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Original article

A preliminary study into the effect of jumping–landing training and strength training on frontal plane projection angle

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ABSTRACT

The presence of increased knee valgus angles during functional tasks has been associated with a range of knee pathologies. A number of different exercise interventions have been undertaken to improve knee alignment during functional tasks. The most successful of these interventions are multi-modal incorporating both strength and jump–landing training. Little research has been undertaken to compare these elements individually to assess if success is due to an individual element or the training as a whole. The study assessed the between group effects of strength training or jump–landing training alone on knee valgus alignment during a number of functional tasks, using a cohort specific treatment superiority design. Thirty asymptomatic female participants undertook a 6 week (minimum 15 sessions) strength or jump–landing programme, the effects of which were examined by assessing for any change in frontal plane projection angle (FPPA) during single leg squat and landing and bilateral drop jump landing. Both training methods had positive effects of FPPA during some but not all of the tasks. Strength training brought about significant changes in FPPA during single leg squat and landing, whilst jump–landing training significantly influenced single leg landing and drop jump landing performance. The changes reported, therefore appear to be related to the nature of the training and the tasks undertaken during that training. The findings indicating that a combined training protocol incorporating both strengthening and jump–landing training may bring about the greatest improvement across a spectrum of tasks for the patient, supporting the previous work on multimodal training.

1. Introduction

Poor limb alignment, specifically increased knee valgus during single leg squat, running and bilateral landing tasks has been associated with both anterior cruciate ligament (ACL) injury and patellofemoral pain (Noyes and Barber-Westin, 2011; Souza and Powers, 2009). Therefore, it would seem sensible to assume that controlling the degree of knee valgus during these tasks would result in lower likelihood of ACL injury and patellofemoral pain.

Weakness of the hip musculature has been shown to correlate with increases in knee valgus angles in healthy participants when assessed using 3D motion capture (Lawrence et al., 2008). In order to reduce the impact of poor limb alignment during these functional tasks, training programmes have been developed primarily to address either the associated muscle weakness or neuromuscular control during these tasks (Herrington, 2010; Khayambashi et al., 2012).

The research literature has provided some limited examples of successful outcomes using both an isolated strengthening approach and a neuromuscular training approach, for instance Khayambashi et al. (2012) undertook strength training programmes which brought about significant changes in knee valgus angles. Likewise, in a study which investigated neuromuscular training in the form of jumping and landing training alone (Herrington, 2010), they found, equally significant positive changes on knee valgus angles during a variety of functional tasks.

To date there appears to be no literature directly comparing the effects of these two approaches on limb alignment control during functional tasks. The aim of this study was to assess the effects of two different training programmes on limb alignment control. Specifically, the study compared the effect of a strength training programme (targeting quadriceps and gluteal muscles) and a neuromuscular control programme (jump–landing training) on

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knee valgus angle assessed using 2D video acquired frontal plane projection angle. The primary hypothesis of the study being exercise will have a significant effect on FPPA.

2. Method

2.1. Participants

Thirty asymptomatic female subjects participated in the testing (mean age 20.4 range 18–26 years, height mean 1.66 m range 1.60–1.76 m, and weight mean 63.9 kg range 58–68 kg). All participants had no history of knee or significant lower limb pathology and had been injury free for 3 months prior to the data collection. All participants provided signed informed consent to participate and the study was approved by a university research ethics committee. The subjects were then block allocated in groups of 5 (two blocks per training group) to one of three groups; strength training, jump–landing training or control. These blocks of subjects were used for pragmatic reasons to avoid having to train subjects individually. The study assessed the between group effects of strength training or jump–landing training alone on knee valgus alignment during a number of functional tasks, using a cohort specific treatment superiority design.

2.2. Measurements

Prior to the training (intervention block) all subjects were tested for isometric hip and knee extensor and hip abductor muscle strength using a handheld dynamometer. The subjects then undertook a number of lower limb loading tasks; single leg squat (SLS); single leg landing (SLL) and bilateral drop jump landing. All these tasks were recorded on video and the frontal plane projection angle (FPPA) of the knee was calculated for each individual for each leg during each task.

2.3. Strength measurement

Maximum isometric strength of the hip abductors, extensors and knee extensors was assessed using a handheld dynamometer (HHD) (MicroFet, Hogan Industries, USA). For the hip abductors, participants were placed in a left side lying position (for the right leg) on a standard treatment couch (right leg on top), the left hip was flexed to 45° and the right knee at 90° for stability. A stabilisation strap was placed around the treatment couch and the subject's legs at a level 10 cm from the right knee lateral joint line. The strap was tightened to offer resistance to the abducting right hip in a 0° hip abduction position. The HHD was placed under the strap against the thigh and the examiner held the HHD and strap in place. For the hip extensions, participants laid on their front, flexed the knee of the tested leg to 90°, a stabilisation strap was placed around the treatment couch and the subject's leg at a level 10 cm above the knee joint line. The strap was tightened to offer resistance to the extending hip in a 0° hip extension position. The HHD was placed under the strap against the thigh and the examiner held the HHD and strap in place. For knee extension, the subject sat on a chair, with the hip and knee at 90° flexion. A stabilisation strap was placed around the chair leg and the subject's legs at a level 5 cm above the ankle joint line. The strap was tightened to offer resistance to the knee extension in the 90° knee flexed position. The HHD was placed under the strap against the tibia and the examiner held the HHD and strap in place. The subjects then undertook 3×5 second maximal isometric contractions with 1 min recovery, against the HHD and strap. Each effort was recorded and the average score calculated. The strength scores were normalised using body weight, hence reported as newtons per kilogram of body weight(N/Kg BW^{-1}).

2.4. Frontal plane projection angle

Two dimensional frontal plane projection angle (FPPA) of knee valgus alignment was measured using the method of Munro et al. (2012). A digital video camera (Sony Handycam DCR-HC37) was placed at the height of the subject's knee, 3 m anterior to the subjects landing target, and aligned perpendicular to the frontal plane. The digital images were imported into a digitizing software program (Quintic 21, Quintic Consultancy Ltd, UK). The angle subtended between the lines formed between the markers at the Anterior Superior Iliac spine and middle of the tibiofemoral joint and that formed from the markers on the middle of the tibiofemoral joint to the middle of the ankle mortise was recorded as the FPPA of the knee. The maximum FPPA was recorded from the video. The average FPPA angle value from three trials (of all tasks) was used for analysis. The tasks assessed were a single leg squat, single leg hop landing and a bilateral drop jump landing.

Bilateral drop jump landing (DJL); the drop jump task involves standing on a 30 cm high bench; the subject was then instructed to drop directly down off the bench on to a mark 30 cm from the bench, landing on both feet and immediately perform a maximum vertical jump, raising both arms to provide countermovement, FPPA being captured at the point of maximum knee flexion during the first landing.

Single leg hop landing (SLL); The hop landing task involves the subject hopping off a 30 cm high bench landing with the same leg onto a mark 30 cm from the bench and holding the landing position for 2 s.

Single leg squat (SLS); subjects were asked to stand on the test limb, facing the video camera. Participants were asked to squat down as far as possible, to at least 45° knee flexion but not greater than 60°, over a period of 5 s. Knee flexion angle was checked during practice trials (maximum of three) using a standard goniometer (Gaiam-Pro, Physiomed, Manchester, UK) observed by the same examiner throughout the trials. There was also a metronome counter for each participant over this 5 s period in which the first count initiates the movement, the third indicates the lowest point of the squat and the fifth indicates the end of the movement with them returning to the start position. Trials were only accepted if the subject squats to the minimum degree of knee flexion (45°) and maintained their balance throughout whilst keeping their hands on their iliac crests (Munro et al., 2012).

2.5. Intervention

The subjects then undertook six weeks of training; 3 sessions per week, 18 sessions in total. Any subject attending less than 16 sessions in total was excluded from the study. All subjects in the intervention groups attended for the minimum of 16 sessions, there were no dropouts. All subjects continued participating in their normal sporting activities for the training period. The control group participated in their normal sporting activities only for the training period. The strength group undertook a training programme involving single leg squats, step ups, bridging and clam exercises, all of which had progressively increased loads applied throughout the period (Table 1) with the exercises being progressed according to a progressive resistance exercise schedule (Table 2). The jump training group participated in a previously reported jump training programme (Herrington, 2010) which involves progressively more demanding landing tasks being undertaken, starting with bilateral