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April Ross of USA in action with Kerri Walsh of USA during the final match against during Chantal Laboureur and Julia Sude of Germany during the FIVB Beach Volleyball World Tour Fuzhou Open on April 24, 2016 in Fuzhou, China. (Photo by Zhong Zhi/Getty Images)

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Message from the Chief of Sport Performance

Alan Ashley

Welcome to another exciting issue of Olympic Coach in this Games Year. We are in the midst of qualifying Team USA athletes for the Olympic and Paralympic Teams and making our final preparations on the group for the Rio 2016 Olympic and Paralympic Games. August is approaching quickly and Team USA athletes, coaches and high performance staffs are preparing for the opportunity to maximize their performances on the world's greatest stage in Rio de Janiero this summer.

Team USA has a lot to defend in Rio this year. Over the past four years the competition has become even tougher making the preparation and planning for Rio de Janeiro Games even more important. Team USA had a great performance in London and we have seen many outstanding performances since then in World Championships, World Cup, Grand Prix and Diamond league events. It is amazing to watch the success of teams such as women's Water Polo, Men's and Women's volleyball, women's triathlon, the men's epee Fencing team and the continuous improvements in all the disciplines of Wrestling. We have also witnessed great comeback stories in swimming, newcomers in track and field, and an overall surge by many of our best athletes, supported by great coaches and support staff - as we count down to the beginning of Rio 2016 Games.

We are less than 100 days out from the Olympic Opening Ceremony and now it's more important than ever to keep focused and make sure we are doing everything possible to achieve competitive excellence in Rio and give our best athletes a chance to inspire the world.

Elite Athletes and Sleep: How Much are they Getting? What Happens when they Don't Get Enough? Why Short Term Sleep Extension might be a Performance Enhancement Strategy

Lindsay Thornton, Senior Sport Psychophysiologist, United States Olympic Committee

Sleep plays an important role in the recovery and health of athletes. Sleep supports healthy cognition, mood, metabolism (appetite and weight), tissue repair, immune function, among other important processes in the brain and body. Given the importance of the 2016 season, athletes and coaches are taking a careful look at the details of athletes' daily lives and determining what might be modified to further address performance. This article will review the literature of what we know about the amount of sleep elite athletes get during training and competition, what happens when athletes don't sleep well around competition, the costs associated with getting too little sleep and strategies to address insufficient sleep. A previous *Olympic Coach* (October 2013, Sleep Basics for an Olympic Coach) article detailed sleep needs, what happens when we sleep, and sleep extension and restriction findings. Athletes should be aware that consistent, adequate sleep allows them to wake up a smarter, stronger version of themselves (and in a slightly better mood).

Sleep During Training

Getting insufficient sleep after training short-changes the learning process that the brain goes through to try to download information learned (refinement of technique, new skill development, observation of new patterns, and so forth that are the learning products of training) that day and retain the information in neural networks. During sleep, the brain undergoes important processes for learning (sleep scientists refer to this as sleep dependent learning), two of which are sleep dependent consolidation and sleep dependent plasticity. Just by the terms alone, we can see that learning, in part, depends on sleep. Sleep in one view, is an opportunity for learning to occur, for the brain to download information and integrate it in the memory centers, and for the brain to literally change itself by forging new connections between neurons in order to build the learning into the neural circuitry. Some sleep scientists (Matt Walker and Robert Stickgold in this case) go so far as to say that nighttime sleep or daytime naps may maximize skills by "advancing learning beyond that achieved during initial practice without the need for further task engagement" (2005, pp 316). Of course athletes will further engage in their 'tasks' during ongoing training, but the idea that there is a rebound effect in learning provided by sleep should be highlighted. Eating protein after lifting is a strategy that nearly all elite athletes take advantage of: providing building blocks for muscle repair, protein allows the body to build itself stronger. Athletes should be aware that getting insufficient sleep after training could be analogous to not eating protein after lifting. A lack of understanding of the importance of sleep may lead athletes to prioritize other things over getting adequate sleep and lead to suboptimal learning gains associated with training.

While it is often viewed as the athlete's responsibility to get adequate sleep, coaches, parents, schools and National Governing Bodies should do what is possible to set athletes – particularly adolescents and young adults – up for success. A common strategy used for those wanting to sleep more might be to get to bed early. For those of us who have reached the age of brain maturity (mid-20s for females, late 20s for males) this may be a workable strategy, however for those with brains still in the midst of development, this is difficult. So difficult, the research literature uses the phrase that adolescents are 'biologically incapable' of going to bed earlier, as the drive for sleep does not come until later in the evening. This sleep drive, often called sleep pressure, accumulates slower throughout the day, it is thought, as a byproduct of the vast amount of rewiring that occurs during young adulthood, specifically due to the pruning of neurons. While this may not be true for all adolescents, on average, going to bed earlier is going against biology. During puberty, circadian rhythms shift about two hours, where a pre-teen who typically felt sleepy and went to bed at 8 p.m. would likely have rhythms that shifted to make him sleepy at 10 p.m. as a teen. Studies suggest that falling asleep before 11 p.m. is generally a challenge for adolescents. Even for adults, there is an established "forbidden zone" (as it is called in sleep literature) for bedtime, from 7-10 p.m., where many people have difficulty falling asleep during these hours.

How much sleep do elite athletes need?

The National Sleep Foundation set broad recommendations for hours of sleep for school age children (6-13 years) is 9-11 hours, for teens (14-17 years) is 8-10 hours, for young adults (18-25 years) is 7-9 hours. It is noted that each recommended range has an upper and lower range that "may be appropriate" which stretches the school age range from 7-12 hours, the teen from 7-11 and the young adult from 6-11 hours. Other literature states that adolescents and young adults very specifically need 9.25 hours of sleep per night. Either way, these recommendations are for hours of sleep, not simply hours in bed. Time in bed nearly always exceeds sleep time as it is normal to take some time to fall asleep, to transition in and out of sleep during the night, and to awaken before one's target wake up time. Published data from Stanford student-athletes shows that athletes reported they were getting about an hour more sleep than a sleep measurement device clocked them in at (7.8 hours in self report vs. 6.6 hours according to a sleep watch) during a baseline measurement period, while during an extended sleep period, the student-athletes reported nearly two hours more than the sleep watch (10.4 vs 8.5 hours) (Mah et al., 2011). This data supports the view that time in bed and subjectively reported sleep time typically exceed actual sleep duration.

How much sleep are elite athletes getting?

There is no easy formula for understanding how much sleep elite athletes need. A few studies with elite athletes have been published over the last several years, and they are summarized below to provide an idea of the current sleep habits of elite athletes. The sleep of Team Great Britain Olympic athletes was tracked with the goal of understanding of what "normal" sleep looks like in elite athletes in a 2012 study. The athletes wore sleep watches at home for four nights during a typical training phase (as opposed to nights during competition or during the off season). The athletes were in bed for an average of 8.5 hours per night with seven hours of sleep. A measure of sleep

efficiency, or a measure of minutes asleep out of minutes in bed, in this case is 81 percent. In this study, athletes were compared to non-athlete controls. The non-athletes spent about 30 minutes less in bed, but got about 15 minutes more of sleep per night, bringing their sleep efficiency up to 89 percent. (Leeder et al., 2012)

In a 2015 study in Australia of athletes competing at the national and international level, athletes wore sleep watches for a minimum of seven nights during a training phase. On average, elite athletes spent 8.4 hours in bed with 6.8 hours asleep. Sleep efficiency was 86 percent The average bedtime was approximately 11 p.m. with a wake up time of 7:15 a.m. There was a difference between individual and team sport athlete total sleep time, with individual athletes reporting going to bed earlier and waking earlier, and sleeping 6.5 hours as opposed to team sport athletes going to bed later and waking later with a seven-hour sleep time (Lastella et al., 2015). A different study examined sleep in Australian Rules football players and found longer sleep durations among the athletes of approximately 8.5 hours per night across five nights. (Richmond et al., 2014).

A 2014 study conducted in Australia with elite youth soccer players (average age of 18.5 years) showed that athletes slept an average of 7.5 hours with an 89 percent sleep efficiency over the 18 nights monitored. The study examined the impact of early evening high intensity training on sleep and found no effect on sleep (Robey et al., 2014). A 2015 study of Asian, adolescent, high-level athletes showed that athletes are getting 6.1 hours of sleep on week days and 7.1 hours on weekends. (Suppiah et al.). This study was conducted in Singapore with athletes at high performance sport academies, training in the sports of bowling and badminton. There were 11 participants. We don't know if we can assume the same about American adolescent high level athletes based on this study, however in a 2014 study of American high school student athletes, 77 percent reported getting less than eight hours of sleep per night (Milewski et al.), and a 2006 National Sleep Foundation poll found that 45 percent of teens get less than eight hours, 31 percent get between eight and nine, and 20 percent get nine or more hours. The poll found that as teens got older, they slept less: the average sixth-grader got 8.4 hours compared to the average 12th-grader getting 6.9 hours. A different stream of literature tracking screen time and social media use among teens would suggest that teens are using screens more in 2016 than in 2006, and some of the additional time devoted to screen time cuts into sleep time. A safe assumption might be that the 45 percent of teens reporting less than eight hours of sleep per night in 2006 has grown to become the 77 percent of student athletes in 2014, and the percentage may be higher in 2016.

The change in sleep duration reported in the Singapore athletes from weekday to weekend is called 'social jet lag' and is a worldwide phenomenon observed among adolescents. Collegiate student athletes may have a similar pattern in conjunction with 'training jet lag' if they have morning workouts. In a small study of swimmers conducted during a high intensity training camp before the Beijing 2008 Games, a 'training jet lag' effect was observed between days with and without morning swims. Time in bed on training days was 7.7 hours, and 9.3 for rest days. Sleep time was 5.4 hours on training days and 7.1 on rest days. The sleep efficiency for training days is 71 percent and rest days 77 percent (Sargent et al., 2014). The authors of this study concluded that the early morning swim times severely restricted the amount of sleep of the athletes, noting that habitually getting

less than six hours of sleep per night is associated with difficulties in physiological and psychological functioning. It might also be possible that inadequate sleep during high training loads moves athletes closer to overtraining rather than functional overreaching.

In sum, adult elite athletes report spending about 8-8.5 hours in bed with about seven hours of sleep. Adolescents and student athletes report about 6.5 hours of sleep on average, from small sample studies. A majority of teens report less than eight hours of sleep per night. These shorter than recommended sleep durations are not unique to sport: a study of professional ballet dancers showed that dancers slept seven hours per night on average with 81 percent sleep efficiency (Fietze et al., 2009). It is not known how much sleep elite athletes need according to age or sport demands, however scientists are working to better understand this question. Six and a half to seven hours of sleep may not provide adequate recovery time to support high performance training. It also may allow a large sleep debt to build, which could be exacerbated by poor sleep around travel and competition, becoming a burden on an athlete's mood, brain and body.

As a side note, for those readers who wear sleep bands and see their sleep efficiency score in the high 80s to mid 90s, fight the urge to reach 100 percent and keep your scores where they are. A sleep efficiency goal of 100 is not an efficient goal. It is usually a sign that the person is very tired and is not devoting adequate time in bed. If you are in bed five hours and asleep five hours, this is 100 percent sleep efficiency. If you are in bed 10 hours and asleep nine, you are at 90 percent. Your sleep efficiency should be considered in tandem with total time in bed.

Sleep During Competition

As nearly any athlete or coach would report, sleep prior to competition is likely different from sleep during training. A 2011 study examined the question of how different is sleep prior to important competitions (Erlacher et al., 2011). Sixty two percent of athletes (in this case they were more than 600 German athletes, with an average of 11.5 years of experience training 11 hours per week) reported poor sleep prior to an important competition in the previous year. Eighty percent stated they had difficulty falling asleep due to a variety of factors, including thinking about the competition (77 percent), pre-competition nerves (60 percent) and a lack of familiarity with travel surroundings (29 percent). In spite of a majority of athletes experiencing difficulties with sleep around competition, 57 percent believed that these difficulties had no influence on their performance. Twenty-seven percent did report an increase in daytime sleepiness, 18 percent reported a bad mood, and only 13 percent reported poor performance in a competition due to poor sleep.

A similar study was conducted in Australia with elite athletes (defined as competing at the international or professional level) (Juliff et al., 2015). Sixty-four percent of athletes reported worse sleep on at least one occasion in the nights leading into an important competition in the previous year. The cause of the poor sleep was due to thoughts about the competition (82 percent) and pre competition nerves (44 percent), and 47 percent believed that poor sleep had no influence on their performance. There was a difference between individual and team sport athletes in their agreement with the statement that poor sleep would have no influence on performance. Sixty-four percent of individual sport athletes agreed with this, yet only 40 percent of team sport athletes agreed that poor sleep would have no impact on performance. There may be differences in how sleep

loss impacts performance in different sports. We know generally from sleep restriction studies that mood declines first, then cognition, then physical performance. For sports that include complex skill execution, or fast and accurate decisions, then short term sleep loss may have a greater effect. There was also a difference between athletes in reporting of strategies to promote sleep. Fifty-nine percent of team sport athletes and 32 percent of individual sport athletes reported having no strategy. From these two studies, we can conclude that sleep difficulties around competition are common in athletes. They are likely common in one's competitors as well. It seems worthwhile to learn strategies to help with getting to sleep, including breathing exercises, relaxation exercises and using a notebook to write down ruminations (these are in addition to developing the habit of going through a check list of what will be needed the next day for competition-or training- and reviewing this prior to bed time).

An interesting study was conducted with marathon runners, where athletes were asked on the morning of a race how they slept the night before, and then provided an estimation of how well they would run that day. Seventy percent of athletes reported poorer sleep than usual, however there was no difference between the athletes' actual performance and what they estimated prior to the race (Lastella et al., 2014). Of course, they could have artificially elevated their times as a sort of psychological cushion knowing they didn't sleep well, but in the case that they didn't the results are interesting. There was no impact on the next day performance when the athletes had a not so great night sleep. They did report worse moods – with more tension and fatigue – and these were connected to total amount of sleep, specifically, less sleep was associated with more tension and more fatigue. One takeaway for athletes and coaches is that a night of bad sleep before a competition shouldn't necessarily affect performance – it will more likely negatively affect mood and increase how tired one feels. Expecting and being prepared for mood and energy consequences of poor sleep around competition, and knowing that these are not necessarily connected to performance outcomes, might allow athletes to perform well in spite of them. One final note on sleep restriction studies, and translating to performance – while getting consistent adequate sleep is important, a few nights of poor sleep won't completely derail performance. In studies where performance has been assessed after one night with no sleep, findings include that submaximal – not maximal – efforts are affected, mood deteriorates before strength, and perceived exertion increases while endurance decreases slightly (although this last finding was from a study of active people, not runners). Assuming athletes will exert maximal effort, can manage suboptimal mood and have strategies to monitor exertion outside of their own perception, they can work with themselves to perform in the face of sleep loss.

The Cost of Sleepiness on Athletic Performance

Assessments of sleepiness done with MLB and NFL players suggests that increased sleepiness is associated with decreased career longevity (searching the internet for Chris Winter's work on these topics can bring up more detailed summaries). It seems that on average, lower levels of daytime fatigue is a sort of protective factor against attrition. Getting adequate sleep at night buffers against injuries in high school student athletes. In a 2014 study, chronic lack of sleep was associated with increased sport injuries in adolescents. High school athletes reporting eight or more

hours of sleep per night were 68 percent less likely to injure themselves than their peers who reported sleeping less than eight hours (Mileweski et al., 2014).

Sleep Extension as a Strategy to Enhance Performance

A sleep extension study conducted with the Stanford University basketball program previously elaborated upon in the 2013 “Sleep Basics” Olympic Coach article was associated with significant improvements in sprint times, shooting performance and self-ratings at practice and during games. Similar studies have been conducted with other sports with a baseline period where athletes sleep their usual amount for two weeks, then for six weeks, athletes spend a longer time in bed (approximately 10 hours). Sport skills are assessed during the baseline and sleep extension periods. In swimming, sleep extension findings included improved speed (.51 seconds faster in a 15-meter sprint), reaction time (0.15 seconds faster off blocks), turn time (0.1 second faster) and kick strokes (five kicks more in stroke frequency). In tennis, faster sprint times, improved valid serves and hitting in depth drills were observed. In football, speed in a 20-yard shuttle improved from 4.71 to 4.61 seconds, and in a 40-yard dash, times decreased from 4.99 to 4.89 seconds. It is unknown if the findings from these studies, all conducted with Stanford student-athletes, are generalizable to athletes competing at different levels in other sports, however sleep extension seems a worthwhile strategy to explore for athletes at all levels. It can be done in one chunk, the way the Stanford studies were conducted, or done strategically throughout the season, with extending sleep the two weeks prior to travel or a major event. Sleep extension has no known side effects for healthy sleepers, however for those who struggle with insomnia (consistent difficulty falling asleep/staying asleep) spending more time in bed is not a helpful strategy as it does not address the ability of the brain to obtain more sleep. This issue is best addressed with the help of a sleep specialist.

In summary, athletes and coaches should be aware of the important role sleep plays in recovery, and have an appreciation for the role of sleep in learning. Sleeping after learning allows the brain and body to capitalize upon the effort put forth during training and integrate the new information into memory centers and the brain’s networks. Across the handful of publications examining sleep in elite athletes, it seems that athletes are getting 6.5-7 hours of sleep on average per night, with more hours, somewhere near seven or eight hours in bed. While these may be ‘typical’ amounts, it does not mean that they are ‘ideal’ amounts. Sleep loss affects mood, motivation, perception of effort, in addition to reaction time and decision making. While there is limited evidence of performance decrements in elite athletes in competitive settings with short-term sleep deprivation studies, chronically getting slightly insufficient sleep may be more of a performance barrier. Athletes should understand the importance of getting adequate sleep during training, and allow for the possibility for worse sleep around competition. Sleep extension can be a near term performance enhancement strategy via reducing sleep debt and allowing athletes to more fully recovery, maximize learning gains and experience skill improvements.

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References

Erlacher, D., Ehrlenspeil, F., Adebesan, O. A., El-Din, H. G. (2011). Sleep habits in German athletes before important competitions or games. *Journal of Sports Science*, 29 (8), 859-866.

Juliff, L., Halson, S., & Peiffer, J. (2015). Understanding sleep disturbances in athletes prior to important competitions. *Journal of Science and Medicine in Sport* ,18: 13-18

Lastella, M., Roach, G. D., Halson, S. & Sargent, C. (2015). Sleep/wake behaviours of elite athletes from individual and team sports. *European Journal of Sport Science*, 15 (2), 94-100.

Lastella, M., Lovell, G.P. & Sargent, C. (2014). Athletes' precompetitive sleep behaviour and its relationship with subsequent precompetitive mood and performance. *European Journal of Sports Science*, 14, 123-130.

Leeder, J., Glaister, M., Pizzoferro, K., et al. 2012. Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *Journal of Sports Science*, 30 (6): 541-545.

Mah, C. D., Mah, K. E. Kezirian, E. J. & Dement, W. C. The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep*, 34 (7): 943-950.

Mileweski, M. D., Skaggs, D. L., Bishop, G. A., Pace, J. L., Ibrahim, D. A., Wren, T. A., Barzdukas, A. (2014). Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *Journal of Pediatric Orthopaedics*, 34 (2): 129-133.

Richmond, L., Dawson, B., Hillman, D. R. & Eastwood, P. R. (2004). The effect of interstate travel on sleep patterns of elite Australian Rules footballers. *Journal of Science and Medicine in Sport*, 7 (2): 186-196.

Robey, E., Dawson, B., Halson, S., Gregson, W., Goodman, C. & Eastwood, P. (2014). Sleep quantity and quality in elite youth soccer players: A pilot study. *European Journal of Sport Science*, 14 (5), 410-417.

Sargent, C., Halson, S., & Roach, G. D. (2014). Sleep or swim? Early-morning training severely restricts the amount of sleep obtained by elite swimmers. *European Journal of Sport Science*, 14 (1) 310-315.

Suppiah, H.T., Low, C.Y., & Chia, M. (2015). Effects of sports training on sleep characteristics of Asian adolescent athletes. *Biological Rhythm Research*, 46 (4), 523-536.

Walker, M., & Stickgold, R. (2005). It's practice, with sleep, that makes perfect: implications of sleep-dependent learning and plasticity for skill performance. *Clinical Sports Medicine*, 24 (2), 301-317.

Stuart Mcnay and David Hughes of the United States race in the 470 class during the Sailing World Cup Miami 2016 on January 30, 2016 in Key Biscayne, Florida. (Photo by Mike Ehrmann/Getty Images)

Transformational Leadership Principles: A Pathway from Research to Practice

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At the 2015 National Coaching Conference in Morgantown, West Virginia, this author presented on Transformational Leadership Principles: A Pathway from Research to Practice. This article is a follow-up to that presentation. The task is to review the principles of transformational leadership as found in the current research to make application of these principles to the coaching of sport and to consider a pathway that drives research to practice.

Every human endeavor will rise or fall depending on the quality of leadership. The universality of transformational leadership can be observed through a review of the current literature as extensive studies are to be found in the military, business, education, politics, religion, healthcare, and sport. There is also substantial evidence that transformational leadership is a field that can be taught and learned.

Definition of Transformational Leadership

Transformational leadership can be defined as seeking to satisfy higher needs, engaging the full potential of the follower toward exceeding performance expectations, heightening motivation with extra effort toward attaining designated outcomes (Bass, 1985). Charbonneau, Barling, and Kalloway (2001) further enhance this definition by stating that transformational leadership affects sport performance through the results of intrinsic motivation, which can significantly enhance performance. The research also includes the importance of building relationships based in part on emotional and inspirational communication for the purpose of developing players to their highest potential (Callow, Smith, Hardy, Arthur and Hardy, 2009). Moreover, transformational leadership theory is gaining meaningful professional interest in the coaching of sport (Arthur, Woodman, Ong, Hardy and Ntoumanis, 2011). In part, the reason for this increased attention is the deep value of transformational leaders who stimulate and inspire others to follow them, facilitate a shared vision and goal, and then motivate others to achieve it as they promote autonomous actions (Vella and Perlman, 2014). Scholars such as Stenling and Tafvelin (2014) affirm that transformational leadership is a sound framework that can help coaches develop and increase their effectiveness.

Principles and Outcomes

The basic components of transformational leadership are found in the four I's: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. Current research would add further components to this study, however there is much to be learned and practiced from a primary focus on the four I's. Idealized influence could be described as serving as a role model; displaying high moral and ethical standards; instilling a sense of belonging and pride in one's followers; earning respect and admiration of followers; and creating trust through demonstrating selflessness

and confidence. Inspirational motivation is demonstrated by a leader who displays enthusiasm, passion, encouragement, and positive reinforcement; intentionally builds self-efficacy among followers; articulates a shared vision bringing individuals together; inspires excitement and team spirit; while raising the perception of the full potential to be realized. Intellectual stimulation requires a leader to encourage creativity, innovation, questioning and reframing of issues; seek the follower's perspective in participative decision-making and problem-solving; promote leadership responsibility within a climate of intellectual growth, self confidence and autonomy. Individualized consideration is characterized by an awareness of the needs of followers; a caring people-first philosophy; two-way communication, empathy, support and mentoring; creating opportunity for personal growth and development through delegation and empowerment; while instilling intrinsic motivation to maximize potential (Bass & Riggio, 2006).

The literature consistently substantiates evidence-based expected outcomes, that is to say when the four I's are applied, one could expect extraordinary effort, exceeding performance expectations, higher follower satisfaction and higher commitment to the group (Bass, 1985). Arthur and colleagues (2011) suggest outcomes of increased effort, commitment, performance and intrinsic motivation. According to transformational leadership theory, the key outcomes are personal growth, task cohesion, need satisfaction and intrinsic motivation (Vella & Perlman, 2014). Occhino, Mallett, Rynne, and Carlisle (2014) report outcomes of superior performance, enhanced self-worth, increased effort and self-determined motivation. In summary, research validates the following evidence-based expected outcomes: increased commitment and energy; higher self-esteem and confidence; stronger acceptance of team and individual goals; higher holistic development and personal growth; stronger coach-athlete relationships and team cohesion; and extraordinary performance outcomes.

Themes

Who then are we, who have been given the opportunity to coach sport? Nelson Mandela once stated "Sport has the power to change the world. It speaks to youth in a language they understand." There is a strong consensus in the literature that the themes found in transformational leadership have unmistakable application to the coaching of sport. Five of these themes were selected for this study, including building a framework; coaching is relationship; nurturing a culture built upon a foundation of intrinsic motivation; implementing and sustaining a mastery versus performance climate; and fully embracing a plan for lifelong learning and development. The selection of these themes was based in part on their relationship to the six primary functions of coaching as outlined in the latest International Sport Coaching Framework (ICCE and ASOIF, 2013).

The first theme is to create, develop and articulate a framework based on the sub-themes of philosophy, vision, mission and purpose, team culture, core values and high performance standards. In the sub-theme of philosophy, one would need to begin to answer the question, what is truth for me regarding such important issues of coaching as maintaining a holistic view of life and sport, being an athlete-centered coach, what is my definition of success and how are mistakes to be viewed? The sub-theme of vision must answer such questions as what can the future be, what can we accomplish, how will we do it, what might some of the hurdles be and when do we expect to get there? Mission and purpose will allow a clear articulation of the very reason we exist, the importance of our work, and the assignment, which must be carried out. The next sub-theme would be the development and maintenance of a team culture which encourages a mindset that maximizes a team's ability to achieve

success through support and reinforcement (Lauer and Smith, 2011; Schroeder, 2010). Core values must be stated and modeled with passion, aligned with the mission and purpose, as they are the guiding principles that will dictate conversations, activities, and behaviors, and there must be collective acceptance and genuine embrace. The last sub-theme to be considered is that of high performance standards. This can be demonstrated by a world class work ethic (Babcock and Larson, 2012), pursuit of excellence (Orlick, 2008), and athletic learning outcomes with evidence-based results and conclusions (Côté and Gilbert, 2009). Research suggests that a consistent framework is essential as one faces the difficult coaching decisions and ethical dilemmas that are inevitable.

The second theme identified is that coaching is relationship. Building an appropriate, committed relationship with players based on trust, respect, communication and caring is extremely important. Some would define good coaching practice as effectively teaching the skills, techniques, strategies and tactics of a sport. However, it can also be argued that successful coaching depends on consideration of the ever-changing needs of athletes and the quality of coach-athlete relationships (Jones, Bowes and Kingston, 2010). The sub-theme of communication is an essential personal skill and is important for the forming and maintaining of any relationship (LaVoi, 2007). Communication underpins empathetic understanding and accuracy, which in turn can lead to a more effective coach-athlete relationship. Open communication between coach and athlete is crucial (Lorimer & Jowett, 2013). Healthy open communication skills can be described as intentional, persistent, formal, informal, verbal, non-verbal, listening, empathetic and could include the ever expanding use of social media that immerses our culture. The sub-theme of caring is an athlete-centered holistic approach. Caring is paying particular attention to individual needs, feelings and opinions, while showing a genuine interest in their personal lives. Individual differences are to be respected (Ehrmann, Ehrmann and Jordan, 2011; Kidman and Lombardo, 2010). The sub-theme of trust is building a foundation based on fairness, consistency, mutual respect, transparency, genuineness and integrity through leading by example (Miller, Lutz and Fredenburg, 2012; Purdy, Potrac and Nelson, 2013). The sub-theme of the teaching and development of life skills is dependent upon a coach's ability to develop trusting relationships and to create a caring climate (Trottier and Robitaille, 2014). The final sub-theme selected is the careful examination of a coach's many roles i.e., coach, teacher, mentor, friend and even parent. Understanding these relationships can be of great importance (Becker, 2009).

The third theme of transformational leadership in coaching is to build and nurture a culture that is anchored in a foundation of intrinsic motivation. Studies have shown consistent support for the creation of a motivational climate that fosters psychological need satisfaction. The sub-theme of autonomy encourages an athlete to direct and control themselves within overall team goals. Delegating, participative decision making, entrusting responsibilities, and promoting leadership roles all contribute to autonomy. The sub-theme of relatedness ensures that each athlete feels valued, respected, understood and connected based on interpersonal contact. This is family, they know that they belong. The third sub-theme is competence, the feeling of achievement through improvement, perfecting and mastery of skills. Satisfaction is increased by using praise to highlight their improvements enhancing self-worth, believing in them, treating them as if they have already succeeded in what they potentially can do. Ownership and passion can accomplish a lot toward working harder and learning faster (Deci and Ryan, 2002; Gillet, Vallerand, Amoura and Baldes,

2010; Occhino et al., 2014).

The fourth theme is to implement and sustain a mastery versus a performance climate. Research gives consistent evidence that mastery climates are associated with athletes reporting greater performance improvement and satisfaction with performance (Hodge, Henry and Smith, 2014). This type of climate would emphasize skill development, improvement and the importance of learning, and deemphasize the importance of a focus on winning. Mistakes are to be viewed as part of the learning process, athletes are enabled to take responsibility for their own learning, and focus is placed on effort and controllable aspects of performance (Kidman and Lombardo, 2010). Practices would emphasize game-like situations to meet learning outcomes while using competition to reinforce effort. Enjoyment and fun would be an important part of sustaining a love and passion for the sport (Martens, 2012).

The fifth theme is to fully embrace a plan of lifelong learning and long-term development. The first sub-theme is to begin studying the possible incremental implementation of the principles of transformational leadership. It is suggested that the four I's could be modeled and taught within one's coaching environment and context. It would be important to understand the integration of transformational skills could be a critical competitive advantage in the coaching of sport (Hoption, Phelan and Barling, 2014). The second sub-theme is simply to begin the study and incremental application of the four themes discussed above: creating and developing a frame work; emphasizing and building relationships; shaping a culture of intrinsic motivation and implementing a mastery climate. Though it is not the focus of this study, the author believes there is much to be gained by becoming a student of one's game in the areas of technical and tactical skills (Martens, 2012). In addition, one could make a strong case to stay on the cutting edge in such areas as strength, conditioning, nutrition and recovery protocol. Best practices of teaching and pedagogical knowledge (Nater and Gallimore, 2010), psychological skills as a structured approach to deal with the mental challenges of competition (Weinberg and Gould, 2015), mental toughness, a learnable skill, development and maintenance (Bilas, 2013), would merit consideration. Finally, confidence-building activities, goal setting, outcome, performance, process, both in practice and competition (Weinberg and Gould, 2015), self awareness, reflective practice, and critical reflection (Gilbert and Trudel, 2013), and the study of great coaches using books and quality research would allow the transformational coach important additional knowledge and skill toward a life proficiency in coaching (Kryzewski and Spatola, 2009; Vallee and Bloom, 2005; Wang and Straub, 2012).

Pathways

In the study of transformational leadership, it is widely accepted that there is a significant gap between practice and research. The challenge is for coaches to build a pathway that will allow them to practice these strategies in real life situations. The goal is to construct a plan to lead and to coach in such a manner that it will become the norm for their players to exceed performance expectations, to have higher energy and effort levels, and to maintain higher satisfaction, and commitment to individual and team goals. It is suggested that this pathway must be incremental, consistent, evolving, and measurable. Furthermore, each plan must be flexible and varied depending on the needs of the individual coach, context and environment. It is recommended that as a first step a series of questions related to each theme and each pathway be asked. The individualized answers can give significant impetus toward the design of a focused and succinct pathway for either an immediate or incremental implementation. Suggested for your consideration from the author's experience as a coach and as a

coach educator are the following examples of theme related questions:

- Why do I coach?
- Do I want to live a life that impacts others?
- Do I want my players to enjoy, respect and love playing for me? (Would I love to play for me?)
- Do I really believe that relationship-based people first coaching is a critical element in my success as a coach?
- What are the best methods and practices to build an intrinsic motivational environment?
- Are we experiencing the outcomes of a mastery climate on a daily basis?
- When athletes leave my program what values and life lessons do I want them to take away?

Once the answers to the questions asked are completed, the development of the pathway can begin. Pathways can be quite simple or quite complex depending upon the task at hand. Suggested for your consideration are the following examples of three pathways from my past professional experience, which one may find it to be helpful to review sample plans implemented by our fellow coaches.

Plan 1, Athlete-Centered, People-First Coach: Intentional practice so that my players know that I really care about them as an individual person.

- Schedule one-on-one formal meetings.
- Plan informal meetings.
- Verbal communication/selecting my words carefully.
- Non-verbal communication/body language/hugs.
- Attention to needs, feelings, opinions and dreams.
- Encourage mutual trust and respect.
- Commit to an individual growth and development plan in both sport and personal life for each athlete.
- Believe in them and encourage them often.

This plan must be measurable and have numerous opportunities for feedback.

Plan 2, Professional Growth by Studying Great Coaches: Select one book and one research article per month.

- Read each carefully, making notes on any item that might merit consideration for implementation into my culture.
- Save notes in an understandable and accessible format.
- Review these notes at several different times over the course of 30 days.
- Make the decisions to discard, hold for further review, or begin implementation immediately or incrementally as context may allow.
- When I look back over a 12-month period, significant and meaningful change will have been evidenced.

Plan 3, Quiet Pursuit of Excellence: What do you want excellence to look like in your program and

in your personal life?

- Write a one-page draft describing what excellence will look like in my program and in my personal life.
- Save to the computer and/or as hard copy.
- Commit to reading and reviewing the draft several times a week.
- Make any additions and deletions I believe are important each time I read.
- Always save my very first draft and my most recently updated draft.
- After a period of several weeks, give thoughtful consideration to any of the changes that have been made in my description and what incremental steps might be needed to reach these goals immediately, over the next several months, a year from now or even longer.
- Make this a continuous effort.

Plans will be varied for each individual coach but if these pathways are constructed to be incremental and evolving, based upon the answers to carefully posed questions. Then these pathways can now begin to enable moving in a very defined and deliberate way toward the goal and excitement of a life proficiency in coaching practice.

Conclusions

Clearly it is understood that coaches of sport have a very unique and important role in the lives of their athletes. Coaches have the opportunity to make a significant and meaningful impact enhancing the probability of developing athletes to reach their highest potential both athletically and personally.

It is the author's belief that coaches who recognize the importance of integrating the principles and themes of transformational leadership into their practice of coaching will pour powerful benefits into the lives of the athletes they coach. The task of becoming a transformational leader/coach may at times seem overwhelming. However, as coaches select what is most important in one's given environment and context and begin to move incrementally forward on a carefully designed pathway with perseverance one's players will experience such evidence-based outcomes as: increased commitment and energy; higher self-esteem and confidence; stronger coach-athlete relationship and extraordinary performance outcomes. Let there be no doubt that as a Transformational Leader Coach you will impact and inspire your athletes in ways that are not often experienced.

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References

Arthur, C. A., Woodman, T., Ong, C. W., Hardy, L., & Ntoumanis, N. (2011). The Role of Athlete Narcissism in Moderating the Relationship Between Coaches' Transformational Leader Behaviors and Athlete Motivation. *Journal of Sport & Exercise Psychology*, 33(1), 3-19.

Babcock, M., & Larson, R. (2012). *Leave No Doubt: A credo for chasing your dreams*. Canada: McGill-Queens University Press.

Bass, B. M. (1985). Leadership: Good, better, best. *Organizational Dynamics*, 13, 26-40.

Bass, B. M., & Riggio, R. E. (2006). *Transformational leadership* (2nd ed.). Mahwah, N.J.: L. Erlbaum Associates.

Becker, A. J. (2009). It's Not What They Do, It's How They Do It: Athlete Experiences of Great Coaching. *International Journal of Sports Science & Coaching*, 4(1), 93-119. doi: 10.1260/1747-9541.4.1.93

Bilas, J. (2013). *Toughness: Developing True Strength on and off the Court*. New York, New York: Penguin Group.

Callow, N., Smith, M. J., Hardy, L., Arthur, C. A., & Hardy, J. (2009). Measurement of Transformational Leadership and its Relationship with Team Cohesion and Performance Level. *Journal of Applied Sport Psychology*, 21(4), 395-412. doi: 10.1080/10413200903204754

Charbonneau, D., Barling, J., & Kalloway, E. K. (2001). Transformational leadership and sports performance: the mediating role of intrinsic motivation. *Journal of Applied Sport Psychology*, 31(7), 1521-1534.

Côté, J., & Gilbert, W. (2009). An Integrative Definition of Coaching Effectiveness and Expertise. *International Journal of Sports Science & Coaching*, 4(3), 307-323. doi: 10.1260/174795409789623892

Deci, E. L., & Ryan, R. M. (2002). *Handbook of self-determination research*. Rochester, NY: University of Rochester Press.

Ehrmann, J., Ehrmann, P., & Jordan, G. (2011). *InSideOut coaching : how sports can transform lives* (1st Simon & Schuster hardcover ed.). New York, NY: Simon & Schuster.

Gilbert, W., & Trudel, P. (2013). The Role of Deliberate Practice in Becoming a Expert Coach: Part 2 Reflection. *Olymic Coach Magazine*, 24(1), 35-45.

Gillet, N., Vallerand, R. J., Amoura, S., & Baldes, B. (2010). Influence of coaches' autonomy support on athletes' motivation and sport performance: A test of the hierarchical model of intrinsic and extrinsic motivation. *Psychology of Sport and Exercise*, 11(2), 155-161. doi:

10.1016/j.psychsport.2009.10.004

Hodge, K., Henry, G., & Smith, W. (2014). A Case Study of Excellence in Elite Sport: Motivational Climate in a World Champion Team. *Sport Psychologist*, 28(1), 60-74. doi: 10.1123/tsp.2013-0037

Hoption, C., Phelan, J., & Barling, J. (2014). *Transformational leadership in sport* (2 ed.). New York: Routledge.

ICCE, & ASOIF. (2013). *International Sports Coaching Framework Version 1.2*. Champaign, IL: Human Kinetics.

Jones, R., Bowes, M., & Kingston, K. (2010). *Complex Practice in Coaching: studying the chaotic nature of coach-athlete interactions*. London: Churchill Livingstone/Elsevier.

Kidman, L., & Lombardo, B. (2010). *Athlete-centered Coaching: Developing Decision Makers*. Worcester, UK: IIPC Print.

Kryzewski, M., & Spatola, J. K. (2009). *The Gold Standard: Building a World-Class Team*. New York, NY: Defense, LLC.

Lauer, L., & Smith, R. (2011). Changing a Team Culture: Championships are Founded in Program-Wide Trust. *Olympic Coach Magazine*, 22, 18-24.

LaVoi, N. M. (2007). *Interpersonal communication ad conflict in the coach-athlete relationship*. Chicago, IL: Human Kinetics.

Lorimer, R., & Jowett, S. (2013). *Empathetic understanding and accuracy in the coach-athlete relationship.* London: Routledge.

Martens, R. (2012). *Successful Coaching* (4th ed.). Champaign, IL: Human Kinetics.

Miller, G. A., Lutz, R., & Fredenburg, K. (2012). Outstanding high school coaches: Philosophies, views, and practices. *Journal of Physical Education, Recreation & Dance*, 83(2), 24-29.

Nater, S., & Gallimore, R. (2010). *You haven't taught until they have learned : John Wooden's teaching principles and practices* (2nd ed.). Morgantown, WV: Fitness Information Technol ogy.

Occhino, J. L., Mallett, C. J., Rynne, S. B., & Carlisle, K. N. (2014). Autonomy-Supportive Pedagogical Approach to Sports Coaching: Research, Challenges and Opportunities. *International Journal of Sports Science & Coaching*, 9(2), 401-415.

Orlick, T. (2008). *In Pursuit of Excellence: How to win in sport and life through mental training* (4th ed.): Human Kinetics.

Purdy, L., Potrac, P., & Nelson, L. (2013). *Exploring trust and distrust in coaching*. London: Routledge.

Schroeder, P. J. (2010). Chaning Team Culture: The Perspectives of Ten Successful Head Coaches. *Journal of Sport Behavior*, 33(1), 63-87.

Stenling, A., & Tafvelin, S. (2014). Transformational Leadership and Well-Being in Sports: The Mediating Role of Need Satisfaction. *Journal of Applied Sport Psychology*, 26(2), 182-196. doi: 10.1080/10413200.2013.819392

Trottier, C., & Robitaille, S. (2014). Fostering Life Skills Development in High School and Community Sport: A Comparative Analysis of the Coach's Role. *Sport Psychologist*, 28(1), 10-21. doi: 10.1123/tsp.2012-0094

Vallee, C. N., & Bloom, G. A. (2005). Building a successful university program: Key and common elements of expert coaches. *Journal of Applied Sport Psychology*, 17(3), 179-196. doi: 10.1080/10413200591010021

Vella, S. A., & Perlman, D. J. (2014). Mastery, Autonomy and Transformational Approaches to Coaching: Common Features and Applications. *International Sport Coaching Journal*, 1, 173-179.

Wang, J., & Straub, W. F. (2012). An Investigation into the Coaching Approach of a Successful World Class Soccer Coach: Anson Dorrance. *International Journal of Sports Science & Coaching*, 7(3), 431-444.

Weinberg, R. S., & Gould, D. (2015). *Foundations of Sport and Exercise Psychology* (6th ed.). Champaign, IL: Human Kinetics.

Jenny Arthur competes in the women's 69kg clean and jerk weight class at the USA Olympic Team Trials for weightlifting at the Calvin L. Rampton Convention Center on May 8, 2016 in Salt Lake City, Utah. (Photo by Melissa Majchrzak/Getty Images)

Sleep Hygiene for Optimizing Recovery in Olympic/Paralympic Athletes

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What You Need to Know: Main Points

1. There are three 'pillars of health' that include diet, sleep and exercise; if you ignore one, the other two will suffer. Optimizing these three are by far the most important to recovery, more so than any supplement or recovery technique commonly employed by athletes. For elite athletes who already exercise at a high level, diet and sleep are even more critical.
2. There are many ways to identify a sleep disorder. Athletes who snore or have daytime sleepiness may have sleep apnea. Athletes who can't fall asleep or stay asleep may have insomnia that can be addressed by medical experts. Many athletes simply do not prioritize sleep and insufficient sleep duration has clear negative effects on performance.
3. There are numerous studies that illustrate the negative effects of sleep deprivation on performance, including reaction time, accuracy, energy/vigor, submaximal strength and endurance. Cognitive functions such as judgment and decision-making also suffer, which is crucial in the outcomes of elite sports.
4. Sleep extension (increasing sleep time) on the other hand can improve performance; studies show improved reaction times, energy and mood, faster sprint times, tennis serve accuracy, swim turns and kick stroke efficiency, and increased free throw and three-point accuracy.
5. Peak athletic performance can be influenced by one's circadian rhythm, or internal body clock. Physiological changes occur throughout the day that may affect exercise. There is some evidence suggesting athletic performance may be best in the afternoon or early evening as compared to late night. However, since the data are unclear and the timing of competition is often

outside an athlete's control, coaches are encouraged to facilitate adequate sleep for their athletes.
6. For athletes who are traveling across time zones, peak performance may be impaired. Jet lag symptoms are usually worse when flying from east to west rather than west to east. The more times zones crossed, the more difficult it may be to adapt. The implications of flying north-south is not as well understood, but changing the natural light and dark exposure to the body can influence wakefulness. The best strategy may be to arrive at the destination well in advance of competition.
7. Many athletes turn to sleep supplements and medications, however there are many unknown side effects and they may not necessarily improve sleep quality. Thus, their use is generally discouraged. Athletes must check if these substances are also on the WADA Prohibited List.
8. There are many natural ways to restore sleep and maximize sleep hygiene (see tables below). Sleep hygiene is particularly important for people with insomnia. For people who are sleep deprived, making sleep a priority may be the most important intervention. Olympic athletes exercise at the highest level; they equally should achieve an 'Olympic level' of sleep.

Introduction

Sleep is an essential body function that frequently does not get sufficient attention. Many different sleep disorders exist, and often people remain undiagnosed and untreated. Even elite athletes can suffer from these conditions and may be unaware of them unless specifically evaluated.

Sleep apnea is a common condition that affects roughly 10 percent of the U.S. population. Although typically considered a disease of obese men, many lean individuals including elite athletes may suffer from this problem. Similarly, insomnia is a common condition that can be treated effectively if the problem is recognized and appropriately addressed. Even in people without sleep disorders, insufficient sleep duration has negative health effects that can impact all aspects of an individual's well-being.

The Three Pillars of Health

We consider the three 'pillars of health' to be diet, exercise and sleep and argue that ignoring one makes the other two suffer. For example, people who are sleep deprived tend to perform poorly in peak exercise, and tend to crave unhealthy foods that can promote weight gain. Similarly, dietary indiscretions can yield poor sleep, and may impair athletic performance as well. We believe optimizing all three pillars is by far the most important to overall health and recovery, much more so than any quick fix supplement or recovery technique commonly tried when athletes are feeling fatigued and lack adequate sleep.

Sleep Deprivation and Sleep Disorders in Elite Athletes

Studies have shown that elite athletes have less total sleep time than non-athletes (Lastella, Roach, Halson, et al., 2015; Leeder, Glaister, Pizzoferro, et al., 2012). This pattern is not limited to any one sport, and is present with both individual and team sports in multiple disciplines (e.g., canoeing, diving, rowing, speedskating, endurance cyclists). Some Olympic athletes have been

reported to sleep approximately 6.5 to 6.8 hours, (Lastella, Roach, Halson, et al., 2015; Leeder, Glaister, Pizzoferro, et al., 2012) much less than the traditional eight hour recommendation. Furthermore, research has shown that even when Olympic athletes report adequate sleep time of at least eight hours, they have longer sleep latency (time it takes to fall asleep) and lower sleep efficiency (lower quality of sleep) than non-athletes, resulting in a lower total time asleep of 6.5 hours (Leeder, Glaister, Pizzoferro, et al., 2012).

There can be numerous reasons for this (Halson & Stealing, 2015). Athletes have long had rigorous and strict training schedules, travel obligations and time zone changes. Historically, athletes have also downplayed the importance of sleep, considering it optional compared to other aspects of training. In modern times, the ever-growing prevalence of smartphones and other devices can further disrupt sleep. Athletes and non-athletes alike report being "glued" to their phone, checking messages, playing games/apps or communicating via social media. All of this unfortunately is commonly done at night and disrupts good sleep hygiene. The blue-light emission from the screens further disrupts the body's natural melatonin production (which helps regulate one's circadian rhythm) and can affect next-morning alertness (Chang, Aeschbach, Duffy, Czeisler, 2015). And finally, although many athletes focus on a good night's sleep the night before competition, the natural stress and 'revved up' feeling athletes report before an important competition will impair healthy sleep. Focusing on healthy sleep throughout training is thus important, not just the night before competition when sleep may be the most difficult and the damage already done (Halson & Stealing, 2015).

Negative Effects of Sleep Deprivation

Most adults require seven to nine hours of sleep per night. (Mukherjee, Patel, Kales, Ayas, Strohl, Gozal, Malhotra, 2015). Athletes however may need more due to the increased stress of intensive exercise. Inadequate sleep duration has been associated with a myriad of negative health effects including neurocognitive, metabolic, immunologic and cardiovascular dysfunction. For example, people who are sleep deprived may have impaired brain function that could affect judgment and/or decision-making during athletic performance. From a metabolic standpoint, sleep deprivation has been associated with obesity (Patel, Malhotra, White, Gottlieb, Hu, 2006) and diabetes. Sleep deprived individuals crave unhealthy foods and show impairments in glucose sensitivity (Morselli, Laproult, Balbo, Spiegel, 2010), which may impair glycogen repletion and potentially affect appetite, food intake and protein synthesis (all important for athletic performance). Impaired sleep also negatively affects growth hormone and cortisol secretion (Mougin, Bourdin, Simon-Rigaud, Nguyen, Nhu, Kantelip, Davenne, 2001). There are numerous other studies that have shown further negative effects, ranging from increased pro-inflammatory cytokines (impairing immune system function), impaired muscle damage recovery and repair, autonomic nervous system imbalance (simulating overtraining symptoms), slower/less accurate cognitive performance and altered pain perception (Haack, Mullington, 2005; Haack, Sanchez, Mullington, 2007; Haack, Lee, Cohen, Mullington, 2009).

Furthermore, sleep deprivation specifically in athletes has extensively been studied. Table 1 lists numerous examples of how less sleep can negatively affect performance (multiple). Studies have spanned multiple sports, both power and endurance, team and individual, male and female. While some studies used rather extreme examples such as 24 hours without sleep (and up to 64 hours!),

many show negative effects with just two hours of less sleep per night. Overall, it appears that while some basic motor functions such as brief bouts of strength and anaerobic power may be relatively preserved, prolonged exercise and submaximal performance can decline. Possibly even more important, reaction time and many cognitive functions such as judgment and decision making significantly suffered. This is a crucial area in elite sports, where all athletes are on a similar level of fitness, and high-level cognitive function is what makes or breaks a competition outcome.

Table 1: Negative Effects of Sleep Deprivation

Study	Population/Activity	Sleep Deprivation	Effect
Reilly and Deykin 1983	Excercise trained men	2.5hr total sleep/night over 3 nights	Multiple psychomotor functions negatively affected. Gross motor function (strength, lung power, endurance running) unaffected
Takeuchi et al 1985	40m dash; leg extension exercise	64hr sleep deprivation	No effect on 40m dash, isometric strength, or peak torque; authors conclude brief anaerobic performance may be maintained with sleep deprivation
Reilly and Hales 1988	Women	2.5hr total sleep/night over 3 nights	Similar findings in women as above study; more notable negative effects on reaction time than gross motor function
Sinnerton & Reilly 1992	Swimmers	2.5hr less sleep /night over 4 nights	No effect on gross motor function (back & grip strength, lung function) or swimming performance. Depression, tension, confusion, fatigue, anger all increased, vigor decreased
Reilly and Percy 1994	Weightlifting; bench press, leg press, deadlift, bicep curl	3hr total sleep/night over 3 nights	Significant decrease in submaximal lifts on all tasks, and decrease in max bench press, leg press, deadlift
Bulbulian et al. 1996	Exercise-trained men; isokinetic knee extension & knee flexion exercise	30hr sleep deprivation (1 night of no sleep)	Isokinetic peak torque significantly impaired
Souissi et al. 2003	Cycling; max, peak, & mean power	24hr & 36hr sleep deprivation	Anaerobic power (max, peak, mean) unaffected at 24h but decreased at 36h of no sleep
Blumert et al. 2007	Collegiate weightlifters; snatch, clean, jerk, front squat	24hr sleep deprivation	Mood suffered; increased confusion, fatigue total mood disturbance, less vigor, however no difference in snatch, clean, jerk, front squat, total volume or training intensity
Souissi et al 2008	Male students majoring in physical education; Wingate test	4hr delayed bedtime vs earlier rising time, with 4hr sleep deprivation (either at beginning or end of night)	4hr sleep deprivation at end of night affects peak, mean, & max power more than sleep deprivation at beginning of night; authors conclude early rising more detrimental than late bedtime
Azboy and Kaygisiz 2009	Male runners and volleyball players; incremental ergometer exercise test	One night (25-30hr) sleep deprivation	Decreased exercise minute ventilation and faster time to exhaustion; seen more in volleyball than runners
Oliver et al. 2009	Recreationally active healthy males; 30min treadmill run at 60% VO2max	24hr sleep deprivation	Less total running distance covered (6,037m vs 6,224m); authors suggested reduced performance due to increased rate of perceived exertion

Skein et al. 2011	Male team-sport athletes; 15m sprint times, double leg bounds, max knee extension	30hr sleep deprivation	Decreases mean and total sprint times, altered sprint pacing strategies, decreased muscle glycogen, decreased peak force, increased perceptual strain
Taheri and Arabameri 2011	Male collegiate athletes; Wingate test & reaction time task	24hr sleep deprivation	Decreased reaction time; no difference in anaerobic power (peak & mean)
Reyner and Horne 2013	Semi-professional tennis players; tennis serve accuracy	5hr total sleep/night, tested with and without caffeine following day	Tennis serve accuracy decreased after sleep deprivation; caffeine had no beneficial effect
Souissi et al 2013	Judo athletes; maximal voluntary contraction, grip strength, and Wingate tests before and after judo competition	4hr sleep deprivation either at the beginning or end of the night	Sleep deprivation at the end of the night decreased muscle strength and power on following day, more so in the afternoon than morning; authors conclude early rising more detrimental than late bedtime
Mejri et al. 2016	Male Taekwondo athletes; Intermittent running recovery test (Yo-Yo)	4hr sleep deprivation at beginning of night vs end of night	Both types of sleep deprivation affects running performance (sleep deprivation at end of night more so than beginning); Lactate levels affected only with deprivation at end of night. Peak HR and rate of perceived exertion unaffected

Circadian Aspects

The body's natural clock has a profound effect on most biological functions. The body clock, or circadian rhythm, is an important factor in optimizing sleep duration. For example, many people sleep poorly if they attempt to do so when they are "out of phase" (their circadian phase). This situation commonly occurs in individuals with jet lag or frequently crossing time zones. Similarly, circadian factors may have a role in peak performance of athletes. In a recently published study (Smith, Efron, Mah, 2001), the outcomes of NFL football games were compared in east coast teams playing on the west coast vs. west coast teams playing on the east coast. The study accounted for the point spread to take into account the many known external factors that may influence outcomes of games (e.g., better teams, home field advantage, team injury reports, etc.). For afternoon games, no difference in outcome was observed; athletes performed similarly in a 1 p.m. vs. 4 p.m. game regardless of time zone. For evening games however, the east coast teams, on average, consistently performed poorly on the west coast and did not beat the point spread. For an east coast athlete, playing a west coast night game, the game may end at close to 2 a.m. from the standpoint of their body clock. This disadvantage was consistent across four decades of NFL games, suggesting a major impact of circadian factors above and beyond known sources of variance.

Mitigating Jet Lag

The more east-west time zones crossed, the more difficult it may be to adapt. As a rough guide, jet lag symptoms may last for one day per time zone crossed when travelling eastward, and a half a day per time zone crossed when travelling westward. Taking this adjustment period into account when making travel plans could be helpful (Leatherwood, Dragoo, 2013; Forbes-Robertson, Dudley, Vadgama, Cook, Drawer, Kilduff, 2012). Jet lag with north-south flights is not as well un-

derstood as one may not technically change time zones, but there may be a change in the ratio of light to darkness as you move away from/to the equator (Rowland, 2011). The sun is a powerful regulator of circadian rhythm. Therefore, once in a new time zone, a simple option would be to get as much sun exposure during daylight hours (National Sleep Foundation). Avoid being indoors if possible. This is especially important in the morning to "reset" the body's clock to the sun's new rise/set times. For those seeking an individualized travel plan according to destination, a more complex light exposure schedule can be created (e.g., http://www.jetlagrooster.com, other sites available). Resetting your watch/phone's clock to the destination time while in-flight can help with the adjustment too. The 'first night effect' (National Sleep Foundation) is a well-known phenomenon that can disrupt sleep, as your body adjusts to a new sleep environment. Bringing objects from the home sleep/wake environment (pillows, blankets, photos, favorite coffee mug) can ease the transition. Many turn to sleep aids such as supplements and medications. However, the side effects can be significant, and they do not actually reset the body clock. Finally, melatonin is a body hormone that regulates sleep. It is turned off by bright sun in the morning, and increases in production at night, resulting in sleepiness. Blue light from smartphones and computers also turn off melatonin. Athletes have tried melatonin supplements, but supplements are not FDA-regulated. They have variable potency, may have side effects, and furthermore may contain contaminants resulting in a positive drug test. Therefore, getting natural sun outdoors early in the morning and avoiding artificial bright light at night (including phones and computers) may be the best strategy (National Sleep Foundation).

Athletes have also tried changing exercise timing to maximize performance and "reset" their circadian rhythm if in jet lag (see following section).

A Note on Exercise Timing

There are many anecdotal reports that athletes tend to perform best in the early to late afternoon. This may coincide with various diurnal/circadian changes in the body. In the afternoon, core temperature is reaching its peak, which is known to speed everything from enzymatic reactions, metabolic processes and nerve conduction in the body. Cardiovascular function and VO2 max appear to peak in the afternoon. Gene signaling factors for muscle hypertrophy also appear to peak at this time. While some contend since testosterone production is higher in the morning that strength exercise may be optimal in the a.m., however the ratio of testosterone to cortisol (the body's stress/catabolic hormone) appear to be better in the afternoon. For endurance athletes, an overly excessive rise in body temperature with prolonged endurance exercise can be detrimental, so it is sometimes suggested to do endurance activities early in the day (resting heart rate also may be lower here, resulting in a larger net "reserve" HR).

Therefore, there is limited evidence suggesting an advantage to scheduling practice or competition at a time of day when the daily physiological changes seem to be maximized for exercise. Regardless, poor sleep can disrupt all of these natural rhythms and negatively affect recovery and performance. Since the timing of competitions is outside of an athlete's control, it is suggested for coaches to schedule practices and team meetings to maximize athletes' sleep.

Positive Effects of Sleep Extension

Sleeping adequately has clear benefits. Increasing sleep duration among people who are sleep deprived has been shown to improve multiple measurements of function. For example, if we disrupt our natural circadian rhythm, cortisol levels (our stress hormone) rise and athletes go into a catabolic state. Athletes may turn to illegal substances such as anabolic steroids and growth hormone to stop this catabolism and improve recovery. However, if athletes restore natural sleep patterns, these hormones they are seeking may naturally improve. There are numerous cognitive performance improvements with increased sleep as well. Therefore, athletes who sleep adequately prior to competition are likely to benefit from the standpoint of peak performance. Table 2 illustrates various examples of how better sleep can improve cognitive and physical performance (multiple). Overall, it shows that restoring adequate sleep can result in better reaction times, energy (vigor)and mood, sprint times, tennis serve accuracy, swim turn and kick stroke efficiency, free throw and three-point accuracy. Even if an athlete cannot get an adequate night's sleep, studies show that at least a nap the following day may be beneficial. Sleep extension research in athletes is still in early stages, however many studies recommend to increase sleep by two hours, with a goal of at least nine hours of sleep. This may seem excessive to athletes, but given the absolute importance of sleep to performance, the three pillars of health cannot be understated. To elite athletes, sleep must be emphasized and made top priority. Future research should cast more light on the benefits of increasing sleep duration in elite athletes.

Table 2: Positive Effects of Sleep Extension

Study	Population/Activity	Extension	Effect
Gillberg et al. 1996	Healthy volunteers	Midday ½ hr nap following night of sleep deprivation (4hr total sleep)	Nap after restricted sleep brought performance on psychomotor vigilance tasks back to baseline; alertness improved, sleepiness decreased
Kamdar et al. 2004	Healthy college students	sleep as much as possible/ night over 7 nights (~2hr more sleep/night, from ~7 to 9hr)	Reaction time improved; daytime alertness, vigor, mood improved; fatigue decreased
Hayashi et al. 2005	Healthy university students	Midday nap following sleep deprivation (1.5hr less total sleep)	Alertness and performance on psychomotor vigilance tasks improved after nap, more so with stage 2 sleep vs stage 1
Brooks and Lack 2006	Healthy young adults	Afternoon nap following night of sleep deprivation (5hr total sleep)	Nap improved cognitive performance tasks, sleepiness, fatigue, vigor, alertness
Waterhouse et al. 2007	Healthy males	Midday ½ hr nap or sit quietly following night of sleep deprivation (4hr total sleep)	Reaction time accuracy improved, 2m & 20m sprint times improved; alertness & short-term memory improved; sleepiness decreased
Mah 2008	Men's and women's collegiate swimming teams	Increase to minimum 10hr in bed/night over 5-7 weeks (~2hr more sleep/night)	15-meter sprint swim improved, faster reaction times off the blocks, improved turn times, increased kick strokes; daytime sleepiness decreased mood & vigor improved, fatigue decreased

Mah et al. 2011	Men's collegiate varsity basketball team	Increase to minimum 10hr in bed/night over 5-7 weeks (~2hr more sleep/night)	Half-court & full-court sprints improved, shooting accuracy improved (free throw and 3-point field goal percentage 9-9.2%); vigor & mood improved; sleepiness & fatigue decreased
Schwartz and Simon 2015	Collegiate varsity tennis players	Increase to at least 9hr sleep/night over 1 week (~2hr more sleep/night)	Tennis serve accuracy improved (35.7% to 41.8%), sleepiness levels (Epworth & Stanford Scales) decreased

Sleep Hygiene Strategies

Athletes are often forced to adhere to strict competition and travel schedules, and must maintain rigorous training that may interfere with their ability to get good sleep. Although making sleep a priority is an important recommendation, some individuals have difficulty initiating and maintaining sleep. These athletes may benefit from improved sleep hygiene. Healthy sleep can be trained and improved upon by utilizing regular routines, creating a healthy sleep hygiene, the optimal environment for sleep. Please see Table 3 for well-established and researched healthy sleep hygiene recommendations, and Table 4 for additional (less traditional) options (Schwartz & Simon, 2015). Athletes may not be able to adopt all sleep hygiene recommendations, but should attempt to integrate as many as possible to maximize this vital body function.

Table 3

Healthy Sleep Hygience "Top Ten" Recommendations (reference: UCSD Center for Pulmonary and Sleep Medicine)	
1.	Don't go to bed until you are sleepy. If you aren't sleepy, get out of bed and do something else until you become sleepy.
2.	Regular bedtime routines/rituals help you relax and prepare your body for bed (reading, warm bath, etc.)
3.	Try to get up at the same time every morning (including weekends and holidays).
4.	Try to get a full night's sleep every night, and avoid naps during day if possible (if you must nap, avoid after 3pm and limit to 1 hour).
5.	Use the bed for sleep and intimacy only; not any other activities such as watching TV, smartphone use, etc.
6.	Avoid caffeine if possible (if must use caffeine, avoid after lunch).
7.	Avoid alcohol if possible (if must use alcohol, avoid right before bed).
8.	Do not smoke cigarettes or use nicotine, at all.
9.	Consider avoiding high-intensity exercise right before bed (extremely intense exercise may raise cortisol which impairs sleep).
10.	Make sure bedroom is quiet, as dark as possible, and a little on the cool side rather than warm (in a way, like a cave).

Table 4

Other "Tips and Tricks"	
1.	Avoid "blue light" emitted from screens at least 2 hours before bed (smartphones, laptop, monitors). Blue light suppresses melatonin productions which is needed to induce sleep. Avoid text messaging, social medial, games, app use, i.e., "Put down that phone."
2.	Get bright, natural light (the sun) upon awakening (the sun is ideal, but some suggest at least a 10,000 lux lamp if artificial)
3.	Don't hit the snooze button. It does not improve sleep quality.
4.	If you have difficulty getting up, some suggest a dawn-simulator alarm clock.

5.	If you must use your computer at night, consider installing color-adjusting and blue light reducing software. Some have even utilized blue-light blocking glasses at night.
6.	Meditation may be helpful. Brainwave entrainment (e.g., binaural beats) is considered expertimental.
7.	Higher carbohydrate (namely high glycemic index foods) at night may improve sleep, as well as high protein including tryptophan. High fat intake at night may disrupt sleep. Inadequate total caloric intake during the day may impair sleep at night.
8.	Topical magnesium (e.g., Epsom salt bath, mineral oil during massage treatments) may possibly help, if you are deficient in magnesium (the hot bath or massage itself however may be giving more of the actual effect).
9.	Melatonin naturally occurring in foods (e.g., tart cherry juice, raspberries, goji berries, walnuts, almonds, tomatoes) may improve sleep.
10.	Don't fall asleep to the TV. Sleep studies show you frequently wake up during the night and have poor quality sleep.
11.	Herbal supplements are largely unknown with potential serious side effects, and may be on WADA-prohibited lists. May even result in positive banned substance test.
12.	Consider reducing your fluid intakes before bed so you don't get up to go to the bathroom (only if you can maintain enough hydration during the day).
13.	Cooling your body temperature may improve sleep. Some suggest keeping room between 60 - 70 degrees; however, keep hands and feed warm (consider socks and gloves, e.g., if have Raynaud's phenomenon).
14.	Check that mattress - chances are it is already too old (mattresses last a maximum of 9 to 10 years), and may have allergens.
15.	Recovery methods from exercise should not only focus on muscle recovery. Reducing/minimizing brain fatigue is just as important. Reduce external stressors in your life.

Getting Evaluated

Athletes who can't fall asleep or stay asleep may have sleep apnea, insomnia or insufficient sleep duration. It is difficult to self-diagnose however, as often we do not know if we are snoring or having disrupted sleep. Athletes who are sleepy during the day may not "just be tired," they may have a sleep condition. If an athlete believes he or she may have a sleep problem, it can be addressed by medical experts. For example, Shaquille O'Neal once participated in a video to increase awareness about sleep apnea in athletes (Halson, 2014). https://www.youtube.com/watch?v=4JkiWvWn2aU

Conclusion

Sleep serves an absolutely vital physiological function, and is arguably the single most important factor in recovery. Many in the strength and conditioning and exercise science worlds talk about "quality exercise," "quality movement patterns," and "quality training programs." However above them all, adequate restorative "quality sleep" should be the foundation of an elite athlete's training. Simply put, Olympic and Paralympic athletes need to get an Olympic level of sleep. Building this vital function into an athlete's routine must be emphasized. Athletes can train themselves to improve their sleep if they have deficits, which by all measures should translate into improved performance in competition. Therefore, the old saying, "you snooze, you lose" should actually read, "you snooze (more), you win."

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References

Azboy O, Kaygisiz Z. Effects of sleep deprivation on cardiorespiratory functions of the runners and volleyball players during rest and exercise. *Acta Physiol Hung*. 2009 Mar;96(1):29-36.

Blumert P, Crum A, Ernsting M, Volek J, Hollander D, Haff E, Haff G. The acute effects of twenty-four hours of sleep loss on the performance of national-caliber male collegiate weightlifters. J *Strength Cond Res* 2007; 21:1146-1154.

Brooks A, Lack L. A brief afternoon nap following nocturnal sleep restriction: which nap duration is most recuperative? *Sleep*. 2006 Jun;29(6):831-40.

Bulbulian R, Heaney J, Leake C, Sucec A, Sjoholm N. The effect of sleep deprivation and exercise load on isokinetic leg strength and endurance. *Eur J Appl Physiol Occup Physiol* 1996; 73:273-277.

Chang AM, Aeschbach D, Duffy JF, Czeisler CA. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proc Natl Acad Sci U S A*. 2015 Jan 27;112(4):1232-7.

Forbes-Robertson S, Dudley E, Vadgama P, Cook C, Drawer S, Kilduff L. Circadian Disruption and Remedial Interventions: Effects and Interventions for Jet lag for Athletic Peak Performance. *Sports Med* 2012; 42(3): 185-208.

Gillberg M, Kecklund G, Axelsson J, Akerstedt T. The effects of a short daytime nap after restricted night sleep. *Sleep*. 1996 Sep;19(7):570-5.

Haack M, Mullington JM. Sustained sleep restriction reduces emotional and physical well-being. *Pain* 2005 Dec 15;119(1-3):56-64.

Haack M, Sanchez E, Mullington JM. Elevated inflammatory markers in response to prolonged sleep restriction are associated with increased pain experience in healthy volunteers. *Sleep* 2007 Sep;30(9):1145-52.

Haack M, Lee E, Cohen DA, Mullington JM. Activation of the prostaglandin system in response to sleep loss in healthy humans: potential mediator of increased spontaneous pain. *Pain*. 2009 Sep;145(1-2):136-41.

Halson S. Sleep in Elite Athletes and Nutritional Interventions to Enhance Sleep. *Sports Medicine*. May 2014, Volume 44, Supplement 1, pp 13-23.

Halson S. Stealing sleep: is sport or society to blame? *Br J Sports Med* published online November 26, 2015.

Hayashi M, Motoyoshi N, Hori T. Recuperative power of a short daytime nap with or without stage 2 sleep. *Sleep*. 2005 Jul;28(7):829-36.

http://www.jetlagrooster.com. Accessed March 9, 2016.

Kamdar BB, Kaplan KA, Kezirian EJ, Dement WC. The impact of extended sleep on daytime alertness, vigilance, and mood. *Sleep Med*. 2004 Sep;5(5):441-8.

Lastella M, Roach GD, Halson SL, et al. Sleep/wake behaviours of elite athletes from individual and team sports. *Eur J Sport Sci* 2015;15:94–100.

Leatherwood WE, Dragoo, JL. Effect of airline travel on performance: a review of the literature. *Br J Sports Med* 2013: 47:561-567.

Leeder J, Glaister M, Pizzoferro K, et al. Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *J Sports Sci* 2012;30:541–5.

Mah CD, Mah KE, Kezirian E, Dement WC. The Effects of Sleep Extension on the Athletic Performance of Collegiate Basketball Players. *Sleep*. 2011 Jul 1; 34(7): 943–950.

Mah CD. Extended Sleep and the Effects on Mood and Athletic Performance in Collegiate Swimmers. SLEEP 2008 22nd Annual Meeting of the Associated Professional Sleep Societies (APSS). Jun 9 2008.

Mejri MA, Yousfi N, Mhenni T, Tayech A, Hammouda O, Driss T, Chaouachi A, Souissi N. Does one night of partial sleep deprivation affect the evening performance during intermittent exercise in Taekwondo players? *J Exerc Rehabil*. 2016 Feb 1;12(1):47-53.

Morselli L, Leproult R, Balbo M, Spiegel K. Role of sleep duration in the regulation of glucose metabolism and appetite. *Best Pract Res Clin Endocrinol Metab*. 2010 Oct;24(5):687-702.

Mougin F, Bourdin H, Simon-Rigaud ML, Nguyen Nhu U, Kantelip JP, Davenne D. Hormonal responses to exercise after partial sleep deprivation and after hypnotic drug-induced sleep. *J Sports Sci.* 2001;19:89–97.

Mukherjee S, Patel SR, Kales SN, Ayas NT, Strohl KP, Gozal D, Malhotra A. An Official American Thoracic Society Statement: The Importance of Healthy Sleep. Recommendations and Future Priorities.; American Thoracic Society ad hoc Committee on Healthy Sleep. *Am J Respir Crit Care Med*. 2015 Jun 15;191(12):1450-8.

National Sleep Foundation. https://sleepfoundation.org/. Accessed March 9, 2016.

Oliver SJ, Costa RJ, Laing SJ, et al. One night of sleep deprivation decreases treadmill endurance performance. *Eur J Appl Physiol*. 2009;107(2):155–161.

Patel SR, Malhotra A, White DP, Gottlieb DJ, Hu FB. Association between reduced sleep and weight gain in women. *Am J Epidemiol*. 2006 Nov 15;164(10):947-54.

Reilly T, Deykin T. Effects of partial sleep loss on subjective states, psychomotor and physical performance tests. *J Hum Mov Stud*. 1983;9:157–170.

Reilly T, Hales A. Effects of partial sleep deprivation on performance measures in females. In: McGraw ED, editor. *Contemporary ergonomics*. London: Taylor and Francis; 1988. pp. 509–513.

Reilly T, Piercy M. The effect of partial sleep deprivation on weight-lifting performance. *Ergonomics*. 1994;37(1):107–115.

Reyner LA, Horne JA. Sleep restriction and serving accuracy in performance tennis players, and effects of caffeine. *Physiol Behav*. 2013 Aug 15;120:93-6.

Rowland TW. *The Athletes Clock: How Biology and Time Affect Sport Performance*. Champaign, IL: Human Kinetics; 2011.

Schwartz J, Simon RD Jr. Sleep extension improves serving accuracy: A study with college varsity tennis players. *Physiol Behav*. 2015 Nov 1;151:541-4.

Shaq Attacks Sleep Apnea. Harvard Medical School. https://www.youtube.com/watch?v=4JkiWvWn2aU. Accessed March 9, 2016.

Sinnerton S, Reilly T. Effects of sleep loss and time of day in swimmers. In: Maclaren D, Reilly T, Lees A, editors. Biomechanics and medicine in swimming: swimming science IV. London: *E and F.N Spon*; 1992. pp. 399–405.

Skein M, Duffield R, Edge J, et al. Intermittent-sprint performance and muscle glycogen after 30 h of sleep deprivation. *Med Sci Sports Exerc*. 2011;43(7):1301–1311.

Smith RS, Efron B, Mah CD, Malhotra A. The impact of circadian misalignment on athletic performance in professional football players. *Sleep* 2013 Dec 1; 36(12):1999-2001.

Souissi N, Chtourou H, Aloui A, Hammouda O, Dogui M, Chaouachi A, Chamari K. Effects of time-of-day and partial sleep deprivation on short-term maximal performances of judo competitors. *J Strength Cond Res*. 2013 Sep;27(9):2473-80.

Souissi N, Sesboue B, Gauthier A, Larue J, Davenne D. Effects of one night's sleep deprivation on anaerobic performance the following day. *Eur J Appl Physiol* 2003; 89:359-366.

Souissi N, Souissi M, Souissi H, Chamari K, Tabka Z, Dogui M, Davenne D. Effect of time of day and partial sleep deprivation on short-term, high-power output. *Chronobiol Int*. 2008 Nov;25(6):1062-76.

Taheri M, Arabameri E. The Effect of Sleep Deprivation on Choice Reaction Time and Anaerobic Power of College Student Athletes. *Asian J Sports Med* 2012 Mar; 3(1): 15–20.

Takeuchi L, Davis GM, Plyley M, Goode R, Shephard R. Sleep deprivation, chronic exercise and muscular performance. *J Ergonomics* 1985 Mar; 28(3):591-601.

Waterhouse J, Atkinson G, Edwards B, Reilly T. The role of a short post-lunch nap in improving cognitive, motor, and sprint performance in participants with partial sleep deprivation. *J Sports Sci*. 2007 Dec;25(14):1557-66.

Kyle Snyder and Jake Varner compete during their 97kg championship match on day 2 of the 2016 U.S. Olympic Team Wrestling Trials at Carver-Hawkeye Arena on April 10, 2016 in Iowa City, Iowa. (Photo by Jamie Squire/Getty Images)

Rate of Force Acceptance as an Injury Prevention Strategy in Athletic Populations

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Summary

In the pursuit to better create injury prevention strategies, it is important to dissect and learn more about the mechanisms of injury. In the training environment, high performance practitioners typically associate the concept of rate of force development (RFD) with acceleration characteristics mainly in the form of concentric-focused exercises (e.g., sprints, jumps, throws, and pulls). Although the literature shows a strong relationship between athletic activities, RFD, acceleration and concentric-based movements, the underlying factor associated with injury is often ignored. Research suggests that injures are typically correlated with eccentric muscle actions (Ibikunle et al, 2014; Mann, 1994; Peterson, Alvar, Rhea, 2006; Reiser, Rocheford, Armstrong, 2006; Schmidtbleicher, 1992). The premise of this article is to bring awareness to the rate of accepting forces rapidly for injury prevention.

Introduction

The ability to rapidly generate muscular force is a factor that separates athletes at various levels. Rate of force development is the ability to produce rapid force movements under significantly short time periods. It is defined as the slope of the force-time curve obtained for any given type of muscle action (Aagaard et al., 2002). Although there have been several important findings correlating rate of force development to athletic performance (Kraska et al., 2009), injury prevention is another underlying factor under the performance umbrella. Since decelerating-based movements typically occur eccentrically, it is important to attain a high level of strength and eccentric rate of force acceptance to help prevent injuries.

Importance of Eccentric RFA on Injury

Human musculature acts to manipulate forces in one of three conditions to produce skeletal movement: eccentrically absorbing (muscle lengthening), isometrically redirecting (no change in muscular length), and concentrically applying (muscle shortening). The inability to tolerate high forces rapidly in either of these muscle actions is a commonly overseen mechanism of injury. However, since practitioners typically associate performance with speed and quickness, it is important to understand that these movements are primarily concentric-based and focused on acceleration. Non-contact movement injuries have been linked with all causes of severe injures (Agel et al., 2007). Straining injuries are amongst the highest ranking and tend to result from stretching forces leading to structural

changes within the tissue (Merreck, 2002). Existing evidence has shown non-contact athletic activities such as jumping, landing, turning, twisting, running and kicking to play a prominent role for injury occurrence (Ibikunle, Ani, Useh, Akosile, 2014). These activities share a common denominator: the ability to match and overcome initial ground contact forces under 250ms driven strictly from eccentric muscle actions (Reiser, Rocheford, Armstrong, 2006), an underestimated factor associated with injury. For example, planting the foot on the ground requires the ability to maintain strength and stability within all joints as the initial ground contact is made. Hence, the importance of eccentric RFA. In other words, athletes must be able to match the speed at which contact is made and apply a force great enough to meet and overcome the initial onset of stimulus.

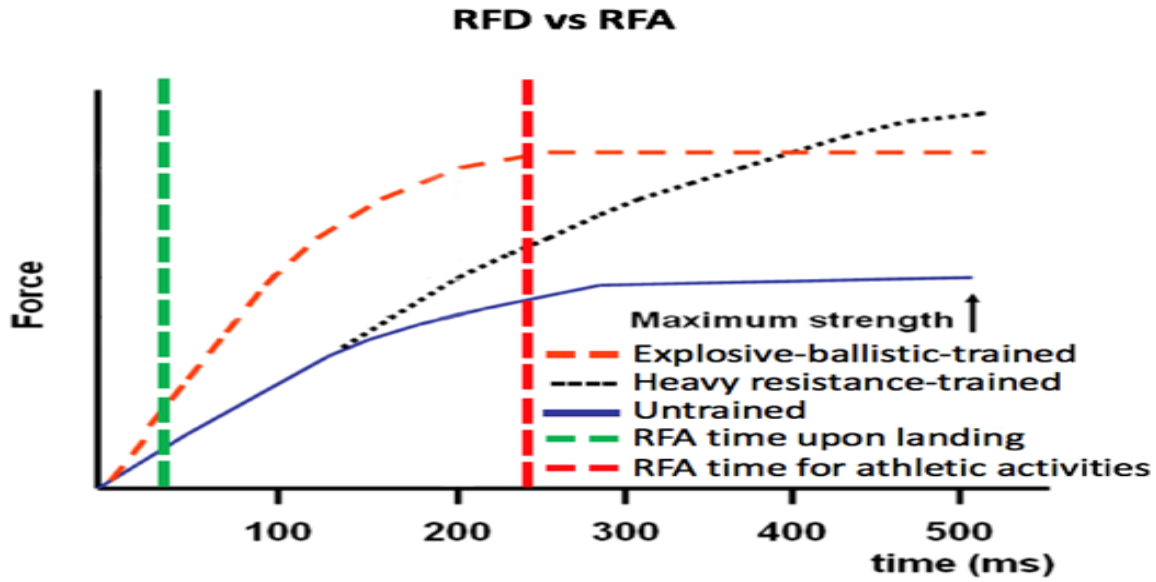

Figure 1: Difference between rate of force development and rate of force acceptance.

Nervous System and RFA on Injury

Human movement is a process; it is also the product of many complex biological systems. Without the deep interaction and simultaneous involvement of these systems, human movement could not take place (Partridge, 1966). To better understand these systems, we can use the following analogy: The nervous system functions in a manner that is similar to how a driver operates a vehicle. Just as a driver controls the direction and speed of the vehicle, the central nervous system is responsible for controlling the speed and direction of human movement. If and when the nervous system loses control, it can result in excessively higher forces being placed on ligamentous structures (Hoogenboom, 2010). It has been shown that stronger athletes produce more force at critical time intervals of 50ms, 90ms, and 250ms (Mann, 1994; Peterson, Alvar, Rhea, 2006, Schmidtbleicher, 1992), which increases their chances of avoiding injury. Since athletic demands of sport occur in less than 250ms (Reiser, Rocheford, Armstrong, 2006), the ability to generate peak forces under this time frame will allow a high force tolerance for muscles, tendons and ligaments during athletic participation. An athlete who takes more than 250ms (Reiser, Rocheford, Armstrong, 2006) to produce peak force is potentially at a higher risk of not being physically prepared to take on the impact of high forces associated with athletic competition.

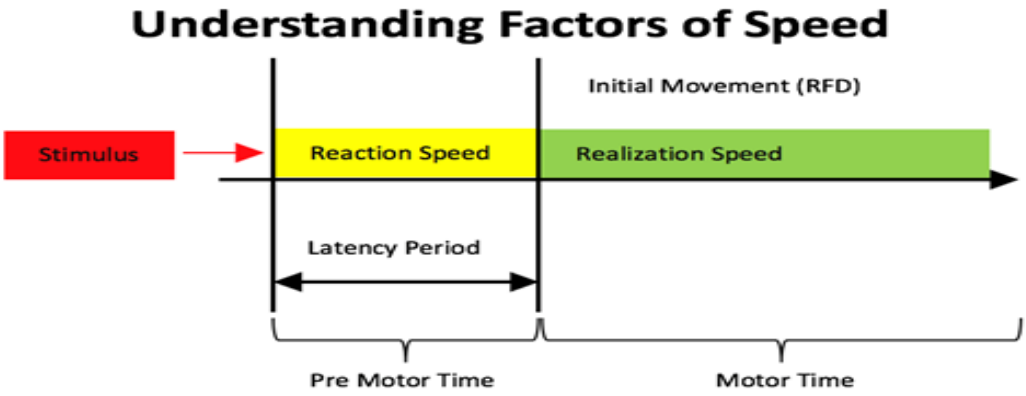

Figure 2: Specific periods of time associated with speed abilities.

Strength's Role on RFA

The evidence suggests strength serves as the foundation for all other essential athletic characteristics, allowing factors relating to athleticism to adapt more efficiently (Tabor, Bellon, Abbott, Bingham, 2016). In sport, athletes are constantly exposed to environmental factors that create potential for injury (McNitt-Gray, 1991). Eccentric strength and rapid neural recruitment are required to slow down the forces involved with momentum when landing, decelerating or changing direction. Studies have shown landing forces peak between 0-30ms upon ground contact (Bisseling, Hof, 2006) and range from 3.5-7.1 times the body weight (Gross & Nelson, 1988). As athletes reach higher velocities, the magnitude of these loads increase exponentially (McNitt-Gray, 1991). In order to tolerate these forces, the quality of our brakes (eccentric strength) and RFA must exceed the demands at which external forces act on the human body.

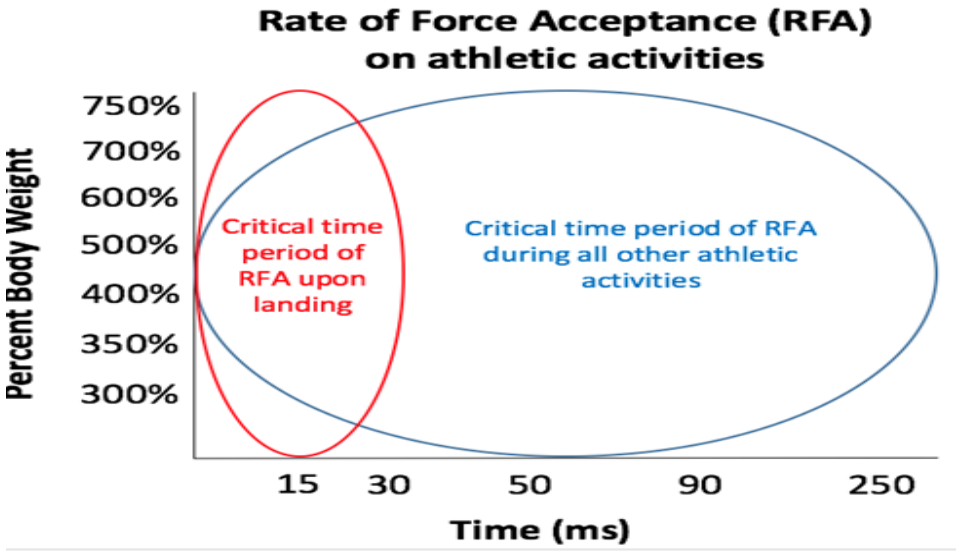

Figure 3: Importance of eccentric rate of force acceptance during landing and all other athletic competition (5,16,22,24).

Mechanism of Injury: RFA on the Spine

In jumping-based sports, athletes are exposed to a potential spinal whiplash affect upon landing. This potential affect requires a certain level of strength and RFA in upper and lower body muscles to prevent spinal flexion while receiving vertical landing forces. Preventing lumbar flexion during these activities is not only a result of lower body musculature (e.g. glutes, hamstrings, quadriceps, etc.), but also those attaching directly to the vertebra: multifidi, quadratus lumborum, longissimus and iliocostalis (Griffin, et al, 2000), all of which help an athlete maintain an upright torso when strength and eccentric RFA are achieved. Figure 4 (left) shows a favorable position allowing the transfer of forces (compressive and shearing) into the hips that helps protect the spine and rest of the skeleton (Cholewicki & McGill, 1996). Figure 4 (right) shows an athlete who lacks strength or the ability to eccentrically recruit muscles quickly (RFA) under a high load matching ground contact times of 0-30ms (Bisseling & Hof, 2006). This forces us to explore strategies to improve our stability during vulnerable times by increasing the rate at which we can accept force.

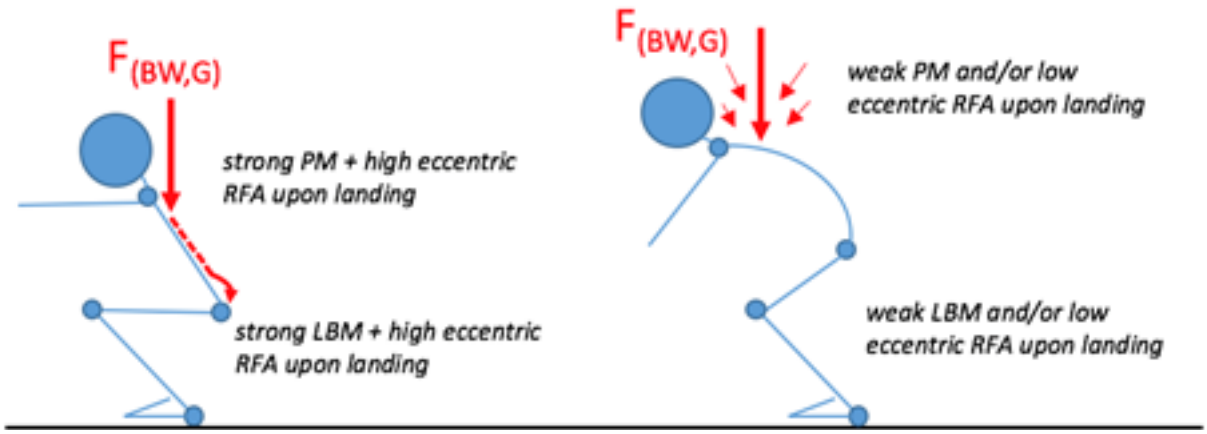

Figure 4: Left: strong lower and upper musculature accepting high forces quickly (RFA). Right: weaker lower body resulting in less force absorption from the legs and more from the back (18). PM= Paraspinal Musculature; LBM= Lower Body Musculature; F= Force; BW= Body Weight; G= Gravity

Mechanism of Injury: RFA on ACL

With an estimated high of 80,000 anterior cruciate ligament (ACL) injuries occurring annually in the United States (Griffin et al., 2000), it is important to understand the mechanisms in order to help prevent them. Evidence suggests that most ACL injuries occur during non-contact movements such as decelerating, pivoting or landing (Hewitt et al., 2005). Ligament dominance is a condition where muscles lack the ability to absorb ground reaction forces (Hoogenboom, 2010). This leaves joints and ligamentous tissue no other option but to absorb these forces, resulting in potential ligament ruptures. Musculature responsible for stability of the knee comprise of the gluteals, hamstrings, gastrocnemius and soleus (Hoogenboom, 2010). Weakness or inability to fire these muscles quickly is a common mechanism of ACL injury. Newton's third law of motion states that for every given action there is an equal and opposite reaction. When a volleyball player is landing from a jump or a soccer player is changing direction, there is an equal and opposite force directed toward the body's center of mass.

These reaction forces are two to three times the initial force (Hoogenboom, 2010). If our trunk (typically the center of mass) is shifted away from ground contact by lateral flexion or trunk instability, GRF will follow in the direction of the trunk (COM), causing force vectors to place a valgus torque on the knee. Frontal plane core and hip control is important to help prevent ACL injuries.

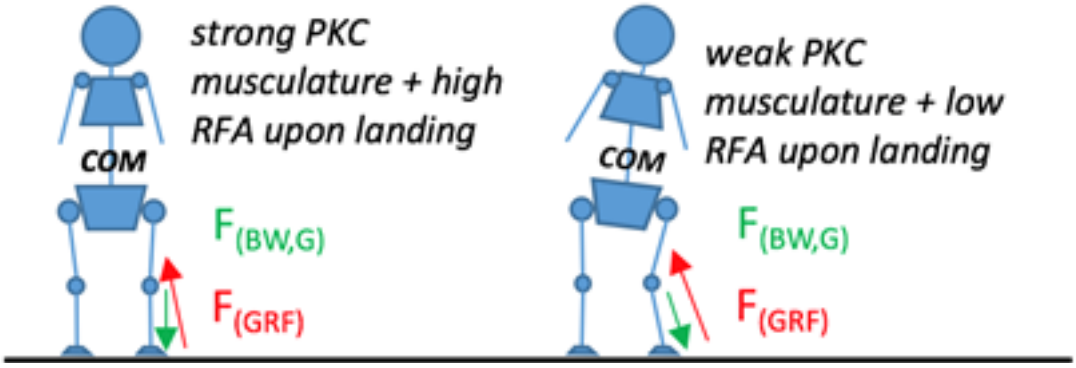

Figure 5: Mechanism of ACL injury when landing.

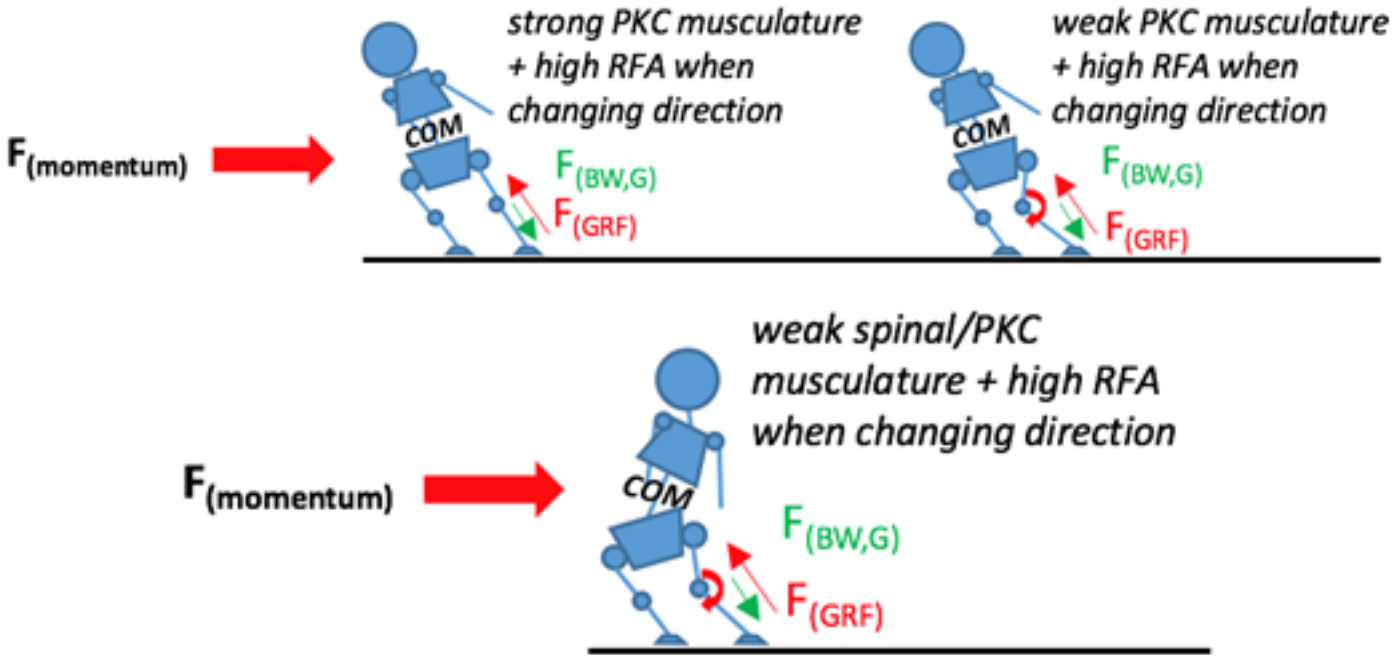

Figure 6: Mechanism of ACL injury when changing direction. PKC = Posterior Kinetic Chain (spinal erectors, hip external rotators, and hip abductors); RFA = Rate of Force Acceptance; GRF = Ground Reaction Force.

Understanding RFD: Importance of Intention on Neural Recruitment

To better understand the importance of eccentric movements, we will discuss the role of concentric actions. Although rapid movements are important, the intention to move rapidly is another underlying factor. By observing the force-time curve, we can expect higher accelerations during a lighter loaded movement versus the contrary. Studies have shown that training with light loads of 15-35% of one's repetition maximum (RM) helps improve the high velocity portion of a force-time curve (Kaneko,

Fuchimoto, Toji & Suei, 1983; McBride, Triplett-McBride, Davie & New-Ton, 2002), while training with heavy loads (90% 1RM) improves the high force portion assuming maximal intentional dynamic efforts (Kaneko, Fuchimoto, Toji & Suei, 1983). In other words, lighter loads lead to faster athletic movements, while heavier loads lead to higher force production. However, since movement velocities are determined by impulses applied by the musculoskeletal system to accelerate external load (McBride, Triplett-McBride, Davie & New-Ton, 2002), contrary research evidence exists. Behm and Sale compared isometric/isokinetic protocols to help explain the justification behind intentional explosive movement on velocity-specific responses of an isometric versus isokinetic ankle dorsiflexion (5.23 rad·s–1). While attempting to move quickly under both scenarios, results showed similar high velocity-specific responses during both protocols (Behm & Sale, 1993). Therefore, attempting to move quickly under higher resistances was concluded to be a better method for improving rate of force development as the heavier loaded protocol yielded the generation of higher force (Behm & Sale, 1993). Though it is unclear which training method will elicit greater rate of force development adaptations, both mechanisms are important. Strength professionals are constantly working to improve the ability to tolerate forces at unpredictable intensities for the sake of injury prevention. Therefore, by training with light/heavier loads (15-35% and 85-90% 1RM respectively) and producing maximal dynamic efforts with intent, we are stimulating two underlying factors relating to injury prevention: speed of force and the ability to elicit force tolerance at high speeds. By stimulating these types of adaptations, we are not only preparing athletes to tolerate forces at a rate less than 250ms (Reiser, Rocheford, Armstrong, 2006), we are also prepping them to express higher percentages of their overall strength during these vigorous times.

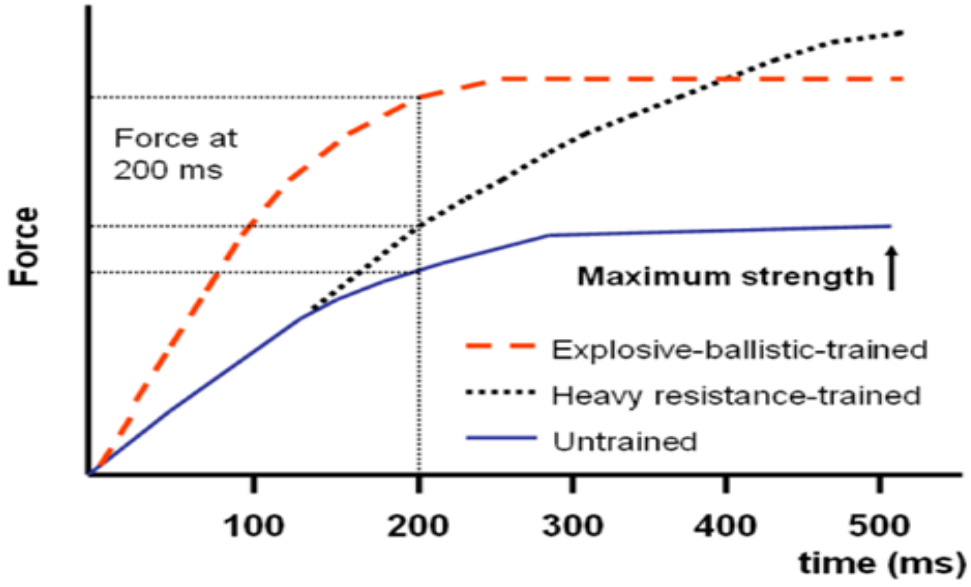

Figure 7: Rate of force development (26) – Founded on the idea of concentric activity: Maximum concentric force output (CFO) is reached at higher time intervals whereas lower CFO is seen during lower time intervals.

Understanding Force Vectors

Force is generated by the ability to either push or pull against a given object. In order to describe how objects act in relation to one another, forces possess vectors that contain a magnitude and a direction. In an athletic environment, athletes work to manipulate three external forces to produce move-

ment: contact forces (forces transferred from one object to another), non-contact forces (e.g. gravitational force acting on an object or person) and air resistance (Kawamori, Nosaka & Newton, 2013). By understanding force vectors, we can begin to appreciate the need to position our bodies in favorable ways to absorb, redirect and apply forces more efficiently. By doing so, we can improve qualities relating to athletic performance and injury prevention. By improving our body positioning, we can achieve positions that improve the vectors in which we receive and apply force. For example, by lowering our center of mass and positioning our levers appropriately when changing direction, we improve efficiency. The ability to manipulate force vectors is a highly sought-after characteristic of elite athletes.

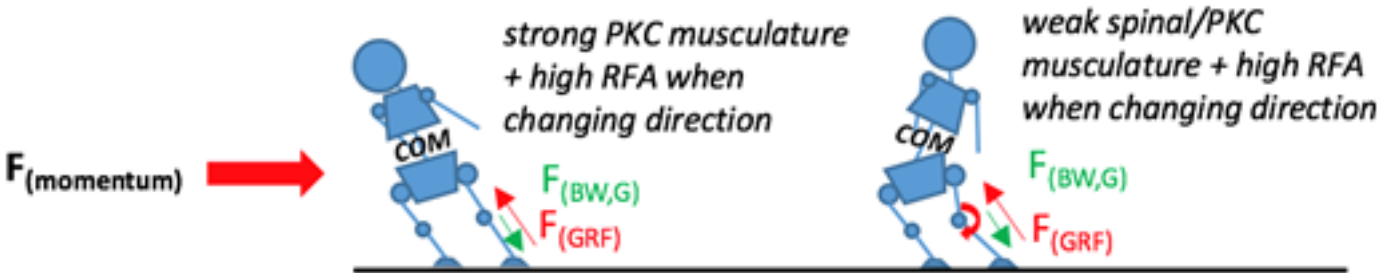

Figure 8: Athletes changing direction – Left: Maintains proper force vectors allowing them to change directions more efficiently. Right: Lacks the ability to maintain rigidity leading to the inability to maintain proper force vectors.

Conclusion

Although producing high forces is important, perhaps the most important factor for injury prevention in sport is the ability to decelerate against the forces occurring in less than 250ms (Reiser, Rocheford & Armstrong, 2006). It is important to respect and train concentric action to improve athletic abilities (e.g., speed, power and quickness), but the research discussed in this article supports the idea of also working to improve the speed at which we can absorb force. Moreover, these training qualities feed off one important element: strength. Newton's second law states that higher forces result in higher accelerations (f=ma). Without a higher force production, athletes are limited to the demands of external force tolerance. Furthermore, by emphasizing eccentric muscle actions under light and heavy loads, we are assuring that two underlying factors relating to injury prevention are stimulated: speed of force and percentage of total force applied during decelerating demands. Applying these vital factors to our understanding of force vectors increases the likelihood of our athletic population to stay injury-free and equipped with the prerequisites for enhancing all other athletic abilities. We can apply corrective exercises, monitor training loads and prescribe self-care strategies in hope to limit potential for injury. However, if we are not training to tolerate high eccentric force actions, we will continue to see injuries within the athletic population.

References

Aagaard, P., Simonsen, E.B., Andersen, J.L., Magnusson, P. and Dyhre-Poulsen, P. (2002) Increased Rate of Force Development and Neural Drive of Human Skeletal Muscle Following Resistance Training. *Journal of Applied Physiology* 93(4), 1318-1326.

Agel, J., Evans, T. A., Randall, W. D., Putukian, M. & Marshall, S.W. (2007). Descriptive epidemiology of collegiate men's soccer. *Journal of Athletic Training*, 42(2), 270-277.

Anderson, K. G., & Behm, D. G. (2004). Maintenance of EMG activity and loss of force output with instability. *The Journal of Strength & Conditioning Research*, 18(3), 637-640.

Behm, D.G., & D.G. Sale. Intended Rather Than Actual Movement Velocity Determines Velocity-Specific Training Response. *Journal of Applied Physiology*. 74:359– 368. 1993.

Bisseling, R. W., & Hof, A. L. (2006). Handling of Impact Forces in Inverse Dynamics. *Journal of Biomechanics*, 39(13), 2438-2444.

Chiel, H. J., & Beer, R. D. (1997). The Brain Has a Body: Adaptive Behavior Emerges from Interactions of Nervous System, Body and Environment. *Trends in Neurosciences*, 20(12), 553-557.

Cholewicki, J., & McGill, S. M. (1996). Mechanical Stability of the in vivo Lumbar Spine: Implications for Injury and Chronic Low Back Pain. *Clinical Biomechanics*, 11(1), 1-15.

Griffin, L. Y., Agel, J., Albohm, M. J., Arendt, E. A., Dick, R. W., Garrett, W. E., & Johnson, R. J. (2000). Noncontact Anterior Cruciate Ligament Injuries: Risk Factors and Prevention Strategies. *Journal of the American Academy of Orthopedic Surgeons*, 8(3), 141-150.

Gross, T. S., & Nelson, R. C. (1988). The Shock Attenuation Role of the Ankle During Landing from a Vertical Jump. *Medicine and Science in Sports and Exercise*, 20(5), 506-514.

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S., Colosimo, A. J., McLean, S. G., ... & Succop, P. (2005). Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes a Prospective Study. *The American Journal of Sports Medicine*, 33(4), 492-501.

Hoogenboom, B. J. (2010). NAJSPT. *North American Journal of Sports Physical Therapy*, 5(4), 234.

Ibikunle, P.O., Ani, U.K., Useh, U., & Akosile, C.O. (2014). Mechanisms of Sports Injuries Among Professional Footballers: A Review. *African Journal for Physical, Health Education, Recreation & Dance*, 20(2.1), 453-479.

Kaneko, M., T. Fuchimoto, H. Toji, & K. Suei. Training Effects of Different Loads on the Force-Velocity Relationship and Mechanical Power Output in Human Muscle. *Scandandinavian Journal of*

Sports Science, 5:50–55. 1983.

Kawamori, N., Nosaka, K., & Newton, R. U. (2013). Relationships Between Ground Reaction Impulse and Sprint Acceleration Performance in Team Sport Athletes. *The Journal of Strength & Conditioning Research*, 27(3), 568-573. Chicago.

Kraska, J., Ramsey, M., Haff, G. , Fethke, N. , Sands, W. , et al. (2009). Relationship Between Strength Characteristics and Unweighted and Weighted Vertical Jump Height. *International Journal of Sports Physiology and Performance*, 4(4), 461-473

Mann R. *The Mechanics of Sprinting and Hurdling*. Orlando: Compusport; 1994.

McBride, J.M., T. Triplett- McBride, A. Davie, & R.U. New- Ton. The Effect of Heavy- vs. Light-Load Jump Squats on the Development of Strength, Power, and Speed. *The Journal of Strength & Conditioning Research*. 16:75–82. 2002.

McGill, S. M. (2001). Low Back Stability: From Formal Description to Issues for Performance and Rehabilitation. *Exercise and Sport Sciences Reviews*, 29(1), 26-31.

McNitt-Gray, J. L. (1991). Kinematics and Impulse Characteristics of Drop Landing from Three Heights. *International Journal of Sport Biomechanics*, 7(2), 201-224

Merrick, M.A. (2002). Secondary Injury After Musculoskeletal Trauma: A Review and Update. *Journal of Athletic Training*, 37(2), 209-217

Partridge, L.D. (1966). Nervous System Actions and Interactions: Concepts in Neurology. *American Journal of Physiology*, 210, 1178–1191

Peterson MD, Alvar BA, Rhea MR. The Contribution of Maximal Force Production to Explosive Movement Among Young Collegiate Athletes. *The Journal of Strength & Conditioning Research*. 2006;20:867–873.

Reiser RF, Rocheford EC, Armstrong CJ. Building a Better Understanding of Basic Mechanical Principles Through Analysis of the Vertical Jump. *The Journal of Strength & Conditioning Research*. 2006;28:70–80

Schmidtbleicher D. *Training for Power Events. In: Komi PV, ed. Strength and Power in Sport*. London: Blackwell Scientific Publications; 1992:381–395.

Taber, C., Bellon, C., Abbott, H., & Bingham, G. E. (2016). Roles of Maximal Strength and Rate of Force Development in Maximizing Muscular Power. *Strength & Conditioning Journal* (Lippincott Williams & Wilkins), 38(1), 71-78.

Training speed abilities. Graphs. Retrieved from: https://publi.cz/books/52/09.html

On the cover: Kelly Catlin (L), Chloe Dygert (2nd L), Sarah Hammer (2nd R) and Jennifer Valente (R) of USA celebrate after winning the Women's Team Pursuit Final during Day Three of the UCI Track Cycling World Championships at Lee Valley Velopark Velodrome on March 4, 2016 in London, England.

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