Endurance Training Program Design: An Evidence-Based, Physiological Perspective on “Why We Do What We Do”
Endurance Training Program Design: An Evidence-Based, Physiological Perspective on “Why We Do What We Do”

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Presentation Overview

• Part I: Speaker Background
• Part II: What This Presentation Is Not
• Part III: Training Program Philosophy
• Part IV: Training – Art & Science
Presentation Overview

• Part V: Maximal Aerobic Power \( (\dot{VO}_2^{\text{MAX}}) \)

• Part VI: Lactate Threshold \( (LT) \)

• Part VII: Running Economy \( (RE) \)

• Part VIII: The Long Run \( (LR) \)
Presentation Overview

• **Part IX**: Protein Requirements & Protein Distribution in Endurance Athletes

• **Part X**: Mitochondrial Quality versus Mitochondrial Quantity

• **Part XI**: Acknowledgments

• **Part XII**: Questions & Discussion
Presentation Overview

• Part XIII: Appendices
Part I

Speaker Background
Evidence-Based Inquiry

• “I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind”

Lord Kelvin
Evidence-Based Inquiry

• “If I have seen further than others, it is by standing upon the shoulders of giants”

Isaac Newton
Speaker Background

• Education – **Ph.D. in exercise physiology w/ concentration in exercise biochemistry (Arizona State University, 2004)**
  
  – M.S. Exercise Science (*Arizona State University, 1995*)
  – M.B.A. (*Duke University, 1992*)
  – B.A. Economics (*Wesleyan University, 1984*)

• Experience – **Darien High School (2.0 Years), Desert Vista High School (2.5 Years), Queen Creek High School (1.5 Years), Xavier College Preparatory (6.5 Years), & Desert Vista High School (2013 / 2014 / 2015 / 2016 / 2017 / 2018 / 2019)**
Speaker Background

- Coaching Influences
  - Chris Hanson / Ellie Hardt / Dave Van Sickle
  - Dan Beeks, Michael Bucci, Renato Canova, Robert Chapman, Steve Chavez, Liam Clemons, Bob Davis, Erin Dawson, Marty Dugard, Jason Dunn, John Hayes, Brad Hudson, Jay Johnson, Tana Jones, Arthur Lydiard, Steve Magness, Joe Newton, Dan Noble, Jim O’ Brien, Tim O’Rourke, Rene Paragas, Haley Paul, Louie Quintana, Ken Reeves Alberto Salazar, Jerry Schumacher, Tom Schwartz, Brian Shapiro, Scott Simmons, Mando Siquieros, Renee Smith-Williams, Doug Soles, Danna Swenson, Bill Vice, Joe Vigil, Mark Wetmore, & Chuck Woolridge
Speaker Background

- **Tara Erdmann**, 2:14 / 4:54
- **Kari Hardt**, 2:11 / 10:26
- **Baylee Jones** 2:16 / 4:55 / 10:36
- **Danielle Jones**, 2:09 / 4:39 / 10:09
- **Haley Paul**, 2:13 / 4:51
- **Two (2) Foot Locker National (FLN) Championship qualifiers**
Speaker Background

- **Sarah Penney**, 2:11 / 10:39
- **Mason Swenson**, 2:16 / 4:59 / 10:56
- **Jessica Tonn**, 2:13 / 4:50 / 10:21
- **Sherod Hardt**, 4:10 / 8:59
- **Garrett Kelly**, 4:17 / 9:18
- **4 x 1,600-m Relay** (20:14 / 20:52 / 21:37 XCP) & **4 x 800-meter Relay** (8:57 XCP / 9:01 DVHS)

- **2012 Mt. SAC Relays**: 4 x 1,600-m Event – 3 teams / 12 student-athletes averaged 5:13 per split
- **Four (4) time NXN team participant** across two schools & two genders (**XCP, DVHS**) and one (**1**) time NXN individual qualifier

From: LA84 Cross Country Coaches Clinic Webinar 7/8/2020
Part II

What This Presentation Is Not
“What this presentation is not”

Xavier College Preparatory or Desert Vista High School Training Philosophies or Training Programs

https://www.highschoolrunningcoach.com/
Part III

Training Program Philosophy
Program Philosophy

• Emphasize Plan, Structure, & Discipline

• Cumulative, Consistent Aerobic Development

• Conjugate Periodization
Program Philosophy

• **Consistent Patterns of Weekly, Phasic, Seasonal, and Annual Training**

• **Individualization & Development**

• **Shared Responsibility**
Part IV

Training - Art & Science
**Art & Science: Energetic Demands of a 5-Kilometer Race**

Energy Source Comparisons for Middle Distance and Distance Events

### “Classic” Model

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>400</th>
<th>800</th>
<th>1,500</th>
<th>5,000</th>
<th>10,000</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic (%)</td>
<td>18.5</td>
<td>35.0</td>
<td>52.5</td>
<td>80.0</td>
<td>90.0</td>
<td>97.5</td>
</tr>
<tr>
<td>Anaerobic (%)</td>
<td>81.5</td>
<td>65.0</td>
<td>47.5</td>
<td>20.0</td>
<td>10.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

### “Current” Model

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>400</th>
<th>800</th>
<th>1,500</th>
<th>5,000</th>
<th>10,000</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic (%)</td>
<td>43.5</td>
<td>60.5</td>
<td>77.0</td>
<td>94.0</td>
<td>97.0</td>
<td>99.0</td>
</tr>
<tr>
<td>Anaerobic (%)</td>
<td>56.5</td>
<td>39.5</td>
<td>23.0</td>
<td>6.0</td>
<td>3.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*The “current” model was determined using the latest methodology in oxygen uptake kinetics and with a much more elite subject population than the “classic” model.*
Art & Science: Physiological Correlates of Endurance Performance Potential

Equivalent VO₂-max

(80%) LT
Superior RE – 80% is effectively “only 78%”

15:32 5-K

(80%) LT

15:45 5-K

(65%) LT

16:30 5-K

(65%) LT

17:30 5-K

From: LA84 Cross Country Coaches Clinic Webinar 7/8/2020
Part V

Maximal Aerobic Power ($\dot{VO}_2\text{-max}$)
Maximal Aerobic Power ($\dot{VO}_2$-max)

- **Endurance / Aerobic Training** …
  - Improves $\dot{VO}_2$-max or, more specifically, …
  - **Enhances** cardiovascular function (*maximal cardiac output*)
  - **Increases** total blood volume
  - **Enhances** capillary density
  - **Improves the** detraining response
  - **Elevates** mitochondrial content
Improving the Maximal Rate of O$_2$ Delivery

From: LA84 Cross Country Coaches Clinic Webinar 7/8/2020
Training Increases $\dot{\text{VO}_2}$-max

• Typical training regimen
  
  – $\sim 70\% \ \dot{\text{VO}_2}$-max
  – 30 - 40 minutes * day$^{-1}$
  – 4 - 5 days * week$^{-1}$
  – 3 - 5 months

• Typical increase in $\dot{\text{VO}_2}$-max $\sim 10 - 20\%$
  
  – Subjects who were previously sedentary
    • Larger % increases
  
  – Subjects with higher initial $\dot{\text{VO}_2}$-max
    • Smaller % increases
    • *Essentially all of the increase due to increased maximal $Q$*
Training and VO₂-max: 3 Human Studies

(*Gollnick et al.; Wibom et al.; and Howald et al.*)

- **Training**
  - **Cycle ergometer**
  - **Training period, Frequency, Duration, Intensity**
    - Gollnick et al.: 5 months, 4 d/wk, 1 hr/d, 75-90% VO₂-max
    - Wibom et al.: 6 wk, 4 d/wk, 36 min/d, 70% VO₂-max
    - Howald et al.: 6 wk, 5 d/wk, 30 min/d, 72% VO₂-max

- **Improvements in VO₂-max (i.e. Aerobic Capacity)**
  - Gollnick: 13% (46.5 to 52.5 ml \cdot min⁻¹ \cdot kg⁻¹)
  - Wibom: 9.6% (44.0 to 48.2 ml \cdot min⁻¹ \cdot kg⁻¹)
  - Howald: 14% (43.2 to 49.4 ml \cdot min⁻¹ \cdot kg⁻¹)
Adaptive Increase in VO₂-max Is Dependent Upon Training Stimulus

- More strenuous regimens elicit greater increases

- Hickson et al. (J. Appl. Physiol. 42: 372-376, 1977)
  - Protocol (8 healthy subj, age 20-42, 6 d/wk exercise, 10 wk):
    - 3 d/wk: Interval cycling 6 x 5’ @ 100% VO₂max: 2’ @ 50%
    - 3 d/wk: Run steady rate as far as possible in 40’
  - Results:
    - Mean increase in VO₂max = 44%! (from 38.2 to 55.0 ml/kg/min)
    - Increased VO₂max correlated with improved endurance
    - One subject continued to train an additional 3 wks - total increase was 77% (22.8 to 41.0 ml/kg/min)
### Training Increases Ventricular Size and $Q_{\text{max}}$
*(Adapted from: Rerych, S.M. et al. Am. J. Cardiol. 45: 244-252, 1980)*

<table>
<thead>
<tr>
<th></th>
<th>Heart Rate <em>(b/min)</em></th>
<th>EDV <em>(ml)</em></th>
<th>SV <em>(ml)</em></th>
<th>Ejection Fraction <em>(%)</em></th>
<th>Cardiac Output <em>(l/min)</em></th>
<th>Total Blood Volume <em>(liters)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>74</td>
<td>133</td>
<td>95</td>
<td>73</td>
<td>6.9</td>
<td>8.7</td>
</tr>
<tr>
<td>After</td>
<td>61*</td>
<td>167*</td>
<td>112*</td>
<td>67</td>
<td>6.7</td>
<td>11.4*</td>
</tr>
<tr>
<td><strong>Maximal Exercise</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>185</td>
<td>166</td>
<td>144</td>
<td>87</td>
<td>26.6</td>
<td>8.0</td>
</tr>
<tr>
<td>After</td>
<td>181</td>
<td>204*</td>
<td>176*</td>
<td>86</td>
<td>32.0*</td>
<td>10.8*</td>
</tr>
</tbody>
</table>

18 college swim athletes studied before and after 6 mo. intensive training
Mean age = 19 yrs; 6 females, 12 males
Aerobic High-Intensity Intervals

Helgerud et al. (2007)

• Long, slow distance running (LSD)
  – Continuous run @ 70% of HR$_{MAX}$ ($137$ bpm) for 45-minutes

• Lactate threshold running (LT)
  – Continuous run @ 85% of HR$_{MAX}$ ($171$ bpm) for 24.25-minutes
Helgerud et al. (2007)

• **15 / 15 interval running** *(15 / 15)*
  
  – 47 repetitions of 15-second interval runs @ 90 - 95% of HR$_{\text{MAX}}$ *(180 - 190 bpm)* interspersed w/ 15-second active recovery periods @ 70% of HR$_{\text{MAX}}$ *(140 bpm)*

• **4 x 4 interval running** *(4 x 4)*
  
  – 4 x 4-minute interval runs @ 90 - 95% of HR$_{\text{MAX}}$ *(180 - 190 bpm)* interspersed w/ 3-minute active recovery periods @ 70% of HR$_{\text{MAX}}$ *(140 bpm)*
Helgerud et al. (2007)

Which training intervention is relatively more effective in eliciting improvement(s) in maximal aerobic capacity, stroke volume, running economy, and / or lactate threshold?
Helgerud et al. (2007)

Δ VO₂-max (%)

20.0%
18.0%
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%

LSD   LT   15/15   4 X 4

Training Intervention
Helgerud et al. (2007)
Potential Interpretation: Long, slow distance training and/or threshold training may not be particularly effective in improving maximal aerobic capacity in already well-conditioned individuals.
Helgerud et al. (2007)

• Physiological Correlate

\[ \dot{V}O_2^{\text{MAX}} = Q^{\text{MAX}} \times (a-v)O_2^{\text{DIFF}} \quad (Fick \ Principle) \]

\[ \dot{Q}^{\text{MAX}} = \dot{H}R^{\text{MAX}} \times S V^{\text{MAX}} \]

– Endurance Training (ET) does not Increase \( H R^{\text{MAX}} \)

– Thus, one Focus of ET should be Enhancement of \( S V^{\text{MAX}} \)
Helgerud et al. (2007)

Potential Application: Consistent (for example, weekly) incorporation of a workout or workouts emphasizing approx. 4-minute repetitions @ 90 – 95% of HR$_{\text{max}}$ may induce a very potential stimulus for enhancement of both maximal stroke volume and maximal aerobic capacity.
Mitochondrial Content: Effects of Training  

<table>
<thead>
<tr>
<th>Mitochondrial Volume Density (% of Total Cell Volume)</th>
<th>Untrained</th>
<th>Trained</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type I Fibers</strong></td>
<td>6.18%</td>
<td>8.36%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*(35%)</td>
</tr>
<tr>
<td><strong>Type IIa Fibers</strong></td>
<td>4.54%</td>
<td>7.02%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*(55%)</td>
</tr>
<tr>
<td><strong>Type IIx Fibers</strong></td>
<td>2.33%</td>
<td>3.55%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*(52%)</td>
</tr>
</tbody>
</table>
### Skel. Muscle Capillarization: Effects of Training and Detraining


<table>
<thead>
<tr>
<th></th>
<th>Before Training</th>
<th>Weeks After Training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Capillaries per fiber</td>
<td>2.07 ± 0.11</td>
<td>120.3 ± 7.9</td>
</tr>
<tr>
<td>Caps around each fiber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST</td>
<td>5.35 ± 0.29</td>
<td>123.4 ± 7.9</td>
</tr>
<tr>
<td>FTa</td>
<td>5.14 ± 0.13</td>
<td>120.8 ± 5.9</td>
</tr>
<tr>
<td>FTb</td>
<td>4.27 ± 0.17</td>
<td>129.7 ± 6.9</td>
</tr>
</tbody>
</table>

Detraining values are expressed as % pretraining value
All values at “0 weeks’ posttraining are significantly higher than pretraining
All values during detraining are significantly lower than the “0 weeks” values except for *
Values are means ± SE (n = 5 - 6)
Detraining Effects On $\dot{V}O_2$-max


- **Protocol**
  - Training as before (6 d/wk, 40 min/d, 10 wk)
  - After 10th wk training reduced to either 2 or 4 d/wk

\[ \begin{align*}
\text{\dot{V}O}_2\text{max} & \text{ (ml/kg/min)} \\
2 \text{ d/wk} & \text{ (blue)} \\
4 \text{ d/wk} & \text{ (gray)} \\
\end{align*} \]

\[ \begin{align*}
\text{training} & \quad \text{reduced training} \\
0 \text{ (wks)} & \quad 25 \text{ (wks)} \\
\end{align*} \]

\[ \begin{align*}
\sim 25\% \text{ increase} & \quad \text{essentially no decrease} \\
\text{due to training} & \quad \text{with reduced training} \\
\end{align*} \]
VO$_2$-max and HIIT


- Analysis reviewed studies published in English from 1965 – 2012

- Study inclusion criteria involved 6- to 13-week training periods, $\geq 10$-minutes of HIIT in a representative training session (i.e. workout), and a $\geq 1:1$ work:rest ratio
**VO$_2$-max and HIIT**

- Authors note “conventional wisdom” that repetitions of 3- to 5-minutes are thought to be particularly effective in invoking enhanced aerobic capacity.

- Current analysis strongly supports this perspective; the nine (9) studies that associate with the greatest increases in maximal aerobic capacity ($VO_2$-max) involve 3- to 5-minute intervals and relatively high intensities ($\geq 85\%$ of $VO_2$-max).
VO_{2}\text{-max} and HIIT

197 articles identified through PubMed search

30 articles examined in full

70 additional articles included from author search and reference review

37 articles included in synthesis

40 cohorts included in meta-analysis

167 articles excluded from title and abstract:
- Intervals that were too short (n=7)
- No IT on a bike or a treadmill (n=82)
- No useful data (n=10)
- Rest periods too long (n=2)
- Study duration too short (n=8)
- Subjects too old (n=9)
- Trained subjects (n=41)
- Unhealthy subjects (n=7)
- W:R ratio too low (n=1)

63 articles excluded after review:
- No IT (n=17)
- W:R too low (n=8)
- IT duration too short (n=7)
- Insufficient data (n=18)
- Same subjects (n=1)
- Exercise frequency too low (n=4)
- Subjects too old (n=1)
- Nonhuman subjects (n=1)
- Trained subjects (n=3)
- Study duration too short (n=1)
- Training intensity too high (n=1)
- Training intensity too low (n=1)
Percent

Observed Changes in VO2 Max

Upper Limit

Lower Limit

Estimate

VO2_max and HITT
VO$_2$-max and HIIT

**Potential Interpretation:** Emphasize repetitions of, for example, 800-m, 1,000-m, and 1,200-m in order to provide a robust stimulus for enhancement of maximal aerobic capacity *(and include very brief, for instance, repetitions of 150-m and 200-m to provide a complementary stimulus for enhancement of both maximal aerobic capacity and running economy, Gibala et al., 2012)*
Adaptations to Aerobic Interval Training


- **Experimental Objective:** To compare the effects of three distinct 7-week interval training programs varying in duration but matched for effort in trained cyclists
Adaptations to Aerobic Interval Training

• Experimental design

  – Thirty-five (35) well-trained (pre-training $VO_2$-peak = 52 ± 6 ml $O_2$ * kg$^{-1}$ * min$^{-1}$) cyclists

  – Four distinct seven-week training protocols

  – Average of approximately five (5) training sessions per week for the seven-week training period

  – All participants completed pre- and post- maximal aerobic capacity testing and time trial evaluation
Adaptations to Aerobic Interval Training

• Experimental design

  – One group (six males, two females) engaged strictly in low-intensity, continuous training four to six times per week {"long, slow distance"}

  – One group (seven males, two females) executed two weekly sessions of 4 x 16-minutes (w/ a three-minute recovery) in addition to two-to-three weekly, low-intensity, continuous training sessions {"threshold training"}
Adaptations to Aerobic Interval Training

• Experimental design

  – One group (nine males) executed two weekly sessions of 4 x 8-minutes (w/ a two-minute recovery) in addition to two-to-three weekly, low-intensity, continuous training sessions {“Supra-threshold, sub-VO$_2$-max training”}

  – One group (seven males, two females) executed two weekly sessions of 4 x 4-minutes (w/ a two-minute recovery) in addition to two-to-three weekly, low-intensity, continuous training sessions {“VO$_2$-max training”}
Adaptations to Aerobic Interval Training

Table 3. Physiological test results before and after training

<table>
<thead>
<tr>
<th></th>
<th>Low (n = 8)</th>
<th>4 × 16 min (n = 9)</th>
<th>4 × 8 min (n = 9)</th>
<th>4 × 4 min (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRE mean (SD)</td>
<td>POST</td>
<td>PRE</td>
<td>POST</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>80.4 (12.5)</td>
<td>79.5* (12.2)</td>
<td>83.8 (10.8)</td>
<td>81.6* (11.0)</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>20.8 (7.2)</td>
<td>20.0* (7.2)</td>
<td>22.2 (5.4)</td>
<td>20.7 (5.2)</td>
</tr>
<tr>
<td>HF_{peak}</td>
<td>182 (12)</td>
<td>182 (9)</td>
<td>183 (9)</td>
<td>178* (8)</td>
</tr>
<tr>
<td>V_{E_{peak}}(L/min)</td>
<td>157 (35)</td>
<td>169 (40)</td>
<td>155 (35)</td>
<td>158 (39)</td>
</tr>
<tr>
<td>Lactate_{peak} (mmol/L)</td>
<td>14.9 (1.6)</td>
<td>13.7* (1.0)</td>
<td>14.8 (1.6)</td>
<td>13.9 (1.5)</td>
</tr>
<tr>
<td>RPE_{peak}</td>
<td>19.4 (0.5)</td>
<td>19.5 (0.5)</td>
<td>19.3 (0.7)</td>
<td>19.6 (0.5)</td>
</tr>
<tr>
<td>VO_{2peak} (L/min)</td>
<td>4.2 (0.7)</td>
<td>4.3 (0.7)</td>
<td>4.3 (0.5)</td>
<td>4.5* (0.7)</td>
</tr>
<tr>
<td>(ml kg/min)</td>
<td>52.7 (8.0)</td>
<td>54.5 (6.9)</td>
<td>51.1 (5.8)</td>
<td>54.4* (5.2)</td>
</tr>
<tr>
<td>Power VO_{2peak} (W)</td>
<td>349 (44)</td>
<td>358 (48)</td>
<td>361 (51)</td>
<td>372* (50)</td>
</tr>
<tr>
<td>(W/kg)</td>
<td>4.5 (0.6)</td>
<td>4.6 (0.6)</td>
<td>4.3 (0.4)</td>
<td>4.6* (0.4)</td>
</tr>
<tr>
<td>Power_{4mM} (W)</td>
<td>222 (42)</td>
<td>239* (38)</td>
<td>228 (51)</td>
<td>249* (45)</td>
</tr>
<tr>
<td>TTE80% (min)</td>
<td>10.86 (2.6)</td>
<td>12.14 (3.2)</td>
<td>8.52 (1.8)</td>
<td>13.83* (4)</td>
</tr>
</tbody>
</table>

*P<0.05 vs the pre-test value.
Adaptations to Aerobic Interval Training

The 4 x 8-minute group realized superior improvement in maximal aerobic capacity, peak power output, and endurance time trial performance.
Adaptations to Aerobic Interval Training

**Potential Interpretation:** By slightly reducing training intensity below near-VO$_2$-max intensity and extending total training volume (32-minutes relative to 16-minutes), participants training at approximately 90% of maximal heart rate achieved greater overall adaptive effects than participants training at a higher, relative intensity.
Adaptations to Aerobic Interval Training

**Potential Application:** Emphasize “combination workouts” that incorporate a spectrum of repetitions (for example, 2 x 1,200-m, 4 x 800-m, & 6 x 400-m) and thus provide a complementary, aggregate stimulus for the improvement of both physiological characteristics (\(VO_2\)-\text{max}) and assessment measures (time trial performance).
Part VI

Lactate Threshold ($LT$)
Lactate Threshold

The lactate threshold is the maximal effort or intensity that an athlete can maintain for an extended period of time with little or no increase in lactate in the blood. It is an effort or intensity and not a specific lactate level. It is most often described as a speed or pace such as meters per second, or times to achieve certain distances such as minutes per mile or kilometer for running and minutes per 100-m in swimming, or as a power measure such as watts.
Lactate Threshold


- Multiple decades of experimental work such as Billat (1996) has catalyzed a general scientific and practitioner’s consensus that an improvement in lactate threshold results in an improvement in endurance performance.
Lactate Threshold

Typical Lactate Performance Curves

- **Sprinter**
- **Middle Distance**
- **Marathoner**

Lactate mmol/l vs. Speed m/s

- Estimated Lactate Threshold
- Lactate Threshold
Lactate Threshold

Effect of Training on the Lactate Threshold

Graph showing the relationship between speed (km/h) and lactate levels.
Question: Do We Know How to Consistently, Significantly Improve Lactate Threshold?
Lactate Threshold


- This research synthesis concluded that highly-trained individuals may need to train at much higher than lactate threshold intensities in order to enhance the lactate threshold.

From: LA84 Cross Country Coaches Clinic Webinar 7/8/2020
Lactate Threshold


• Eight (8) male middle- & long-distance runners
• Mean Age: 20 years old
• Initial VO\(_2\)-max: 68.7 mL O\(_2\) * kg\(^{-1}\) * min\(^{-1}\)
• Study Duration: 14-weeks
• One (1) 20-minute threshold session * week\(^{-1}\) @ 85% vVO\(_2\)-max
• Percentage (%) LT Improvement: 4.3
Lactate Threshold

- Twenty (20) male middle-distance runners
- Age: 19 - 23 years old
- Initial VO$_2$-max: 64.4 mL O$_2$ * kg$^{-1}$ * min$^{-1}$
- Study Duration: 17-weeks
- Two (2) or more weekly sessions at $V_{LT}$ or slightly above $V_{LT}$ ($70 \pm 5\%$ VO$_2$-max) for a total weekly duration of 60- to 90-minutes
- Percentage (%) LT Improvement: 3.8
Lactate Threshold


- Six (6) female middle- & long-distance runners
- Mean Age: 19 years old
- Initial VO$_2$-max: 51.8 mL O$_2$ * kg$^{-1}$ * min$^{-1}$
- Study Duration: 8-weeks
- Six (6) 20-minute threshold sessions * week$^{-1}$ @ 91% vVO$_2$-max
- Percentage (%) LT Improvement: 10.3
Lactate Threshold

**Question:** Do We Know How to Consistently, Significantly Improve Lactate Threshold?
Lactate Threshold

• Perhaps young runners might benefit from a combination of \textit{(approximate)} LT and supra-LT training

  – Threshold Training \textit{(Progression Runs versus Tempo Runs)}

  – \textit{“Critical Velocity”} Training – \textit{“Tinman”}
    • $v\Delta_{50}$ Training
Part VII

Running Economy ($RE$)
Running Economy

• The “oxygen cost” (i.e. rate of oxygen consumption) of running at a specific speed

• Example:
  – Runner A consumes 55 milliliters of $O_2 \times kg^{-1} \times min^{-1}$ at 10 miles*hour$^{-1}$
  – Runner B consumes 50 milliliters of $O_2 \times kg^{-1} \times min^{-1}$ at 10 miles*hour$^{-1}$

• Accordingly, Runner B is more economical
Running Economy (RE)

• Plyometric Training and Ascent (Hill) Training …
  – Improve running economy or, more specifically …
  – Enhance so-called elastic energy return within the musculotendinous unit
  – Recruit / Train muscle spindles (through rapid stretch / shortening cycle repetitions) (NOTE: muscle spindles contain the contractile proteins actin and myosin and thus possess a contractile apparatus that can contribute to skeletal muscle force and power production)
Explosive Training, Heavy Weight Training, & Running Economy

Objective: To Evaluate the Effect of Concurrent Training on Running Economy (RE) in Endurance Athletes
Denadai et al. (2016)

- Searched PubMed database
- Searched Web of Science database
- Reviewed reference lists from selected studies
- Searched studies published up to August 15th, 2015
- Incorporated Inclusion / Exclusion Criteria
- One-hundred and nineteen (119) relevant studies were identified
Denadai et al. (2016)

Ultimately, sixteen (16) studies were formally assessed to meet all requisite criteria and thus be sufficiently rigorous to be included in the quantitative analysis.
Denadai et al. (2016)

- Percentage (%) change in RE ranged from -12.52 to +0.72
- Overall, concurrent training had a positive effect: -3.93%
- Only heavy weight training (HWT) and explosive training (EXP) presented a % change significantly lower than zero

Millet et al. (2012): -12.52% change in RE consequent to HWT emphasizing half-squat and heel raises

Saunders et al. (2006): -3.63% change in RE consequent to EXP emphasizing foundational plyometric movements
Denadai et al. (2016)

- Short- and medium-term training periods (6- to 14-weeks) of concurrent training were sufficient to enhance RE in recreationally-trained endurance runners.

- Relatively longer training periods (14- to 20-weeks) in combination with relatively high weekly training volumes of endurance running were requisite to enhancing RE in highly-trained individuals.
Denadai et al. (2016)

- **Practical applications:**
  
  - **Consistently incorporate** age-appropriate, beginning- and intermediate-level plyometric training **throughout the season** for both novice and experienced endurance athletes in order to duly emphasize foundational RE enhancement.

  - **Consider the eventual, selective incorporation** of specific, lower-limb, heavy resistance exercises **in order to further amplify foundational improvements in RE**.
Plyometric Training & Endurance Performance


- Primary study objective was to assess the effect(s) of concurrent endurance and plyometric training on both endurance time trial performance and explosive strength in competitive middle- and long-distance runners.
Plyometric Training & Endurance Performance

• 36 participants (14 women, 22 men)
• Mean age of 22.7 ± 2.7 years
• Minimum of 2-years of competitive national and / or international experience
• Personal best performances ranging from 3:50 to 4:27 (min:sec, 1,500-m) and 2:32 to 2:52 (hours:min, marathon)
Plyometric Training & Endurance Performance

- Mean weekly endurance training volume of $67.2 \pm 18.9$ kilometers

- Mean pre-study 2.4-km time trial performance of approximately 7.8-minutes (i.e. 5-minute, 13-second per mile pace for approximately 1.5-miles)
Plyometric Training & Endurance Performance

• Six (6) week plyometric training intervention

• Two (2) plyometric training sessions per week

• Less than thirty (30) minutes per session

• All plyometric training involved depth jumps (2 x 10 jumps from a 20 cm box, 2 x 10 jumps from a 40 cm box, and 2 x 10 jumps from a 60 cm box)

• Fifteen (15) second rest intervals between repetitions and two (2) minute rest intervals between sets
# Plyometric Training & Endurance Performance

<table>
<thead>
<tr>
<th>Plyometric</th>
<th>Control</th>
<th>Plyometric</th>
<th>Control</th>
<th>Plyometric</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4-km TT</td>
<td>2.4 km TT</td>
<td>20-m Sprint</td>
<td>20-m Sprint</td>
<td>CMJA</td>
<td>CMJA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7.6 to 7.3-minUTES</th>
<th>8.0- to 7.9-minUTES</th>
<th>3.92 to 3.83 seconds</th>
<th>3.97 to 3.94 seconds</th>
<th>36.1 to 39.3 cm</th>
<th>34.1 to 36.3 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9% faster</td>
<td>1.3% faster</td>
<td>2.3% faster</td>
<td>0.8% faster</td>
<td>8.9% higher</td>
<td>6.5% higher</td>
</tr>
</tbody>
</table>

From: LA84 Cross Country Coaches Clinic Webinar 7/8/2020
Plyometric Training & Endurance Performance

**Potential Interpretation:** Incorporate plyometric training into the ongoing endurance training of student-athletes in order to both enhance muscular strength / power and improve endurance performance.
Uphill Interval Training

Barnes et al. (2012)

• Introduction
  – Uphill running is a form of running-specific resistance training
  – Optimal parameters for prescribing uphill interval training are unknown
  – Dose-response approach might yield specific insight as to program design
Barnes et al. (2012)

- **Methods**
  - Twenty well-trained runners performed VO$_2$-max, running economy and 5-k time trial assessments
  - Subsequent random assignment to one of five intensities of uphill interval training
  - 20 x 10-sec. intervals at 120% of VO$_2$-max w 18% grade / 2 x 20-min. intervals at 80% of VO$_2$-max w 4% grade
• Results
  – Improvement in *running economy* was greatest at the highest intensity of hill interval training
  – There was no clear optimum for improvement of 5-K time trial performance
• Discussion
  – Uphill interval training @ 95% \( \dot{V}O_2\)-max (8 x 2-min intervals) produced greatest improvements in most physiological measures related to performance
  – However, running economy improved most dramatically at the greatest (120% \( \dot{V}O_2\)-max) intensity
Barnes et al. (2012)

- **Conclusion(s)**
  - “Until more data are obtained, runners can assume that any form of high-intensity uphill interval training will benefit 5-k time trial performance”
  - Integrate short- and intermediate-/long-hill repetitions into hill training workouts
Part XIII

The Long Run (LR)
The Long Run (LR)

- **Endurance / Aerobic Training …**
  - Improves aerobic conditioning or, more specifically, …
  - **Enhances** cardiovascular function
  - Increases total blood volume
  - **Enhances** capillary density
  - **Improves the** detraining response
  - **Elevates** mitochondrial content
The Long Run ($LR$)

Thus, the long run is (*in simplest terms*) a relatively robust manifestation of foundational aerobic / endurance training.
The Long Run ($LR$)

- **Goals of a Long Run**
  - Induce significant skeletal muscle glycogen depletion
  - Induce comprehensive skeletal muscle fiber recruitment
  - MANY others!
The Long Run & Glycogen Depletion


- *PGC-1α* is an acronym for peroxisome proliferator-activated receptor gamma co-activator 1 alpha

- “from a molecular perspective, the key to endurance training adaptations is to maximize *PGC-1α* activity with training”
The Long Run & Glycogen Depletion


- Glycogen depletion activates adenosine monophosphate-activated protein kinase (AMPK)

- “AMPK is one of the most potent regulators of PGC-1α activity”
The Long Run & Glycogen Depletion


• Glycogen depletion activates p38 mitogen-activated protein kinase (p38MAPK).

• p38MAPK is a similarly potent regulator of PGC-1α activity.
The Long Run & Glycogen Depletion

- **Summary of the previous two (2) slides**

- Glycogen $\rightarrow$ Increased AMPK activity $\rightarrow$ Increased PGC-1$\alpha$ activity $\rightarrow$ *mitochondrial biogenesis*

- Glycogen $\rightarrow$ Increased p38MAPK activity $\rightarrow$ Increased PGC-1$\alpha$ activity $\rightarrow$ *mitochondrial biogenesis*
The Long Run & Glycogen Depletion


- *Is glycogen depleted via a long run?*
The Long Run & Glycogen Depletion


- Lower-limb skeletal muscle glycogen is significantly depleted across all three fibers types with 1) moderate-intensity, long duration aerobic exercise and / or 2) high-intensity, intermediate duration aerobic exercise.
The Long Run & Glycogen Depletion


- Moreover, there is significant muscle fiber recruitment across Type I, Type IIa, and Type IIx muscle fibers with 1) moderate-intensity, long duration aerobic exercise and/or 2) high-intensity, intermediate duration aerobic exercise.
The Long Run (LR)

- **GOALS** of a Long Run
  - Induce significant skeletal muscle glycogen depletion
  - Induce comprehensive skeletal muscle fiber recruitment
The Long Run (LR)

- **OUTCOMES** of a Long Run
  
  - Induce significant skeletal muscle glycogen depletion
  
  - Induce comprehensive skeletal muscle fiber recruitment
The Long Run (LR)

- **ADAPTIVE OUTCOMES** of a Long Run
  
  - Robust stimulus to induce mitochondrial biogenesis

  - Robust stimulus to recruit and thus train ALL muscle fiber types \((I, \text{IIa, and IIx})\)
Part IX

Protein Requirements & Protein Distribution in Endurance Athletes
Protein Requirements in Endurance Athletes

Protein Requirements in Endurance Athletes

**Objective:** To quantify the recommended protein intake in endurance athletes during an acute, three-day training period using the indicator amino acid oxidation (IAAO) method.
Protein Requirements in Endurance Athletes

- Six male, endurance-trained adults
- Mean VO$_2$-peak = 60.3 ± 6.7 ml *kg$^{-1}$ * min$^{-1}$
- Acute training session (20-km treadmill run)
- Post-training consumption of variable protein mass

Utilize labeled phenylalanine method in order to quantify both estimated average protein requirement and recommended protein intake

From: LA84 Cross Country Coaches Clinic Webinar 7/8/20
Protein Requirements in Endurance Athletes

- **Current Recommended Dietary Allowance (RDA) is 0.8 grams PRO * kg\(^{-1}\) body mass * day\(^{-1}\)**

- **Current recommendations for endurance athletes are 1.2 – 1.4 grams PRO * kg\(^{-1}\) body mass * day\(^{-1}\)**
Protein Requirements in Endurance Athletes

- Experimental results yield an estimated, average, post-training protein requirement of 1.65 grams PRO * kg\(^{-1}\) body mass * day\(^{-1}\)

- Experimental results yield an estimated, average, post-training recommended protein intake of 1.83 grams PRO * kg\(^{-1}\) body mass * day\(^{-1}\)
Protein Requirements in Endurance Athletes

**Potential Interpretation:** The metabolic demand for protein intake (1.83 grams PRO * kg\(^{-1}\) body mass * day\(^{-1}\)) in trained endurance athletes engaged in high-volume and / or high-intensity training is not only greater than their sedentary counterparts but also greater than current recommendations for endurance athletes (1.2 – 1.4 grams PRO * kg\(^{-1}\) body mass * day\(^{-1}\))
Protein Distribution in Endurance Athletes

Protein Distribution in Endurance Athletes

Distribution of dietary protein intake throughout the day among athletes

- **Reference**: by Jenna B. Gillen et al. USNEM 2017, Apr;27(2):105-114
- **Designed by**: @YLMSportScience

<table>
<thead>
<tr>
<th>Time</th>
<th>Protein Intake (grams)</th>
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<tbody>
<tr>
<td>Breakfast</td>
<td>0</td>
</tr>
<tr>
<td>Morning snack</td>
<td>1.2</td>
</tr>
<tr>
<td>Lunch</td>
<td>36%</td>
</tr>
<tr>
<td>Afternoon snack</td>
<td>36%</td>
</tr>
<tr>
<td>Dinner</td>
<td>8%</td>
</tr>
<tr>
<td>Evening snack</td>
<td>0</td>
</tr>
</tbody>
</table>

This survey of athletes revealed they habitually consume > 1.2 g protein/kg/d, but the distribution throughout the day may be suboptimal to maximize the skeletal muscle adaptive response to training.
Protein Distribution in Endurance Athletes

- Experimental results indicate that surveyed athletes habitually consume more than 1.20 grams PRO * kg\(^{-1}\) body mass * day\(^{-1}\).

- Experimental results additionally suggest that the distribution of protein intake throughout a day may be decidedly suboptimal to maximize the skeletal muscle adaptive response to training.
Protein Distribution in Endurance Athletes

Potential Interpretation: The skeletal muscle adaptive response to training in trained endurance athletes engaged in high-volume and / or high-intensity training may be enhanced and, indeed, optimized through relatively even distribution of daily protein intake across the waking cycle (Witard et al., {2019}, Table II)
Mitochondrial Quality versus Mitochondrial Quantity

MacInnis et al. (2017)

- Ten (10), young, active males ($VO_2$-peak $= 46.2 \pm 2 \text{ ml O}_2 \text{ * kg}^{-1} \text{ * min}^{-1}$)

- Single-leg cycle ergometry

- All subjects could thus perform high-intensity interval training (HIIT), moderate-intensity continuous training (MICT), AND serve as their own control
MacInnis et al. (2017)
MacInnis et al. (2017)

- HIIT legs performed six (6) sessions of 4 x 5-minutes @ 65% of mean $W_{peak}$ interspersed by 2-minute active recovery periods @ 20% of mean $W_{peak}$

- MICT legs performed six (6) sessions of 30-minutes @ 50% of mean $W_{peak}$

- Consequently, total work was equivalent across the HIIT and MICT training
MacInnis et al. (2017)

- Muscle biopsies were drawn from the vastus lateralis of HIIT & MICT legs both pre- and post-training

- Mitochondrial QUANTITY was assessed (maximal $O_2$ respiratory rates $\{JO_2\}$)

- Mitochondrial QUALITY was assessed (mitochondrial mass-specific $JO_2$)
MacInnis et al. (2017)

• Notable Data

– Whole muscle mitochondrial (*citrate synthase*) enzyme activity demonstrated significantly greater percentages increases (39%) consequent to HIIT training relative to MICT training (11%)
MacInnis et al. (2017)

• Notable Data

- Similar whole muscle mitochondrial enzyme activity increases were significantly greater in multiple electron transport chain enzymes (22% \{HIIT\} vs. -7% \{MICT\} for Complex I and 22% \{HIIT\} vs. -9% \{MICT\} for Complex I + Complex II)
Notable Data

- Mitochondrial-specific $JO_2$ (i.e. mitochondrial quality) appears to be largely unaffected by short-term training intervention(s) and relatively modest differences between MICT and HIIT training intensities

- However, Granata et al. (2016) has previously demonstrated that sprint interval training (SIT) is associated with increased mitochondrial-specific $JO_2$ (i.e. enhanced mitochondrial quality)
MacInnis et al. (2017)

- Potential Interpretation(s)

  - So-called high-intensity interval training should necessarily include both HIGH-intensity movement (such as sprinting or near-sprinting) and sufficient duration (such as nine {9} weeks per Granata et al. {2016}) in order to elicit improvement in mitochondrial quantity and/or mitochondrial quality
Part XI

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- Sherod Hardt (Queen Creek HS, ‘10)
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- Savannah Gaffney *(XCP, ‘14)*
- Sophi Johnson *(DVHS, ‘15)*
- Baylee Jones *(DVHS, ‘17)*
- Danielle Jones *(DVHS, ‘15)*
- Lauren Kinzle *(XCP, ‘15)*
- Natalie Krafft *(DVHS, ‘13)*
- Kyra Lopez *(DVHS, ‘15)*
- Jenna Maack *(DVHS, ‘13)*
- Samantha Mattice *(XCP, ‘14)*
- Jane Miller *(XCP, ‘16)*
- Jessica Molloy *(MBHS, ‘15)*
- Shannon Molvin *(XCP, ‘15)*
- Laura Orlie *(XCP, ‘12)*
- Caroline Pass *(DVHS, ‘16)*
- Tessa Reinhart *(DVHS, ‘15)*
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- Emily Smith *(DVHS, ‘16)*
- Mason Swenson *(DVHS, ‘16)*
- Brittany Tretbar *(DVHS, ‘16)*
- Julianne Vice *(XCP, ‘14)*
- Kate Welty *(XCP, ‘14)*
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- Kate Yanish *(XCP, ‘12)*
- Aubrey Worthen *(DVHS, ‘16)*
Part XII

Questions & Discussion
Questions & Discussion
Part XIII

Appendices
Appendix A: Warm-up A

- 1,000-meter jog
- Step-Outs with Torso Rotations (4 Step-Outs with 6 Rotations per Step)
- Forward Lunge with Right / Left Torso Rotation (6 repetitions)
- Forward Lunge with Rotating Twist & Reach (6 repetitions)
- Forward Lunge with Two-Arm Vertical Reach (6 repetitions)
- Modified Power Walks (20 Repetitions)
- Carioca (2 x 8 repetitions)
- Progressive Speed A-Skips (24 Repetitions)
- B-Skips (24 repetitions)
- Progressive Turnover High Knees (50 repetitions)
- Two (2) to Four (4) x 100-meter Strides
- WORKOUT or RUN
Appendix B: Warm-up B

- 1,000-meter jog
- Hip-Twist with Ankle Hops (20 hop repetitions & 30 hop/twist repetitions)
- Progressive Speed Base Rotations (50 repetitions)
- Lateral Lunge with Rotation (6 repetitions/3 per side)
- Backward Lunge with Vertical Reach (6 repetitions)
- Forward Lunge with Hamstrings Group Stretch (6 repetitions)
- Modified Power Walks (20 Repetitions)
- Carioca (2 x 8 repetitions)
- Hamstrings Group Kicks (Fifteen {15} "touches" per leg)
- B-Skips (24 repetitions)
- Progressive Turnover High Knees (50 repetitions)
- Two (2) to Four (4) x 100-meter Strides
- WORKOUT or RUN

From: LA84 Cross Country Coaches Clinic Webinar 7/8/2020
Appendix C: Warm-up C

- 1,000-meter jog
- Ten (10) Alternating Knee Hugs with Heel Raise
- Ankling (approximately 25- to 35-meters)
- Hamstring Kicks (Fifteen {15} ”touches” per leg)
- Side Walking Lunge (Eight {8} Rightward / Eight {8} Leftward Lunges)
- Side Shuffle with Arm Swing (Eight {8} Rightward / Eight {8} Leftward Shuffles)
- Lateral A-Skips (Twelve {12} Rightward / Twelve {12} Leftward Skips)
- Backward Run (approximately 30- to 50-meters)
- Single Leg Skip (approximately 20- to 40-meters; alternate lead leg)
- Two (2) to Four (4) x 100-meter Strides
- WORKOUT or RUN
Appendix D: Warmdown A

- Nick Swings *(4 right circles, 4 left circles)*
- Arm Swings *(4 forward circles, 4 backward circles)*
- Chest Stretch
- Trunk Rotation *(4 right circles, 4 left circles)*
- Rock Squat *(10 repetitions)*
- Quadriceps Group Stretch *(10 count per quadriceps group)*
- Piriformis Stretch *(10 count per quadriceps group)*
- Hamstrings Group Stretch *(10 count per hamstrings group)*
- Lunge Stretch *(10 count per lunge)*
- Gastrocnemius / Soleus Stretch *(10 count per leg)*
Appendix E: General Strength (GS) / Plyometric Routine I

- “Runner’s” Push-ups (30-seconds of continuous repetitions = 1 set)
- “Russian” Twists (30-seconds of continuous repetitions = 1 set)
- Hyperextensions (30-seconds of continuous repetitions = 1 set)
- “Prisoner” Squats (30-seconds of continuous repetitions = 1 set)
- Ankle Hoops (30-seconds of continuous repetitions = 1 set)
- Split Squat Jumps (30-seconds of continuous repetitions = 1 set)

- 1 set of every GS / Plyometric movement = 1 circuit

- Perform continuous circuits utilizing a 30-second “on” / 20-second “off” work / recovery combination for a total of 10- to 20-minutes
Appendix F: General Strength (GS) / Plyometric Routine II

- **Abdominal Crunches** *(30-seconds of continuous repetitions = 1 set)*
- **Rocket Jumps** *(30-seconds of continuous repetitions = 1 set)*
- **“V” Sit-Ups** *(30-seconds of continuous repetitions = 1 set)*
- **Supine Bridge with Alternating Leg Raises** *(30-seconds of continuous repetitions = 1 set)*
- **Right “Plank” with Left Leg Raises** *(30-seconds of continuous repetitions = 1 set)*
- **Left “Plank” with Right Leg Raises** *(30-seconds of continuous repetitions = 1 set)*

- 1 set of every GS / Plyometric movement = 1 circuit

- Perform continuous circuits utilizing a 30-second “on” / 20-second “off” work / recovery combination for a total of 10- to 20-minutes
Appendix G: General Strength (GS) / Plyometric Routine III

- Prone “Plank” with Alternating Leg Raises (30-seconds of continuous repetitions = 1 set)
- Continuous Hurdle Jumps (30-seconds of continuous repetitions = 1 set)
- Supine “Plank” with Alternating Leg Raises (30-seconds of continuous repetitions = 1 set)
- Scissor Jumps for Height (30-seconds of continuous repetitions = 1 set)
- Side-Ups (30-seconds of continuous repetitions = 1 set)
- Skips for Vertical Displacement (30-seconds of continuous repetitions = 1 set)

- 1 set of every GS / Plyometric movement = 1 circuit

- Perform continuous circuits utilizing a 30-second “on” / 20-second “off” work / recovery combination for a total of 10- to 20-minutes
Appendix H: General Strength (GS) / Plyometric Routine IV

- Donkey Kicks (*30-seconds of continuous repetitions = 1 set*)
- Straight-Arm Prone Plank w/ Single Leg Stride (*30-seconds of continuous repetitions = 1 set*)
- Push-up to Prone Plank w/ Bilateral Hip / Knee / Ankle Flexion & Extension (*30-seconds of continuous repetitions = 1 set*)
- Donkey Whips (*30-seconds of continuous repetitions = 1 set*)
- Lateral Plank w/ Straight Leg Raise (*30-seconds of continuous repetitions = 1 set*)
- Modified Russian Twist (*30-seconds of continuous repetitions = 1 set*)

- 1 set of every GS / Plyometric movement = 1 circuit

- Perform continuous circuits utilizing a 30-second “on” / 20-second “off” work / recovery combination for a total of 10- to 20-minutes
Appendix I: General Strength (GS) / Plyometric Routine V

- Lateral Lunge Walks w/ Runner’s Arms (30-seconds of continuous repetitions = 1 set)
- Lateral Shuffle w/ Runner’s Arms (30-seconds of continuous repetitions = 1 set)
- Lateral A-Skips (30-seconds of continuous repetitions = 1 set)
- Lateral Plank w/ Lower Limb Ankle / Knee / Hip Flexion & Extension (30-seconds of continuous repetitions = 1 set)
- Lateral Plank w/ Straight Leg Raise (30-seconds of continuous repetitions = 1 set)
- Lateral Leg Swings (30-seconds of continuous repetitions = 1 set)

- 1 set of every GS / Plyometric movement = 1 circuit

- Perform continuous circuits utilizing a 30-second “on” / 20-second “off” work / recovery combination for a total of 10- to 20-minutes