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.

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

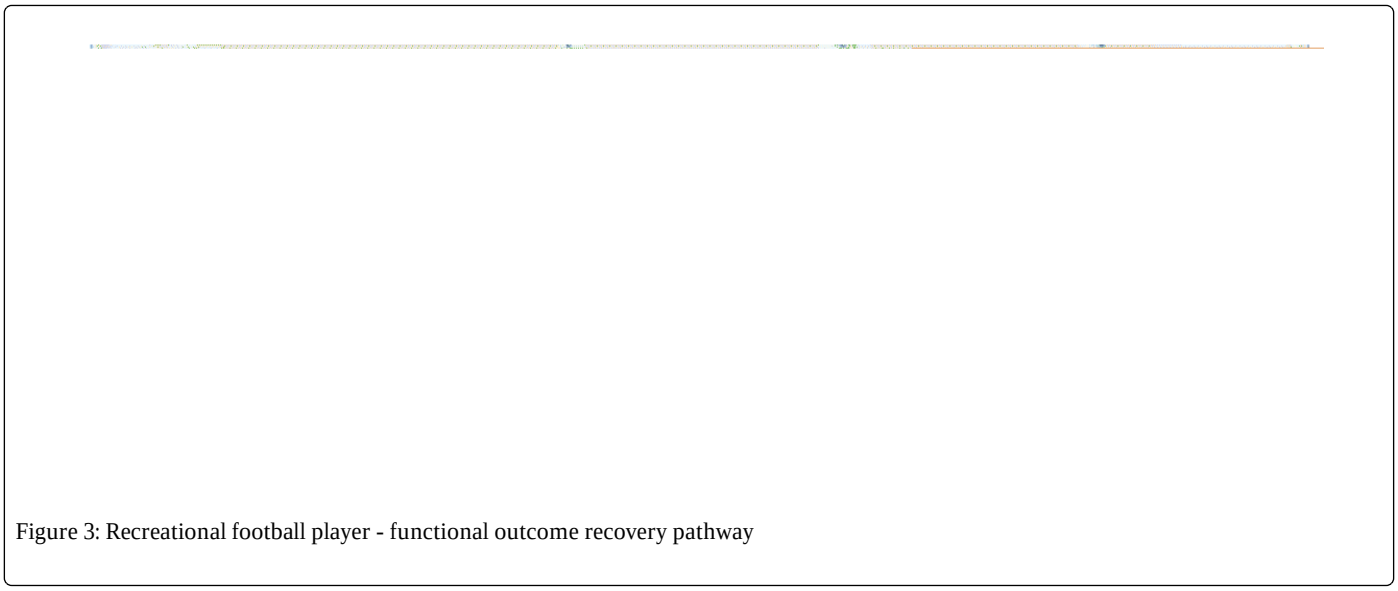

Figure 3: Recreational football player - functional outcome recovery pathway

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.

References

1. Chmielewski TL, Stackhouse S, Axe MJ, Snyder-Mackler L (2004) A prospective analysis of incidence and severity of quadriceps inhibition in a consecutive sample of 100 patients with complete acute anterior cruciate ligament rupture. J Orthop Res 22: 925-930.
2. Hart JM, Pietrosimone B, Hertel J, Ingersoll CD (2010) Quadriceps activation following knee injuries: a systematic review. J Athl Train 45: 87-97.
3. MacIntyre DL, Eng JJ, Allen TJ (2005) Recovery of lower limb function following 6 weeks of non-weight bearing. Acta Astronaut 56: 792-800.
4. Lentz TA (2012) Return to Preinjury Sports Participation Following Anterior Cruciate Ligament Reconstruction: Contributions of Demographic, Knee Impairment, and Self-report Measures. J Orthop Sports Phys Ther 42: 893-901.
5. Keays SL, Newcombe PA, Bullock-Saxton JE, Bullock MI, Keays AC (2010) Factors involved in the development of osteoarthritis after anterior cruciate ligament surgery. Am J Sports Med 38: 455-463.
6. Park J, Grindstaff TL, Hart JM, Hertel JN, Ingersoll CD (2012) Knee-extension exercise's lack of immediate effect on maximal voluntary quadriceps torque and activation in individuals with anterior knee pain. J Sport Rehabil 21: 119-126.
7. Rice DA, McNair PJ (2010) Quadriceps arthrogenic muscle inhibition: neural mechanisms and treatment perspectives. Semin Arthritis Rheum 40: 250-266.

8. Bolgla LA, Shaffer SW, Malone TR (2008) Vastus medialis activation during knee extension exercises: evidence for exercise prescription. J Sport Rehabil 17: 1-10.
9. Irish SE, Millward AJ, Wride J, Haas BM, Shum GL (2010) The effect of closed-kinetic chain exercises and open-kinetic chain exercise on the muscle activity of vastus medialis oblique and vastus lateralis. J Strength Cond Res 24: 1256-1262.
10. Paoletti P, Mahadevan L (2012) Balancing on tightropes and slacklines. J R Soc Interface 9: 2097-2108.
11. Demoriane H. Funambulus/Funambule: Rope Walkers & Equilibrists: A Potted History Using Quotes & Anecdotes Through the Centuries.
12. MacKinnon CD, Winter DA (1993) Control of whole body balance in the frontal plane during human walking. J Biomech 26: 633-644.
13. Keller M, Pfusterschmied J, Buchecker M, Müller E, Taube W (2012) Improved postural control after slackline training is accompanied by reduced H-reflexes. Scand J Med Sci Sports 22: 471-477.
14. Collins JJ, De Luca CJ (1993) Open-loop and closed-loop control of posture: a random-walk analysis of center-of-pressure trajectories. Exp Brain Res 95: 308-318.
15. Granacher U, Iten N, Roth R, Gollhofer A (2010) Slackline training for balance and strength promotion. Int J Sports Med 31: 717-723.
16. Gabel CP, Osborne J, Burkett B (2013) The influence of 'Slacklining' on quadriceps rehabilitation, activation and intensity. J Sci Med Sport .
17. Park J, Hopkins JT (2013) Within- and between-session reliability of the maximal voluntary knee extension torque and activation. Int J Neurosci 123: 55-59.
18. Springer S, Vatine JJ, Lipson R, Wolf A, Laufer Y (2012) Effects of dual-channel functional electrical stimulation on gait performance in patients with hemiparesis. ScientificWorldJournal: 530906.
19. Hellman KM (1979) The Neuropsychological Basis of Skilled Movement in Man, in Handbook of Behavioral Neurobiology, M. Gazzaniga Kluwer Academic/Plenum Publishers: New York 447-461.
20. Lashley, K.S(1951) The Problem of Serial Order Behaviour, in Cerebral Mechanisms in Behaviour, L.A. Jeffress California Institute of Technology (Caltech): Pasadena. p. 112-136.
21. Hoffman J, Gabel P (2013) Expanding Panjabi's stability model to express movement: a theoretical model. Med Hypotheses 80: 692-697.
22. Smith TO, Bowyer D, Dixon J, Stephenson R, Chester R, et al. (2009) Can vastus medialis oblique be preferentially activated? A systematic review of electromyographic studies. Physiother Theory Pract 25: 69-98.
23. Wasielewski NJ, Parker TM, Kotsko KM (2011) Evaluation of electromyographic biofeedback for the quadriceps femoris: a systematic review. J Athl Train 46: 543-554.
24. Davies GJ, Ellenbecker T (2004) Application of Isokinetics in Testing and Rehabilitation in Physical Rehabilitation of the Injured Athlete, 4th. Ed., J. Andrews, G.L. Harrelson, and K. Wilk W.B. Saunders: Philadelphia 216-242.
25. Davies GJ(2010) An integrated approach to using open and closed kinetic Chain exercises in rehabilitation in CU SPORTS MEDICINE SYMPOSIUM Denver.
26. Castillo-Lozano R, Cuesta-Vargas A, Gabel CP(2014) Analysis of arm elevation muscle activity through different movement planes and speeds during in-water and dry-land exercise. J Shoulder Elbow Surg 23: 159-165.
27. Gabel CP, Mendoza S (2013) “Slacklining” - a self-generated, graded training program for lower limb rehabilitation. IJATT 18: 14-19.
28. De Franceschi, P.A. Le slackline(2012) un outil prophylactique au service des joueurs de badminton de haut niveau Masters Thesis - Entraînement Sportif de Haut Niveau, 12 pages.
29. Mayer C, Siems W (2011) Patellaluxationin 100 Krankheitsbilder in der PhysiotherapieSpringer Berlin Heidelberg: Berlin 146-157.
30. Strejcova B, simkova L, Balas J (2012) Ankleisokinetic strength and postural stability in “slackliners” (English Abstract). Czech kinanthropology 16.