

Protective and Supportive Garments and Bracing to Enhance Extreme Sport Performance and Injury Prevention

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SUMMARY

Background. Protective and supportive trunk, limb and joint garment or brace use to enhance performance and prevent injury among extreme sport athletes is evolving.

Methods. This review discusses protective and supportive trunk, limb and joint garment or brace use from the perspective of the essential mental and physical demands of extreme sports with special consideration for improving capsuloligamentous, musculotendinous, and myofascial system function.

Results. Bracing to protect or support, preserve and promote natural joint function is evolving from the use of heavier, rigid, over-constraining and poorly fitting devices to lighter, more flexible, lower profile, function-enhancing garments or braces. Therapeutic exercises that combine task-specific self-efficacy and problem-solving skill development may best optimize innovative protective and supportive trunk, limb and joint garment or brace use.

Conclusions. Through greater surface contact area and enhanced cutaneous, capsuloligamentous, musculotendinous and myofascial system mechanoreceptor function, a new evolution of protective and supportive trunk, limb and joint garments or braces may be better able to effectively facilitate more natural joint protection, proprioception/kinesthesia and dynamic stability.

KEY WORDS

Experiential rehabilitation; adventure sports; therapeutic exercise.

INTRODUCTION

Given the dynamic environments in which extreme sport athletes perform, adaptability and creativity are needed when rehabilitation clinicians provide guidance about protective and supportive trunk, limb and joint garment or brace use. Similarly, rehabilitation clinician interactions should consider environmental demands, the unique needs of the rehabilitating extreme sport athletes and the specifics of essential task performance. Task performance parameters should be manipulated from physical, cognitive and environmental perspectives (1). To best refine participant judgement and decision making, it is important that the extreme sports athlete is an active participant in the learning experience (1).

Through soft tissue mobilization, massage, and stretching techniques, myofascial tissue have become a growing rehabilitation treatment intervention focus. Altered coordination, proprioception, balance, pain levels, and cramping are often associated with the deep fascia and epimysium, as they influence muscle, nerve, blood vessel, and organ functions (2). In contrast, the superficial fascia is more often associated with lymphatic and superficial vein circulation and thermoregulatory functions.

Athletes can display addiction-like behaviors (3). These behaviors often lead them to devote continually increasing time and monetary resources to perform their preferred sport at higher skill levels, with progressively greater

injury risks (4). In addition to the increased injury risk associated with extreme sport participation, when these athletes are prevented from sport participation because of defective, restrictive, or poorly fitting equipment, they may suffer emotional or mental distress with powerful physiological and psychological symptoms (4). Therefore, the functionality, durability and ease of use of recommended protective and supportive garments or braces is essential to use adherence.

MENTAL AND PHYSICAL DEMANDS

The demands of climbing and abundance of both psychological and physiological data (5) makes it an intriguing model for discussing the potential rationale for supportive and protective garment and brace use. Climbing intensity increases from either greater upper limb muscle engagement or greater whole body effort (6). Increased climbing route difficulty redistributes the workload to smaller muscle groups, particularly in relationship to grip-surface reductions (6). Climbing research has focused primarily on its physical requirements, placing little emphasis on its cognitive, psychological and behavioral aspects (7). Climbing, like many other extreme sports, incorporates strong physiological and psychobehavioral links (6,8,9). Climbing not only requires a profound understanding of how to recognize and interpret environmental constraints such as weather conditions (temperature, humidity, wind velocity, etc.) and rock, ice or other surface characteristics, but also requires instantaneous adaptability and highly tuned skills (10) (**figure 1**). In this context, when protective and supportive garments and braces are used, they must adapt instantaneously to changing environmental conditions and not negatively influence the climber's ability to perform skillful movements.

Combined mental and physical climbing demands, in combination with exercise-induced central and peripheral fatigue, increases heart rate, cortisol and lactate concentrations (8). Magiera et al (6) studied athletes under high, moderate, and low physical and psychological demand climbs. They identified lower physiological demands with climbing route familiarity and the performance of single moves of comparable difficulty. Physical exercise exerts considerable salivary cortisol concentration increases, when exercise intensity exceeds 60% VO_2 max or lasts at least 20-30 min (11). Cortisol levels increase within 10 minutes and reach a maximum at the 10th to 30th minute after stress cessation (12). Similar cortisol concentration increases have also been reported for downhill mountain biking (13). Magiera et al. (6) reported that three repetitions of a difficult climbing route with a short recovery time increased post-climbing cortisol concentrations. The highest cortisol levels were observed immediately following climb descent. Even antic-

ipation of stressful experiences cause sympathetic nervous system and hypothalamic-pituitary-adrenal axis activation, resulting in cortisol release (12). Selected protective and supportive devices also should not contribute to heightened climber stress levels.

When exercise intensity exceeds the anaerobic threshold, lactate accumulates in skeletal muscle, resulting in decreased intramuscular pH (14). Lactate removal can be improved by increasing blood flow to other body parts and enhancing its oxidation through greater use of previously inactive muscles or other organs such as the liver (15). Intense or prolonged forearm muscle activation increased lactic acid concentrations, while aerobic metabolism across greater muscle mass improved its clearance. Blood lactate concentrations after rock climbing are lower than cycling because of the smaller total muscle mass that is exercised (16). During treadwall climbing until exhaustion, maximum blood lactate concentrations are higher (10.2-11.1 mmol/l) (17) than during actual climbing (< 6.8 mmol/l)(18). The aerobic and anaerobic alactic systems are the primary energy systems used during indoor rock climbing (19). When climbing wall angles exceed vertical, grip strength decreases and blood lactic acid concentrations significantly increase (20). Magiera et al. (6) found that peak heart rate was the most sensitive mental and physical stress level and workload measurement among rock climbers. Protective and supportive devices should not restrict the circulatory function necessary for lactic acid clearance and active recovery. Seifert et al. (21) showed that more experienced climbers used more diagonal hip positions relative to the climbing wall when using holds that necessitated a side-on coordination pattern. Experienced climbers also had a larger



Figure 1. Environmental conditions, equipment needs.

movement pattern repertoire so they could better adapt to constraints as climbing hold orientations changed. The learner's movement intentions are, in some ways, determined by their pre-existing coordination repertoire. The way an athlete explores and learns a new task is influenced by the number of movement solutions that they possess under an already experienced existing set of constraints (22). Implications for extreme environment climbing are that climbing walls with planned route variability can provide effective learning contexts for movement skill development when they are accompanied by opportunities that enhance environmental knowledge and decision-making skills. Safely exploring new movement coordination patterns and the complex alignment of cognitive and sensorial experiences is paramount to extreme sport performance adaptations and safety (23). While protecting or supporting a specific joint or body region, the selected brace or garment should not adversely affect adjacent joint function or otherwise restrict the climber's ability to assume essential positions.

SYNERGISTIC TRUNK, LIMB, AND JOINT MYOFASCIAL SYSTEM ENHANCEMENT

Muscle fibers are contractile components of a functional complex that is inseparable from its parallel and series

non-contractile fibrous components. Activated muscle forces depend not only the anatomical structure of the muscle or muscle group, but also on the angle at which its fibers attach to intramuscular connective tissues, the epimysium and the deep fasciae (24). Fascia is an elastic tissue with established extensibility limits that effectuate motor coordination, movement perception and postural variation signaling (25). The endomysium, perimysium, epimysium and deep fasciae are fundamental to muscular force transmission, with each tissue possessing a specific role (24).

The myofascial system originates proximal to the upper and lower extremities to provide both joint and extremity protection, containment and stability. Neurophysiologists support the presence of a peripheral movement coordination system activated through gliding fascial layers (26). The brain interprets movement as three-dimensional agonistic synchrony during spatial movement task performance, not as independent muscle actions (27). Located within high muscular traction zones are densely innervated myofascial coordination centers (26). Through its basal tension, myofascial structures help maintain appropriate body posture. Acute injury or chronic inflammatory conditions at these centers can densify the tissue with unorganized collagen fibers, leading to pain. The body neutralizes this pain by adopting a compensatory, maladaptive posture to better



Figure 2. Evolving knee brace designs (A. Genu Medi Pro Knee Support; B. E + Motion Soft Support).

re-establish basal tension. During healing, newly developed collagen fibers can only align themselves along the normal segmental force lines when normal basal myofascial tension exists (26). Myofascial system activation during movement can vary from individual motor units to multiple myofascial unit sequences across adjacent joint segments. To better engage myofascial system synergies, innovative protective and supportive garment or brace interfaces are being developed that blend compressive fit with embedded diagonal straps, mediolateral hinges, physiological monitoring (position, temperature, force, etc.) and region-specific capsuloligamentous, musculotendinous and myofascial augmentation to provide protection or support without over-constraint (28,29) (**figure 2**). Many of these products attempt to combine the positive attributes of conventional garments and braces with athletic and kinesiotaping concepts that enhance proprioception/kinesthesia and natural myofascial system gliding function (**figure 3**). In association with this, fasciocytes produce hyaluronan to reduce friction, improving fascial mobility and decreasing myofascially-mediated pain (30). Stecco et al (31) reported that the gluteus maximus - fascia lata attachment was so large that the iliotibial tract was effectively its tendon of insertion. Thoracolumbar fascia forces can be transmitted from the gluteus maximus to the knee and from the latissimus dorsi to the shoulder. Painful patellar tendon conditions often occur from uncoordinated muscle or muscle group activation in the presence of anomalous myofascial tension (26). For these conditions, the treatment focus should not be at the local site of tendon pain, but rather it should be directed toward identifying the location of the myofascial incoordination (32). Myofascial continuity between the thoracolumbar fascia-abdominal muscles and the erector spinae – rectus abdominis also helps ensure dynamic postural trunk stability (33).

The supplemental limb and joint protection and support that used to be exclusively dependent on external brace use, now may at least partially be provided through innovative surgical internal bracing or supplemental extra-articular soft tissue repair (34). When feasible, surgical internal bracing may better facilitate capsuloligamentous tissue repair, concurrently retaining proprioceptive elements commonly lost during ligament reconstruction or joint replacement. Greater use of less rigid, functionally firm, protective and supportive garment or braces might be analogous to the contrasting properties of anatomical surgical repair versus reconstruction. Through more distributed surface contact area, these devices may enable better cutaneous, capsuloligamentous, musculotendinous and fascial mechanoreceptor function for dynamic joint stability than rigid braces, without reducing joint range of motion or impairing neuromuscular and neurovascular function. These



Figure 3. T-25 thigh compression garment to enhances dynamic knee control (CEP Topical Gear).

evolving supportive and protective garments or braces are being designed in concert with growing efforts to preserve joint health whenever feasible through more anatomical and biological surgical and non-surgical joint repair, rather than reconstruction. Impaired ACL injury neurosensory proprioception combined with ipsilateral rigid brace use may be related to the increasing frequency of contralateral, non-contact knee ACL injuries that have been observed. Use of regenerative biological healing progenitors such as stem cells, plasma-rich in platelets, or amniotic membrane tissue represents a developing and exciting contemporary healthcare sector. Innovations like these challenge rehabilitation clinicians to carefully determine the best combination of progressive joint loads, sport movement-based therapeutic exercises, and garment or brace use to accelerate both tissue healing and motor learning. This will ultimately result in more functionally responsive neuromuscular activation patterns and remodeled tissues that more closely match pre-morbid histology, morphology and biomechanical characteristics.

FOOTWEAR AND GLOVES

The combination of feet pushing against the ground (**figure 4**) and the arms pulling generates holistic energy transfer throughout the entire body. Because of the close relationship between shoe-surface interactions and injury risk, footwear outsole configuration and its influence on locomotor traction is the most studied athletic footwear parameter (35). Cleats without studs provoke more vertical lower leg alignment at running stance phase initiation in combination with lower ankle and knee joint moments (36). Soft ground interfaces decrease foot movement in combination with increased ankle and knee moments (36). Extreme sport athlete footwear considerations should balance the increased primary and adjacent torsional joint injury risk



Figure 4. Climbing shoe – hold interface.

associated with footwear stud use and the potential for injury from increased slipping risk without their use (35, 36). Use of shorter, stubbier cleats have been recommended to prevent football knee injuries (37). Across a wide range of traditional and extreme sports, specialty gloves have been developed to enhance hand and wrist joint protection and support, touch perception, grip strength and proprioceptive awareness (**figures 5**). Sports that necessitate direct skin contact such as climbing often use more traditional athletic taping techniques to enhance joint stability without compromising fingertip sensory grip perception.

EVOLVING PROTECTIVE AND SUPPORTIVE GARMENTS AND BRACES

Bracing to protect or support, preserve and promote natural joint function is evolving from the use of heavier, rigid, over-constraining and poorly-fitting devices to lighter, more flexible, lower profile, function-enhancing garments or braces. This evolution is intended for three-dimensional protection, while not generating maladaptive primary or adjacent joint kinematics, or impaired/inhibited neuromuscular activation, neurovascular function or altered peak joint forces. Conceivably, protective and supportive garments or braces such as these may also provide a better foundation for enhancing cutaneous, capsuloligamentous, musculotendinous and myofascial system proprioception/kinesthesia and dynamic joint stability (**figure 6**). With a growing appreciation for the importance of peripheral, non-contractile joint stabilizers such as the anterolateral knee ligament (38), posterolateral and posteromedial corner knee and antero-inferior shoulder capsuloligamentous tissues (**figure 7**), rehabilitation clinicians are seeking better ways to enhance



Figure 5. Hand-wrist supports. A. finger pulley taping; B. wrist and thumb stabilization; C. proprioceptive-gripping; D. full hand-wrist protection.



Figure 6. Wall climbing wearing compressive calf sleeves.

dynamic joint stability with improved patient comfort and use compliance. Athletic footwear has also evolved away from rigid, high motion control shoe designs to more preemptively protect and control the ankle, subtalar, transverse and longitudinal arches and first metatarsophalangeal joints, without the overconstraint that transfers loading forces proximally to the knee, hip and low back. The growing use of low movement control shoes in an attempt to modify running mechanics toward more forefoot-directed contact patterns with greater intrinsic core foot muscle use may help mitigate the influence of excessive, poorly controlled knee and hip joint loading forces.

Sleeve-based protective and supportive garments or braces have the advantage of simpler, quicker application, avoidance of piston-like positional changes that lead to slippage during joint movements and easier adaptation to neuromuscular inhibition/atrophy and activation recovery/hypertrophy limb girth changes. Protective and supportive garments or braces can also be more easily integrated into compressive sport shirts, shorts and leggings with or without additional orthosis use (28,29).

Therapeutic exercises that combine task-specific self-efficacy and problem-solving skill development may best optimize innovative protective and supportive garment or brace use. Given the variety of movements that come under the extreme sport definition, appropriate therapeutic exercise selection or creation provides an ideal method for the athlete to learn from, “if this, then that,” situations and scenarios to simulate the sport-specific movements needed to optimize joint specific, regional, and whole body coordinated neuromuscular, sensorimotor, and vestibular system protective responses. Well-designed movement-based task- and sport-specific therapeutic exercise programs should more effectively transition from higher level, executive cognitive function with careful attention to developing movement quality and form to lower level, automatic responses



Figure 7. Glenohumeral joint support using the DonJoy Sully Shoulder Stabilizer.

as the athlete is confronted with random perturbations or unexpected chaos. To better enable healing tissue remodeling, whenever feasible, the extreme sport athlete should periodize protective or supportive garment or brace use. As with the stress shielding of cast immobilization and limited weight bearing crutch use, biomechanically competent tissue healing only promotes tissues remodel in response to progressively greater natural joint loading conditions. Rigid braces will always have a vital role in athletic rehabilitation and recovery, such as when repetitive or higher energy contact or collision risks can be expected (downhill skiing, American football) or when high joint movement or alignment constraints are needed. These supports may also be the ideal intervention with treating the extreme sport athlete who has sustained a severe multi-ligament bi-cruciate or cruciate-corner knee injury, when natural joint kinematics have not been precisely restored, when articular

incongruity (step-off) remains, when osteoarthritic joint changes exist, or when chondral surface repair or reconstruction warrants off-loading or re-alignment osteotomy.

SUMMARY

Through greater surface contact area and enhanced cutaneous, capsuloligamentous, musculotendinous and myofascial system mechanoreceptor function, a new evolution of protective and supportive trunk, limb and joint garments or braces may more closely simulate the subtle, sequential natural protection and proprioception/kinesthesia and dynamic joint stability

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests (39).

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