    • Temperature, pH, water, PO₂
  – Plastic
    • change to a great extent to ensure rigid variable consistency
      – Heart rate, blood vessel constriction/dilation
• Allostasis is how the body responds to maintain homeostasis
• Can improve homeostasis level with training
“Biochemical Adaptations”

• The changes to the multiple functioning systems within the organism to improve the ability to maintain internal milieu
  – Multiple systems involved
  – Goal is to maintain homeostasis through changing environments

• What it is and how we look at it in athletics
  – How adaptations occur in the organism
    • Improvements in performance due to long-term, cumulative changes
    • Training completed leads to these net effects
Biochemical Adaptations to Training

• Every training session/exercise triggers an acute adaptation process
  – Body adjusts functions to corresponding level of elevated energy metabolism

• Systematic repetitions create long-term, sustainable adaptations
  • Achieved through training resulting in structural and metabolic enhancements
  • Long-term planning is crucial to ensure proper stable adaptations are created

• Nature of the chosen exercises determines long-term training adaptations
  – Specific training strategies for desired adaptations
    • Intensity and duration
      – Both determine energy systems used
Determine the Needs of Every Athlete

• Knowing each exercise causes specific adaptations, coaches must understand physiology and requirements of each competitive event

• Use 3 categories for simplicity – all require different parameters
  
  – Maximal effort – Weight lifting
    • Near-maximal recovery from every rep
    • High force output required
  
  – Repeat sprint effort – many team sports need to optimize this ability
    • Dependent on multiple qualities gained through training
  
  – Cyclic effort – distance running
    • Relies on cardiac output, aerobic ATP production and tolerance to energy metabolites
Repeat Sprint Ability

• Main focus
  – Mixture of multiple sport activities
  – Requires functional systems to adapt optimally for success
    • Rapid force production
    • Energy availability and capacity
    • High recovery rate
    • Cardiac output and blood flow
    • Metabolite production and clearance
Immediate Adaptations to Stress

• Organism survival is of upmost importance

• Muscles need energy to do work

• Rapid mobilization of energy for increased work output (glucose, protein, and fat)
  – Glucocorticoids, glucagon, epinephrine and norepinephrine
  – Glycogen to glucose
  – Triglycerides to free fatty acids and glycerol
  – Protein to amino acids (non-exercising muscles) to liver glucose

• Increased heart rate, blood pressure, and ventilation to get energy to the working muscles
Immediate Adaptations to Stress (cont.)

• Body halts long-term building processes (digestion, protein synthesis, and immune system)
  – If organism doesn’t survive none of these matter

• Pain reception is blunted

• Improvements in sensory skills (senses and cognition sharpen)
Determinants of Immediate Adaptations

- Extent of response depends on multiple factors
  - Irritant’s intensity
  - Athlete’s current functional resources
    - Previous adaptations
      - Training age
      - Prior day’s training
    - Nutritional status
    - Arousal level
    - Genetics
    - Fiber composition

- Represented by temporary reactions and transformations
Sympathetic Nervous System

- Activated at onset of stress (pre-competition anxiety)
- Assists to complete the above stress responses
  - Stimulates secretion of epinephrine/norepinephrine
  - Dilate pupils
    - Improved vision capabilities
  - Increases concentration
  - Increases heart rate, blood pressure, peripheral muscular blood flow
  - Inhibits digestion
  - Inhibits immune system
Stress Response

• Stress response involves multiple systems

• Surviving in a changing environment depends on brain, endocrine, immune system, and their communication

• Understand all bodily systems function as one

• Communication is bi-directional
  – Immune system can influence release of hormones along with the activity of the nervous system and vice versa
HPA Axis

• Complex set of interactions among 3 endocrine glands
  – Major controller of stress reactions and bodily process regulation
    • Metabolic
    • Cardiovascular
    • CNS

• Responds to stress via sympathetic nervous system activation
  – Training, illness, cortisol levels, sleep
Hormones Involved in Stress Response

• Epinephrine/norepinephrine
  – Act within seconds of release
  – Generally stimulatory in nature
    • Mobilization of energy sources

• Glucocorticoids (Most well known is CORTISOL)
  – steroid hormone secreted by the adrenal gland
  – Often act similar to epinephrine
    • Regulation of metabolism of glucose
  – Take time for their effects to be realized

• These two account for a large percentage of stress response
Other Hormones Involved in Stress Response

- **Glucagon**
  - Assists epinephrine and glucocorticoids in increasing glucose circulation
- **Insulin**
  - Inhibited
  - Responsible for increasing storage
- **Growth Hormone**
  - Released to improve mobilization of energy
  - Building function blocked
    - Decreased sensitivity
Hormonal Response

• 3 Responses
  – Rapid
    • Increase seen in first few min of exercise
    • Epinephrine and norepinephrine increases seen in 6 sec. of max effort
    • Due to higher nervous centers (HPA axis)
  – Moderate
    • Gradual increase in production
    • May continue beyond exercise time
  – Lagged
    • Delayed response in hormone increase
    • Dependent upon cumulative effects of exercise
    • Determines final blood hormone concentrations
Rate of Hormonal Response

Rate of Response

<table>
<thead>
<tr>
<th>Rate of Response</th>
<th>Rapid</th>
<th>Moderate</th>
<th>Lagged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hormone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catecholamines</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corticotropin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cortisol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angiotensin II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucagon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcitonin</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

End of Stress Stimulus
Determinants of Hormonal Response

• Training age
• Nutritional status
  – Glucose availability
• Temperature
  – Hydration regulation
• Hormonal threshold
  – Closely related to the anaerobic threshold
    • close relationship between lactate levels and cortisol
• Exercise Stimulus
  – Increased recruitment enables greater hormone-tissue interaction
• Duration is a greater determinant than intensity
  – Limitations of athlete to maintain high intensities
Other/Metabolic Responses

• Increase glycogen phosphorylase (increase glycogen breakdown)
  – calcium and sodium ions, along with acetylcholine all increase glycogen phosphorylase activity
    • all involved in muscle contraction (neural or ion channels)

• PFK also increases with increased ADP and AMP
  – also responsible for glucose use

• Lactate inhibits a number of enzymes responsible for creating glycogen
  – want to keep resources mobilized
Stable adaptations

- Reflects the net cumulative training effect
  - Adaptation is specific to training executed
    - Max speed vs. conditioning example
- Potential stable adaptations
  - Cardiac
  - Muscular/CT
  - Metabolic
  - Endocrine
  - Nervous system
- Quantitatively measured by athletic condition and top form
  - Testing to determine adaptations
Cardiac adaptations

• Foundation for all performance parameters
• Improved efficiency through training
  – Central
    • Increased stroke volume
    • Improved contraction force/velocity
  – Peripheral
    • Improved oxygen kinetics
      – Increased hemoglobin concentration
      – Increased capillary density
      – Improved O₂ extraction
• Fick Equation
  – \( VO_2 = SV + HR - aVO_2\text{diff} \)
  • \( VO_2 \) still not perfect predictor of RSA
Muscular/CT adaptations

- Tissue Remodeling
  - Improved myosin-attachment
    - Increased titin activity?
- Muscle contractile steps
- Muscle action occurs at a higher rate
- Stretch shortening cycle
Metabolic adaptations

- Increase cellular resources due to training reduces need for increased systemic mobilization of resources during vigorous exercise
  - Body becomes “better prepared” to a stimulus
  - Homeostatic reactions may also diminish to some extent
  - Potential decrease in exercise-induced hormonal responses or avoid them altogether
- Oxidative
- Glycolytic
- Cr-P
Nervous system adaptations

• Rate of force development
  – Crucial in high-velocity movements

• Two phases
  – Early – neural
    • Recruitment
      – Selective in learned skill
    • Rate coding
      – Doublet occurrence
    • Synchronization
  – Late – muscular
    • Already covered
Stable endocrine adaptations

• Related to change in threshold intensity
  – Threshold intensity of exercise is shifted to a higher level
    • Need higher intensities to achieve hormonal response
  – In maximal intensity cases hormonal responses are magnified in athletes
    • Actual training-induced changes in the hormone response to exercise depend on a combination of various alterations in the organism

• Training induced adrenal hypertrophy is associated with an increased number of mitochondria
  – Duration plays major role in hormonal response
    • mitochondria and endoplasmic reticulum are the main sites of biosynthesis of glucocorticoids
Stable endocrine adaptations

- Acute responses more critical to tissue remodeling
- Many studies have not shown a significant change during resistance training despite adaptations
  - Other factors play a large role in stable adaptations
    - Non-training stress factors
    - Nutrition
    - Overtraining and detraining
    - Circadian patterns of hormone secretion
Stable training program

• Systematic, specific stress model
  – Block periodization
    • Residual effects

• Modified undulated training

• Specific muscle action training
  – Eccentric and Isometric stronger
Testing Protocols

• Transfer of training
  – Test for adaptations related to qualities used in competition

• Tests must be specific for desired adaptation
  – HR recovery
  – Repeat sprint ability
  – Lactate tolerability/clearance
Heart rate recovery

- Efficiency of cardiac/circulatory components
- Adaptations over specific training cycles
- Vital role in recovery aspect
Repeat sprint ability

- Maximal intensity and Recovery rate
  - Similar to team sports

- Percent change in sprints

- 10 – 30 yard sprints

- Visual for athlete
Lactate tolerability/clearance

- 2 – 300 yard shuttles
- 3-5 min recovery between
- Current lactate system status
Conclusion

- Body adapts specifically to stressors applied
- Determine needs of each sport
- Acute endocrine response to stress is more important for stable adaptations
- Stable adaptations are the net effects of training
- Maximize adaptations using the specific stress training model
- Test athletes appropriately based on needs
References

References