Dynamic compression for recovery in athletes

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US Olympic Committee researchers have found that peristaltic pulse compression of the lower extremities may provide a means of enhancing the rheological properties of the lower extremities without resorting to extreme temperatures, expensive body work, or stretching.

By William A Sands, PhD, FACSM, CSCS

Limb compression has involved massage, specialized compression garments and devices, and water submersion. My experience with limb compression came informally and later formally as an athlete, coach, sport physiologist, and director of the US Olympic Committee (USOC) Recovery Center in Colorado Springs, CO.[1] I served as the director of the Recovery Center from its inception in 2005 and for the three years leading up to and following the Beijing Olympic Games in 2008. The development, study, and conduct of athlete recovery were among my responsibilities.

As director, head of Sport Biomechanics and Engineering, and a senior sport physiologist at the USOC, I was intensely interested in finding and exploiting technology, therapies, and training methods that could give US athletes a competitive edge. Of course, any technology or methodology had to conform to the rules of each sport, the USOC, and the International Olympic Committee (IOC).

I became interested in limb compression for enhancing recovery because of the donation of several devices from NormaTec. The compression characteristics of these devices were described as “peristaltic pulse compression” (PPC). Peristalsis is a sequential wave of pressure produced by the tension and relaxation of muscles radially along a hollow tube. Peristalsis produces a wave of pressure that promotes the movement of materials through a tube, such as the esophagus, intestines, blood vessels, and lymphatic structures. PPC refers to a sequential pressure wave applied through circumferential leggings. The leggings are composed of segmented tubes that permit computer-controlled pressure variations in each cell and from cell to cell. By increasing and decreasing cell pressures in a peristaltic manner, PPC leggings can promote the movement of tissue materials and fluids within the lower extremities.

I was largely free to explore these devices and their use with athletes. However, my work with any technology or methodology was and is constrained by the fact that any device I investigated could do no harm, had to function within existing USOC and IOC rules, and had to result in large effects. Sport scientists are bound ethically and pragmatically by a high regard for the time and effort of their athletes. High-performance athletes have enormous demands on their time; they simply cannot, and usually will not, take part as a research volunteer unless there are direct benefits to them. In short, I could not simply study something that was of academic interest to me; the study had to exhibit a large probability of performance and recovery enhancements.

I began by showing the athletes how PPC worked. I knew that if the athletes did not like the devices, whether because of appearance, discomfort, excessive time commitment, or whatever, the devices would fail. However, from the outset athletes were offering unsolicited and glowing reports. A gymnast wanted to know what the “deal” was with these devices because, following use, he had the best training session in his memory. A mountain bike athlete was so impressed that he bought one and encouraged USA Cycling officials to buy them for use during domestic and foreign competitions. Athletes sought me out to report that they were suddenly more flexible than ever, and delightedly showed me that they could palm the floor with straight knees for the first time.

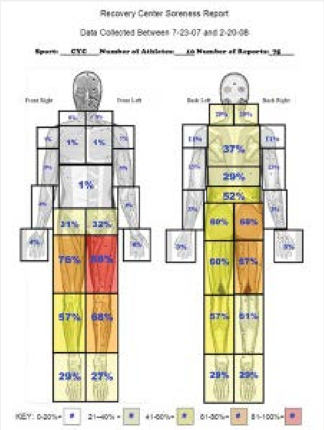

Figure 1. Soreness records from the US Olympic Training Center Recovery Center. Note that this image shows the results of athletes’ selection of body regions and soreness ratings—low, medium, and high. These records were obtained by direct computer input as the athletes entered the Recovery Center. This group of track cyclists shows that some areas of the body tend to show greater soreness and pain than others.

The flexibility changes led to a study of the use of PPC to enhance short-term flexibility.[2] The study confirmed that PPC could enhance flexibility among collegiate dancers in a split position. My proposed mechanism was the enhancement of muscle thixotropic properties.[3-6] In addition to enhanced flexibility, there were other benefits of treatment identified by the athletes. The athletes reported that they felt fresher following PPC, even into the next day. Users also noted a reduction in leg agitation while sleeping.

The study of recovery

Studying recovery is problematic. As a sport physiologist, I have often lectured that there is nothing performance-legal (ie, outside of steroids, stimulants, etc) that is powerful enough to overcome stupid coaching, bad planning, and no talent. Moreover, recovery and the other side of the same coin, fatigue, are multidimensional. Long-term observations of recovery modalities and their effects on athletes has shown that recovery effects are short-lived (hours to a couple of days),[7,8] highly susceptible to placebo effects,[9] and may make athletes feel better but may not transfer to performance.[10,11] Fatigue serves as a stimulus that causes an adaptive response (ie, supercompensation).[12] Athletes need to walk a tightrope above failure; they can fall to the side of undertraining and lose because other athletes out-train them. In contrast, athletes can fall from the tightrope to the other side and suffer overtraining[13,14] or under-recovery,[15] in which they succumb to poor performance,[16,17] infection,[18] illness,[19] injury,[20-22] depression,[23,24] and other debilitating problems.

Figure 2. NormaTec leggings deflated. The subject sat in this position for 15 minutes while the leggings were inflated in a PPC sequence (experimental condition) or delated (control condition).

There appears to be little consensus on the definitions of fatigue and recovery. Fatigue is usually operationalized as: the inability of an athlete to attain or maintain a specific force level or the failure to persist in the performance of successive repetitions of some movement skill.[25-28] My personal experience with fatigued athletes has shown that the use of force development or persistence at a skill was not adequate to cover the constellation of factors that influence an athlete’s perception of fatigue. Moreover, there may be placebo effects at work[29,30] and athletes playing different sports may manifest fatigue in different ways. Athletes may express fatigue and soreness unilaterally, regionally, and in skill-specific or sport-specific ways (Figure 1). Placebo effects are likely to occur when the involved recovery modalities rely heavily on the rapport developed among the athlete, therapy, and therapist.[9] The influence of placebo effects is relatively well known in circumstances in which people are led to believe that a treatment is efficacious in spite of a lack of empirical evidence.[30-32]

Although numerous variables confound the study of fatigue and recovery, aspects that are ubiquitous among athletes are pain, stiffness, and soreness.[33-36] These symptoms may provide a window through which to explore fatigue and recovery when studying athletes from different sports. Pain, stiffness, and soreness can arise from the inflammatory cascade, including edema, enhanced immune response, altered endocrine response, and disability.

Although a number of studies have

investigated exercise-induced edema and the constellation of related symptoms,[37-55] this information has yet to permeate athlete training, recovery, and rehabilitation. Unfortunately, exercise-induced edema can rise to the level of rhabdomyolysis when exercise is too intense, rest is insufficient, or circulation is compromised for an extended period.[56-59]

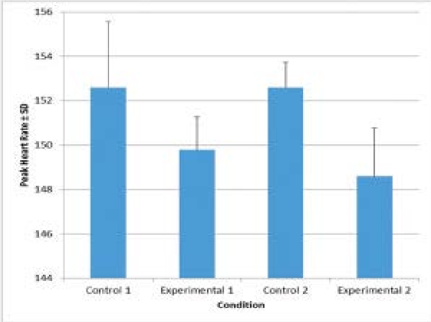

Figure 3. Peak heart rate response. Single-subject design experiment. Note that each bar represents the average of five stair-climbing interval sessions.

Recent discourse has questioned the time-honored use of ice for tissue cooling and as a means of reducing edema, aiding recovery, and healing.[60-62] Cryotherapy as the default therapy for recovery enhancement and nearly any injury has recently come under scrutiny.[61,63-65] Moreover, there is some evidence that compression alone is as effective as cryotherapy and compression.[65]

Effects of PPC in athletes

To investigate the use of PPC on athletes, I conducted a study[66] of 24 US national team athletes (12 women), 12 in an experimental group and 12 in a control group. Athletes in the experimental group wore the PPC leggings, which were inflated by a computer-controlled air pump. The control group wore leggings that were not inflated by the computer pump.

The experimental and control treatments followed the same protocol, which involved sitting in a chair with feet elevated on a second chair for the duration of the inflated or noninflated conditions. An algometer and pressure-to-pain (PtP) threshold assessed the amount of pressure that induced pain from the gastrocnemius, vastus lateralis, and biceps femoris muscles. PtP was first tested in the athletes at rest following morning training. Each group then received the experimental or the sham treatment. The athletes were retested immediately using PtP threshold and again following afternoon training.

The results showed statistically significant improvements in PtP thresholds, with the athletes in the experimental group able to tolerate more pressure before experiencing pain compared with their baseline measures and with control athletes. All test sites showed improvements in PtP threshold with no statistical interactions among muscles and treatment sequence. Moreover, the effects persisted after the afternoon training session.[66] This study has been accepted for publication.

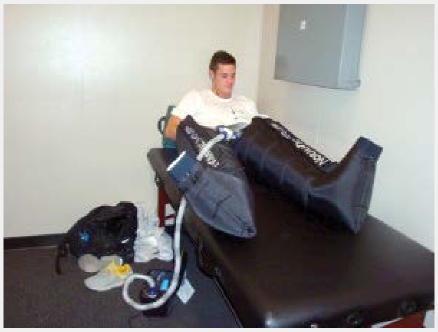

Figure 4. David Boudia, USA Diving team member and London 2012 Olympic champion, using PPC to enhance his diving performance and recovery.

Interestingly, resident athletes at the USOC also commented that PPC aided performance when used prior to their workout. Recovery modalities may be similar to the "prehabilitation" exercises that are often prescribed by coaches, therapists, and physicians in an effort to prevent or reduce the consequences of injury.[67,68] Athletes do the same exercises in both prehabilitation and rehabilitation, but in the former the intent is injury prevention and amelioration by enhancing fitness of muscles and joints before an injury occurs, thereby shortening rehabilitation time. The observation of these athletes led to an exploratory single-subject design study.

The study I conducted sought to determine heart rate response to the use of PPC prior to 10 stair-climb intervals experienced five times per week. The single-subject design was a classic A-B-A-B experiment.[69-71] Each A or B segment involved five separate days/sessions of stair climbing. The A segment involved the control condition, in which the subject wore the leggings in the noninflated condition for 15 minutes (Figure 2). Following the A segment control treatment, the subject performed 10 stair-climb interval repetitions. For the B days/sessions, the subject wore the leggings, which were inflated by the computerized air pump, and then removed them prior to the 10 stair climbs. Pressure, duration (15 minutes), and rest periods were set at factory defaults.

The athlete climbed the stairs of the athletic dome at East Tennessee State University in Johnson City 10 times for each session. Peak heart rate was recorded following each climb and descent, and the A,B,A, and B average peak heart rates were lower during the experimental conditions than the control conditions (Figure 3). Thus, the results indicate that some aspect of the PPC was enhancing metabolic response by reducing the metabolic cost of the stair-climbing exercise. A single-subject design experiment, while valid, is seldom conclusive, suffering from low external validity.[69,72] In spite of these limitations, these results and the anecdotal athlete reports suggest that PPC appears to be a promising enhancer for both recovery and performance.

The conjunction of enhanced flexibility and enhanced recovery may point to similar mechanisms within the field of rheology. Thixotropy is a property of rheology that concerns viscous fluid transitions to and from liquid and gel-like states. Previous work in the use of vibration to enhance lower extremity flexibility appears to support the concept of thixotropy in that shaking, agitating, or stressing fluids within tissues leads to large enhancements of range of motion acutely and long term.[73-83] PPC may be another means of applying agitation to tissues that enhances the transition from a gel-like state to a more liquid-like state, promoting ease of motion within the tissue. Muscle “stiffness” is a common complaint among athletes who are recovering from hard training. Thermal, vibrational, or compressive stress to the stiff tissues may improve the athlete’s motion capabilities and reduce the pain associated with muscle stiffness.

Implications

PPC is being used in many sports with athletes at many levels. Figure 4 shows David Boudia, a US Olympic diving champion in the London 2012 Games, using the compression devices. Diving is just one sport in which we have found that regular and systematic use of PPC enhances performance.

Dynamic compression of the lower extremities may provide elite athletes, recreational athletes, and patients with a means of enhancing the rheological properties of the lower extremities without resorting to extreme temperatures,[84-88] expensive body work,[7,89-92] or stretching.[93] Future research and clinical assessments should incorporate wider-ranging populations, longer treatment periods, and adjustments of pressures used for compression.

William A Sands, PhD, FACSM, has served as a sport scientist, physiologist, and biomechanist at the University of Utah in Salt Lake City, the US Olympic Training Center in Colorado Springs, CO, and the National Strength and Conditioning Association in Colorado Springs.

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