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BUDAPEST, HUNGARY - JULY 27: Gold medalists
The United States pose with the medals won during
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of the Budapest 2017 FINA World Championships on
July 27, 2017 in Budapest, Hungary. (Photo by Lau-
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Message from the
Chief of Sport Performance
Alan Ashley



Welcome back to *Olympic Coach*! We have so much excitement happening around Team USA, and we're glad to share it with you.

In this issue of *Olympic Coach*, authors share information on inclusion for all athletes, recovery protocols for coaches, and information on building athlete confidence - all key for performance. Special shout out to Liz Fusco and Tim Pelot, part of the Team Behind the Team, for contributing to this issue.

We're gearing up for PyeongChang 2018 – as I write this, we're only 6 months out. Our Winter athletes had very strong showings this past year, are transitioning to in-season and build on strong performances in Sochi. Mark your calendars for February 9 through 25 for the Olympic Winter Games, and March 9 through 18 for the Paralympics.

Our broadcasting partner NBC launched the Olympic Channel over the summer that will bring you programming on Olympic and Paralympic events, athletes, and their stories. Team USA fans will be able to experience live events, including world championships and qualifying events for PyeongChang. You can watch original programming, including the Scouting Camp: Next Olympic Hopeful pitting 91 athletes from around the country vying for the opportunity to represent Team USA in 4 sports - Bobsled, Cycling, Rugby and Skeleton. We're so excited to share this with you as you'll get to know the Team USA athletes and carry the Olympic and Paralympic spirit year round.

And finally, we're nearing the IOC's announcement for the 2024 Olympic Bid. Los Angeles has a rich sport history and offers fantastic resources, venues, and community support to host a summer Olympic and Paralympic Games. LA2024 has put together a great bid and would be an outstanding city to again host the world at the Olympic and Paralympic Games. The IOC has determined that both bid cities – LA and Paris – offer exciting opportunities for games. So it's not a matter of "if" the US will again host the Olympic and Paralympic Games, but "when" as the IOC will award the 2024 and 2028 Games in September during their meeting in Lima, Peru. We're grateful for our partners at LA2024 and for the support of the LA community in bringing the games home to the US.

Please enjoy this issue – and as always, please let us know what you think!

Creating Confidence: The Four Sources of Self-Efficacy

**Matthew Buns, Assistant Cross Country and Track & Field Coach,
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“Whether you think you can or think you can’t, you’re probably right.” – Henry Ford

Introduction

Rarely in competitive athletics is the importance of the mind doubted. Specialists in sport psychology are often asked some variation of the question “How do I make my athletes more confident?” There are many aspects of training and competing that may shake an athlete’s confidence, from the importance of the event, to fearing certain fellow competitors, to the challenge of the race course. Coaches often wish for their athletes to simply trust in their training, but it’s not always as simple as that. The purpose of this article is to provide a blueprint for coaches to teach mental readiness and demonstrate why it can be just as critical to performance as physical readiness. A coach does not need to be a sport psychologist in order to realize how performance improves with a mental edge in track and field. In order to be mentally ready to compete and put forth an optimal performance in track and field, athletes must be confident in themselves’ and have a high level of self-esteem. Above this, an athlete must possess something more specific: a high level of self-efficacy. Self-efficacy, in and of itself, has been shown to be a better predictor of performance than just outcome expectations (goal setting) before a performance and as good of a predictor as anxiety levels (Gernigon & Dolloye, 2003). It is one of the most important, situation specific, mental aspects that a track and field coach can instill within their athletes.

Operationalizing and Conceptualizing Self-Efficacy

Before discussing the sources of self-efficacy in track and field athletes, it is necessary to first understand what exactly self-efficacy is and how it is set apart from other psychological definitions. Albert Bandura, the founder of the concept, defines self-efficacy as “the belief a person has in their ability to complete an objective successfully in order to obtain a specific goal” (Bandura, 1977a). In other words, someone with high self-efficacy has an unquestionable belief in their ability to go out and do something in order to achieve their goal. It is very specific to the task at hand and at that time. Therefore, in this case it must be very specific to the athlete in regards to their sport of track and field.

Upon reading this definition, one might think that it is just another word for self-confidence, self-esteem, outcome expectations or another seemingly interchangeable word. This, however, is not the case. As stated above, self-efficacy is a term that is specifically related to the task at hand. In order to grasp this, some time must be taken to separate it from its would-be synonyms.

The difference between self-efficacy and self-confidence can be discrete and hard to understand to anyone who is not familiar with the terms, but it is a stark and important difference that must be



understood in order to coach it. Confidence, first and foremost, is a general term about a broad subject. One can be confident in many things, including failure. Someone can be confident about a lot of things. For example, a track athlete may be confident that they are going to run poorly and not achieve their goal. Efficacy, however, does not have that possible negative side. It is also specific to the task at hand, whereas confidence may spill over to many different areas of life, not focusing on a single event. The most important thing to take away from the difference between the two is that confidence allows room for failure, but a person with high self-efficacy believes they will go out and succeed in their task no matter what (Bandura, 1997).

A difference must also be established between self-efficacy and self-esteem. Once again, this focusses around the specificity that is self-efficacy. Self-esteem, essentially, is a value of self-worth. It can apply to a lot of different areas in one's life, all of which may never cross over and affect the other. For instance, a track and field athlete may have high self-esteem in the classroom and in their social life, but may still not care and perform poorly on the track without affecting that self-esteem. Self-efficacy, once again, deals solely with the task at hand and cannot cross over to other areas.

There is one final distinction to be made in terms of defining self-efficacy and that is the difference between it and outcome-expectancy. This difference can be understood by looking at the former as half of an equation and the latter as the entire equation. Outcome expectancy is the belief that if you perform something a certain way, then the outcome will be a certain way resulting from that performance. Self-efficacy, on the other hand, is the conviction that one can do that performance successfully and that the successful performance will yield a favorable result. It is essentially outcome-expectancy, plus the part that has to happen before it and the belief that the outcome will be positive no matter what (Gernigon et al., 2003).

Sources of Self-Efficacy

Now that self-efficacy has been defined and set apart from anything else, the major questions and main focus of this article can be addressed. How does a coach find sources of self-efficacy, and how does he or she coach and instill it within their athlete? As it is, there are four main sources of self-efficacy: mastery experience, modeling, social persuasion and physiological factors (Bandura, 1977b).

Mastery/Past Performance

Mastery experience, or an accomplishment in a past performance, is the first source of self-efficacy in an athlete. It is also the most powerful source of high self-efficacy in an athlete, as it is driven by themselves (Bandura, 1977b). Simply put, "success breeds success." The successful completion of a task will raise future self-efficacy, and likewise, the unsuccessful completion will lower it. This has to do with mental processing that occurs when one has completed a task once. "People process, weigh and integrate diverse sources of information concerning their capabilities. They then regulate their choice behavior and effort expenditure on the basis of the perceived self-efficacy" (Bandura, Adams & Beyer, 1977). In other words, a completed successful task can influence the amount of effort and success in a future task. With this in mind, completion of these successful

tasks, however, cannot be an easy, repetitive feat. In a study done on swimmers, there was a negative correlation between high self-efficacy levels and motivation to complete tasks when the goals being set were too low (Miller, 1993). To keep motivation at a high level and promote continually increasing levels of self-efficacy, one must keep the goals and tasks at a high level.

The coach's role in this source of self-efficacy is to provide this opportunity for the athlete. In track and field specifically, this can be done in many ways. The first and most obvious way is with prior competition. A good way to start this is to enter an athlete in an event at a low-key meet and breed the environment for success. Success in small meets like this will build efficacy for larger meets in the future. Consistently reminding the athlete of these successful past performances is also a key role of the coach.

Another way to build self-efficacy through mastery experience is at practice. Specifically with distance runners, this can be done through workouts. In one of the most widely used training systems in the country, interval workouts are done as a primary workout for the week and are done at a pace to build VO2 max, a pace which is essentially 5K race pace. An example workout of this would break down to 8x1000 meters at 5K race pace with short jogs in between (Daniels, 2005). This is an extremely challenging and taxing workout, but it is a pace that should be what an athlete can run for a 5K. They can draw on the mastery experience of completing this workout to build self-efficacy for a future race. Likewise for jumpers and throwers, mastery experience can easily be simulated at practice. Unlike distance athletes, a lot of their practice can be simulating meet day actions. Thus, completion of a certain distance or mark at practice can provide mastery experience for them. Once again, making the athlete aware of mastery experience is just as important as the coach realizing it themselves.

Modeling/Vicarious Experience

The next source of self-efficacy is modeling, or vicarious experience. This is basically mastery experience, except through watching another person. This is especially important with less experienced athletes, as they will often use the success and judgment of others to validate their own success (Gernigon, et al., 2003). Watching others complete a task successfully will increase an athlete's own self-efficacy, and watching others fail at a task will likewise lower self-efficacy (Madux, 1995). Self-modeling, or observing one's self perform successfully repeated times, has also been shown to increase self-efficacy and performance in sports such as hockey (Feltz, Short & Singleton, 2008).

Once again, the role of the coach in this source of self-efficacy is to provide the opportunity to the athlete. Modeling, specifically self-modeling, can be extremely helpful with increasing an athlete's self-efficacy when it comes to running with proper form. Watching and critiquing video of one's self and others running properly will lead to the belief that they can continuously do it properly. This source of self-efficacy, however, is probably best used in more technical events, such as jumping and throwing. Watching others perform the complicated movement sequences and the successful performances that result with the successful completion of the movements can enhance the athlete's self-efficacy about performing the same task. As a coach, one can provide this by bringing a video tape to track meets, having an athlete watch a more skilled teammate perform, or simply by



directing them to videos and coverage of professional events. However, it is best to keep modeling within the same level of competition, as past studies have shown that the modeling source is most effective when used with athletes with similarities to the athlete in question (Weiss, McCullagh, Smith & Berlant, 1998).

Social Persuasion

The third source of self-efficacy, social persuasion, is the verbal encouragement from another. This source most often directly comes from the coach. Although it can come from another athlete or parent, the strength of social persuasion as an effective booster of self-efficacy depends on “the prestige, credibility, expertise and trustworthiness of the persuader” (Gernigon et al., 2003). On most teams, hopefully, that persuader is indeed the coach. One must tread carefully when using this source however, as Bandura (1977a) explains that negative effects on self-efficacy from verbal persuasions have more of an impact and a quicker impact on an athlete than positive effects do. Therefore, it is essential to be consistent with positive feedback, as one negative verbal comment could potentially have a larger effect on an athlete’s self-efficacy than a stream of positive persuasion.

Verbal persuasion from a coach must be sincere and believable, as well. “Persuaders must cultivate people’s beliefs in their capabilities while at the same time ensuring that the envisioned success is attainable” (Pajares, 1997). It is just as important to be realistic with athletes as it is to be positively persuasive, as unrealistic goals and persuasions will ultimately lead to failure in the goal, thereby reducing self-efficacy through negative mastery experience, which as discussed earlier, is the most powerful source of self-efficacy.

In the sport of track and field, verbal persuasion is very similar to any other sport. The easiest way to do this is to remind the athlete of the other two previously mentioned sources of self-efficacy. Use the evidence. Remind them of what they have done, because as stated before, previous mastery experience is the most powerful source of self-efficacy, and reinforcing this through verbal persuasion will only make them all the more strong mentally. It is once again important to use this realistically, however, and this can be done through setting realistic goal times in races, marks in throws and jumps, etc.

Physiological Interpretation

The last source of self-efficacy, but certainly not the least important, is that of physiological factors. Simply stated, this has to do with the athlete’s perceptions of the physiological effects associated with exercise and exertion, such as nervousness, aches and pains, exhaustion, etc., on how they will affect their performance. These factors can have an effect on an athlete’s perceived self-efficacy depending on their current emotional state. A person with high self-efficacy will view these at face value – an effect of exercise – whereas a person with low self-efficacy will think more into these physical signs and let them be viewed as a sign that they cannot complete the task (Bandura, 1997).

Self-Efficacy and Fatigue

It is the coach's job to get the athlete to a point where he or she will view these physiological factors positively and even be able to apply them to a better performance. There are several studies that demonstrate the possibility of performing well and overcoming physiological perceptions during negative physiological effects.

A main focus for distance runners centers around the central nervous system. Tim Noakes has been at the forefront of this research. His research supports the idea that the central nervous system plays a large role in regulating exercise output. This research has formed his professional stance against the "peripheral fatigue model" presented by A.V. Hill in 1923. Noakes (2011) argument contends that the central nervous system is the principle limiting factor in performance. He established the "central governor model", which revolves around the idea that when oxygenation of the heart, brain and other organs reaches a dangerously low level, the brain will begin to shut down systems (muscles and heart work output, etc.) in order to terminate the effort (Noakes, 2002). However, with mental training and experience and in certain situations, this limiting factor can be overridden. This helps to explain many situations that cannot be fully understood with the idea that metabolic and peripheral fatigue are the only limiting factors. An example of this would be how at the end of an "all-out" endurance effort, runners have the ability to have a "finishing kick" at the end even though they are metabolically depleted and have been slowing down throughout the effort. A coach who realizes this can teach their athlete that the brain will try to terminate a run long before the body has exhausted the ability to perform, and the athlete who competes with this in mind will have a higher level of self-efficacy when these factors set in, leading to a more successful performance.

A second example of how physiological factors can be used as a source of self-efficacy can be applied specifically to more explosive events. This has to do with the term "post activation potential" (PAP). Physiologically defined, PAP is a phenomenon that involves increased muscle performance output during a short time frame (less than four minutes) after a high intensity warm-up. It is an interesting phenomenon due to the fact that common sense would make one think that one would be tired and not perform as well after an initial, high intensity activity. However, several studies have shown this not to be the case in many instances. According to DeRenne (2010), there are two main physiological mechanisms that are responsible for this. The first one involves the high intensity warm-up increasing phosphorylation of light chain myosin in the muscle, thereby increasing cross bridge rate within the muscle. The second involves increasing the activity in the spinal cord between afferent and alpha motor neurons. The combination of these two factors results in PAP (DeRenne, 2010).

Gerasimos Terzis et al. (2009) conducted a study to measure the effectiveness of PAP on shot put by using drop jumps as a warm-up. After an intense warm-up of several drop jumps, a significant increase in throwing distance was noted in male throwers. Rixon (2007) conducted another study with jumping using a PAP eliciting warm-up. He found that after a maximal isometric squat warm-up, jump height was significantly higher in athletes compared to not using this type of warm-up. This odd phenomenon is further proof that what an athlete is feeling physically is not the ultimate determinant of performance, as in this case; an exhaustive style of warm-up elicited unseen physi-

ological characteristics that actually improved performance. A coach's job, once again, is to show the athlete that these things are possible and to boost their self-efficacy through knowledge, education and practice of such things.

Conclusion

These four sources are the best and most proven ways to coach self-efficacy in athletes. However, learning how to coach self-efficacy begins by understanding what it really is. It is imperative to understand how self-efficacy is separate from self-confidence, self-esteem and outcome expectancies, as they are not the same thing and often do not go hand in hand. One word that should come to mind when trying to define self-efficacy is specific. It is specific to the situation and in this case, the performance in a track and field event.

Upon understanding self-efficacy, it is important for a coach to realize where its sources can be found and how they can be used. Every source begins with the coach instilling it within the athlete and helping him or her to realize exactly what they are. Opportunities for mastery experience and vicarious modeling should be provided by the coach in order to promote an environment for success. Verbal persuasion means the most when it is coming from the person on the team with the most prestige and influence: the coach. Additionally, the complexities of physiological factors and how to use them to an advantage must be understood and explained in order for the athlete to take full advantage of them in a situation and for the athletes to approach them from a view of high self-efficacy.

As aforementioned, self-efficacy levels are an extremely reliable predictor for future performance. It is crucial to coach a mental edge in athletes because as stated earlier with physiological factors, mental factors can overrule physical ones. Coaching athletes, especially track and field athletes, cannot end with physically preparing them; a strong mental state of self-efficacy must accompany them in order to achieve the highest, optimal performance.



BMW IBSF World Cup Innsbruck - FEBRUARY 04: (L-R) Kaillie Humohries and Melissa Lotholz of Canada, Elana Meyers Taylor and Lolo Jones of the United States and Jamie Greubel Poser and Aja Evans of the United States celebrate after the Women's Bobsleigh final run of the BMW IBSF World Cup at Olympiabobbahn Igls on February 4, 2017 in Innsbruck, Austria. (Photo by Matthias Hangst/

Getty Images For IBSF)

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LONDON, ENGLAND - AUGUST 06: Amy Cragg of the United States celebrates after placing third in the Women's Marathon during day three of the 16th IAAF World Athletics Championships London 2017 at The London Stadium on August 6, 2017 in London, United Kingdom. (Photo by Alexander Hassenstein/Getty Images for IAAF)

Physical Literacy for All

E. Paul Roetert, Independent Sport Science Consultant

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Bob Meserve, Board member - Disabled Sports USA

Athletes with disabilities planning to compete in six different events are currently training hard for the upcoming Paralympic Winter Games to be held in PyeongChang, Republic of Korea from March 9-18, 2018. Two years later, Tokyo will host athletes participating in twenty-two events for the sixteenth Paralympic Summer Games. Hopefully, the Games will draw attention to the tremendous desire, motivation, abilities and overall performances of the participating athletes. Elite athletes can certainly serve as great role models for the younger generation showing what can be accomplished at the highest level through hard work, dedication to training and accomplishing great feats against all odds. Even more than that, these elite athletes can highlight the benefits of sports participation and physical activity in general as well. Considering the concerns regarding physical inactivity in the United States and abroad, this is an important area of focus.

The Centers for Disease Control and Prevention (CDC) states that “too few Americans get the recommended amount of physical activity” and that only “1 in 5 high school students meet the recommended guidelines” but what may not be as well known is that the report also indicates that “youth with disabilities are twice as likely to be physically inactive, resulting in obesity rates almost 40% higher than for youth without disabilities creating much higher risks for health-related diseases.” These findings demonstrate just how important it is for coaches to include athletes with disabilities in their programs wherever possible.

Clearly, to reach the highest levels of competition, excellent coaches typically play a major role in achieving success. Coaches who train athletes both with and without disabilities already work with varying ages, abilities and levels. Athletes with disabilities lie on the same spectrum of performance as other athletes and can, for the most part, be treated and held to the same expectations as the rest of the team. Athletes with disabilities should be held accountable for showing up to practice, completing homework and following instructions. They should also expect to receive the same amount of attention, time and focus of your coaching as your other athletes.

Participating in the Paralympic Games is the pinnacle for an adaptive athlete, however just as most non-disabled athletes don't make the Olympic standard, it is not the be all and end all for most. Just as it is important for the general population to continue to participate in sports and general physical activities throughout a person's full lifespan, it is also important for athletes with disabilities to explore and learn a full range of sports and recreation so they can enjoy a healthy lifestyle alongside their family and friends. In fact, that is the goal of the concept of physical literacy. Coaches can and should play a major role in guiding athletes to reach the best of their personal abilities, which is very much in line with physical literacy. Guided by the work of Dr. Margaret Whitehead, physical literacy was brought to the forefront in the early 1990's, as she started sharing her breakthrough work in the academic literature (Whitehead, 1990). Since then, many countries have embraced the concept and

there has been a significant increase in activity to implement and promote the concept of physical literacy internationally as well as in the United States (Aspen Institute, 2015). Much has been accomplished, but there is still work to do in bringing physical literacy to the forefront, particularly as it relates to athletes with disabilities.

The Concept of Physical Literacy

The International Physical Literacy Association describes physical literacy as “the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life” (IPLA, 2016). A consensus process, involving several organizations in Canada (2015), developed five core principles that underlie the definition. Physical Literacy:

- Is an inclusive concept accessible to all
- Represents a unique journey for each individual
- Can be cultivated and enjoyed through a range of experiences in different environments and contexts
- Needs to be valued and nurtured throughout life
- Contributes to the development of the whole person

What would happen if we adopted the concept of physical literacy, and more specifically applied these principles to our young athletes with physical disabilities? According to Disabled Sports USA, as we consider strategies for improving the level of health and physical activity for all youth, it is important that we pay special attention to including and highlighting ways that kids with disabilities are also encouraged to be active. Are there specific ways in which you can integrate children with disabilities within group lessons or training sessions? Are there better ways in which you as a coach can modify your teaching and coaching techniques? Giving all children regardless of ability a chance to be physically active provides opportunities that will have a significant impact on the quality and also the quantity (lifespan) of life. Some may become great athletes and many can enjoy all the benefits of physical activity that are an integral part of a meaningful life.

As well as the physical benefits of inclusion, there are also tremendous social benefits for the entire team. When children see their peers succeed, they are also more likely to want to continue to participate. Children with disabilities want to be able to stay in sports with their friends, just as any other child would. Inclusive programs not only help these children stay involved and happy, they help the rest of your team to become more positive, creative, empathetic and overall better sportsmen and women. In other words, they will have a positive impact on their environment which will likely make a difference for many others involved in their lives.

The Role of the Coach

We cannot stress enough the importance of coach education and coach development. Coaches working with players at all ages, levels and abilities need to continue to learn about the latest technologies specific to athletes with disabilities, particularly based on the rapid advances in this area. In addition, coaches need to continue to look for ways to integrate athletes with and without disabilities to enhance their own growth and knowledge but also that of the athletes themselves. In all these activities

inclusiveness, individuality and a focus on a lifetime of activity should be the focus. Physical Literacy is clearly based on enjoying sport and other physical activities for the full lifespan (Roetert, et al, 2017). Finally, as it relates to the dream of one day qualifying for the Paralympics, let's continue to look for growth opportunities in the number of sports, particularly as it relates to the Winter Paralympics. Increasing the number of events will help draw more attention to opportunities and in turn help in overall participation numbers.

For more information and resources related to sports inclusion contact www.disabledsportsusa.org.

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Awareness, Nutrition and Recovery for Coaches

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For coaches, it can be very easy to get caught up in the everyday rigors of orchestrating a successful season. The focus tends to be solely on athlete health and wellness, and a coaches' own self-care tends to fall by the wayside. Consider these seven tips to ensure that your own health and wellness isn't compromised, both in the short- and long- term!

1. Prioritize sleep

Sleep is one of the most commonly overlooked aspects of maintaining health. A myriad of repair processes occur during sleep. It's also well known that sleep loss can increase inflammation (Haack, Sanchez, Mullington, 2007, Zhay et al, 2011). For a coach, it's important to have mental rest. To facilitate a good night of sleep, try to unplug from technology before hitting the sack (Christiensen et al, 2016). This can be understandably difficult as it's often the time when strings of emails are sent, but any amount of "unplugged" time is better than none! Establish a routine such as taking a warm shower, bringing along a book to read, or setting your clothes out for the next day. Try to "turn your brain off" from the events of the day as well as the anticipation of the next one. As little as seven hours of sleep a night may be enough to reduce risk of chronic diseases like diabetes and heart disease (Kanegasabai & Chaput, 2017).

If the previous night's sleep was especially poor, consider taking a quick nap after morning or early afternoon training. In fact, coffee naps – that is, drinking a cup of coffee immediately prior to a 10 - 20 minute nap – may help you to feel more energized upon waking (Hayashi, Masuda, & Hori, 2003). Napping for longer than 30 minutes can lead to what is known as "sleep inertia" – a sluggishness that can persist for a few hours, so keep those naps short and sweet (Dhand, Rajiv, Sohal & Harjyot, 2006, Brooks & Lack, 2006)!

2. Don't forget to eat

As a coach managing a team under typically stressful situations, it can be very easy to simply forget to eat. Make sure to consume food throughout the day - that means breakfast, lunch, dinner, and snacks - to balance both energy levels and mood. Skipping meals causes large swings in blood glucose, leading to that "hangry" feeling (hungry-angry; yes, it's a real thing). When it finally does come time to eat, dinner tends to be huge! This can lead to unwanted weight gain, sleep quality can suffer on an overly full stomach, and it can spoil your breakfast appetite. This sets you up for the same problems the following day, and the pattern continues...

So, how can you combat this vicious cycle? For starters, pack a variety of energy bars so that, at the very least, you can have a quick bar. Aim for 15-25 grams of protein, 30-45 grams of carbohydrate, 8-20 grams of fat, and 3+ grams of fiber. These snacks are easy to bring along when traveling domestically or abroad. In the weeks before leaving for a trip, try several varieties of protein bars as a “taste test” to find the ones that are most enjoyable to you. Other smart snacks to pack for snacking throughout the day are beef jerky, nuts and nut butter, trail mix and protein powder. Pair jerky, milk or protein powder with a piece of fruit, a cereal bar, or a palm full of trail mix. Click [here](#) for more quick snack ideas!

3. Stay hydrated

Hydration is important for athletes and coaches alike. It's a critical factor in mental processing and fatigue resistance that can be easily overlooked during a busy day. As a quick assessment on hydration status, check the color of your urine first thing in the morning, and keep an eye on color, amount and frequency of bathroom trips throughout the day. The goal is for urine to be a pale yellow color (USA Weightlifting), a moderate volume, and to use the restroom roughly every 2 hours. If it's dark yellow, low volume, and infrequent, be more proactive with fluid intake throughout the day - try carrying a water bottle around and choosing fluid-rich foods in meals and snacks (e.g. fruits, vegetables, soups) for hydration. Conversely, if using the restroom more than hourly, volume is high and color is clear, try either drinking less at once (e.g. no chugging) or potentially adding electrolytes (either from foods or a sports drink) (USOC Hydration Fact Sheet).

4. Optimize immune health

When the opportunity arises, choose the most colorful and varied fruits and vegetables you can find. These foods help decrease inflammation and oxidative stress associated with training and environmental stressors alike. If access to fruits and vegetables is limited or you're a picky eater, consider taking a simple daily multivitamin to ensure micronutrient needs are met.

Another way to maintain immune health is to consume probiotics. The gut contains billions of both beneficial and harmful bacteria which, when in balance, promote overall health. Bacterial imbalance can occur with antibiotic use, changes in food and water supply, excess physiological stress, emotional stress, fatigue and illness. Probiotic-rich foods and probiotic supplements contain live and active cultures that colonize the gut with beneficial bacteria and ramp up our natural immune responses. Research suggests that taking a probiotic supplement for two weeks prior to and during travel reduces the frequency, duration and severity of illnesses like cold, flu, traveler's diarrhea and upper respiratory tract infections. Probiotics can also improve digestion by promoting regularity, reduce stress on cells, and may even decrease anxiety and improve mood (Pyne, West, Cox, & Cripps, 2014, Hungin & Mulligan, 2013).

Fermented foods such as yogurt, kefir, cottage cheese, buttermilk, kimchi, sauerkraut and kom-bucha are natural sources of probiotics. Probiotic supplements containing at least 10 billion CFU (Colony Forming Units) of lactobacillus, streptococcus and bifidobacterium strains are warranted when traveling to countries with a questionable food and water supply, or if you're especially prone to illness during travel (USOC Sports Nutrition Prebiotics and Probiotics, 2016).

5. Watch your alcohol intake

Being mindful of alcohol consumption is another way to stay healthy. Men should try to limit alcohol consumption to no more than 4 drinks per day (14 per week), and women should aim for no more than 3 drinks per day (7 per week) (NIH: Drinking Levels Defined). Excessive alcohol or “binge drinking” impairs the ability to regulate body temperature, pauses bodily repair processes for up to 72 hours, promotes fluid retention and fat deposition, disturbs cardiovascular function and increases susceptibility to illness (Vella, Cameron-Smith, 2010; NIH: National Institute on Alcohol Abuse and Alcoholism). It also disturbs sleep cycles - although it’s commonly thought that alcohol helps with falling asleep, it completely limits deeper sleep cycles (Thakkar, Sharma, & Sahota 2015).

When drinking, try not to just sit around and drink, which is perhaps the easiest way to go overboard! Play a game or do an activity, drink glasses of water in between, have food throughout the night and choose lower alcohol drinks.

6. Understand the connection between stress and stroke

Poor self-care can lead to chronic elevation of stress hormones that negatively affect health and immunity (Rohleder, 2014). In fact, several recent research studies have found a correlation between self-perceived stress levels and the likelihood of developing of coronary heart disease (Iso & Date, 2002; Booth et al, 2015) and ischemic stroke (Jood et al, 2009). According to the National Stroke Association, an ischemic stroke occurs when blood flow to an area of the brain is reduced or cut off. Brain cells begin to die, which can cause lasting damage to speech, movement, memory, and more (National Stroke Association: Understand Stroke). To spot a stroke, the National Stroke Association recommends to use the acronym F.A.S.T:

- Face dropping,
- Arm weakness,
- Speech difficulty,
- Time to call 9-1-1

If you have a family history of stroke, it’s especially important to know the symptoms; catching early warning signs can save a life. These signs include weakness, vision problems, difficulty speaking, and confusion.

Although this is likely the most difficult factor in this list to control, it’s important to try and locate where stressors are coming from and begin to put a plan in place to reduce the magnitude of effect they have. Focus on your mental health, and reach out for help when you need it. Gain control of your stressors before they control you!

7. Get moving!

Make an effort to stay active all year long, both at home and on the road. During travel, if your hotel has a gym, try to spend at least 30 minutes doing some form of exercise. If that’s not available or you don’t have the time, choose to walk over driving or taking public transport when you can. Even

spending 10 to 15 minutes doing calisthenics or stretching in your hotel room at the beginning or end of the day can be beneficial (CDC: How much physical activity do adults need). Aside from helping with weight maintenance and overall health, exercise is a great way to clear your mind or think through any problems you might be having (Milani & Lavie, 2009; Rejeski, Thompson, Brubaker, 1992). It also has been shown to improve sleep quality (Kelley & Kelley, 2017).

What to do now?

None of these tips are necessarily new. As a sports dietitian, a former college coach and author of *Coach There is Hope*, and occupational therapy student, the authors have both observed and been guilty of these common self-care practices amongst busy people working in sport. Just remember that your personal health is just as important as the health of your athletes. Being a strong, well grounded and healthy leader is a huge step in the direction of success and avoiding burnout. We hope you'll consider our seven suggested tips for success!

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OLSZTYN, POLAND - JULY 20: USA's Phil Dalhausser hits against Argentina's Nicolas Capgrossi during FIVB Grand Tour - Olsztyn: Day 2 on July 20, 2017 in Olsztyn, Poland. (Photo by Adam Nurkiewicz/Getty Images for FIVB)

The Efficacy of Vertical Jump Assessments in Athletic Populations

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Summary

The vertical jump is a test commonly used in many athletic environments. For decades, this test has been the gold standard for coaches who want to quickly and objectively assess an athlete's quickness. In sport, one physiological variable that has been identified as being responsible for the element of quickness is rate of force development. Advancements in technology in the domain of sport science has led to a boom in new methods and devices claiming to provide valuable insight into evaluating athlete quickness. The goal of this review is to revisit the evidence regarding the vertical jump as an assessment tool, investigate the factors involved with an athlete's ability to be quick, and identify which tools are most effective in measuring explosive characteristics in athletes.

Introduction

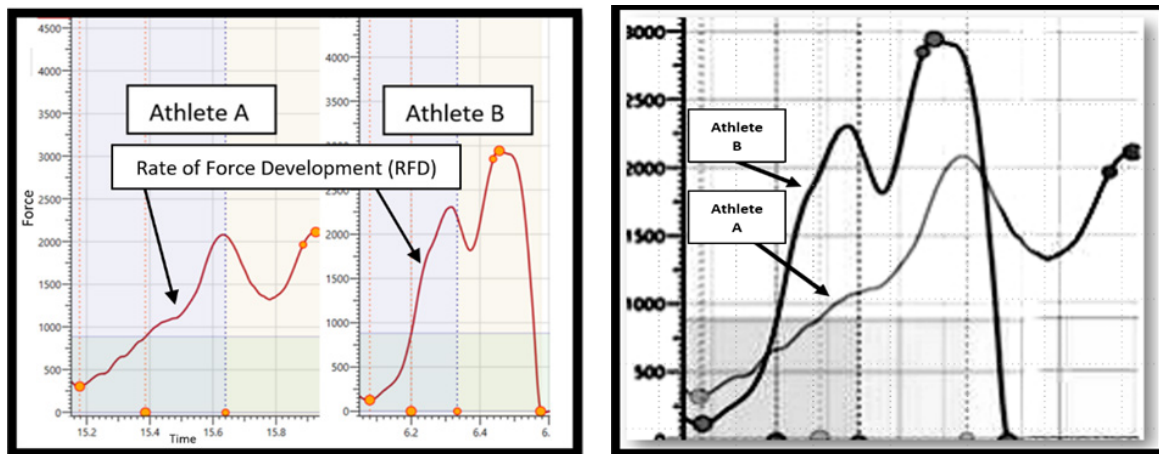
Have you ever watched a sporting event and thought, "Wow! That athlete looks explosive?" Have you ever seen a running back in American football launch himself over a pile of players to successfully get the football into the end zone? Witnessed a basketball player on a fast break leaping up over the defender to successfully score two points with a jaw-dropping slam dunk? Seen a 100-meter sprinter burst out of the starting blocks? Such examples in sporting events happen all the time and they are all great demonstrations of athletic speed and power. The word that comes to mind when describing these actions would be "explosive." The question that continues to be asked by coaches and sport scientists over the years is: are there specific strategies and assessments that can help measure an athlete's level of explosiveness? For many years, coaches have relied on the vertical jump test to best gauge how explosive an athlete is. As a result, this test has become common in many professional sport and collegiate organizations. This article will investigate the efficacy of vertical jump testing and evaluate if it is a relevant tool for measuring, and potentially monitoring, sport performance.

Vertical Jump and RFD

Rate of force development, also known as RFD, is a measure of explosive strength. RFD is defined as the rate in rise of contractile force at the onset of muscle contraction (Aagaard, 2002). In sport, the speed of force production can improve an athlete's ability to perform.

Most sporting actions take place in less than 200 milliseconds, making RFD a variable of critical importance to improving sport movement. RFD serves as a vital component related to in-game success. For example: when two basketball athletes both jump to retrieve the ball during a rebound,

both may be able to jump to the same height, but the one who can produce force the fastest will have the advantage. In baseball, a shortstop with a faster RFD may be able to snag a ball hit in the gap much quicker than an athlete with a lower RFD. When an athlete is required to cover a specific distance quickly, an athlete with a faster rate of force development will be more successful.



Notice: the difference in RFD between Athlete A and Athlete B. Athlete B produces force much quicker than Athlete A. As a result, in sport settings requiring the need to be fast and explosive, Athlete B has an advantage over Athlete A.

Rate of force development can be broken up into two distinct categories: short RFD and long RFD. Short RFD is defined as force produced in less than 250 milliseconds and long RFD is defined as force produced between 250 and 300 milliseconds. Rate of force development is commonly measured in concentric, or shortening, muscle actions. It can also be measured in eccentric, or lengthening, muscle actions.

RFD in these actions can greatly influence jump performance. A vertical jump is completed in roughly 250 milliseconds, so could the vertical jump be a useful tool for information in respect to both short and long RFD? If a correlation between vertical jump and RFD exists, perhaps jump testing may provide deeper insight into outcomes of various training methods. The ability to exert force earlier in movement plays a vital role in many athletic and every day activities (Kraemer et al. 1998).

Numerous studies have found significant correlations between RFD and vertical jump performance:

- Improvements in RFD, increased velocity and net impulse at takeoff resulted in improved vertical jump performance (Cormie et al. 2008, McBride et al. 2010).
- RFD is an important aspect of explosive strength movements, such as jumping with and without load. According to Kraska et al. (2009), "not only does vertical jump demand high levels of force output, but this force must be exerted at a rapid rate to induce the best performances."
- Specifically targeting muscular power, RFD and multi-segmented coordination rather than muscular development alone is recommended because of the positive relationship between peak power and vertical jump (Dowling and Vamos, 1993).
- The contribution of the pre-stretch component involved in jumping creates a strong relationship

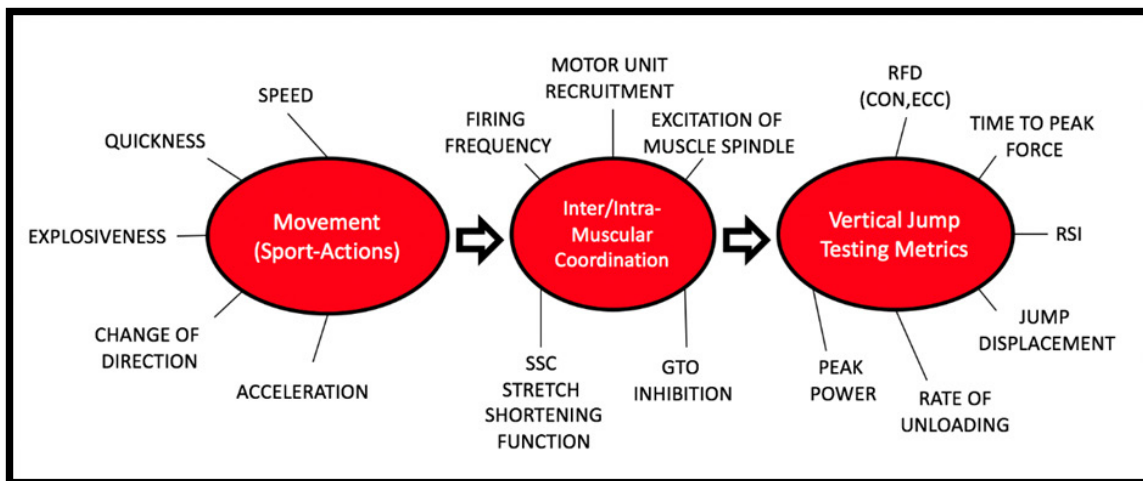
between eccentric RFD and vertical jump performance (Laffaye and Wagner, 2013).

It should be noted that many studies have not been able to establish a significant correlation between RFD and vertical jump performance (Lees et al., 2004; Stone et al., 2003; Kawamori et al., 2006). One possible explanation for this finding is that many of these studies measured RFD from isometric testing, which tests a muscle against an unyielding resistance, which is separate from jump performance, it has been suggested that isometric muscle contractions are not jump-specific enough because no movement occurs during an isometric muscle contraction. Thus, it may not be appropriate to make comparisons of jump performance based on isometric testing, and the specificity of contraction should be included when testing specific populations. Jump specificity is supported by Wilson et al. (1995), who found similarities in contraction times between static jump RFD and sprinting. The following studies have also found a strong correlation between RFD and performance in vertical jump when measurements are taken simultaneously with jump performance: Cormie et al., 2008; Laffaye and Wagner, 2013; Laffaye et al., 2014.

“CMJ performance can be significantly correlated with Eccentric RFD. Eccentric RFD may be a better predictor of CMJ performance than Peak RFD and Concentric RFD.” (Laffaye and Wagner, 2013)

Coordination, Athleticism and the Neuromuscular System

As it relates to sport, coordination could be described as an athlete's ability to synchronize movements smoothly, swiftly and efficiently to perform sport specific actions. The vertical jump is known to be a task that requires high levels of coordination. Measuring jump performance may lead to a better understanding of an athlete's ability to utilize neuromuscular coordination. Neuromuscular coordination is a complicated system made up of two distinct categories: intramuscular coordination and intermuscular coordination.

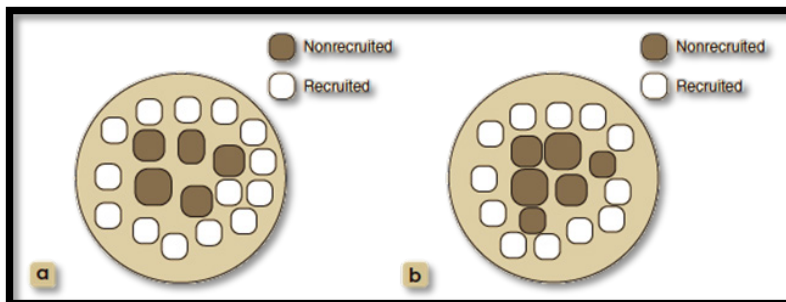


Intramuscular Coordination

Intramuscular Coordination is a term used to describe the coordination of localized muscle recruitment. The process involved with intramuscular coordination works much like the process of learning

how to type. When a person is first learning how to type, keys on a keyboard are difficult to find and putting words together can take a lot of time. Like intramuscular coordination, typing becomes more coordinated and efficient over time and with more practice. Geographical locations of keys become more familiar, and as a result, building words gets quicker. With time and repetition, this process gets more efficient. Improvements to intramuscular coordination happen due to an increase in the frequency of signals the nervous system sends to the muscles. Similar to the time involved with learning how to type, after time is invested into practice and training, the body increases the number of signals it sends to muscles and transmits these signals faster.

Aagaard (2003) and Sale (1998) both published findings that reported specific adaptations within intramuscular coordination following resistance training. Both studies discovered an increased motor unit activation through electromyography (EMG) following strength training, as well as the selective recruitment of fast twitch muscle fibers. These changes can explain the sudden and rapid increase in strength in the early stages of strength training even if there is no noticeable change in the muscle architecture, a concept known as hypertrophy. Aagaard (2003) also reported an increase in afferent neural drive and the increase in firing frequency of motor units after training. From these results, the author surmised that increased firing frequency and neural drive is the reason for increased RFD from heavy resistance training.



“Over time, strength training for intermuscular coordination reduces the motor unit activation necessary to lift the same load, thus leaving more motor units available for higher loads.” – Bompa, 2015

Duchateau (2014) states the primary cause of early improvements in RFD from resistance training is a result of increases in the discharge rates of signals from the central nervous system. Changes to intramuscular coordination seem to be highly sensitive to both heavy and ballistic resistance training (Aagaard et al., 2002; Aagaard, 2003; Aagaard, 2010). Studies show that with training, improvements can be made in firing frequency, activation of more motor units, and an increase in the activation of fast twitch muscle fibers at lower thresholds.

Intermuscular Coordination

Intermuscular coordination is the organization of many different muscle groups working together in sync to create faster and more fluid movement. Take, for example, a conventional arm curl exercise: as the elbow bends, due to a contraction of the biceps, if the triceps are working to extend the arm at the same time, movement at the elbow becomes difficult. Depending upon the intensity of these opposing forces, movement speed is negatively impacted and the elbow joint could potentially become completely immobilized.

Intermuscular coordination operates similarly to how both the gas and the brake pedals coordinate in a vehicle. If the accelerator and brakes are being applied simultaneously, the two pedals create opposing tensions on the vehicle. These tensions increase the resistance placed upon the mechanical components of the vehicle. The increase in resistance impairs quality and reduces movement speed. To drive the vehicle, it takes a combination of both the gas and the brake

Race car drivers arrive at the racetrack many days prior to the day of their big race. They spend these days in practice, putting in countless hours on the track, learning its unique features. As drivers make their way around the track, they are deeply engaged in learning and tuning their abilities in accordance to the needs of the track. As the drivers navigate the winding turns and the high-speed straightaways, they learn how much acceleration and how much braking is needed to improve their efficiency. Much like the driver learning the proper mixture of acceleration or braking, the body learns the necessary intensities and sequences of contraction needed from individual muscles to efficiently complete any given movement task.

Gamble (2015) explains intermuscular coordination as “the recruitment of respective muscle groups involved in a movement and the relative timing of activation between these specific muscles. This includes agonist muscle groups directly involved in producing force, the opposing agonist muscles, and synergist muscles that assist with producing the desired movement without directly contributing to force production.”

A significant adaptation resulting from resistance training is the refinement of the recruitment pattern and coordination of the different muscle groups involved in executing movement. For instance, reduced co-contraction is an important adaptation of intermuscular coordination and allows improved expression of force during movement. Bobbert (1994) explored a simulation of the muscles involved in vertical jumping. The author found that vertical jump height may not improve even if the individual muscle groups involved improve their force generating capacity individually. This finding highlights the importance of including exercises that have a similar recruitment pattern as the skill that is trying to be enhanced. As Young (2006) states, positive transfer can occur if resistance training reinforces the optimum muscle-activation patterns that are required in the execution of the sport skill. Changes to intra- and inter-muscular coordination feature the plasticity of the neuromuscular system, showing that with properly planned interventions, adaptations are beneficial to sport performance can occur.”

Jump Performance and Neuromuscular Function and Fatigue

In recent years, many investigations have explored the relationship between jumping and neuromuscular fatigue. Thorland et al. (2008), Ronglan et al. (2006) and Gathercole et al. (2015) all investigated vertical jump as an assessment of neuromuscular fatigue. Each of these studies found vertical jump to be a valid measurement of neuromuscular fatigue across both short- and long-term periods of time. These investigations provide sound evidence in support of the countermovement jump being a reliable and repeatable assessment when evaluating neuromuscular function.

Gathercole (2015) found that after 72 hours of high-intensity game simulations, athletes could maintain peak vertical jump heights. When fatigued, athletes change their jump technique. Generally, this

means they take more time to produce the force necessary to achieve the same peak vertical jump heights. This change in jumping strategy has been attributed to fatigue of the neuromuscular system.

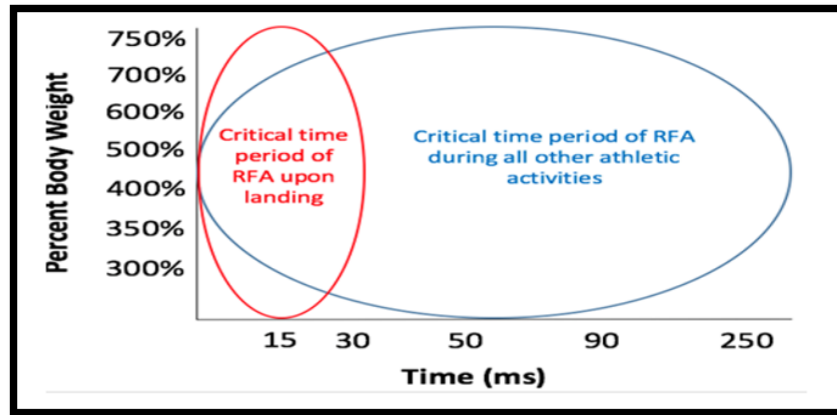
Gathercole also found significant decreases in RFD in jump assessments in the fatigued athletes. This insight suggests that jump testing can be sensitive to changes in intramuscular coordination. Additionally, the author showed that eccentric muscle function is highly sensitive to fatigue. This impairment could signal a change in intermuscular coordination resulting in an alteration or compensation in movement. It is concluded: fatigued athletes can maintain jump heights, but they change their jump technique.

Muscular force is a product of the rate at which neural impulses are discharged from the motor cortex. Neural discharge rates have been found to be a primary contributor for an increase in muscular strength during the early stages of strength development in individuals at the start of a resistance training routine. Kosarov et al. (1979) discovered a positive relationship between the level of muscular tension and neural firing frequency within the biceps brachii. With more intense muscular contraction, the neural firing frequency was also higher.

RFD and Injury Prevention

High performance athletes are often compared to high performance sports cars in analogies and metaphors. Coaches want athletes who have the speed of a Ferrari. Such cars can go from zero to 60 miles per hour in under three seconds, handle well and have a top speed of 217 miles per hour. Yet what happens if an athlete has the speed of a Ferrari and the brakes of conventional mid-sized sedan?

Sports often require athletes to overcome large forces in very short periods of time. These situations usually take place in the form of high-intensity deceleration-type actions: changing direction, landing and stopping are very common forms of high-intensity deceleration-based movements. These types of movements are common place in many sports and take place potentially hundreds of times during game scenarios. Non-contact sport-related injuries have been attributed to an inability to recruit muscles fast enough to provide the strength needed to stabilize joint structures during high-intensity sport situations. Such actions require the body to overcome forces that can range between 3.5 and 7.1 times an athlete's body weight (Gross & Nelson, 1988). Additionally, case studies have shown higher accepted loads in sports like volleyball and gymnastics. As athletes reach higher velocities, the intensity of these loads increase exponentially (McNitt-Gray, 1991). To prevent injury, athletes must be able to overcome such forces in time periods of less than 250 milliseconds. The likelihood of injury is greater when athletes are unable to successfully accept these high forces, when the neuromuscular system lacks the coordination, and when RFD is slow. As a result, the movement strategies become altered and joints are asked to perform in positions that make them very susceptible to injury. Although the ability to produce high force is important, perhaps the most important factor for injury prevention in sport is the ability to decelerate against the forces in less than 250 milliseconds (Reiser, Rocheford & Armstrong, 2006).



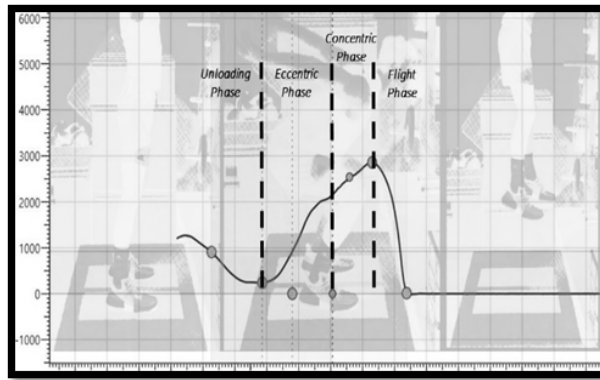
This diagram represents the relationship between a critical time window and the resistances that are placed upon the body during high-intensity sport decelerations. This diagram refers to eccentric rate of force development at rate of force acceptance. Resistances in sport can exceed 12 times an athlete's body weight in less than 90ms (Jeronimo 2016).

Human muscle has an inherent elastic property. This elastic component within muscle enables athletes to be faster and more explosive by taking advantage of stored potential energy. During high-velocity sport maneuvers, these elastic characteristics assist in creation of more force. When a muscle is lengthened, or put on a stretch, it generates tension. This tension is elastic in nature and it has a mechanism that works like a sling shot. When the sling is drawn back, the sling creates stored potential energy. When the sling is released, the object rapidly shot in the opposite direction. The term used to describe this in human muscle is the stretch shortening cycle (SSC).

The SSC occurs when a rapid eccentric (lengthening) contraction is immediately followed by a rapid concentric (shortening) contraction. SSC actions are commonplace in sport and they help contribute to movements such as running, jumping, changing direction, and many others. Movements involving the SSC have been shown to be more powerful and dynamic than actions based on concentric contractions alone (Komi, 2000).

A jump test known as the Reactive Strength Index (RSI) is an easy way to assess SSC function. RSI is collected during a drop/depth jump and is a test that provides an objective measure. The score is created by dividing athlete jump height by ground contact time involved with performing the jumping task. An athlete can improve their RSI score by increasing jump height, decreasing contact time or both (Flanagan and Comyns, 2008). Ground contact time is a valuable metric that may provide insight regarding fatigue and help determine an athlete's status. Regardless if jump heights do or do not change, RSI may bring perspective to possible changes in neuromuscular function.

The countermovement jump is another test that could possibly be used to assess SSC function. Cormie et al. (2010) looked at changes in jump performance following strength and power training. From their observations: "The foundation of the observed changes is believed to be associated with specific changes to jumping mechanics. Force throughout the eccentric phase changes significantly after training (i.e., minimum force, peak eccentric force, and eccentric RFD), but the range of motion during the eccentric phase remain unchanged. Therefore, the stiffness of the system increased, as indicated by the observed data for both groups following training."



Increases in stiffness allow for greater reliance on SSC. This finding supports Cormie et al. (2009), which illustrated greater eccentric RFD adaptations occurring from training loads selected to optimize power, which then lead to an increase in concentric velocity at jump takeoff. The researchers concluded that improvements in peak performance variables were a result of an increased ability to hold higher stretch loads following power-based resistance training.

The SSC aids in establishing an adequate length-tension relationship in which to produce propulsion (Dal Pupo et al., 2011). Improving an athlete's stretch load tolerance promotes the maintenance of an optimal length-tension relationship. A high stretch load capacity enables a higher storage of elastic energy, enabling more efficient and more powerful movement with less metabolic strain.

Wilson and Flanagan (2008) reported that when SSC is optimized, the time between eccentric and concentric muscle actions is kept to a minimum. This mechanism results in higher power output as well as increased RFD. Similar to actions measured for RFD, SSC actions can be broken up into two categories: fast (less than 250 milliseconds) and slow (greater than 250 milliseconds). Current research suggests performance enhancement in slow SSC activities is more reliant on neural potentiation of contractile machinery during the eccentric phase (Jensen et al., 2008), while fast SSC activities rely more on the transfer of stored elastic energy in addition to an increase in neural drive. When performing SSC actions, the eccentric/concentric coupling of muscular contraction produces a more powerful contraction which results from purely concentric muscle actions. (Flanagan and Comyns 2008)

Mooney et al. (2012) investigated the impact of neuromuscular fatigue on match play in Australian rules football. One primary finding of this study was that contraction time was significantly affected when fatigue was present even if flight time was maintained. This prolonged contraction time highlights decreased SSC capability as well as lowered RFD.

Vertical Jump and Implications for Speed, Quickness and Change of Direction

Prior to determining if the vertical jump is an appropriate predictor of acceleration, maximal speed, and change of direction, it is important to understand the underlying mechanisms behind these physiological abilities.

Acceleration, maximum sprint speed and change of direction efficiency are proven key performance indicators for many different sports. Numerous studies have investigated the relationship of jump metrics as it relates to sport-specific motor tasks, and a significant relationship has been established between jump performance and sport-specific motor tasks. This relationship can be traced to the underlying muscle properties involved when jumping, sprinting, and changing direction (Barnes et al., 2007). This relationship was supported by Dowling and Vamos (1993). The authors concluded that due to the strong relationship between peak positive power and vertical jump, targeting muscle power, rate of force development, and multi-segment coordination rather than addressing muscular development alone is advantageous in the physical preparation of athletes.

Cardinale et al. (2011) discusses the underlying principles for change of direction performance: “if utilized effectively, the stretch load provided by the eccentric action can contribute greatly to the production of force in the following concentric action of the muscle. Considering that SSC function is influenced by the rate, magnitude, and load of stretch, and is dependent on a short delay between the eccentric action and initiation of the concentric action, well-developed technique in the deceleration-acceleration sequences of change of direction tasks will allow the athlete to change direction faster.”

Spiteri et al. (2014) further supports improvements in change-of-direction skill when eccentric muscle strength is complimented by an optimized SSC. Additionally, Barnes et al. (2007) found the ability to transmit force vertically as a key factor in change of direction ability and states vertical force application may be a limiting factor in change of direction performance.

Several studies have established strong relationships between jumping performance and athletic tasks such as speed, quickness, and change of direction. The following findings support jump performance as a key performance indicator of speed, quickness, and change of direction:

- Barnes et al. (2007) reported a significant correlation between countermovement jump height and change of direction, in addition to discovering that jump height could explain 34 percent of the variance of change-of-direction performance.
- Marques et al. found a significant correlation between 5-meter sprint time and countermovement jump.
- Wilson et al. (1995) and Young et al. (1995) both linked RFD at 100 milliseconds to both jump and sprint abilities.
- Wisloff et al. found a correlation between maximum strength, vertical jump, and 0 to 30 meter sprints in an elite soccer population.
- Sawyer et al. (2002) found vertical jump performance to be the strongest predictor of football playing ability. The authors go on to surmise that vertical jumps may be an assessment of the athlete's ability to properly time the sequential movements of the skill to optimize the summation of forces necessary for achieving maximum jump height.
- Baker et al. (1993) found a positive correlation between how football coaches ranked player performance to vertical jump performance. Their findings showed a relationship between jumping ability of starting players versus non-starting players across all positions.

Jump performance metrics build more value over time. A jump metric database is a very powerful tool and these types of databases provide insight on potential trends in performance. When referencing an athlete's jump history, jump performance may indirectly provide insight on an athlete's level of physical preparedness. When compared to previous trends in testing metrics, the recognition of large drop offs or rises in jump performance may be associated with potential changes in an athlete's fitness.

A Review of Vertical Jump Testing Options

Jump ability can be tested by a variety of different apparatuses, each of which has unique pros and cons in addition to varying degrees of sophistication. Price, population, space, time, flexibility, quantity and quality of data are all unique factors that need to be taken into consideration. When testing vertical jump, it is important to always be consistent with testing equipment being used. With numerous ways available to collect jump data, almost all methods can be considered valid if the measurement systems involved are consistent. If a measurement system or device is inconsistent and lacks reliability and validity, then loses its value.

Jump and Reach Equipment



The jump and reach test may be the least expensive and simplest system to assess vertical jump. This test can be performed with a wall, a tape measure and some hand chalk. Athletes can simply chalk their hands, jump alongside a wall and touch at the peak of their jumps. The chalk marks on the wall can allow the practitioner to then calculate vertical displacement. These pieces of equipment are easy to use, set up and transport, allowing testing to be done in multiple settings. Whether on a court or a field, this device can be set up and incorporated quickly into a practice session.

Multiple variations of vertical jumps can be performed using jump and reach equipment. Approach jumps, which are used in basketball and volleyball, cannot be performed on devices like contact mats and force plates. The jump and reach test can allow a coach to measure maximal displacement in such sport-specific jumps.

It should be noted that utilizing an arm swing in vertical jump measures can change the kinematics of the jump increasing takeoff velocity between 5 and ten percent (Lees et al., 2004; Harman et al., 1990). This is important to note because the arm swing can introduce variability. This variability may be limited in a jump-specific population, such as volleyball, and might be avoided if working with a non-jump specific population when lower body power assessment is the goal of testing. An additional drawback can come from the measurement of the individual reach introducing possible tester error. Moreover, the jumping surface is important to consider as each surface can amplify or dampen ground reaction forces and cause changes in jump height. A final source of variability can come from an athlete being able to stretch the shoulder during the reach portion of the vertical jump (Glatthorn et al., 2011). It may be necessary to calibrate jump and reach systems periodically as changes may occur within the system.

Contact/Jump Mats



Contact mats are the next in line of price and simplicity. They provide the practitioner with a little more information than only jump output. Contact mats can provide jump output as well as a contact time when performing repeated jump assessments. These systems measure the amount of time that athlete is in the air. Flight time is then calculated into jump displacement. This timing system can allow coaches to compare repeated jumps to single response jumps. This gives the practitioner the ability to gain insight into the athlete's ability to utilize their SSC. These units are also able to be transported easily but require a firm surface on which to be placed. Contact mats are easy to use, do not require adjustment and allow for large numbers of athletes to be tested quickly and efficiently.

Contact mats have also been validated by force plates and 3D camera systems in measuring jump displacement (Leard et al., 2007; Whitmer et al., 2015). Whitmer et al. (2015) showed that while the contact mat is valid measurement for moderately trained athletes, it may over-estimate jump displacement in highly trained power and speed athletes. Picking up the knees, piking, or landing in deep squat can cause an increase in flight time measurements without an actual change in jump displacement. As such, jump and landing strategy should be carefully monitored when using any system that calculates jump displacement through flight time.

Inertial Accelerometers



Inertial accelerometers have gained popularity as velocity-based training has become more prevalent. These devices can measure both peak and mean velocity as well as calculate power based on the load and the velocity in which it is propelled. Wearable versions of these devices are validated in their measurement of jump displacement (Riley and McMahon, 2016; Klinik and Clinic, 2010). Wearable inertial accelerometers test and provide data on a multitude of jumps (including Counter Movement Jumps, Squat Jumps, Loaded Jumps and RSI).

Another feature of this system is the ability to get real time feedback, as well as possibly have information stored in the cloud. The price of these units may be less expensive than contact mats, but they may require the need to purchase multiple devices, accessories to display the information (such as a tablet or a smartphone), and will require users to input individual information about each athlete (such as body mass). Multiple data points can be taken from the measurements gathered, such as peak power, mean power, peak velocity, mean velocity, and RSI.

Possible drawbacks of these systems can be the inconsistent placement of the devices on the athletes and possible variations in jump strategy. Placement of the device should be kept consistent

each time the device is used. Ideally, sensors should be placed as close to the center of mass as possible in order to not record other possible variation in movements during the testing session. Because these systems record displacement of the sensor jump when measuring jump height and velocity, an athlete's jump technique can significantly impact the validity of measurement. If, from repetition to repetition, athletes change the depth of their countermovement prior to jump take off, a larger discrepancy in displacement will be recorded. This will lead to an inaccuracy in actual jump heights. Additionally, this may also occur when athletes are fatigued. As this review has investigated, athletes alter their jump techniques as they become more fatigued. This change in jump strategy will provide inaccurate data when measured with most wearable systems.

Some wearable jump systems have begun to calculate load and energy expenditure based off jump counts and jump volumes collected during training sessions. Many of these systems use a wide range of calculations to interpret information. When these calculations are used, it is important to ensure all variables are accurate and accounted for. If a variable is incorrect or not included (for example, an athlete's body mass), all the collected data should be considered, with the understanding that the data does not paint a perfect picture. One plausible error would be calculating power or energy expenditure without the individual's body mass as part of the calculation. These systems are portable and can be used on multiple surfaces allowing flexibility to the coach. Riley and McMahon did report that power outputs from these devices may be over reported when compared with force plates, but changes may be valid when jumps measured in the same manner are compared to each other.

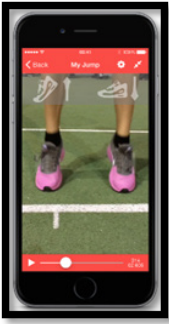
Infrared Platforms



Infrared platforms may be the most versatile device for measuring jump height. This system can be used on almost every surface with an exception for sand-based surfaces. It allows for measurements of horizontal jumps, sprints, and change of direction. Utilizing light sensors, the bars placed on the ground detect interruptions between the transmitter and receiver. This allows the system to detect flight and contact times within a thousandth of a second, providing greater accuracy when compared to switch mats. These systems are also able to sync with video to provide an integrated measurement of kinematic (movement) and kinetic (force) information. They have been validated as a measurement of vertical jump displacement (Glatthorn et al., 2011), and as a way to measure stride length in sprinting (Glazier and Irwin, 2001). This system provides coaches with vertical jump displacement, contact time, and power of jump. The system allows for a variety of evaluations and can be of great value for a coach looking to evaluate horizontal and repeat horizontal jump variation.

High-Speed Cameras

This system records videos of jumps, often in slow motion, to capture the flight time of the athlete. From these recordings, flight time equations can be used to predict vertical jump displacement. These systems are becoming more accessible through the launch of mobile applications, through which the tests and calculations can be performed.



Balsalobre-Fernandez et al. (2015) tested the validity of one such mobile application that utilized a camera phone against force plates. The authors concluded that the mobile application was a valid tool to measure vertical jump displacement for all populations. When utilizing this method, strict standards should be encouraged during both the propulsive and landing phases to ensure that a valid measurement is recorded. High-speed camera systems are also being utilized to capture velocity and power metrics during resistance training, according to Balsalobre-Fernandez et al. (2014). These systems have a wide range of prices, but can be purchased for around ten U.S. dollars. This allows for a low-cost and highly transportable system that can provide coaches valid measurements of vertical jump displacement.

Force Plates



Force plates are considered the gold standard of assessing an athlete's ability to vertically jump. These systems can carry a large price tag, and also often require a skilled technician or software to present the information in useable way. There are commercially viable smaller and more portable force plates available, but we most often find force plates in an academic or laboratory setting.

This is the first system discussed that allows for the assessment of the eccentric portion of the jump and provides in-depth kinetic information on the jump strategy utilized by each individual athlete.

The primary purpose of most vertical jump-capturing tools is to assess the jump height, but force plate systems provide detailed insights into both takeoff metrics and landing metrics. With this increase in insight, force plates help paint a more complete picture of neuromuscular function. Force plate systems can provide the practitioner with hundreds of data points, which can take a skilled expertise to analyze.

Utilizing a dual force plate system allows for the identification of asymmetries through various portions of the jump. This asymmetry information provides possible identification of an athlete's predisposition to injury (Jordan et al., 2014). This information may also allow for the creation of a biologically driven return-to-play protocols, which allows the rehabilitations to be driven by the individual and not a pre-determined timeline. The analysis of both eccentric and concentric portions of the jump can allow for better decision making as well as monitoring during the training program. If synchronized with video analysis, a completely integrated look at the kinematics and kinetics of an athlete may be explored. However, it is worth repeating that the amount of data can be overwhelming, and if not managed correctly, could hinder rather than help the practitioner.

While no perfect system exists, the ideal system would be a combination of multiple aforementioned systems working together simultaneously. An ideal system would utilize dual force plates, a high-speed camera and a 3D motion capture system. The integration of these systems would allow a practitioner in-depth information on both the kinematics and kinetics during the vertical jump.

High-speed camera footage and 3D motion capture provides important time stamps. The force time curves collected by the force-plates allows each frame of movement to be analyzed in conjunction with the forces acting on the athlete at specific points in time. Such a system can collect both kinematic and kinetic information, allowing for the monitoring of jump strategy changes and adaptations from training and fatigue. This information can also be helpful in the analysis of force asymmetry that can be detected by dual force plate systems, allowing for possible understanding of the cause of the force asymmetry through analysis of the movement or vice versa.

Jump Assessment Technique

When testing the vertical jump, attention should be paid to the technique employed by an athlete. Techniques vary and can include use of arm swing, no arm swing with hands on hips, and no arm swing with hands holding a dowel (similar to back squat position). These techniques have all been shown to be valid measurements in testing vertical jump displacement when tested against themselves. Each variation presents possible changes in jump strategy and need to be selected with the knowledge of each technique possibly introducing its own specific variations within the tested population. Once a testing technique is selected, it is very important to maintain consistency when testing to ensure the collection of valid data. Comparison of data collected from different techniques is also not recommended as performance from technique to technique may vary greatly.



The inclusion of arm swing during jump testing can greatly affect jump displacement. Arm swing during the downward phase of the jump increases negative force built up during the eccentric contraction of the countermovement. This energy, if transferred efficiently, can be used to potentiate forces during the concentric phase of the jump, increasing velocity at takeoff and improving vertical jump displacement (Vanezis and Lees, 2005). As much as ten percent of the velocity at takeoff can be attributed to arm swing (Harman et al., 1990). It is also theorized that force created by the upper body during the upward arm swing can be used to assist in pulling the body upward during the concentric phase of the jump, contributing to the increased velocity at takeoff.

Arm swing may also alter the time of the contraction, allowing for optimal velocity in which force can be produced by the muscles of the gluteals and quadriceps (Harman et al., 1990). By swinging the arms, an athlete augments the ability of the muscles around the hip and knee to forcefully extend during the propulsive phase of the jump. This is done by placing the hip and knee joint in an optimal force producing angle as well as limiting the extension of the torso (Feltner et al., 1998). The arm swing may also produce variability in jumping technique, which may introduce error when looking at test-to-test changes in jump performance. This technique may be the most viable option for practitioners that work with jump-specific populations in which an arm swing is utilized, as the technique employed during testing may be closely related to the specific sport action.

By eliminating arm swing, practitioners may be able to limit variability involved with jump assessments. Variability within subjects will decrease with familiarity of testing protocols over time, but elimination of arm swing can also change jumping strategy by increasing the role of hip extension in order to maximize jump displacement. Feltner et al. (1998) reported increased torque at the hip joint during the propulsive phase when performing countermovement jumps without arm swing. This is often seen in jumps performed with a dowel across the back in which athletes often utilize a hip-based jumping strategy (hinging motion) in order to attempt to maximize jump height. This strategy may alter the athlete's normal recruitment pattern when performing jumps outside of testing. It may also increase the amount of horizontal force produced. Whatever jump technique chosen during testing, it is important to make sure that technique is used every testing session.

Considerations for Jump Assessments

Regardless of the system or strategy chosen to assess athletes, many factors that must be taken into consideration prior to assessing vertical jump data.

- First and most importantly: when assessing an athlete's maximal abilities, maximal effort during the assessment trials is a must. If an athlete does not provide a maximal effort during the jumping effort, the validity of the test is substantially diminished.
- Vertical jump is highly sensitive to fatigue and, if tested daily, the information collected can be highly variable. It has been shown that jump height can vary daily and in between jumps in short assessment period. This is based on a variety of factors including low amplitude fatigue (Fowles, 2006).
- When using jump data to track adaptation from resistance training, understand that jump improvement may not be linear and decreases in performance may be expected based training and competition volume.
- When tracking performance trends, it is important to take a long-term approach. Comparing month to month information may provide an incomplete perspective. Each year is cyclical based on the demands and preparations for sport season. As a result, it may not be appropriate to compare data points from consecutive testing sessions. If applicable, it is suggested to compare data points based upon 12-month time cycles.
- Practitioners must also be aware of the population that they are working with. In sports that have high volumes of jumping and landing, such as volleyball and basketball, athletes will be exposed to high volumes of jumps and impact loads from landing. As a result, performing extra jump volume for testing purposes may create more cost than benefit.
- Warming up for jump testing is also a very important variable as maximal jump performance may not be possible if tissue and systems are not in their daily optimal states.
- It is important to consider contraction and ground contact times involved with vertical jump to better understand neuromuscular function. Many researchers found athletes tend to change their jumping technique when they jump in a fatigued state. Fatigue may not impair jump height, but it may impair the speed of the jumping action. Practitioners who assess jump height alone to assess fatigue may be missing the valuable information they are interested in.

Improving the Vertical Jump

The connection between vertical jump and neuromuscular function has been discussed at length, but does a relationship exist between improvements in vertical jump and improvements in neuromuscular performance? What steps can be taken to improve vertical jump ability?

The goal of any properly designed training program is to be able to transfer the skills of strength, speed, and robustness into the sport. Vertical jump can be recognized as an assessment strategy for better understanding the transfer from general to specific types of training. Improvements in vertical jump result from an increase in the athlete's velocity at takeoff. This section will provide some examples and strategies of best practices for improving vertical jump.

Athletes who lack the ability to produce force would be best served by increasing their maximal force-producing abilities. This becomes even more apparent when looking at the ability to produce force in relationship to an athlete's body mass. The relationship between vertical jump and maximal strength is unclear, but when the relationship between vertical jump and strength that is relative to an athlete's body mass is examined, evidence points to a significant correlation between jump performance and relative strength values. Swinton et al. (2014) looked at the relationship between sprinting, jumping, and change of direction tasks and was able to show that "the strongest correlations with performance measures were obtained for maximal strength scores scaled relative to body mass. Haff and Nimphius (2012) reported that strength should be a foundational component of a program designed around increasing power, as stronger athletes have been shown to express higher power outputs. A maximal strength level of squatting twice an athlete's body weight is looked at as an appropriate benchmark for athletes to achieve to be able to optimize the use of more power-based training methods (Stone et al., 2003; Nimphius and Haff, 2012). If an athlete is unable to produce and absorb the forces involved with overcoming their own mass – such as overcoming the momentum of body mass that is generated during high speed sporting situations and overcoming the vertical gravitational forces involved with vertical deceleration motions of body mass – vertical jump performance will suffer.

Jumping is a very rapid and violent maneuver. As a result, high levels of explosive strength are ideal to help athletes maximize their vertical jump performance. Two modalities have been proven to increase explosive strength. One is Olympic weightlifting movements, in addition to their derivatives, and the second is ballistic weight training (such as loaded jump squats, squats jump and bench throws). Olympic weightlifting has been investigated and shown to be an effective training strategy for improving vertical jump. The success of weightlifting activities in vertical jump improvement is believed to be a result of the close relationship in movement patterns between the jumping motion and weightlifting motions (Carlock, 2004). These similar patterns of movement and neural demands, as well as the increased load on the system due to the weight of the barbell, promote better jump ability (Hackett, 2017). Ballistic exercises such as the loaded squat jump have been highly correlated with improvements to countermovement jumps and spike jumps within a specific volleyball population (Sheppard et al., 2012). Ballistic weight training has been shown to improve neural drive through increased firing rates (Aagaard, 2003). For more highly-trained athletes, accentuated eccentric squat jumps have shown to increase vertical jump (Sheppard et al., 2008). Additionally, Sheppard, Newton and McGuigan (2007) also found that when greater than normal eccentric loads were added into vertical jumping task, the acute response results in increased jump height and improvements in kinetic and kinematic values.



Several studies have used vertical jump metrics to validate and evaluate the impact of resistance training routines. They have found that:

- Improvements in RFD are multifaceted and are a result of changes in muscle architecture and improvements in neuromuscular efficiency (Aagaard, 2014).
- Significant changes in peak power, eccentric peak force, peak velocity, concentric and eccentric RFD, and velocity at takeoff have been found in athlete's, immediately following training sessions targeted on power development (Cormie et al., 2008).
- Significant improvements in maximum force and RFD at 100 milliseconds have been found in both the counter movement jump and squat jump following training based around individualized loads to elicit peak power during training (Marion et al., 2016).
- Vertical jump provides good insight regarding RFD. Significant changes have been noticed in RFD and impulse following a simulated handball match (Thorland and Aagaard, 2008). These findings show that vertical jump performance can be used to track long term as well as acute changes to rate of force development. This information strongly suggests that vertical jump performance is a valid measurement for assessing RFD.

Markovic (2007) defined plyometric training as the performance of movements involving a high-intensity concentric contraction immediately after a rapid and powerful eccentric contraction. Primary positive adaptations resulting from plyometric training is attributed to an increased efficiency during rapid eccentric loading and an increased tolerance to higher stretch loads. This increase in efficiency and the improvement of stretch thresholds lead to a rise in the potential of concentric muscle actions (i.e., better acceleration) when jumping (Cormie, 2009).

When deciding which specific exercises to perform in a training setting, learning more about the direct impact of specific plyometric exercises is important. Villarreal et al (2009) has discovered a correlation between the contraction times of plyometric activities and their specific influence on jump performance.

"In general, low-intensity/high-speed movements such as plyometrics improve velocity, high-intensity/low-speed movements such as heavy squats promote force production, and weight-lifting movements augment both force and velocity." – Darmiento 2012

Sheppard et al. (2010) also looked at assisted plyometrics where decreased contact time provides an over-speed training stimulus to the vertical jump. Sheppard proposed that assisted jumping can help leg extensor musculature develop force. In addition, undergoing an increased rate of muscle shortening (in conjunction with more traditional strength and conditioning activities) may have promoted the improvement in jump height of the volleyball players in this study. These methods have been proven to work when placed in a properly programmed, progressed, and periodized physical preparation program. It is perhaps best summarized by Darmiento (2012), which explained that "in general, low-force/high-speed movements such as plyometrics improve velocity, high-force/low-speed movements such as heavy squats promote force production, and weight-lifting movements augment both force and velocity."

Conclusion

- After thorough review of the relevant literature regarding the efficacy of the vertical jump as a performance assessment tool, it is concluded: using vertical jump for both testing and training can be an effective way to identify, predict and improve key variables involved in many different sporting tasks. From the evidence provided, it is possible to say that metrics generated from vertical jumping continues to be a good assessment tool for coaches, sport scientists and other sport providers.
- Information captured from jump testing can give an increased ability to dissect, decipher and identify athletes' specific strengths and weaknesses.
- Jump testing can be a powerful tool to better understand an athlete's maximum speed, ability to accelerate, and ability to change direction quickly.
- Regardless of situational constraints, vertical jump information can bring valuable insight on athletes and can serve as an important resource when designing or modifying strength training prescriptions.
- These findings support the use of vertical jump testing across a wide range of sporting populations.

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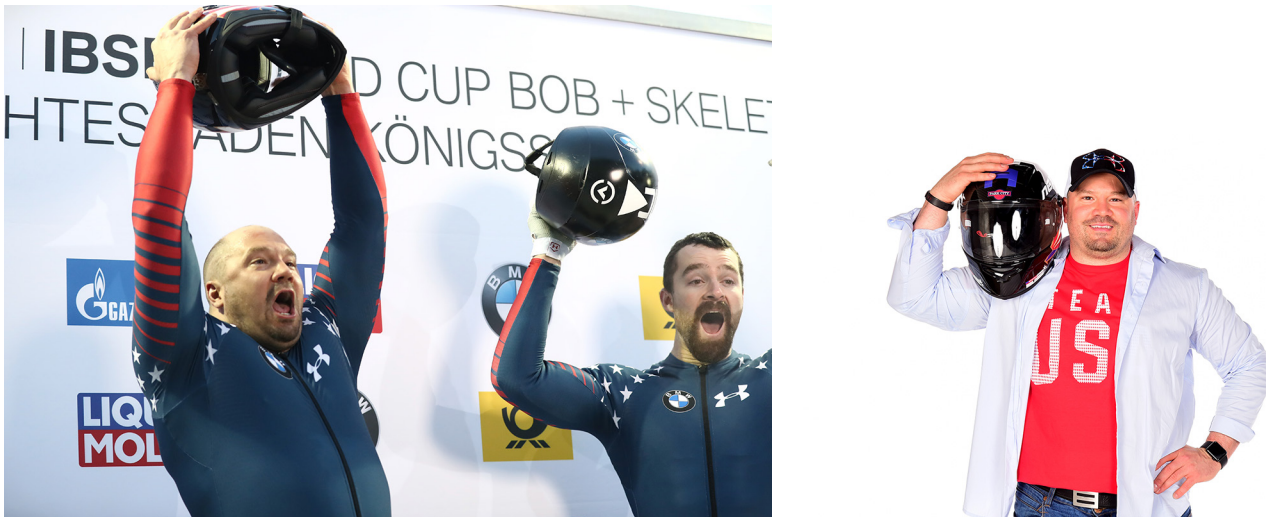
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LONDON, ENGLAND - JULY 09: Vashti Cunningham of the United States competes in the Women's High Jump during the Muller Anniversary Games at London Stadium on July 9, 2017 in London, England. (Photo by Dan Mullan/Getty Images)

Team USA athletes and coaches often seem larger than life - more than human. They are cheered, idolized, and imitated by many for their incredible accomplishments. They continue to push the boundaries of human performance by going higher, faster, and stronger. Though sometimes, we're reminded that they are - in fact - human. When they leave us, they leave a large void in our family.

Team USA lost two members of our family recently: Steven Holcomb, Olympic and World Champion Bobsledder, and Ric Suggitt, former Team USA Women's 7s Rugby Coach. We would be remiss if we didn't mention their passing. In their own ways, they were both larger than life. They leave a legacy of hard work, determination, athletic excellence, and friendships. They have been and will continue to be missed dearly. Our hearts are with their families, friends, and teammates. They will forever be part of Team USA.



(L) KOENIGSSEE, GERMANY - JANUARY 28: Bob pilot Steven Holcomb of USA celebrates with his team mate Carlos Valdes (R) after the 2nd run of the 2-man Bobsleigh BMW IBSF World Cup at Deutsche Post Eisarena Koenigssee on January 28, 2017 in Koenigssee, Germany. (Photo by Alexander Hassenstein/Getty Images For IBSF)

(R) WEST HOLLYWOOD, CA - APRIL 27: Bobsledder Steven Holcomb poses for a portrait during the Team USA PyeongChang 2018 Winter Olympics portraits on April 27, 2017 in West Hollywood, California. (Photo by Harry How/Getty Images)



Coach Ric Suggitt, former Team USA Women's 7s Rugby coach (Photo by Michael Lee/KLC Fotos)

On the cover: LONDON, ENGLAND - AUGUST 12: (L-R) Courtney Frerichs of the United States, silver, Emma Coburn of the United States, gold, and Hyvin Kiyeng Jepkemoi of Kenya, bronze, pose with their medals for the Women's 3000 metres Steeplechase during day nine of the 16th IAAF World Athletics Championships London 2017 at The London Stadium on August 12, 2017 in London, United Kingdom.

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