Stress, Recovery and Performance

We all speak of it and experience it, but what is stress? It is defined as a non-specific response by the body to any demand (stressor) that overcomes, or threatens to overcome, the body’s ability to maintain homeostasis (that state of equilibrium of the body’s internal biological mechanisms) (1 – 2). What this means is that regardless of the nature of the stressor (e.g., exercise, starvation, daily commute, work-related issues), the body perceives stress as a biological event and responds in essentially the same way. What differs is simply the magnitude of our response and this task is assigned to the brain that initiates the appropriate ‘fight-or-flight’ response through our nervous and hormonal systems (3-4). An acute bout of stress and the consequent biological response is quite normal and integral to our survival as a species as long as the body has the opportunity to recover between stressors to restore itself back to baseline (5).

Biological Design:

To gain a deeper insight into our biological stress response, using an example of our ancestors may paint a clearer picture. The nature of their stress was very different to what we typically experience today. Their primary stressors involved a fight for survival or to the death against a predator or aggressor (e.g., raiding party) and the nature of the stress was an intense, acute physiological response (Figure 1). However, after this brief, but stressful encounter, what followed was ample recovery to return to baseline (state of calm – parasympathetic or PNS dominance). This allowed each physiological system (e.g., immune system) time to restore/regenerate itself after fighting to maintain homeostasis.

By contrast, today’s stress generally involves lower-intensity, sustained psychological stressors that sometimes never go away, but accumulate (Figure 2). For example, you might sleep through your alarm and wake up in a panic late for your meeting (stressor), skip breakfast (stressor), get delayed by a slow commute (stressor), arrive late for a presentation (stressor), get reprimanded by your boss (stressor), then finally make it to your office whereupon you receive a call that your child is sick and needs to be picked up from school (stressor) – sound familiar? These sustained stressors, albeit smaller individually accumulate and deny the body that needed time to repair, recover and replenish.
Nonetheless, in either situation (ancestors v. present-day) the body activates its stress response in similar ways, albeit at different intensities and while we are familiar with many responses (e.g., increased heart rate and blood pressure, mobilization of stored fats, increased sweat rates), we may be unaware of others that merit concern (Table 1). For example, elevated levels of epinephrine enhance blood clotting ability by increasing platelet adhesiveness (5). By design, this might be needed to stop one from bleeding to death during a survival fight, but think about this sustained effect upon cardiovascular health.

**Figure 2: Psychological Stress Response**

- **Psychological (Chronic, Moderate, Sustained) Stress**
  - SNS Response
  - Hormonal Response
  - Fight-or-Flight Response
  - Elevated fats in circulation
  - Elevated Cortisol, but no caloric expenditure
  - No Physiological Work
  - Immune system DOES NOT return to baseline
Table 1: Stress Response Influence on Physiological Systems

<table>
<thead>
<tr>
<th>Events Activated</th>
<th>Events Inhibited</th>
</tr>
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<tbody>
<tr>
<td>Increased cardiopulmonary responses</td>
<td>Decreased salivary and digestive enzyme secretion, and digestion</td>
</tr>
<tr>
<td>Increased vessel dilation in needed location</td>
<td>Decreased stomach/small intestinal contractility</td>
</tr>
<tr>
<td>Increased mobilization of fuels</td>
<td>Decreased pain perception (analgesia)</td>
</tr>
<tr>
<td>Increased blood clotting ability</td>
<td>Decreased growth, repair and maintenance</td>
</tr>
<tr>
<td>Increased large intestinal contractility</td>
<td>Decreased reproduction capacity</td>
</tr>
<tr>
<td>Increased bladder contractility</td>
<td>Immune function – sustained long-term</td>
</tr>
<tr>
<td>Increased immune function – short-term</td>
<td></td>
</tr>
<tr>
<td>Increased sweat rates</td>
<td></td>
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</table>

Ever wonder why we experience dry mouth when nervous, why a dog urinates when scared or why you may need to run to the bathroom before a big race? Consider our survival needs – any energy-consuming events deemed unnecessary (e.g., reproduction, growth, maintenance) during periods of intense stress are automatically shut down to provide needed resources and energy to the systems that facilitate survival (e.g., muscles, skin – thermoregulation). The release of saliva, digestive enzymes and mucus in the mouth, stomach and upper GI all consume energy and are therefore shut down during our stress response. Similarly, systems involved in growth, repair, maintenance and reproduction are also temporarily inhibited under stress in order to provide the needed energy and resources elsewhere. By contrast, smooth muscle contractility of the lower GI and bladder become activated to void unnecessary urine and fecal matter that may slow you down if you need to run to survive. Ever witness an athlete suffers what appears to be a painful injury during competition, yet manages to somehow play through it? Our fight-or-flight response also temporarily decreases pain perception to sustain our fight-or-flight response.

Sustained Stress:
So what happens as a consequence of sustained stress that many of us encounter in our daily lives? Cortisol is a key adrenal hormone released under stress that plays an integral role in preserving homeostasis. One essential function of this hormone is to avoid depletion of blood glucose considering how critical this fuel source is for optimal functionality and survival. Increased circulating levels of cortisol that follow liver glycogen depletion or accelerated muscle uptake of blood glucose (i.e., exercise) influence many of our ‘fight-or-flight’ responses, especially those we
need to inhibit (Table 2). Temporarily, these alterations are manageable when spaced few and far between, but when sustained indefinitely, they will compromise health, fitness and performance.

Table 2: Sustained Effects of Elevated Cortisol (1, 2, 5, 6)

<table>
<thead>
<tr>
<th>Target / Hormone</th>
<th>Physiological Role</th>
<th>Effect of Sustained Cortisol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Growth Hormone (HGH)</td>
<td>Promote tissue growth and repair – promote fat utilization</td>
<td>Stimulates somatostatin in hypothalamus that inhibits HGH release from the pituitary gland. May also impact HGH need for fetal development</td>
</tr>
<tr>
<td>Estrogen</td>
<td>Reproductive function; fat distribution in hips/thighs; fat utilization</td>
<td>Inhibits estrogen production in ovaries, fat cells and adrenal gland; decreased fertilization; decreased libido, increased abdominal fat</td>
</tr>
<tr>
<td>Testosterone</td>
<td>Muscle synthesis; may block abdominal fat deposition due to cortisol</td>
<td>Inhibits testosterone production in testes; decreased muscle synthesis; erectile dysfunction; increased abdominal fat</td>
</tr>
<tr>
<td>Thyroid stimulating hormone (TSH)</td>
<td>Manufactures thyroxin and triiodothyroxine to regulate metabolism</td>
<td>Inhibits TSH release – can suppress metabolism up to 20 % = 250 – 300 kcal per day or 25 – 30 lbs. per year</td>
</tr>
<tr>
<td>Leptin</td>
<td>Helps regulate appetite and caloric intake</td>
<td>Increased resistance to leptin</td>
</tr>
<tr>
<td>Ghrelin</td>
<td>Increases hunger; slows metabolism – prevent starvation and malnutrition</td>
<td>Increased sensitivity within ghrelin receptors</td>
</tr>
<tr>
<td>Neuropeptide Y</td>
<td>Neurotransmitter released by hypothalamus – stimulates appetite; inhibited by leptin</td>
<td>Activated by cortisol = greater appetite</td>
</tr>
<tr>
<td>Cholecystokinin (CCK)</td>
<td>Slows GI motility (movement) – enhance digestion/absorption; suppresses appetite ~ 20 minutes after eating</td>
<td>Can inhibit CCK effect on suppressing appetite</td>
</tr>
<tr>
<td>Aging – chromosomes</td>
<td>Telomeres (chromosomal tails) are constantly repaired by telomerase (enzyme) to help keep cells young and healthy</td>
<td>Reduced telomerase activity = telomere shortening and accelerated cellular aging</td>
</tr>
<tr>
<td>Immune system</td>
<td>Repair, recovery, resistance to harmful compounds</td>
<td>Compromised immune function – increased risk for injury and illness</td>
</tr>
<tr>
<td>Brain – Hippocampus</td>
<td>Learning – consolidation of information from short-term to long-term memory</td>
<td>Becomes damaged and smaller – reduces long-term memory</td>
</tr>
</tbody>
</table>
Brain – neurons

| Brain-derived Neurotropic Factor (BDNF) promotes new and healthy neurons; efficient synapses | Decreases BDNF; reduced neurogenesis (new neurons); shortens dendrites = less efficient synapses in brain |

Recovery and Performance:

Although cortisol levels increase in the hours that immediately precede awakening in response to lowered/depleted liver glycogen associated with our overnight fast, this can quickly be reversed with some form of breakfast (with glucose) that elevates insulin to restore liver glycogen, which subsequently returns cortisol back to baseline levels. Ignoring this one homeostatic imbalance for a moment, the early awakened stage from sleep should represent the timeframe where the body is most recovered following the repair and regeneration that occurred during the periodic bouts of stage three and four (deep) sleep overnight. At this time the body should ideally be under the dominance of the PNS and prepared to take on the stressors of the new day. But how do we truly know whether the body is fully recovered from the stress of the previous day?

Many objective and subjective quantifiers exist, although the most familiar methods included monitoring symptoms of overtraining and more recently, the concept of heart rate variability (HRV). As illustrated in Figure Three, HRV describes the fluctuations in the R-R interval in consecutive heartbeats as measured over a period of time (7). Deep breathing and PNS dominance slow heart rate and increase HRV (more variation between R-R intervals) implying a state of calm and recovery – notice how your heart rate accelerates as you inhale and slows down with exhalation? This is actually a good sign. Conversely, SNS dominance decreases HRV (less R-R interval fluctuation) and implies greater stress upon the body (8). During our early awakened state, HRV should be increased which implies greater PNS dominance and readiness for today’s stressors, including a hard workout.

Figure 3: HRV between consecutive heartbeats

Average Heart Rate = 60 BPM

.85 sec  .90 sec  1 sec  .95 sec
Various accurate methods exist by which we can measure our state of recovery – autonomic testing (SNS v. PNS responses to neural impulses) and metabolic markers (ventilation – tidal volumes, breath rates, control pause; RER scores, cortisol) all offer valid information on recovery, but these tests are expensive and impractical for most. Consequently, the fitness and athletic industries have turned to measuring HRV given costs, efficiency of measurement and relevance of the information provided. Although HRV is not new to medicine and diseases (use as a predictor of myocardial infarct for past 40 years), it more has recently emerged in fitness (7). So, how do we measure HRV? A traditional ECG tracing is perhaps the most effective method for determining HRV, but it is impractical for most. Newer technologies are emerging that claim to measure HRV via more portable and cost-effective methods, but their validity and reliability may need to be questioned. Omegawave® mimics a more traditional ECG with leads connected to a chest strap and probably very accurate, whereas products from Polar® and BioforceHRV® use the more conventional chest strap that merits closer examination of the data measured. The same can be said for Ampstrip® which uses adhesive disposable electrodes to collect continuous heart rate and HRV measurements.

For a simpler solution, professionals can still utilize a method we have used for the past 50 years – manual palpation of the radial pulse. As mentioned previously, the early awakened state (assuming natural awakening and not stress-induced via an alarm clock or other trigger) reflects a state of PNS dominance. The habitual practice of measuring a 30-second resting heart rate (RHR) over time provides invaluable information regarding physiological improvement (increased stroke volume = lowered RHR) or symptoms of overtraining (marked by elevated RHR). Any noticeable increases in RHR over a 7-day period should be examined more closely for other symptoms of overtraining that include (1):

- Decreased performance (volume, intensity or rate).
- Stress, irritability, lack of mental attentiveness.
- Muscle soreness, joint ache or general malaise.
- Loss or change in appetite; altered eating patterns.
- Insomnia, sleep disturbance and fatigue.

Coupled with the 30-second heat rate count, individuals can also take 20-30 seconds to become more self-aware of their own HRV by simply monitoring changes within their R-R intervals over this timeframe. Should RHR remain lowered and they identify noticeable HRV, these point towards
good recovery. In contrast, elevations in RHR coupled with small to little noticeable changes in HRV may indicate non-functional overreaching or overtraining. Although not an exact science, these methods of self-awareness can go a long way to helping individual optimize their health, fitness and performance goals.

**Functional overreaching** is a short training phase marked by intense volumes, intensities or rates coupled with appropriate recovery to optimize peak performance prior to competition. **Nonfunctional overreaching** occurs when this intense training is performed for too long or coupled with insufficient recovery and lead to stagnation or some decline – this is considered early stage overtraining.

Applications for Insufficient Recovery:
Looking five years down the road, professionals will have a myriad of valid, portable and cost-effective tools at their disposal like these CNS, cardiovascular and metabolic monitors. However, for today we still need to rely upon our observations of our clients/athletes while simultaneously implementing simple methods to increase self-awareness of physiological recovery from stress. When we do notice symptoms of overtraining that might include elevated RHR or some absence of HRV, we need to understand the physiological implications if these remain unaddressed (i.e., unchecked sustained, elevated cortisol levels). The most immediate response should be an automatic offload – either removing or tapering down whichever stressors can be managed.
Manipulating exercise volume or intensity (e.g., to less than 70% of normal) is perhaps the most basic intervention, but even introducing specific offload programs should be considered (e.g., transitioning from standard linear-loaded exercise programs to unloaded, 3-dimensional movement like yoga). Figure 4 illustrates a simple worksheet to monitor training balances between overload principles (unloaded, loaded, exploded) and specificity (liner – 3-D). Similarly, nutritional and hydration interventions should also be considered (e.g., increasing fluid intake based off of baseline total body water, urine color or urine specific gravity; altering total caloric intake; or undulating macronutrient intake).

**Figure 4: The Program Balance Worksheet (do you have balance between 6 regions?)**

<table>
<thead>
<tr>
<th>Linear</th>
<th>Unloaded</th>
<th>Loaded</th>
<th>Exploded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unloaded</td>
<td>Example = Running</td>
<td>Example = hypertrophy</td>
<td>…</td>
</tr>
<tr>
<td></td>
<td>Example = Yoga</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>Unloaded</td>
<td></td>
<td>Loaded</td>
<td>Exploded</td>
</tr>
</tbody>
</table>

**Unloaded**

**Loaded**

**Exploded**

3-Dimensional
Although exercise is an effective stress-reducing mechanism, many other stress-coping or stress-reducing modalities should also be entertained although each may demonstrate varying levels of efficacy and success with your athletes:

1. **Deep Breathing** (also known as paced breathing; belly, abdominal or diaphragmatic breathing):
   - Find a place (physically or by clearing your mind) free of distractions
   - Close your eyes; and after a few normal breaths, draw in one long-slow breath through your nose engaging your diaphragm (pushing it outwards during inhalation).
   - Pause momentarily, then quickly exhale through your mouth while drawing your belly inwards. Repeat for 30 – 60 seconds.
   - Gradually extending the time between the end of one exhalation and the subsequent normal inhalation (called control pause) normalizes CO$_2$ and O$_2$ levels between the blood and lung tissue which helps with O$_2$ delivery, lactate buffering and reducing inflammation.

2. **Mindful Techniques**:
   - Start by repeating the breathing sequence, but now visualize relaxing scenes or visualize / repeat (slowly) any focus word or phrase that helps you relax.
   - Practice in a place free of distractions 1 – 2 x per day for a minimum of 10 minutes each time.
   - Variations of this technique include:
     - Progressive mind relaxation – gradual intensification of the image, word or phrase.
     - Mindful meditation
     - Yoga, Tai Chi or Qi Gong – including mind-body movements
     - Feldenkrais or guided imagery – super-slow (eyes closed) visualization inducing a deeper sense of mindfulness and mental imagery – often used to rehearse before movement.

3. **Body Sensation Awareness**:
   - Noticing subtle sensations (e.g., itching, tingling) without judgment - let them pass (progressive relaxation techniques).
   - Progressive muscle relaxation – technique of visualizing tension release from muscles using sequential muscle contractions.
   - Noticing emotions and feelings (e.g., anger, sadness) without judgment – accept them and progressively let them pass (diminish).
4. Reprioritization:
   - Create opportunities to reprioritize matters - following a stressful event, spend time on an enjoyable activity or with person(s) who holds high priority in your life (e.g., hugging/playing with your kids)
   - This helps prioritize and build perspective.

5. Social Support:
   - Studies examining primates and our ancestors demonstrated how females, following bouts of stress, resorted to affiliative behaviors such as grooming and hugging that offers a social calming effect (i.e., lowered blood pressure, cortisol levels).
   - Research on oxytocin levels in female primates and human ancestors demonstrated more of a friend-and-befriend response rather than a fight-or-flight response, where they tend to their offspring and bond with one another when stressed (8, 9).
   - For females especially, help plan and develop social support system that offers this same calming effect.

6. Predictive Information:
   - Awareness or anticipation of type, magnitude and duration of stress enables development of effective coping mechanisms
   - For example, planning ahead for a restaurant meal by reviewing the menu when trying to control caloric intake helps cope with the stress of making a rushed decision.
   - Information however, must be relevant (i.e., tied to stressful event) and must time-appropriate (e.g., information provided 3 weeks prior to, or one minute prior to ordering offers little help).

7. Sense of Control:
   - Creating impressions or actually having control of a stressful situation can reduces stress.
   - Low levels of control plus stress demands = poor stress response whereas higher levels of control plus stress demands = better stress responses.
   - With mild-to-moderate stress levels, increased control promotes self-efficacy
   - With high stress levels, one may benefit from less control to avoid extreme pressure, desperation or blame should they not succeed.
8. Cognitive Flexibility:

- This involves developing the ability to remove stressors that you do control, but adapting to those stressors you cannot control. In essence, it helps one interpret things as always improving (i.e., positive outlook with glass half full).

- The Serenity Prayer by Reinhold Niebuhr, a 20\textsuperscript{th} century Theologian helps summarize this strategy:
  
  - “Grant me the serenity to accept the things I cannot change, the courage to change the things I can, and wisdom to know the difference”

Closing Remarks:

We work long and hard to help our athletes achieve their peak performance. Considering our biologically-designed stress response and how we, as a species, have deviated from that function, perhaps it is time we prioritize recovery and smart training over hard training. Why waste the time, effort and valuable resources on a great program, yet neglect what is perhaps the overall governor of it all – the ability or inability to properly recover. What are you doing to ensure your athletes kick start their training day optimally?

References: