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*Kristin Armstrong of the United States competes in the Cycling Road Women's Individual Time Trial on Day 5 of the Rio 2016 Olympic Games at Pontal on August 10, 2016 in Rio de Janeiro, Brazil. (Photo by Phil Walter/Getty Images)*

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Message from the  
**Chief of Sport Performance**  
**Alan Ashley**



Welcome back to *Olympic Coach*! On the heels of highly successful Olympic and Paralympic Games in Rio, we've been celebrating Team USA coaches and athletes, including the White House visit with President Obama and the Team USA Awards. We're fortunate as we have so much to celebrate!

There were so many fantastic performances in Rio including the first Olympic gold medal in Women's Wrestling for Helen Maroulis, the "McSweep" in women's Paralympic wheelchair racing for Tatyana McFadden, Amanda McGrory and Chelsea McClammer, the return to the podium for USA Weightlifting with Sarah Robles' bronze medal, USA Track and Field's distance success for Emma Coburn in the 3000 meter Steeplechase, Galen Rupp in men's Marathon, Jenny Simposon and Matt Centrowitz in the 1500 meters, the first gold medal for women's shot put by Michelle Carter, the defense of her gold in London for Kayla Harrison of USA Judo, and podium sweeps for our women's 110 meter hurdles - Brianna Rollins, Nia Ali, and Kristi Castlin, and the first-ever Para-triathlon event for Allysa Seely, Haley Danisewicz, and Meilssa Stockwell, And so many more!

Team USA earned 121 Olympic medals led by Team USA Male and Female Athletes of the Games Michael Phelps and Katie Ledecky, the Women's Gymnastics Team (Simone Biles, Gabby Douglas, Laurie Hernandez, Madison Kocian and Aly Raisman) won Team of the Games, and Coach of the Games Adam Krikorian, who defended Team USA's first ever Olympic gold medal in women's Water Polo for a matching set. On the Paralympic side, 104 medals were earned by Team USA led by Tatyana McFadden and Brad Snyder as Male and Female Athletes of the Game, and the Women's Sitting Volleyball Team earning Team of the Games. Needless to say, the athletes of Team USA provide us with an unforgettable summer of outstanding performances. The performances were supported by an amazing team of coaches, service providers, technicians, staff ,and volunteers – not to mention the parents, community members, and support clubs. These individuals each fulfilled their role in providing the environment and leadership necessary to let the athletes do exactly what they were capable on and off the field. I am personally very thankful for the efforts of everyone involved in supporting this effort.

As we close out the Rio 2016 games, we look toward Pyeong Chang 2018 and our winter sports. Winter season is kicking off now and we'll look forward to supporting our winter partners as they move toward winter championships and preparation for 2018 just over a year away.

We thank you for your support in following Team USA's successes. As we face challenges against powerhouse countries, we know that we have the best fans in the world and we look forward to continuing to make you proud. Go Team USA!

## **A Review: Use of Whole-Body Vibration on Human Performance and Recovery**

**Luis Jeronimo, CSCS, Strength and Conditioning Mentee, United States Olympic Committee**

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### **Introduction**

In recent years, the use of whole body vibration (WBV) has gained popularity as a potential training modality for enhancing recovery and athletic performance. Recent documentation has shown improvement in strength and power with vibratory stimulation (Issurin, 1999; Delecluse, 2003; Rønnestad, 2009; Rønnestad, 2009; Stewart, 2009). WBV involves a subject standing or performing exercises on a platform generating vertical and horizontal vibrations at various frequencies (Delecluse, 2003). Additionally, studies have shown a decrease in delayed-onset muscle soreness (DOMS) with the implementation of WBV (Aminian-Far, 2011; Bakhtiary, 2007; Rhea, 2009). Since exercise induced muscle damage (EIMD) may jeopardize training status for athletes, recovering quickly will enable athletes to train more frequently, thus increasing performance. This review will attempt to provide a coherent interpretation of existing research to help explain potential benefits behind WBV training.

### **Whole-Body Vibration and the Prevention and Treatment of Delayed-Onset Muscle Soreness**

The purpose of this article was to investigate the acute effect of WBV on the prevention of delayed-onset muscle soreness (DOMS) before eccentric exercise. Thirty-two untrained university participants volunteered for the study. WBV subjects (n=15) underwent vibratory stimulation (35 Hz at 5 mm) in a half-squat position for one minute followed by an eccentric training protocol of six sets for ten repetitions (6x10) on an isokinetic dynamometer. Non-WBV subjects followed similar protocol without vibrant stimulation. Measured variables of interest included muscle soreness levels measured by a 10 mm visual analog scale (far-left indicating no pain and vice versa). Measurements were taken pre- and post-testing on days 1, 2, 3, 4, 7 and 14. Results showed a decrease in soreness levels with the implementation of WBV.

***Research conducted by Tehran University of Medical Sciences, Iran; Semnan University of Medical Sciences, Iran***

### **Acute and Residual Effects of Vibratory Stimulation on Explosive Strength in Elite and Amateur Athletes**

The purpose of this article is to examine the acute and residual effects of vibratory stimulation on explosive strength. Twenty-eight male athletes were divided into two groups: group one consisted of Israeli national athletes with training experience, and group two of amateur athletes with minimal

training experience. Participants were instructed to perform maximal biceps curls on a bilateral biceps curl machine containing an imposed vibratory stimulation device (44 Hz, 3 mm). Subjects performed two separate biceps curl sessions, one with vibratory stimulation and one without, of three repetitions with measured variables of max and mean power. Results showed an increase of maximal and mean power in elite athletes ( $30.1 \pm 15.3$  and  $29.8 \pm 16.6$ , respectively) and amateur athletes ( $20.0 \pm 16.9$  and  $25.9 \pm 18.9$ ), respectively.

***Research conducted by Ribstein Center for Research and Sports Medicine Sciences, Israel***

### **Strength Increase after Whole-Body Vibration Compared with Resistance Training**

The purpose of this article was to compare the effects of a twelve-week period of whole-body vibration training and resistance training on knee-extensor strength. Sixty-seven untrained female athletes participated in the study over a twelve-week period. The four groups included a WBV (35-40 Hz, 2.5-5 mm), resistance training, control and placebo group. Isometric and dynamic knee extensor strength were measured to determine the effect of WBV. Results showed the highest increase in dynamic and isometric strength with the WBV group (16.6% and 9.0%, respectively). Furthermore, the counter movement jump (CMJ) height increased by 7.6% in WBV only.

***Research conducted by Katholieke University, Belgium***

### **Influence of Vibration on Delayed Onset of Muscle Soreness Following Eccentric Exercise**

The purpose of this article was to investigate the effect of vibration training (VT) on DOMS after eccentric exercise. Fifty untrained athletes (25 M and 15 F) were assigned to a VT and non-VT group. A vibration stimulator (50 Hz) was applied to the lower body musculature (quadriceps, hamstring, and calves) of the VT group for one minute followed by a 10 degree decline treadmill walk at 4km/hr. Non-VT group followed the same protocol excluding exposure to vibration. Isometric maximum voluntary contraction (IMVC) force measured by a load cell connected to the distal end of the subject's leg and muscle soreness measured by a Visual Analogue Scale (0, no soreness and 10, severe soreness) were measures of interest. Results showed lower soreness levels with the VT group, 0.4 (right limb) and 0.5 (left limb), compared to the non-VT group 2.3 (right and left). Additionally, IMVC force showed an increase in the VT group (37.2) compared to the non-VT group (-39.6).

***Research conducted by Semnan University of Medical Sciences, Iran***

### **Acute Effect of Whole-Body Vibration on Sprint and Jumping Performance in Elite Skeleton Athletes**

The purpose of this article was to assess the effects of WBV on lower body power. Seven elite level athletes (1 M and 6 F) performed squat jumps (SQJs), countermovement jumps (CMJs), and a 30-meter sprint. WBV group underwent a vibratory stimulation (30 Hz,  $\pm 4$  mm amplitude) before and after, whereas the non-WBV did not. Results showed no significant effects of WBV on sprint or vertical jump performance in elite athletes.

***Research conducted by the Australian Institute of Sport, Australia; Charles Sturt University, Australia; New Zealand Academy of Sport, New Zealand; University of Calgary, Canada***



## **Acute Effects of Various Whole-Body Vibration Frequencies on Lower-Body Power in Trained and Untrained Subjects**

The article was designed to examine the acute effects of WBV with different vibration frequencies on power production during the squat jump (SJ) and countermovement jump (CMJ). Seventeen trained and untrained subjects (13 M and 4 F) were divided into two groups: untrained (no strength training experience) and trained (two to three strength training sessions in the last six months). Participants were exposed to four different WBV frequencies (0, 20, 35 and 50 Hz, 3 mm) while performing two repetitions of SJ and CMJ with an external load of 20, 40 and 60 kg. Results showed improvement in peak average power production in SJ with a vibratory stimulation of 50 Hz for both groups while peak average power was only improved with untrained athletes during the CMJ. Frequencies of 0, 20 and 35 had no significant effect on peak average power in both groups.

***Research conducted by Lillehammer University, Norway***

## **Effects of Itonic Whole-Body Vibration on Delayed-Onset Muscle Soreness among Untrained Individuals**

The study presented examined the influence of WBV and stretching on reducing delayed-onset muscle soreness. Sixteen male untrained subjects (no resistance training experience) participated in vigorous resistance training (eccentric phase focused) of a back squat, leg extension, leg curl, heel raises, and deadlifts followed by repeated sprints. Participants were divided into two groups (WBV and non-WBV stretching). WBV subjects performed two sessions of massage vibratory stimulation at 50 Hz, 2mm and stretching at 35 Hz, 2 mm, immediately after testing and one later within the same day, on a platform for three consecutive days. The non-WBV group followed the same stretching protocols without a vibratory stimulation. Results showed a reduction of muscle soreness on a visual analogue scale (0, no pain to 100, maximum pain) in the WBV group ( $p < 0.05$ ). Perceived pain for the WBV group peaked 24 hours post training at 40/100 whereas the stretching non-WBV group peaked at 48 hours with a reporting pain of 70/100.

***Research conducted by A.T. Still University in Missouri, USA; European University of Madrid in Spain; Southern Utah Physical therapy in Utah, USA***

## **Acute Effects of Various Whole-Body Vibration Frequencies on 1RM in Trained and Untrained Subjects**

This article examined the acute effects of WBV at different vibratory frequencies on one repetition maximum (1RM) between trained and untrained subjects. Sixteen subjects (13 M and 3 F) were divided into two groups based on training status: untrained (no resistance training experience during the last six months) and trained (two strength training sessions per week during the last six months). Subjects received a vibratory stimulation of various frequencies (0, 20, 35 and 50 Hz, 3 mm) while performing a 1RM back squat on a Smith Machine. Results showed strength gains in both trained and untrained groups while exposed to WBV with a frequency of 50 Hz, 3 mm ( $7.5 \pm 1.4$  and  $12 \pm 1.9$  kg, respectively). No significant difference was shown between frequencies of 0, 20 and 35 Hz.

***Research conducted by Lillehammer University, Norway***



## Differential Effects of Whole-Body Vibration Durations on Knee Extensor Strength

The purpose of the article was to investigate continuous exposure effects of three different WBV time durations on isometric knee extensor strength. Twelve trained male subjects performed right knee maximal voluntary isometric contractions on a dynamometer while exposed to three different vibratory time frames (two, four and six minutes) at 26 Hz, 4 mm. Results showed a significant increase in peak torque with the two-minute protocol (+3.8%) compared to the four- and six-minute stimulation (-2.7% and -6.0%, respectively).

**Research conducted by New Zealand Institute of Sport, New Zealand; Massey University, New Zealand**

## The Acute Effect of Whole-Body Vibration on Muscle Activity, Strength, and Power

The purpose of the study was to investigate the effectiveness of WBV on isometric squat (IS) and countermovement jump (CMJ) performance. Nine moderately trained male subjects followed a countermovement jump with vibration (CMJ-V), CMJ with no vibration (CMJ-S), isometric squat with vibratory stimulation (IS-V), and IS with no vibratory stimulation (IS-S). CMJ-V and IS-V received a 30-second WBV stimulus (30 Hz, 2.5 mm amplitude) before the testing protocol was assigned. Results showed an increase in jump height for the WBV group. No other significance was found.

**Research conducted by Appalachian State University, North Carolina, USA**

## Conclusion

Based upon the research presented, vibratory stimulation could represent a potential benefit for enhancing strength and power, and decreasing DOMS at specific range frequencies. Existing evidence has shown frequency levels between 30-50 Hz to be most effective (Kosar, 2012; Bull-ock, 2008; Luo, 2005; Rønnestad, 2009; Rønnestad, 2009). Although still questionable, two to four minutes of continuous vibratory stimulation could be an effective time frame for improving strength and power, and alleviating DOMS, while four plus minutes has been documented to jeopardize performance (Stewart, 2009; Torvinen, 2002). Among published literature, WBV training before and after exercise can be beneficial, although more documentation is needed for specific timing of application. Since DOMS often results from eccentric exercises such as the downhill running (Connolly, 2003), change of directions, or the down phase of a squat, for example, it is important to know the potential benefits from WBV. If the purpose is to enhance strength and power, and decrease DOMS levels, WBV is an effective exercise intervention.



Study	Subjects	Intervention	Frequency (Hz)	Variables	Results
Aminian-Far et al. (1)	15 WBVT and 17 non-WBVT	WBVT/non-WBVT: eccentric training protocol 2 sessions per week with 2-3 day rest in between	35 Hz, 5 mm amplitude	strength, pressure pain threshold, plasma CK activity, muscle soreness, and thigh circumference	WBV: soreness levels ↓ on visual analog scale
Issurin et al. (6)	28 male athletes	Elite/Amateur: Biceps curls on a bilateral biceps curl 2 sessions of 3 repetitions each	44 Hz, 3 mm amplitude	Max and mean power	Elite: ↑ in maximal and mean power of 30.1 ± 15.3 and 29.8 ± 16.6, respectively; Amateur ↑ in maximal and mean power of 20.0 ± 16.9 and 25.9 ± 18.9, respectively
Delecluse et al. (5)	67 untrained females	WBV/non-WBV/ Placebo/Control: Static and dynamic knee-extension (35-40 Hz for WBV) 3 sessions per week for 12 weeks	35-40 Hz, 2.5-5 mm amplitude	Strength	WBV and RES increase dynamic and isometric strength by 16.6 ± 10.8%; 9.0 ± 3.2% and 14.4 ± 5.3%; 7.0 ± 6.2%, respectively. PL and CO showed no significant increase. CMJ (explosive power) increases by 7.6% in WBV group only
Bakhtiary et al. (2)	25 M and 25 F untrained subjects	VT/non-VT: 10 degree decline treadmill walk	50 Hz	IMVC force, CK levels, and muscle soreness	VT: decrease soreness levels of 0.4 (right limb); .05 (left limb) respectively and increase IMVC force (37.2)
Bullock et al. (3)	1 M and 6 F elite athletes	SQJs, CMJs, and 30-meter sprint 2 sessions on consecutive days	30 Hz, ± 4 mm amplitude	Power output	No significant effect of WBV on sprint or vertical jump
Rønnestad et al. (11)	13 M and 4 F trained/untrained subjects	SJ and CMJ with 0, 20, 35, and 50 Hz stimulation 8 different visits	0, 20, 35, or 50 Hz, 3 mm amplitude	Power output	Both increase peak average power in SJ and 50 Hz. Peak average power increase with untrained at 50 Hz
Rhea et al. (9)	16 M untrained subjects	Eccentric training followed by sprints	Massage: 50 Hz, 2 mm amplitude; Stretch: 35 Hz, 2 mm amplitude	DOMS	WBV showed DOMS decrease of 40/100 on perceived pain scale
Rønnestad et al. (10)	13 M and 3 F trained/untrained subjects	1RM back squat on Smith Machine	0, 20, 35, or 50 Hz, 3 mm amplitude	Strength	Increase strength in trained/untrained at 50 Hz (7.5 ± 1.4 and 12 ± 1.9 kg respectively)
Stewart et al. (12)	12 trained males	Knee MVIC on dynamometer	26 Hz, 4 mm amplitude	Strength	Increase peak torque with 2 min protocol (+3.8%)
Cormie et al (4)	9 M subjects	CMJ-V, CMJ-S, IS-V, and IS-S	30 Hz, 2.5 mm	Power output	Increase jump height. No other significance was found

\*WBVT= whole body vibration training; non-WBVT= no use of vibratory stimulation; VT= vibration training; CK= creatine kinase; Hz= Hertz; SQJs= Squat jumps; CMJs= countermovement jumps; SJ= static jump; IMVC= isometric maximum voluntary contraction; RM= repetition maximum



## References

- Aminian-Far, A., Hadian, M. R., Olyaei, G., Talebian, S., & Bakhtiary, A. H. (2011). Whole-body vibration and the prevention and treatment of delayed-onset muscle soreness. *Journal of Athletic Training*, 46(1), 43-49.
- Bakhtiary, A. H., Safavi-Farokhi, Z., & Aminian-Far, A. (2007). Influence of vibration on delayed onset of muscle soreness following eccentric exercise. *British Journal of Sports Medicine*, 41(3), 145-148.
- Bullock, N., Martin, D. T., Ross, A., Rosemond, C. D., Jordan, M. J., & Marino, F. E. (2008). Acute effect of whole-body vibration on sprint and jumping performance in elite skeleton athletes. *The Journal of Strength & Conditioning Research*, 22(4), 1371-1374.
- Connolly, D. A., Sayers, S. E., & McHugh, M. P. (2003). Treatment and prevention of delayed onset muscle soreness. *The Journal of Strength & Conditioning Research*, 17(1), 197-208.
- Cormie, P., Deane, R. S., Triplett, N. T., & McBride, J. M. (2006). Acute effects of whole-body vibration on muscle activity, strength, and power. *The Journal of Strength & Conditioning Research*, 20(2), 257-261.
- Delecluse, C., Roelants, M., & Verschueren, S. (2003). Strength increase after whole-body vibration compared with resistance training. *Medicine and Science in Sports and Exercise*, 35(6), 1033-1041.
- Issurin, V. B., & Tenenbaum, G. (1999). Acute and residual effects of vibratory stimulation on explosive strength in elite and amateur athletes. *Journal of Sports Sciences*, 17(3), 177-182.
- Kosar, A. C., Candow, D. G., & Putland, J. T. (2012). Potential beneficial effects of whole-body vibration for muscle recovery after exercise. *The Journal of Strength & Conditioning Research*, 26(10), 2907-2911.
- Luo, J., McNamara, B., & Moran, K. (2005). The use of vibration training to enhance muscle strength and power. *Sports Medicine*, 35(1), 23-41.
- Rhea, M. R., Bunker, D., Marín, P. J., & Lunt, K. (2009). Effect of iTonic whole-body vibration on delayed-onset muscle soreness among untrained individuals. *The Journal of Strength & Conditioning Research*, 23(6), 1677-1682.
- Rønnestad, B. R. (2009). Acute effects of various whole body vibration frequencies on 1RM in trained and untrained subjects. *The Journal of Strength & Conditioning Research*, 23(7), 2068-2072.
- Rønnestad, B. R. (2009). Acute effects of various whole-body vibration frequencies on lower-body power in trained and untrained subjects. *The Journal of Strength & Conditioning Research*,



23(4), 1309-1315.

Stewart, J. A., Cochrane, D. J., & Morton, R. H. (2009). Differential effects of whole body vibration durations on knee extensor strength. *Journal of Science and Medicine in Sport*, 12(1), 50-53.

Torvinen, S., Kannus, P., Sievonen, H., JaÈrvinen, T. A., Pasanen, M., Kontulainen, S., ... & Vuori, I. (2002). Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. *Clinical Physiology and Functional Imaging*, 22(2), 145-152.

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*Team USA celebrates after winning the Women's Bronze Medal Match between Netherlands and the United States on Day 15 of the Rio 2016 Olympic Games at the Maracanazinho on August 20, 2016 in Rio de Janeiro, Brazil. (Photo by Phil Walter/Getty Images)*

## **Mindfulness Training in Sport Comes of Age with UCSD's mPEAK Program**

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**Steven Hickman, Psy.D., Executive Director, University of San Diego Center for Mindfulness**

**Pete Kirchmer, mPEAK Program Director, Senior MBSR Teacher, University of San Diego Center for Mindfulness**

The last 35 years have traced an explosive pattern of growth for the role of formal mindfulness training to contend with stress, pain, and illness. The body of accumulated research has grown exponentially, showing benefits for people facing human suffering of all sorts, and it has become accepted as a viable means of coping with these conditions. It has also shown to prevent relapse in major mental and substance abuse disorders, and positively impact quality of life in a variety of measurable and significant ways.

More recently, attention has turned to the positive benefits of the systematic cultivation of mindfulness towards achieving peak performance in the areas of attention, concentration, emotional regulation, resilience, and communication. Emerging research is supporting the notion that simply practicing the disciplined application of non-judgmental attention to each moment as it arises can train the brain to be less reactive, more attentive and more easily redirected to the task at hand. Professional athletes and coaches, like Phil Jackson, Shaquille O'Neal, Michael Jordan, Kobe Bryant, and the Seattle Seahawks, have found the benefits of meditation and yoga in their athletic successes. More recent research is beginning to catch up with what many sport superstars have come to know first-hand: the systematic cultivation of present moment awareness through the practice of mindfulness meditation leads to improved outcomes in sports, as well as in life, through mental discipline and focus that can be found routinely among elite athletes, whether they have formally cultivated it or not.

As described below, the study of mindfulness training in military special forces and active duty military yielded valuable neuroscientific data about the resilience of the human brain and what can be accomplished through this training. Publicity around these findings has fueled interest in mindfulness across elite, amateur and professional athletes. As a result, the University of California at San Diego and the UCSD Center for Mindfulness designed a program of mindfulness training aimed specifically at peak performers of all types.

The Mindful Performance Enhancement, Awareness & Knowledge (mPEAK) program is a new mindfulness training designed for athletes and other peak performers. The foundation of the program is based on the highly respected and empirically-supported Mindfulness-Based Stress Reduction



(MBSR) program (Kabat-Zinn, 1982). In addition, mPEAK focuses on increasing a resilient response by the athlete when facing significant emotional or physical strain. Thus, the purpose of the mPEAK program is to enhance resilience in high-level sport performers, with the integration of a mindfulness training approach, and to help them concentrate and optimally perform when under performance-related stress.

Resilience is a complex construct that supports adaptive coping responses to stressful events (Campbell-Sills, Cohan, & Stein, 2006; Sarkar & Fletcher, 2014). In lay terms, we often think of resilience as the ability to bounce back from difficulty. Respected resilience researchers Masten, Best, and Garmezy (1990) define resilience as “the process of, capacity for, or outcome of successful adaptation despite challenging or threatening circumstances” (p. 426). This is what the mPEAK program is designed to address, offering athletes educational and applied practices to help them become more resilient to sport-related threats, such as competitive anxiety, choking, physical discomfort, or fear of failure. When more resilient, an athlete can adaptively cope with naturally occurring challenges in sport, such as disappointment, failure, and fear. A resilient athlete can become more proactive in its effort to optimize performance versus feeling aversive emotions and mindlessly using maladaptive, habitual coping mechanisms.

### The mPEAK Program

Lori Haase, Steven Hickman, and Martin Paulus at the University of California at San Diego designed the mPEAK program, which was established on neuroscience-based experimental evidence and research on optimal performance to create the performance-focused mindfulness training. The mPEAK Intervention is offered as either a three day intensive or an eight week (twenty hour) intensive mindfulness training course that was initially built around four core sessions (three hours per session) with six foundational practice sessions (60 minutes per session), with practice sessions included to strengthen the skills being taught. One of the goals of mPEAK is to teach and support the ongoing integration of mindfulness practices and responses within the training and competitive environment of high-level sport. The consistent effort to connect the training to sport is novel within the mindfulness training programs in sport. Though MSPE does include a prompt to make the connection of the mindfulness training to the participant’s sport, mPEAK includes a consistent focus on supporting the athlete to apply the insights from formal mindfulness practice to the competitive sport arena. All sessions provide educational information, an opportunity to practice mindfulness, and a forum for discussion.

There are four mPEAK “pillars” that corresponds to the four core sessions, which are described next.

***Inhabiting Your Body.*** The first core session introduces the athletes to the concept of mindfulness, both from an educational and activity based approach (e.g., formal breathing practice). The individual’s experience of the physical body is the primary focus of attention and platform upon which mindfulness unfolds. Interoception is noticing and accepting somatic experience in sport training and competition. The awareness of body experiences is core to the design of the mPEAK program. Within the brain, interoceptive information is processed within the insula (Craig, 2003). Research conducted by Paulus and colleagues suggests that efficient interoceptive processing – that is, attenuated insula brain response to aversive interoceptive stimuli – may be the neural marker of optimal performance (Paulus et al., 2009; Paulus et al., 2012). Furthermore, mindfulness-based training has been shown to



modulate interoceptive processing in relatively healthy non-treatment seeking marines, in such a way that their brain response is more similar to that of an optimal performer (Haase et al., 2014). Through discussion, the athletes consider how such body awareness, while both training and competing, could contribute to sport performance. In addition, participants are prompted to consider how our interpretations of body experience (e.g., “My legs feel tired, that means I am going to lose this race.”) or stories we make up (“I could never beat him”) can thwart performance. Part of the goal of mPEAK is to support athletes in becoming more aware of body experience and, at once, become more resilient in the face of unpleasant or difficult interoceptive experience. The training is geared to help athletes learn to more efficiently notice aversive experience, label the experience and self-regulate through attentional control.



*Claressa Maria Shields of the United States celebrates victory over Nouchka Fontijn of the Netherlands in the Women's Middle (69-75kg) Final Bout on Day 16 of the Rio 2016 Olympic Games at Riocentro - Pavilion 6 on August 21, 2016 in Rio de Janeiro, Brazil. (Photo by Alex Livesey/Getty Images)*

**Getting Out of Your Own Way and Letting Go.** The second core session is devoted to addressing initial challenges encountered by participants when engaging in formal and daily living practice of mindfulness. The second pillar of the mPEAK program is devoted to addressing obstacles that athletes encounter with regard to the wandering mind, the identification of one's performance story, and the influence both have on athletic performance. The human mind spends a considerable amount of time in the past and future, rather than what is taking place in the present, resulting in unhappiness (Killingsworth & Gilbert, 2010). Over the last decade, functional neuroimaging studies have delineated a medial default mode network, a frontal control network, and a limbic salience network (Spreng, Sepulcre, Turner, Stevens, & Schacter, 2013). The DMN is a network of brain regions that are active when the mind is not engaged with the outside world (Raichle et al., 2001). The DMN is thought to play a role in mind wandering, (Fox et al., 2015) and in self-related and self-referential aspects

of cognitive processing (Brewer & Garrison, 2014; Whitfield-Gabrieli & Ford, 2012). Brewer and colleagues have conducted a series of studies showing reduced DMN activation in experienced meditators during meditation (Brewer et al., 2011; Garrison et al., 2015). Taken together, research suggests that mindfulness training can result in reduced mind wandering and changes in brain function within the DMN.

This session empowers the athlete to experience a changed relationship with thoughts that threaten the athlete's ability to perform. Common challenges are addressed, such as the wandering mind and the fruitlessness of trying to stop the mind from wandering. Another aligned pivotal idea in session two is the importance of recognizing "story" and how the way we think can influence how we perform (i.e., how we make up stories like "my coach hates me," which can become quite distracting and get in the way of practice and performance). In addition to mindfulness-based body awareness (including yoga and mindful breathing), participants retrospectively reflect on times when their thinking was inconsistent with outcome (e.g., the thought, "I can't win this one today" followed by a win). Part of the goal of mPEAK is to support athletes in becoming more aware of the wandering mind and bringing awareness to their "performance story." Training is aimed at helping the athlete see how their uninvited thoughts (i.e., wandering mind) can offer thoughts or stories that potentially thwart performance unless the athlete establishes a different relationship with such thoughts.

***Working with Stress, Fear and Failure.*** The third core session is intended to challenge the notion that avoidance is the best strategy when it comes to difficulty (e.g., pain, fear, stress, failure, etc.), and to use the experience of working with the body as a way of grounding oneself in the moment, in the face of difficulty. Competitive sport is a culture that values being successful. There is little value put on failure, with failure often associated with humiliation and quiet internal suffering. Unless directed to do otherwise, athletes often prefer to avoid or ignore thoughts and feelings associated with failure or unpleasant physical sensations. However, attempts to suppress painful experiences can often result in greater distress (Cioffi & Holloway, 1993). Coaches, athletes and the sport culture teaches performers to not accept failure, and to divorce themselves from such feelings. The zero tolerance for failure leaves many athletes and high-level performers quite susceptible to harsh self-criticism. Ironically, their unwillingness to accept their experience of failure makes it more difficult to move beyond. With acceptance of failure, the athlete is freed to learn from it and move on. Everyone fails. Being willing to face failure as a normal part of the performance experience may be essential for optimal sport performance. The same holds true for being willing to experience unpleasant physical sensations. Such tolerance includes bodily signals related to train at the right level and intensity (and minimize over-training or damaging the body). Such tolerance minimizes reactive thoughts that can also thwart performance. Mindfulness training can modulate one's experience of painful physical sensations (Zeidan, Gordon, Merchant & Goolkasian, 2010) and emotions (Zeidan et al., 2013), and change how the brain responds to pain (Zeidan et al., 2011). The mPEAK approach offers a radical different pathway to optimal performance, which aligns with the current challenge of the acceptance commitment (Hayes, 2004). In addition to mindfulness breathing practice, athletes are also prompted to recall a failure or difficulty in sport, and practice maintaining awareness with the associated interoception. The goal in the competitive sport environment is not to stop our thinking and feeling, but to change our relationship to such experience. Athletes are commonly surprised and relieved when coming to sense



with this alternative approach. Part of the goal of mPEAK is to challenge the notion that avoidance is the best strategy when it comes to difficult experiences (e.g., pain, fear, stress, failure, etc.). Exercises are focused on working with the body as a way of grounding oneself in the moment of difficulty, to help remain present to their performance.

***The Challenges of Perfectionism and the Glitches in Goal Setting.*** The fourth and final core session deals specifically with the contradictory nature of some mental approaches and attitudes that athletes may perceive as beneficial but, in fact, become problematic for optimal performance. Athletes may perceive the drive for optimal training and performance as an outgrowth of perfectionism. Athletes may also come to believe that offering harsh self-criticism when they fail can be good motivators. One of the pillars of mPEAK is about encouraging athletes not to be perfectionistic and introducing self-compassion as an alternative. Perfectionism is a personality disposition or habitual approach to life that is characterized by striving for flawlessness and maintaining extreme performance standards. Perfectionistic athletes also tend to be harshly self-critical and highly concerned about the evaluation of others (Stoeber, 2012). Perfectionism has long been considered a sign of psychological maladjustment, if not pathological. When athletes are perfectionistic, they are at risk for being excessively concerned over mistakes, experiencing intense self-doubt and often, for the younger athletes, having concern with parental perception and expectations (Gould, Dieffenbach & Moffett, 2002). This intolerance of mistakes becomes particularly noteworthy when athletes face the inevitable failures and losses of an athletic career, making it particularly difficult to overcome these challenges to persist and improve performance.

High-level athletes must consistently work toward improvement, from the physical capacity of strength and fitness to the tactical excellence. Success is often measured in differences of split seconds. The vulnerability of becoming perfectionistic is quite tempting for those constantly striving toward improvement and holding high standards. The issue is not the high standards, but instead how the individual responds to not meeting those standards. Gould and colleagues (2002) found that when Olympic athletes maintained high standards and had relatively lower concerns of mistakes, that such an approach was positively associated with achievement. Whether such athletes were defined perfectionistic or not, the results are compelling: helping athletes maintain high standards and adaptively cope with performance disappointments helps to optimize performance and is one of the pillars of the mPEAK design.

We will next emphasize the inclusion of self-compassion directly into the mindfulness training for sport through mPEAK. mPEAK is the first training to integrate both mindfulness meditation and self-compassion, together, as an intervention for sport (though addressed only in session two below of the mPEAK program). Kristin Neff (2003a, 2003b) has led the way in bringing research and applied attention to the Buddhist concept of self-compassion. At first consideration, the concept of kindness to self when suffering seems antithetical to the realm of competitive sport and performance. Yet high self-compassion athletes respond in healthier ways (compared to low self-compassion athletes) to emotional difficulty (Reis et al., 2015). Other benefits of athletes with higher self-compassion include less maladaptive issues with the body (e.g., body shame, body surveillance), reduced fear of failure and negative evaluation, and less social physique anxiety (Mosewich, Kowalski, Sabiston, Sedgwick, & Tracy, 2011).

Self-compassion in performance is called for when maladaptive emotions or thoughts arise as a result



of perceptions of failure, from feeling inadequate (e.g., compared teammates or opponents) to coping with difficult physical pain (e.g., chronic sport injury). When responding with self-compassion, the athlete learns to accept such personal, internal experiences (though the strong preference is to experience something else) and can, in turn, experience enhanced emotional safety. When feeling emotionally safe enough to face and accept such range of difficulty, the performer is free to focus on requisite performance cues.

**Practice Sessions.** The four core sessions (presented in two day-long sessions) are followed by six foundational mindfulness and self-compassion practice sessions. These sessions are dedicated to checking in with participants, supporting their ongoing, individual formal meditation practice. The sessions include both formal mindfulness practice and invited inquiry and discussion. Each session also includes a specific relevant topic, drawn from the four core sessions, to focus the meeting and reinforce the importance of continued practice. When engaged in the mPEAK intervention, participants are encouraged to practice mindfulness and self-regulation skills daily, for at least 30 minutes.

### **The mPEAK Study: MBX Professional Cyclists**

Haas et al. (2015) conducted a study using mPEAK as the intervention with the U.S. BMX (Bicycle Motocross) Cycling Team ( $n = 7$ ) who participated in the 8-week mPEAK program. The primary aim of the investigation was to examine if the mPEAK intervention, aimed at improving mindfulness and self-compassion, would modify how the brains of elite athletes processed aversive interoceptive stimuli. In addition, the researchers explored if this modification would be related to the self-reports of being better able to adjust physically and emotionally to extreme conditions. This section briefly considers the design and result of the study. (Please refer to Haase et al., in press, for a full consideration of the design, results and discussion.)

Based on fMRI pre-mPEAK and post-mPEAK data, the mPEAK training resulted in changes in self-reported interoceptive awareness and sensitization of interoceptively-relevant brain structures. Greater body awareness, coupled with greater attentional control, following mPEAK training may result in more efficient neural processing (in the brain) during the anticipation of and recovery from aversive interoceptive experience. Such findings were supported by the BMX cyclist self-reports. Following the mPEAK training, the BMX athletes reported significantly less difficulty identifying feelings, reported great levels of self-regulation and trust, as well as greater levels of being able to describe/label their experience with words (e.g., this is overwhelming; I am exhausted and may not be able to overtake the rider in front of me).

### **Conclusions**

The mPEAK intervention is a mindfulness-based intervention in sport from neuroscientists and expert MBSR mindfulness teachers. The program offers both core concepts from MBSR and the integration of important new scientific ideas, aimed at helping high-level athletes integrate the core tenets of Buddhist mindfulness into their training, competing, and daily living.

The mPEAK program maintains a consistent focus on helping athletes make the knowledge-based and psychological connection between their sport world and formal mindfulness mediation prac-



tice. In terms of the efficacy of mPEAK, initial results are promising, particularly with paired fMRI data and qualitative reports of BMX cyclists reporting an enhanced ability to cope with difficult interoceptive experience, and an improved ability to be more resilient. The BMX study offers initial evidence that the response of the body and mind to extreme distress can be trained to more adaptively cope, which is experienced as less reactivity to external stress and threat. The development of the mPEAK intervention offers a pathway to help athletes become more resilient to sport-related distress via the integration of formal mindfulness training, expert guidance to help bridge the ideas to the sport context, the inclusion of self-compassion in the training, and an emphasis on interoceptive awareness and tolerance, marking a significant contribution to our understanding of how mindfulness training can facilitate enhancing performance.

*UCSD is a member of the USOC's National Medical Network, providing services and resources to Team USA athletes, coaches, and staff. For more information on UCSD's Center for Mindfulness, please visit the mPEAK website (<http://mpeak.org>) or email them directly at [mpeak@ucsd.edu](mailto:mpeak@ucsd.edu).*



*(L-R) Race Imboden, Miles Chamley-Watson, Gerek Meinhardt and Alexander Massialas of the United States celebrate after winning bronze in the Men's Foil Team event on Day 7 of the Rio 2016 Olympic Games at Carioca Arena 3 on August 12, 2016 in Rio de Janeiro, Brazil. (Photo by Ezra Shaw/Getty Images)*

## References

- Brewer J.A., Garrison K.A. (2014). The posterior cingulate cortex as a plausible mechanistic target of meditation: findings from neuroimaging. *Annals of the New York Academy of Sciences*, 1307;19-27.
- Brewer J.A., Worhunsky P.D., Gray J.R., Tang Y., Weber J., Kober, H. (2011). Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences*. doi: 10.1073/pnas.1112029108.
- Campbell-Sill, L., Cohan S.L., & Stein M.B. (2006). Relationship of resilience to personality, coping, and psychiatric symptoms in young adults. *Behaviour Research and Therapy*, 44 (4), 585-599.
- Cioffi D., & Holloway J. (1993). Delayed costs of suppressed pain. *Journal of Personality and Social Psychology*, Feb; 64(2):274-82.
- Craig A.D. (2003). Interoception: the sense of the physiological condition of the body. *Current Opinion in Neurology*, 13: 500-505.
- Fox K.C.R., Spreng R.N., Ellamil M., Andrews-Hanna J.R., Christoff K. (2015). The wandering brain: Meta-analysis of functional neuroimaging studies of mind-wandering and related spontaneous thought processes. *NeuroImage*, 111:611-621.
- Garrison K.A., Scheinost D., Worhunsky P.D., Elwafi H.M., Thornhill T.A., Thompson E., et al. (2013). Real-time fMRI links subjective experience with brain activity during focused attention. *NeuroImage*, 81,110-118.
- Gould, D., Dieffenbach, K., & Moffett, A. (2002). Psychological characteristics and their development in Olympic champions. *Journal of Applied Sport Psychology*, 14(3), 172-204. DOI: 10.1080/10413200290103482
- Haase L., Thom N.J., Shukla, A., Davenport P.W., Simmons A.N., Paulus, M.P., Johnson D.C. (2014). Mindfulness-based training attenuates insula response to an aversive interoceptive challenge. *Social Cognitive and Affective Neuroscience*, doi: 10.1093/scan/nsu042.
- Haase L., Thom N.J., Shukla, A., Davenport P.W., Simmons A.N., Paulus, M.P., Johnson D.C. (2014). Mindfulness-based training attenuates insula response to an aversive interoceptive challenge. *Social Cognitive and Affective Neuroscience*, doi: 10.1093/scan/nsu042.
- Haase, L., May, A.C., Falahpour, M., Isakovic, S., Simmons, A.N., Hickman, S.D., Liu, T.T., Paulus, M.P. (2015). A pilot study investigating changes in neural processing after mindfulness training in elite athletes. *Frontiers Behavioral Neuroscience*, 9:229.
- Hayes, S.C. (2004). *Acceptance and Commitment Therapy and the new behavior therapies: Mind-*



*fulness, acceptance and relationship*. In S.C. Hayes, V.M. Follette, & M. Linehan (Eds.), *Mindfulness and acceptance: Expanding the cognitive behavioral tradition* (pp. 1 – 29). New York: Guilford.

- Kabat-Zinn J. (1982). An outpatient program in behavioral medicine for chronic pain patients based on the practice of mindfulness meditation: theoretical considerations and preliminary results. *General Hospital Psychiatry*, 4 (1), 33-47.
- Killingsworth M.A. & Gilbert D.T. (2010). A wandering mind is an unhappy mind. *Science*, 330: 932.
- Masten A., Best K., Garmezy N. (1990). Resilience and development: Contributions from the study of children who overcome adversity. *Development and Psychopathology*, 2:425-444.
- Mosewich, A.D., Kowalski, K.C., Sabiston, C.M., Sedgwick, W.A., & Tracy, J.L. (2001). Self-compassion: a potential resource for young women athlete. *Journal of Sport and Exercise Psychology*, 33, 103-123.
- Neff, K.D. (2003a). The development and validation of a scale to measure self-compassion. *Self and Identity*, 2, 223-250.
- Neff, K.D. (2003b). Self-compassion: an alternative conceptualization of a healthy attitude toward oneself. *Self and Identity*, 2, 85-102.
- Paulus M.P., Tapert S.F., Schulteis G. (2009). The role of interoception and alliesthesia in addiction. *Pharmacology, Biochemistry and Behavior*, 94, 1-7.
- Paulus M.P., Flagan T., Simmons A.N., Gillis K., Kotturi S., Thom N., et al. (2012). Subjecting elite athletes to inspiratory breathing load reveals behavioral and neural signatures of optimal performers in extreme environments. *PLoS ONE*, 7:e29394 10.1371/journal.pone.0029394
- Raichle M.E., MacLeod A.M., Snyder A.Z., Powers W.J., Gusnard D.A., Shulman G.L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*. Jan 16;98(2):676-82.
- Reis, N.A., Kowalski, K.C., Ferguson, L.J., Sabiston, C.M., Sedgwick, W.A., Crocker, P.R.E. (2015). Self-compassion and women athletes' responses to emotionally difficult sport situations: An evaluation of a brief induction. *Psychology of Sport and Exercise*, 16;18-25.
- Sarka, M., & Fletcher D. (2014). Psychological resilience in sport performers: A review of stressors and protective factors. *Journal of Sports Sciences*, 32 (15), 1419-1434.
- Spreng R.N., Sepulcre J., Turner G.R., Stevens W.D., Schacter D.L. (2013). Intrinsic architecture underlying the relations among the default, dorsal attention, and frontoparietal control networks of the human brain. *Journal of Cognitive Neuroscience*, Jan;25(1):74-86.



- Stoeber, J. (2012). *Perfectionism and performance*. In S.M. Murphy (Ed.), *Oxford handbook of sport and performance psychology* (pp. 294-306). New York: Oxford University Press.
- Whitfield-Gabrieli S., & Ford J.M. (2012). Default mode network activity and connectivity in psychopathology. *Annual Review of Clinical Psychology*, 8:49-76.
- Zeidan F., Gordon N.S., Merchant J., Goolkasian P. (2010). The effects of brief mindfulness meditation training on experimentally induced pain. *The Journal of Pain*, Mar,11(3):199-209.
- Zeidan F., Martucci K., Kraft R.A., Coghill R. (2013). Neural correlates of mindfulness meditation-related anxiety relief. *Social Cognitive and Affective Neuroscience*, 9(6).
- Zeidan F., Martucci K.T., Kraft R.A., Gordon N.S., McHaffie J.G., Coghill R.C. (2011). Brain mechanisms supporting modulation of pain by mindfulness meditation. *Journal of Neuroscience*, Apr 6; 31(14):5540-5548.



Silver medal Chelsea McClammer, Gold medal Tatyana McFadden and Bronze medal Amanda McGrory of the United States celebrate the triple American podium in the Women's 5000m - T54 Final on day 8 of the Rio 2016 Paralympic Games at the Olympic Stadium on September 15, 2016 in Rio de Janeiro, Brazil. (Photo by Buda Mendes/Getty Images)

# Long-Term Athlete Development (LTAD) Model: Practical Coaching Insights

Christine M. Brooks, University of Florida

## Introduction

Around twenty years ago, Istvan Balyi introduced the long-term athlete development (LTAD) model that is in wide use today (Balyi & Way, 1995). At that time, athlete development models were structured around chronological age and were described using complex academic jargon. Balyi framed his model around biological age-specific training. He also used language coaches easily understood, and more than anything else, probably contributed to widespread adoption of his model. The USOC recently introduced an Americanized version of Balyi’s framework named the American Development Model (ADM) (USOC, 2016).

The traditional LTAD model incorporates seven developmental stages clustered into four pathways of physical literacy, excellence, elite and active for life. Figure 1 is a depiction of the traditional LTAD model I use for my teaching purposes, but many creative graphical representations exist. In all cases, the goal is twofold: 1) to provide a guide for developing elite talent for international competition; and 2) to persuade those lacking elite potential to become life-long sports participants at the recreational level for health and self-improvement purposes. The LTAD model has many critics because specific research support remains scant and largely animal based. However, the Balyi LTAD model remains unchallenged in terms of its usefulness for guiding the coaching practices of coaches working with the pediatric athlete.

Figure 1.

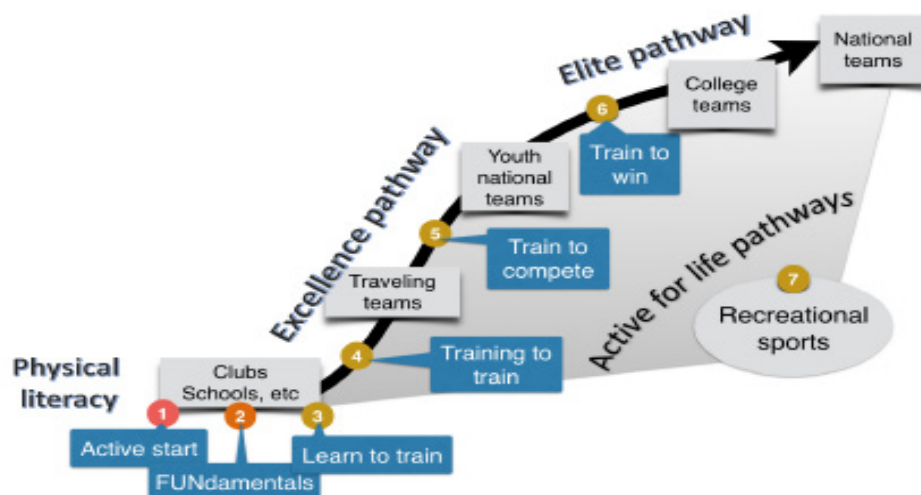


Figure 2.

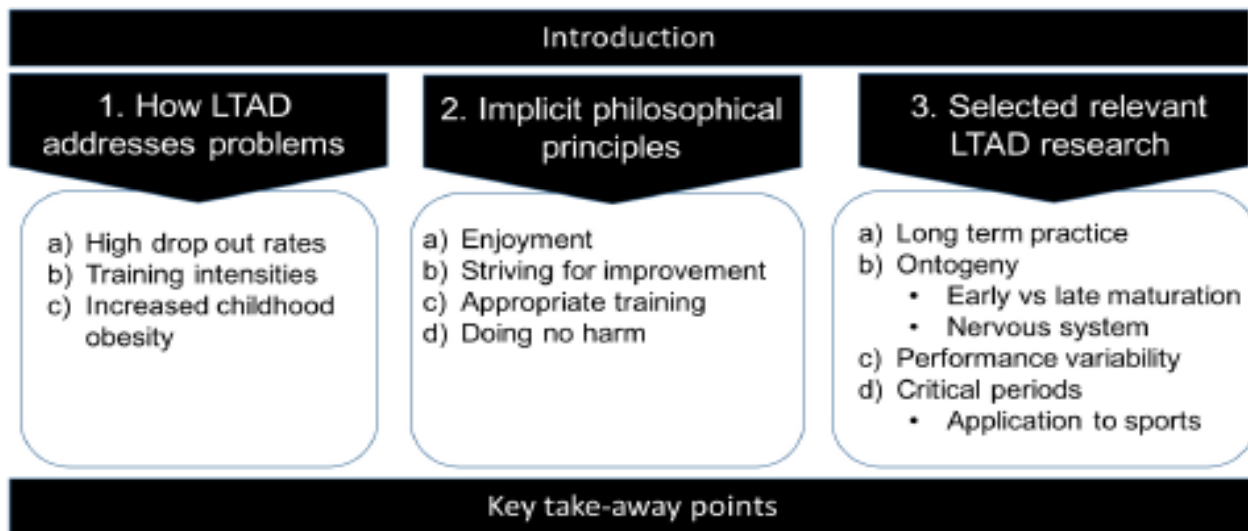


Figure 2 presents the outline of this paper. The learning objective is to provide coaches with a basic understanding of the five key components of the popular LTAD model that directly guides coaching pedagogy. Upon completion of this paper a coach will be able to:

1. Discuss how the LTAD model potentially helps curb current problems related to high drop-out rates, overtraining and injuries, and childhood obesity.
2. Develop strategies for incorporating the implicit philosophical principles underlying the LTAD model of enjoyment, striving for improvement, appropriate training, and doing no harm to the athlete into day-to-day coaching practices.
3. Explain how training, genetics and environment determine a young athlete's optimal sports potential.
4. Explain the relevance of maturation to a young athlete's performance.
5. Discuss the impact of enriched environments, and the timing of exposure to these environments, on the optimization of the young athlete's sports potential.

In this paper the term 'young athlete' refers to girls up to age eleven and boys up to age 13. 'Adolescent athletes' include girls ages twelve to 18 and boys ages 14 through 18. 'Pediatric athletes' refers to all athletes under 18 years of age. Much of what I discuss in this paper is presented in more detail in a free Coursera course I recently released through the University of Florida entitled, "The science of training young athletes" (<https://www.coursera.org/learn/youth-sports>).

### How the LTAD model helps address three current problems

Three current problems the LTAD framework addresses includes:

- there is a high pediatric dropout rate from sports (Sabo & Veliz, 2008; Aspen Institute, 2016);

- coaches are using higher training intensities at younger ages than ever before possibly causing long-term harm to young athletes (Hebestreit & Bar-Or, 2007);
- there is an increase in childhood obesity and subsequent health problems (Ahima, 2014).

**High drop-out rates:** Surveys of six to 17 year-old U.S. kids suggest anywhere between 54 and 59 percent join sports teams. An estimated 70 percent of these kids drop out before their high school graduation. Even younger children are being affected. Between 2008 and 2013 there were 2.6 million fewer six to twelve year-old kids participating the six traditional sports. Track & field was down almost 14 percent, football down almost 29 percent and softball down 31 percent (Aspen Institute, 2016; Sabo & Veliz, 2008). One LTAD goal is to retain youth in sports through the end of puberty.

**Higher training intensities:** Youth are being trained at higher intensities than ever before. Unfortunately, the possible health impact of high-intensity training on maturing organ structures is not well understood or researched. In 2007 the International Olympic Committee Medical Commission collaborated with the International Federation of Sports Medicine to examine current research about specific physiological characteristics, responsiveness to training, and possible health hazards of high intensity training on developing bodies. A summary of this research was published in a document entitled "The Young Athlete" (Hebestreit & Bar-Or, 2007). The LTAD model attempts to guide coaches about the appropriate training for children who are at different maturational phases.

**Increase in childhood obesity:** In the United States, 17 to 31 percent of children and adolescents are obese (Ahima, 2014; Ogden et al., 2014). This, in addition to the decline in pediatric sports participation and high dropout rates, is not good news for sports organizations because this reduces the pool of potential elite talent. Nor is it good news for the nation's health care system that must incur the medical problems of an increasingly sedentary society (Ahima, 2014). For their own self-interest, all coaches and sports organizations need to join the childhood obesity battle. The active lifestyle pathway of the LTAD framework is believed to focus attention on providing for the sports participation needs of all children.

### **Implicit philosophical principles**

While not explicitly stated, all LTAD models, before and since the Balyi model, embrace four implicit philosophical principles. These include the principles of:

- enjoyment,
- enabling all participants to strive for, and improve, their performance to their genetic potential,
- encouraging coaches and parents to use appropriate training intensities, and
- doing no harm to athletes by ensuring coaches and parents have adequate sport science knowledge.

### **Principle of enjoyment**

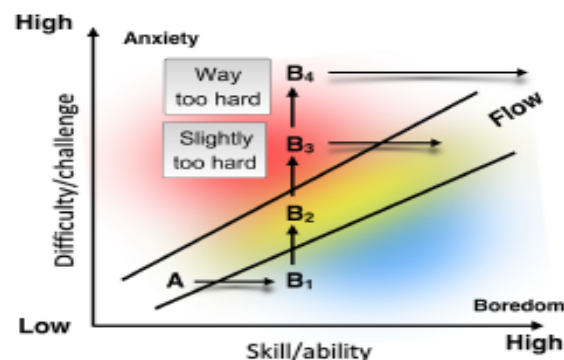
The Principle of enjoyment embraces Mihály Csíkszentmihályi's notion of 'FLOW,' (Csíkszentmihályi, 2008) that in turn, explains why individuals enjoy an activity. FLOW is an ultimate happiness



associated with undertaking challenges within the scope of an individual's abilities. Encompassing the notion of FLOW into the LTAD model ensures training does not cause athletes to become over anxious on one end of the scale, or totally bored on the other end. Approximately 40 percent of pediatric athletes in one survey claim they dropped out of sports because they were not having fun (Table 1).

Figure 3 illustrates the delicate balance between the challenge of a task and FLOW. It is based on the flow model Dr. Michael Wu, chief scientist and video game developer at Lithium, used to predict why individuals become addicted to playing video games (Wu, 2016). An easy task, located in the blue zone, and a hard task located in the red zone, takes the athlete out of FLOW. An easy task eventually causes the athlete to become bored making the task unenjoyable. A hard task raises anxiety, and the athlete may decide to walk away from the challenge rather than continue to face it.

Figure 3.



The yellow portion represents the FLOW zone. When athletes are in the yellow zone, such as they might be at point A, they are in FLOW. Athletes who keep practicing an easy task will slowly move to B1 that is located in the early boredom zone. If they keep training in this zone they will become increasingly bored. To avoid this, it will be necessary to increase the challenge slightly so the athlete moves back into FLOW. That is, the task becomes sufficiently challenging to become interesting again. The athlete returns to a 'happy place.'

If the skill is slightly hard, as it might be at B3, the athlete will take a slightly longer time to return to FLOW. Anxiety will rise slightly. If the skill is well above an athlete's current level of skill attainment or ability, such as is illustrated at B4, attendance may become inconsistent and risk of dropping out is increased. Being in FLOW means the athlete feels sufficiently challenged, yet not overwhelmed to the point of feeling incompetent. How quickly an athlete becomes anxious or bored will be different for each athlete. Learning requires that athletes are slightly aroused and have an ongoing belief they can ultimately accomplish the skill. The coaching goal is to train athletes in small, manageable learning steps so they remain in the zone of FLOW. Research indicates that educated coaches lower kids' anxiety levels and lift their self-esteem (Gould, Cowburn, Shields, 2014).

**Principle of striving for improvement**

This involves enticing young athletes to constantly strive for the upper limits of their genetic potential while concurrently keeping them in FLOW. If they are out of ‘FLOW,’ it is theoretically impossible to motivate ongoing practice and striving, and therefore progress toward full genetic potential will be blunted. The components of the skill, and the training challenge, requires variety so the child maintains emotional connection to the purpose behind their training. Interestingly, the data suggest that only around 15 percent dropout because they felt they were not good enough (Table 1).

Table 1. Reasons for dropping out of sports

	Girls	Boys
I was not having fun	38	39
I wanted to focus on grades	36	26
Didn't like the coach or teammates	34	40
Had health or injury problems	27	29
Wanted to do other things	22	
Wasn't good enough	15	15
Family worried about injuries	14	12

*From: Sabo and Veliz (2008). Go out and play: Youth sport in America. p130.*

**Principle of appropriate training**

The Principle of appropriate training goes hand-in-hand with the child’s growth and maturation. There is rapid growth during infancy, steady growth throughout pre-puberty, rapid growth again during the early phases of puberty, followed by slower growth during the final stage of puberty. The nervous, hormonal and musculoskeletal systems develop at various rates during each of these phases, and this affects the child’s physical and mental capacity to train and learn skills (Brooks, 2016). The LTAD model attempts to match structural growth and maturation to the appropriate motor skill complexity and intensity of physical training.

**Principle of doing no harm**

Sports fall under the general umbrella of the health care system, and for this reason the ideals of the Hippocratic oath of ‘first, to do no harm’ apply. The mental and physical health of the athlete supersedes all other training goals. Four million school-age children in the U.S. are injured while playing sports every year (Monroe, Thrash, Sorrentino, King, 2011). The reason can partly be attributed to stressing a body that has immature balance and coordination beyond its capacity (Brooks, 2016). Coaches and parents are often oblivious to the damage overuse can cause to an open physis (a segment of bone responsible for lengthening) when rapid bone growth outpaces the growth of muscles and tendons, and maturing cartilage. As training becomes more intense the risk of injury and permanent damage increases. A young athlete’s career can end before it has begun. Sports training systems are at fault when there are high injury rates among pediatric populations.



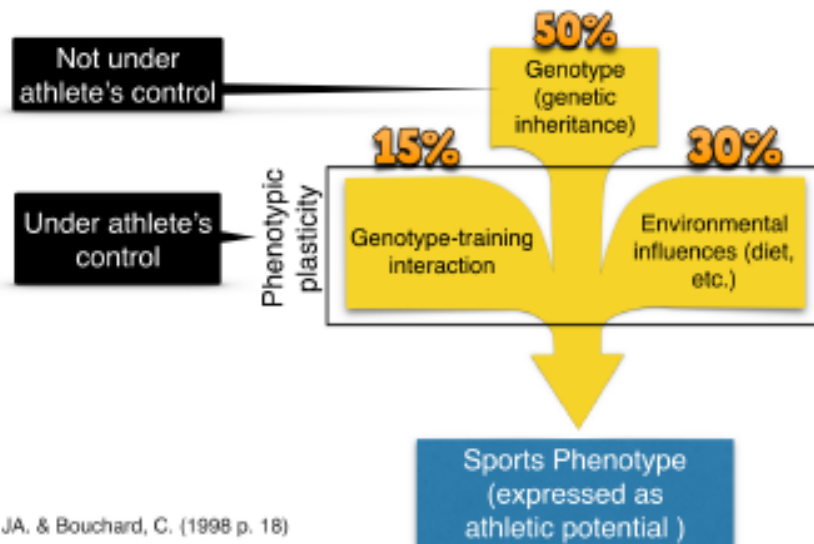
## Selected relevant LTAD research

### *Long term practice*

The ‘long term’ component of the LTAD framework focuses attention on the years of practice required to acquire sport expertise. According to Ericsson (Ericsson, Krampe, Tesch-Romer, 1993) it is simply a matter of practicing for 10,000 hours to stimulate the relevant dormant genes within our DNA, and anyone can become an expert at anything. While waking up ‘expert’ genes with 10,000 hours of practice is an intriguing notion, research does not support it. We are not created equal when it comes to genes. However, we can all agree that reaching our potential at sports, like any other complex endeavor, requires a substantial amount of practice.

Current knowledge suggests developing the appropriate sport-specific phenotype is a critical goal. A phenotype is the athlete’s observable characteristics that results from the interaction between genotype, training and the environment. Developing the relevant sports phenotype is discussed in Brooks (Brooks, 2016), and in the Coursera course mentioned earlier. A sport-specific phenotype is approximately 50 percent influenced by genetics, 15 percent by the genotype-training interaction that reflects response to training, and 30 percent due to environmental influences (diet, opportunities, motivation, health, etc.) (Simoneau, Bouchard, 1998; Klissouras, Pigozzi, 2009). The remaining five percent is data error. This means that 45 percent of a young athlete’s sports potential is considered ‘plastic’ and within the control of the parent, coach and athlete (Figure 4).

Figure 4.



Adapted from Simoneau, JA. & Bouchard, C. (1998 p. 18) and Klissouras & Pigozzi (2009).

### *Growth and maturation*

Growth and maturation are two different biological processes. Growth refers to changes in body size such as height, weight, and fat-to-muscle ratio. External growth reflects internal organ growth. Maturation describes the child’s progress toward sexual maturity. An increase in hormones, such as

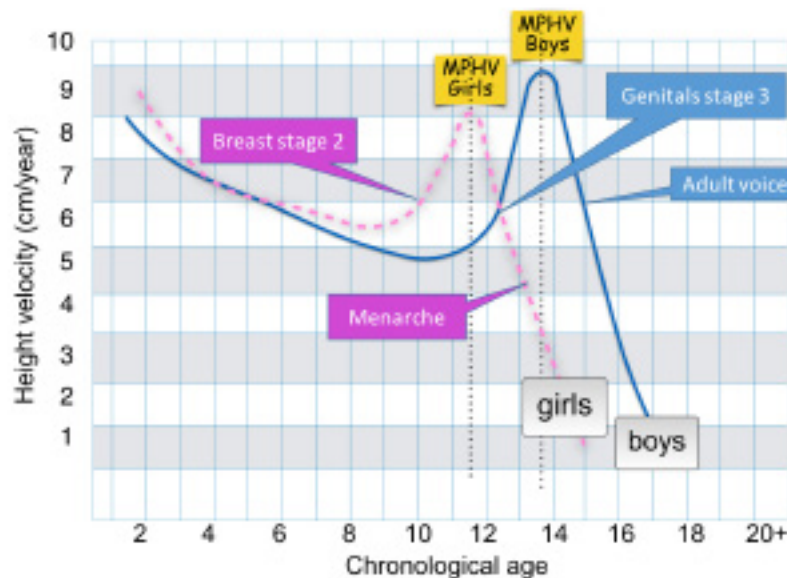


testosterone, growth hormone and estrogen stimulate internal structural growth, thereby affecting sports performance.

The curves in Figure 5 graphically illustrate the speed with which the child grows. During the first two years after birth there is very rapid growth (not shown). Then the speed of growth gradually slows until age nine for girls and eleven for boys. This is the pubescent phase. Puberty accompanies a period of accelerated growth in both height and weight and is referred to as the “growth spurt” or “peak height velocity.” On average, girls enter into the growth spurt around nine years of age, and boys enter around eleven years of age with the most rapid phase of growth occurring over two to three years. About two years after peak height velocity, the rate of growth slows and finally stops (Tanner, Whitehouse, Takaishi, 1966). Maximum peak height velocity (MPHV) occurs at a mean of 13.5 years in boys, and eleven and a half years in girls.

The start of breast development precedes peak height velocity by about one year, and indicates the stimulus for the growth spurt has begun for girls. In females, menstruation begins around one year after peak height velocity indicating completion of most of the growth spurt. In boys, changes in the penis precedes maximum peak height velocity by about one year. This stage indicates the growth spurt has begun for boys. The adult voice for boys appears about one year after the maximum peak height velocity. It indicates the growth spurt phase is ending.

Figure 5.



Growth and maturation play a dominant role on the physical work capacity and exploitation capabilities for both boys and girls (Brooks, 2016). Natural progress towards the genetic ceiling slows when growth and maturation ends and training becomes the dominant force for improved performance.



### Early-maturing versus late-maturing athletes

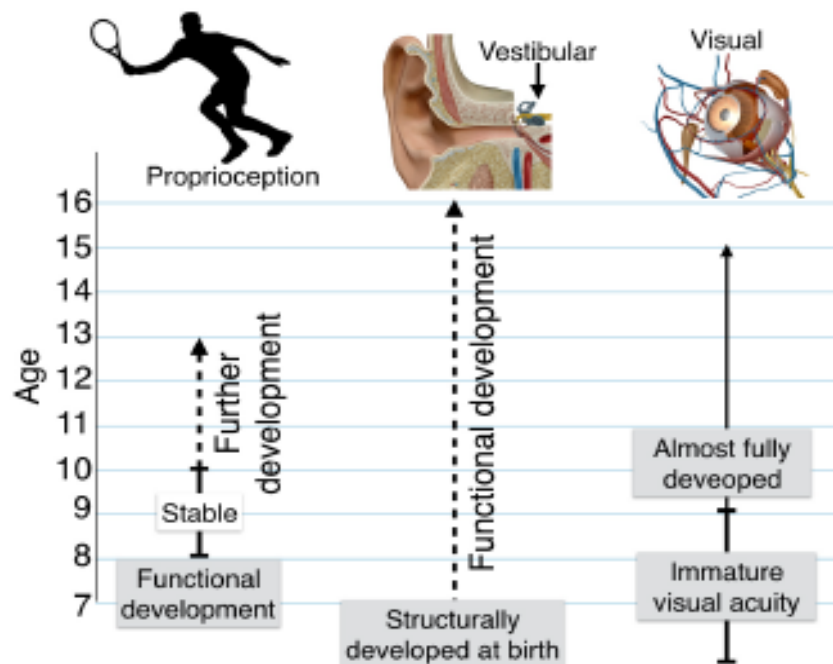
Athletes of the same chronological age can be up to five years apart in sexual maturity. Children entering sexual maturity early are referred to as ‘early maturers,’ and those who have delayed sexual maturity are ‘late maturers.’ The superior performance of early maturing children is due, in large part, to physical size, and not necessarily because they have superior talent. Late maturing children may eventually be taller than early maturers because they are in the growth phase longer before the onset of puberty. Early maturing boys have the additional testosterone advantage sooner than late maturers that, in turn, influences muscle development and reduces body fat. Estrogen begins increasing in girls around ten years old and brings with it increases adipose tissue deposits. This can provide an advantage in strength sports, but a disadvantage for speed and power performance.

Early maturing children often receive more coaching attention because they perform at a higher level than the late maturer. A young athlete’s sport performance before puberty is often a deceiving indicator of their overall potential once they are fully matured. Assuming a late maturer does not have elite potential, and therefore paying less attention to them, may permanently negate their ability to reach their exceptional genetic potential. An elite athlete may be forever lost.

### Nervous system maturation

By age eight, the child’s brain is 90 to 95 percent fully developed (Steindl, Kunz, Schrott-Fischer, Scholtz, 2006). Kinesthetic senses, permitting detection of body orientation in space, improve by almost 75 percent between ten and eleven years of age. Training appears to enhance kinesthetic senses. Postural control during the performance of sport skills requires well-developed vestibular, visual and proprioceptive systems. These three systems are structurally present at birth and continue to mature until approximately age 16 (Figure 6).

Figure 6.



Proprioception allows the athlete to sense the orientation of their limbs and body in space and has largely matured by approximately three to four years of age. Proprioception continues functional maturation until seven to eight years and then stabilizes. Further improvement occurs between ten to 13 years coinciding with the growth spurt. Movement accuracy relies on good proprioception.

Static and dynamic balance depends on the vestibular system that is located in the inner ear. This system is structurally well-developed at birth but takes 15 to 16 years for full functional maturation. The vestibular system coordinates eye and head movements, helps maintain normal muscle tone, affects balance and equilibrium, and helps coordinate both sides of the body, permitting skills such as catching and kicking a ball.

Visual input is important to postural control, especially when the support surface is unstable. It also permits tracking ability. Before age nine, visual tracking acuity is immature, making it difficult to accurately track long kicks or kick a ball off the ground. Beginning at approximately age ten, the visual tracking acuity achieves an adult pattern, although development may continue until 15 to 16 years.

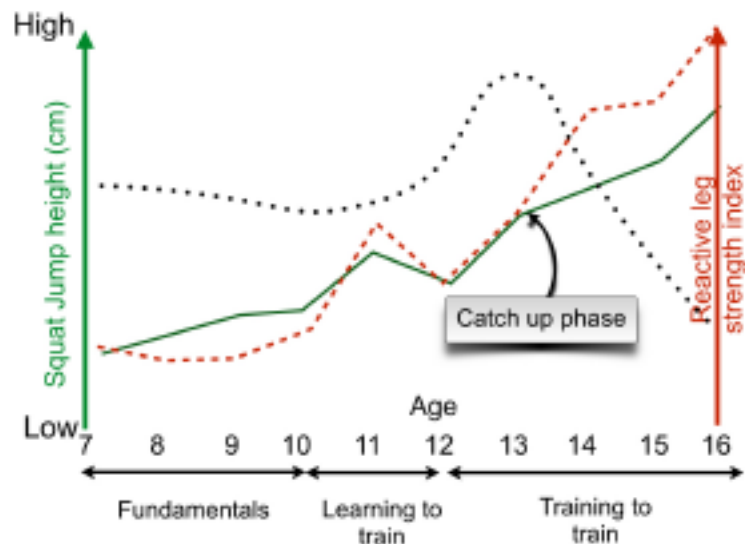
In essence, nervous system development is a bit of a mixed bag. It is largely structurally developed by age twelve, and a child can learn to perform complex skills. However, the vestibular, visual and proprioceptive systems are not functionally mature until around 15 to 16 years. Therefore, the coordination abilities of the maturing child will not stabilize until around 16 years.

### ***Performance variability***

Body structures do not evolve into the adult form at a uniform rate. For this reason, pediatric athletes have periods of rapid skill improvement interspersed with periods of no improvement, and even decline. Research on the leg stiffness of seven to 17 year-old boys (also referred to as 'reactive strength') illustrates this phenomenon (Lloyd, Oliver, Hughes, Williams, 2011). Leg stiffness refers to the amount of knee bend occurring during foot touchdown while running or jumping, and reflects the maturation of the stretch-shortening cycle.

Reactive strength was assessed using a hopping test involving five maximal vertical hops on a contact mat capable of measuring contact time and flight time. The boys were instructed to maximize jump height and minimize ground contact time. In equation form: Reactive strength = jump height (mm)/ground contact time (milliseconds). The data are presented in Figure 7. The black dotted line is the speed of growth of the child. The red dotted line represents the leg reactive strength index indicating how quickly the stretch sensors in the muscle and tendon react to maintain leg stiffness. Notice how reactive strength increases linearly between age nine and ten. Then, there is a rapid increase between age ten and eleven followed by a decline between age eleven and twelve years. This decline occurs immediately before the growth spurt. During the growth spurt there is an increase in leg stiffness that continues until age 16. Other motor performance abilities of endurance, speed and strength show a similar fluctuation between accelerated improvement, followed by a decline, then followed by an accelerated increase. The notion of critical and sensitive periods provide insight into what might be happening during the phases of acceleration and regression of the child's sport performance.

Figure 7.



There are two possible explanations for the period of decline in leg stiffness and other motor performance abilities.

- The body may have insufficient energy to concurrently manage both sexual maturation and improvements in motor abilities.
- The body needs to direct all resources to building structures for maturation. When the maturation structural building phase is complete, resources are then redirected back to improving structures necessary for the motor abilities so they match the new maturation level of the body.

In essence, motor abilities accelerate in order to “catch up” to the child’s enhanced physical growth and sexual maturation.

### Critical periods

Contemporary child development theory suggests that neural circuits controlling organ systems such as breathing, heart rate and reflexes are prewired. However, other neural circuits are rudimentary, and their formation depends upon environmental stimulation and experiences. If neural connections are not stimulated, or are only weakly stimulated, they are “pruned away.” Highly used neurons integrate into the circuitry of the brain. Rudimentary circuits are wired and mature in slightly different ways depending on an athlete’s environmental exposure. Even the neural circuits of identical twins are wired differently because their experiences are not identical (Rennie, 2005).

Two streams of research help us understand how rudimentary circuits become fully wired and integrated into brain functioning. The brain structures of animals raised in normal, deprived or enriched environmental settings provides insights into the influence of the environment on rudimentary nervous system pathways. Animals in enriched settings, where they interacted with toys, treadmills and obstacle courses, had larger brains with more synaptic connections than animals raised in deprived

environments. Extrapolation of this research to the sports setting suggests that exposure to various forms of movement experiences affects the development of a child's motor coordination abilities, thereby determining long-term sports potential.

Animal research suggests the existence of critical and sensitive periods for exposure to enriched environments. 'Critical period' refers to developmental stages where certain types of movement exposure appear compulsory for optimal development of a sports skill later on in life. Research on vision and language has consistently demonstrated the importance of early exposure to development of both vision and language. The apparent existence of critical periods is the rationale for establishing the government-sponsored Head Start program. Lack of varied movement exposures during a "critical period" theoretically permanently affects the child's ability to ever perform sports skills effectively because the cortical areas allocated to the motor programs do not develop correctly. Remediation cannot completely make up for this lack of development.

From the perspective of maximizing sport performance what insights does this animal research on enriched environments, critical and sensitive periods have on our understanding of motor skill development for sport? Does this suggest that a child's ability to reach their genetic ceiling for a sport will be permanently impaired? These remain largely unanswered questions and still debated. Long term athlete development researchers tend not to discuss the possibility that missing a critical or sensitive period leads to permanent damage. The belief is that the hypothetical windows of opportunity narrow, but do not completely close. The skill can still be learned, albeit at a slower and more difficult rate.

### **Suggested application to sports**

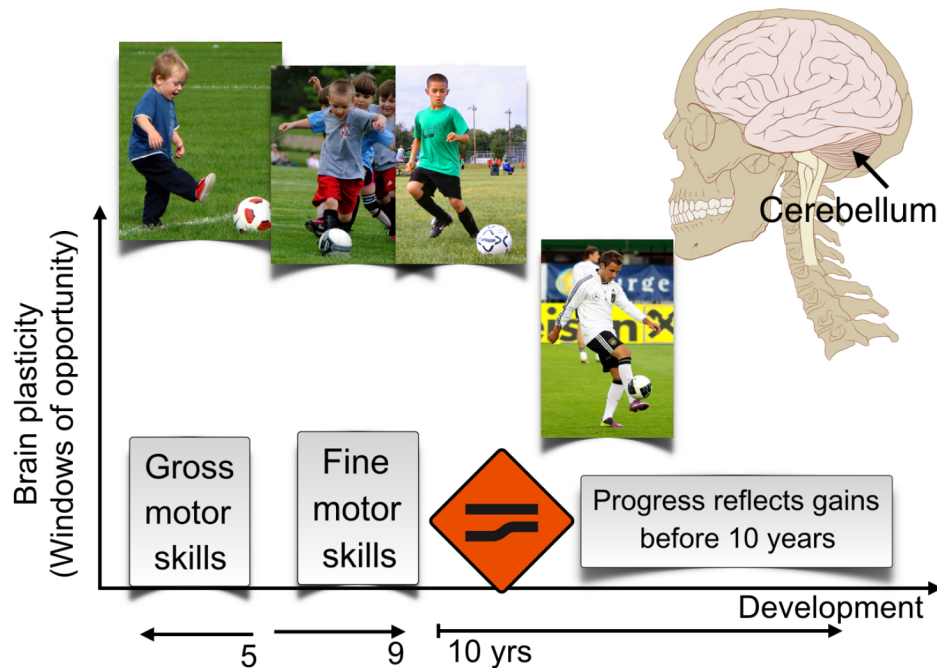
Brain circuits important for sports performance develop at different times, and this affects the appropriate introduction of specific forms of training. The general window of opportunity for most gross motor skills is open between birth to around age five (Hensch, 2004) (Figure 8). Movement experiences during this period lay down the brain circuits dedicated to motor control. These circuits connect to the cerebellum that receives information from the sensory systems, the spinal cord and other parts of the brain, and then regulates motor movements such as posture, balance and coordination, resulting in smooth and balanced muscular activity. Before age five, different movement experiences have a strong relationship with early brain development and motor control.

The window of opportunity for fine motor control typically follows the peak in gross-motor development and is open until around age nine. Movement experiences during this time develop the primary circuits needed for learning the type of sports skills requiring a high degree of hand, foot and limb dexterity and coordination. The general window of opportunity for attaining proficiency of most motor abilities narrows around age ten. The ability of the child to easily learn the more complex motor skills after age ten reflects experiences gained before age ten. Accelerated development of motor performance abilities occur in two phases.

- One phase occurs before puberty and is related to enhancements in neuromuscular efficiency due to the maturing nervous system.
- The second phase occurs during and after puberty when hormone levels increase, muscle fiber-type develop, and muscle mass increases.



Figure 8.



Adapted from Hensch, TK (2005) Nature Reviews Neuroscience 6(11). 877-888

Pre-pubertal movement exposure while the body is slowly evolving is analogous to putting the throttle for developing future athletic potential half way down. Theoretically, during accelerated periods of growth, the addition of a wide variety of movement exposures pushes the throttle closer to the floor, thereby further accelerating and enhancing motor development beyond what might occur naturally. That is, the more movement experiences the child is exposed to during these accelerated phases of growth, the better. It is not possible to raise the athlete’s genetic ceiling. However, exposure during these sensitivity windows potentially optimizes, or perhaps even enhances structural growth, and therefore positively impacts motor performance abilities allowing an athlete to more easily reach their genetic potential after maturity. Enriched movement exposures could also permit athletes to reach their genetic potential sooner providing a fully developed athlete with a longer time for maximal sport performance - i.e., five years instead of three years. Whether this effect occurs is not known and requires additional research.

Key take away points:

- While the LTAD model has not been well researched, it is a valuable guide for ensuring long-term pediatric participation in sports. It focuses attention of some important coaching philosophies that appear to be ignored by uneducated coaches. These principles include ensuring enjoyment, enabling all athletes the sense they are improving, the application of appropriate training based on biological age rather than chronological age, and doing no harm to the athlete.
- Encouraging long-term participation in sports serves two functions. It allows time for elite talent to emerge, and it addresses the health issues associated with a sedentary lifestyle.
- The LTAD model focuses attention on the interaction between growth and maturation, and the natural time frames for introducing skills and the appropriate training. There is considerable debate about the windows of opportunity. However, this provides insights into why specific forms of

training should be introduced during specific phases of growth and maturation.

- The LTAD model provides a terminology framework that can improve communication and the sharing of ideas among coaches.

## References

- Ahima RS. *Childhood Obesity: Prevalence, Pathophysiology, and Prevention*. Oakville, ON: Apple Academic Press; 2014.
- Aspen Institute. Facts: Sports Activity and Children | Project Play. <http://www.aspenprojectplay.org/the-facts>. Accessed May 19, 2016.
- Balyi I, Way R. Long-term planning for athlete development: The training to train phase. *BC Coach*. 1995;2-10.
- Brooks C. The science of training young athletes. 2016. <http://www.learnitez.com/HighPerformanceScience/manual-for-physiological-development-through-the-lifespan/>.
- Csikszentmihalyi M. *Finding Flow: The Psychology of Engagement with Everyday Life*. Reprint edition. New York: Basic Books; 1998.
- Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev*. 1993;100(3):363-406.
- Gould D, Cowburn I, Shields A. *Sports for All – Summary of the Evidence of Psychological and Social Outcomes of Participation*. Washington, D.C.: President's Council for Fitness, Sports and Nutrition; 2014.
- Hebestreit H, Bar-Or O, eds. *The Young Athlete*. Blackwell Publishing Ltd; 2007.
- Hensch TK. Critical Period Regulation. *Annu Rev Neurosci*. 2004;27:549-579.
- Klissouras V, Pigozzi F. Genetic limits of sport performance: Quo vadis? *J Sports Med Phys Fitness*. 2009;49(1):1-5.
- Lloyd RS, Oliver JL, Hughes MG, Williams CA. The Influence of Chronological Age on Periods of Accelerated Adaptation of Stretch-Shortening Cycle Performance in Pre and Postpubescent Boys: *J Strength Cond Res*. 2011;25(7):1889-1897.
- Monroe KW, Thrash C, Sorrentino A, King WD. Most common sports-related injuries in a pediatric emergency department. *Clin Pediatr (Phila)*. 2011;50(1):17-20.
- Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*. 2014;311(8):806-814.



- Rennie M. Body maintenance and repair: how food and exercise keep the musculoskeletal system in good shap. *Exp Physiol*. 2005;90(4):427-436.
- Sabo D, Veliz P. *Go out and Play: Youth Sport in America*. Women's Sports Foundation; 2008:192.
- Simoneau J., Bouchard C. The effects of genetic variation on anerobic performance. In: Praagh E., ed. *Pediatric Anaerobic Performance*. Human Kinetics; 1998:5-21.
- Steindl R, Kunz K, Schrott-Fischer A, Scholtz A. Effect of age and sex on maturation of sensory systems and balance control. *Dev Med Child Neurol*. 2006; null(06):477-482.
- Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. I. *Arch Dis Child*. 1966;41(219):454-471.
- USOC. American Development Model. Team USA. <http://www.teamusa.org/About-the-USOC/Athlete-Development/American-Development-Model>. Accessed May 19, 2016
- Wu M. 2011 09-15 magic potion of gamification: Slide # 9. 00:53:56 UTC. <http://www.slideshare.net/mich8elwu/2011-0915-magic-potion-of-gamification>. Accessed May 20, 2016.

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On the cover: (L-R) Bronze medalist Kristi Castlin, gold medalist Brianna Rollins and silver medalist Nia Ali of the United States celebrate with American flags after the Women's 100m Hurdles Final on Day 12 of the Rio 2016 Olympic Games at the Olympic Stadium on August 17, 2016 in Rio de Janeiro, Brazil.

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