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Slacklining: A Novel Exercise to Enhance Quadriceps Recruitment, Core Strength and Balance Control

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Abstract

Quadriceps activation is critical for lower limb movement and subsequent rehabilitation. However, selective quadriceps activation is compromised by impaired neuro-motor activation, loss of function and pain. A recently introduced method of prehab- and rehabilitation exercise to recruit quadriceps is 'Slacklining'. This is a complex neuromechanical task that involves balance retention on a tightened band where whole-body dynamics drive the response to external environmental changes. A challenge to the implementation of slacklining is the understanding of its mechanisms of action, a standardized protocol for 'slackline' training and the incorporation of this technique into exercise programs along with knowledge of the literature supporting its use. This article summarizes the background to the use of slacklining and how it can supplement recovery goals through a stimulating positive therapeutic experience. It details slacklining's ability to automatically recruit the quadriceps, the research support for this use, the proposed sequential and progressive protocols for both clinical and research application, areas of caution and the directions for future use and research. Slacklining provides a unique composite-chain activity with higher levels of quadriceps activation and recruitment than traditional exercises that are achieved with significantly less exertion. This enables a positive and progressive form of rehabilitation that achieves outcomes at a potentially faster rate. This is of particular relevance for the outpatient setting and circumstances where the quadriceps is inhibited and activation is required.

Keywords: Slackline; Quadriceps; Activation; Recruitment; Composite-chain

Background

Activation of the quadriceps muscle is a critical aspect of knee and lower limb function and an integral part of rehabilitation. Following a knee injury or surgery, voluntary quadriceps activation is markedly reduced or fully inhibited [1]. The inhibition process can then lead to weakness and secondary problems [2] including loss of function [3], a failure to return to sport or work [4] and sometimes premature osteoarthritis [5]. Real or perceived knee and lower limb pain causes losses of up to one third of maximal isometric knee extension torque [6]. Consequently the rehabilitating therapist's dilemma is in finding simple, efficient techniques that achieve active, selective quadriceps activation [7]. Even more important is finding exercises that are easy to perform, that rapidly gain specific activation and are achieved without significant pain or perceived exertion [8]. The efficiency is further enhanced if the exercise and activity is fun, happens innately, and the patient does not think but simply 'does it' [8,9]. One way of achieving this is to introduce 'slacklining into the rehabilitation program.

What is Slacklining

'Slacklining' is a 'trendsport' and modern adaptation of rope-walking or funambulism (Figure 1). It is defined as 'the action of standing or moving on a tightened band and retaining balance' [10]. The history of slacklining as a derivative of rope-walking dates back the Ancient Greek Olympics where it was assimilated as a performance component and not as a competitive component or part of gymnasts where it was seeking to be recognized. Through the centuries till the current day, rope or tightrope walking have had an established place in in European and Central Asian cultural tradition where it is both respected and heritage listed [11]. Consequently, the modern adaptation to slacklining by climbers using webbing between trees and in student campus quadrangles in the early 1980s is simply an evolution of rope-walking where modern technology has been incorporated to make the line lighter, safer, more elastic and both easier and quicker to install by means of a ratchet or pulley system.. The progression into therapy has been a natural process through informal inclusion for both injury prevention and rehabilitation. This interest derives from four uniquely integrated qualities that are present in use of slacklining: neuromechanical demand (the integration of the body's neurobiological, biomechanics and sensory components [10]), balance (the state of equilibrium control that regulates dynamic movement of the body's segments and centre of mass within the base of support [12]), postural control (the controlling of the body's position in space [13, 14], and muscle strength (the force generated by muscle/s [15]). Together these enable a whole body activity dynamically driven and responding to external environmental changes [10]. In addition to these attributes, slacklining also has the ability to automatically recruit the quadriceps, particularly in individuals with local muscle inhibition [16].

Figure 1: Slacklining in a clinical rehab setting

The Importance of Quadriceps Recruitment

Gaining rapid immediate changes in quadriceps activation and torque may entail external dis-inhibitory interventions. These may include cryotherapy [17], external facilitators, like stimulation [18], or innate activation [19] and the use of exercises that specifically induce a higher level of desired activation in the targeted muscle group, specifically the quadriceps [9]. The concept of the body as a global system is well accepted. Body movement has been recognized for some time as 'a dynamic, constantly active … composite of interacting systems … as spinal animals scarcely exhibit serial [sequential] activity' [20]. The body works in patterns and activities, not single muscle activation [21]. It is this innate activation process that we can seek to use for rehabilitation and re-education. If the quadriceps is selectively activated by certain innate processes while simply performing an activity, then subsequent recruitment and control will be facilitated [9]. This aspect of knee exercise and quadriceps activation is an area of significant importance and recommended as requiring further research [2 22,23].

When we think of recruiting the quadriceps it can be through isolation - muscles alone, or integration - combining stability and mobility [21]. Traditional rehabilitation is a graded progression from isolation - getting it to work, to eventually making it part of the body's integrated movement process. In traditional rehabilitation a muscle group or component is isolated, as in the medial quads exercises. This enables the patient to see, feel and understand the actions and activity of the required muscle and why it needs to work. Electromyographic (EMG) biofeedback is one way to facilitate this process, helping the brain realize and accept what is happening, that it is a positive action, and that it should be continued and established as a normal function. Once inhibited or weak muscles have been recruited and voluntary activity and intensity gained, therapists in rehabilitation usually progress rehabilitation and exercise therapy to more complicated and combined movements before the more contiguous parts of daily function and activity are focused upon. The problem with this process is that, though foundations of movement are considered and accepted, it can be slow, stages must be learnt, frustration creeps in, and once learnt, they must often be effectively unlearnt to get the required integrated activity and return to 'normal' function.

Weight-bearing or non-weight-bearing knee-extension exercises are well recognized as not acutely changing quadriceps torque or activation levels [6]. Selective muscle activation is difficult due to pain inhibition, functional loss and impaired neuro-motor activation [17]. The process of any muscle activity including quadriceps) occurs through one of three methods: open, closed or composite-kinetic chain activity – this occurs when there is a weak link in the kinematic chain that creates abnormal motor synergy patterns [24]. It's this latter, less-recognized aspect that is perhaps an untapped resource. It occurs when there is a weak link in the kinetic chain and abnormal motor synergy patterns occur—such as when the contact surface moves freely or in three dimensions [25], as on a slackline. This is most commonly achieved in rehabilitation through aquatic therapy where the immersed, supported body starts progressive sequential movements, early active motion and stabilization in an integrated and appropriate manner [26]. Consequently, it is critical for individuals with a knee injury to initiate early quadriceps activation and preferably with minimal perceived voluntary activation [6]. This an area in which the slackline can be used.

Slacklining as a Therapeutic Exercise

The response strategies that occur during slacklining are relevant to prehabilitation, rehabilitation, sporting achievement and simply having fun. However, practitioners should consider how to quantify a patients' progression through the sequential stages of motor learning from 'novice' to 'accomplished'. This progression can be achieved and documented in a standardized way through the use of a four-stage, 20-step program for slacklining as proposed by Gabel and Mendoza (Table 1) [27].

Stage and Steps	**Description of Position**
	Each description of stages 1 -4 are for the slackliner standing on a slackline of 3 meters length at strong tension anchored at each end 25 cm above soft terrain such as sand or grass.
1-Beginner: Stand	(Dominant leg or foot is that which is the natural weight bearing leg or foot or the uninjured)

1	Single leg stand - on the dominant leg
2	Single leg stand - on the non-dominant leg
3	Single leg stand - dominant leg, other foot touching side of line 1 foot length in front
4	Single leg stand - dominant leg, other foot touching side of line 1 foot length behind
5	Single leg stand - non-dominant leg, other foot touching side of line 1 foot length in front
6	Single leg stand - non-dominant leg, other foot touching side of line 1 foot length behind
2-Moderate: Walk	
1	Walk forward along the line with minimal to no pause between steps
2	Walk Backward along the line with minimal to no pause between steps
3	Tandem Stance with the dominant leg back or closest to the anchor point
4	Tandem Stance with the dominant leg forward or furthest from the anchor point
3-Intermediate: Tandem	(Tandem stance is both feet in contact 1 immediately behind the other)
1	Tandem - dominant leg behind - pivot 180 degrees - toward dominant side, feet stay in contact
2	Tandem - dominant leg forward - pivot 180 degrees - toward non-dominant side, feet in contact
3	Tandem - dominant leg behind - pivot 180 degrees on dominant foot to non-dominant side, one foot contact, non-dominant foot returns to the line and remains in front
4	Tandem - dominant leg front - pivot 180 degrees on non-dominant foot to non-dominant side one foot contact, dominant foot crosses returns to the line and remains in front
5	Side Stand 'Surfer posture' – feet perpendicular to Slackline and balance
4-Advanced: Squats	
1	Squat in Tandem, dominant leg behind - feet along the line approaching buttocks to the line
2	Squat in Tandem dominant leg in front - feet along the line approaching buttocks to the line
3	'Surfer' position and Squat down feet perpendicular to the line approaching buttocks to the line
4	Single leg Squat all weight on the dominant leg - approaching buttocks to the line
5	Single leg Squat all weight on the non-dominant leg- approaching buttocks to the line
5-Extreme	Without using arms. Without sight. Bouncing.
6-Tricks: Performance	Heel raises, walking on toes, jumps, spins, somersaults on line or as dismounts.
	External focus (eg throwing ball, juggeling ball).
	Surfing (on very slack line) with oscillations or swinging perpendicular to the line.

Table 1: Slacklining progressive competency phases - 4 Stages and 20 steps

This protocol provides a suggested method and process of standardized progressions as an optimal pathway for therapists to progress individualized rehabilitation or injury prevention programs.

The protocols are sequential, but recognize that individual variation will occur due to the process of motor learning [27].

In this way standardization is achieved between therapists and research studies to ensure that guidelines that progress slacklining safely and effectively are applied appropriately and consistently (Figure 2).

Figure 2: Stages of slacklining progression

Two separate publications have demonstrated how these proposed protocols can be implemented within the clinical settings and optimized by and research findings. In the first study the proposing authors used two case examples of an injured junior professional surfer and a recreational athlete. In this formative paper the case studies demonstrated implementation of the protocols within an individualized rehabilitation program over a series of weeks with a visual history and outcome pathway (Figure 3) [27]. The second research paper demonstrated the effectiveness of slacklining as a separate form of exercise through a study that analyzed, determine and compared the level of quadriceps activation for knee-injured participants. The results categorically demonstrated that lower limb injured patients could obtain effective and advantageous rehabilitation of the quadriceps muscle through the use of slacklining. This study followed the proposed protocols in the rehabilitation of the patients with the analyzed data obtained from the initial step up or 'Stage 1 Step 1' [16].

This second study provided significant research findings as the level of quadriceps activation for knee-injured participants was determined during kinetic open-chain, closed-chain and composite-chain (slackline) clinical exercises using a repeated measures (within-subjects) ANOVA design [16]. The study recruited acute knee-injured patients that were assessed for quadriceps activation using skin-mounted EMG during five exercises: inner-range quads, straight-leg raise, step-down, step-up and slacklining step-up. The outcomes had highly significant findings. The initial four standard open- and closed-chain exercises overlapped almost completely with the results indicating that they were largely indistinguishable. By contrast, the level of EMG recorded quadriceps activity during slacklining was significantly higher and did not overlap with the other four exercises ($F(2.52, 121.00)=21.53$, $p<0.0001$). Furthermore, the participants perceived level of exertion was significantly lower for slacklining ($F(1.62, 77.70)=26.88$, $p<0.0001$), while the four standard exercises were again largely equivalent. This study confirmed that slacklining, as a consequence of its composite chain activity requirements, was a unique and different form of exercise that enabled rapid automatic recruitment of the quadriceps at a significantly higher level of activity and at a significantly lower level of perceived exertion [16].

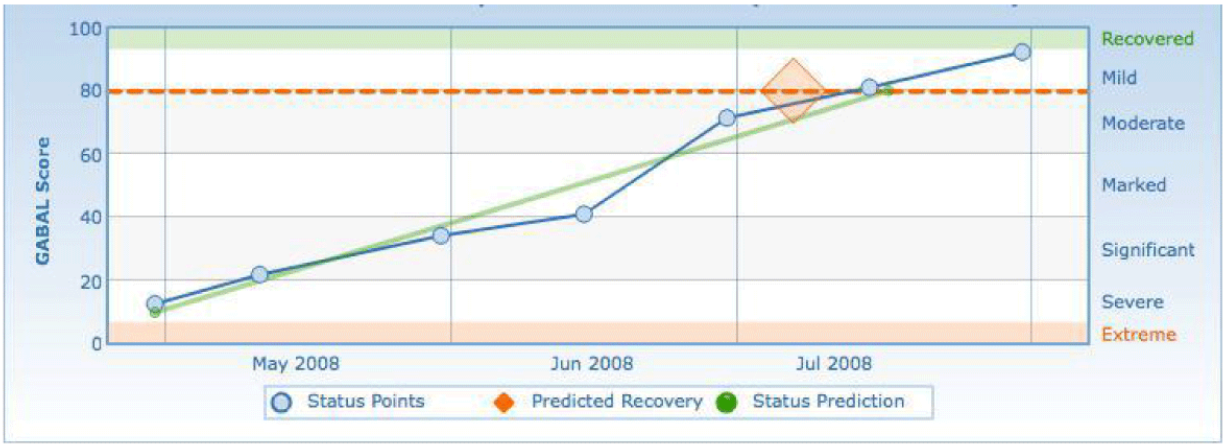

Figure 3: Recreational football player - functional outcome recovery pathway

1: Weeks 1-3: Initial acute phase, transition from PWB to FWB, initiation of physiotherapy and rehab.

2: Weeks 4-6: Graded return to running, introduction to sports specific activity

3: Week 7: Slackling Stage #1 -2 Initiated, concurrent rehab reduced, discharge from physiotherapy

4: Week 8: Slackling Stage #3 initiated, running with directional change performed with confidence

5: Weeks 9-10: Slackling Stage #4 initiated and return to non-competitive sports

6: Weeks 11-16: Slackling Stage #5 initiated and full resumption of recreational sports and activity

General Implications of Slacklining as a Therapeutic Exercise

So what does it all mean? Slacklining provides a unique activity with higher levels of quadriceps activation than traditional exercises and the recruitment is achieved with significantly less exertion [16]. These findings support earlier research that suggests slacklining can be utilized both as a prophylactic or pre-habilitation exercise [28, 29] as well as in the more traditional rehabilitation settings [15, 30]. Furthermore, the innate or automatic muscle activation occurs during dynamic whole body activities [8, 9] . As with all exercise therapy slacklining isn't a panacea and not suited to every patient and every age group. Caution will be required in the older age groups and for those patients who have problems with balance and systemic movement control - such as Parkinson's disease. However, with consideration the exercises can be adapted and used with caution in the older age group, particularly at a lower height above a soft surface such as matting, grass or sand - as shown in the recent study that included participants up to 72 years of age in a controlled and established environment [16].

Conclusions

Slacklining appears worthwhile, particularly for self-motivated, self-reliant patients as it provides spontaneous activation that is selective and simple. Furthermore it is achieved at a lower level of perceived exertion. For patients where the quadriceps is inhibited and activation is required, these features of slacklining enable a positive and progressive form of rehabilitation with outcomes that may be achieved at a potentially faster rate. This is of particular relevance for the outpatient setting and circumstances where the quadriceps is inhibited and activation is required. Future research will be required to determine if the muscular recruitment effects found for the quadriceps are transferable to other muscle groups such as the gluteals and core, and if the gains that can be achieved will transition to other areas such neurological rehabilitation.

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