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Exercise intensity progression for exercises performed on unstable and stable platforms based on ankle muscle activation

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ABSTRACT

Ankle sprains are a common sports injury. The literature focuses on the application of neuromuscular training for the improvement of balance, injury prevention and rehabilitation. However, there is a dearth of knowledge about the appropriate prescription of exercises using unstable platforms and surfaces. The purpose of this study was to devise an ankle rehabilitation or training program with exercise progression based on the extent of muscle activation, employing platforms with different levels of stability and additional resistance. A descriptive study of electromyography (EMG) during ankle exercises was performed with a convenience sample of healthy subjects. Forty-four subjects completed 12 exercises performed in a random order. Exercises were performed unipedally or bipedally with or without elastic tubing as resistance on various unstable (uncontrolled multiaxial and uniaxial movement) and stable surfaces. Surface EMG from the tibialis anterior (TA), peroneus longus (PL) and soleus (SOL) were collected to quantify the amount of muscle activity. Significant differences were found between exercise conditions for PL ($p < .001$), TA ($p = .011$), and SOL ($p < .001$). The greatest EMG activity for all muscles occurred with an upright unipedal stance on a soft stability surface with resistance. The least EMG activity for the TA and SOL were in a seated position and for the PL in an erect bipedal position without resistance. Based on the level of ankle muscle activation, exercises for the ankle should progress from bilateral exercises on exercise balls (lowest intensity), to a unipedal position on a soft surface in combination with elastic tubing (highest intensity) in order to achieve progressively greater ankle muscle activation.

1. Introduction

The ankle is the second most commonly injured area of the body during sport practice and is thus in frequent need of physical therapy assessment and rehabilitation [1]. Considering all types of ankle injuries, sprains are the most common injury [1–3] (incidence rate of 85% of all ankle injuries are acute lateral sprains) [4]. It is common that ankle injuries involve long-term alterations in postural control [5,6], as well as ankle proprioceptive and neuromuscular functions [7]. Deficits in balance lead to an elevated risk for ankle injuries [6,8]. Reviews have corroborated that a key to the reduction of recurrent ankle sprains occur when the individuals perform a neuromuscular training program, and thus restoring postural control has been suggested as an important component to reducing injury recurrence [7]. Postural control restoration may be the key to the recurrent ankle sprains reduction [9]. Some authors [9,10] recommend balance training for the prevention and rehabilitation of ankle sprains. Balance training is a common rehabilitation tool for ankle injury and a safe first step in rehabilitation if progressed appropriately [11]. The utilization of unstable surfaces and platforms has shown effectiveness for increasing the sensorimotor control of soft tissues that stabilize the knee and ankle joints [12,13].

In addition to its use as a rehabilitation tool, instability or balance training can be an important prehabilitation or preventive training tool for the general healthy population. The Canadian Society for Exercise Physiology states that, "Individuals who are involved with rehabilitation, health-related fitness pursuits or cannot access or are less interested in the training stresses associated with ground based free weightlifts, can also receive

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beneficial resistance training adaptations with instability devices and exercises to achieve functional health benefits" [14]. Furthermore, the American College of Sports Medicine position stand [15] recommends that an increase in the level of difficulty of balance training progression exercises can be achieved by progressively reducing the base of support, performing dynamic movements that disturb the center of gravity, stressing postural muscles or reduce the sensory inputs. In the same vein, Muehlbauer et al. [16] recommends the combination of sensory and postural manipulations in all phases of balance training. Behm et al. [17] stated that a progressive decrease in the amount of stability support during resistance training may be recommended with rehabilitation. Whereas there are many articles reporting upon the positive training effects of instability resistance training, there are far fewer articles establishing appropriate intensity progressions using these exercises. For example, Anderson and Behm [18] demonstrated higher soleus activation with squats performed on unstable versus stable surfaces but did not provide recommendations on progression of exercises. Many interventions applying neuromuscular training have been published [2,19,20] despite the lack of scientific evidence of the appropriate frequency, duration, intensity [10,15,21] and optimal progression methods [16,21]. Appropriate neuromuscular adaptations from training are sought during prehabilitation and rehabilitation, which involves prescribing exercises that activate a range of muscle fibers and challenge the sensorimotor system.

It is unknown if additional resistance applied to postural stability exercises performed on stable platforms would increase exercise intensity by promoting higher ankle muscle activation. Thus, the aim of this study was to investigate the amount of muscle activity in a series of balance exercises with differing levels of stability and additional resistance to establish a progression based on the amount of muscle activation. It was hypothesized that activities placing subjects at greater risk of instability with higher resistance would elicit the greatest muscle activation.

2. Methods

2.1. Subjects

Young university students (24 men and 20 women) participated voluntarily in this study. Subject characteristics, separated by sex, are presented in Table 1. Subjects included in the research had a minimum of 1 year of experience with resistance training. Exclusion criteria included musculoskeletal pain, neuromuscular disorders, joint or bone disease, previous ankle sprains and tendon, fascia or ligament inflammation. All subjects signed an informed consent form before starting the protocol, and the institution's review boards approved the study. All procedures described in this section comply with the requirements listed in the 1975 Declaration of Helsinki and its amendment in 2008.

2.2. Procedures

Each subject took part in 2 sessions: familiarization and data collection. The familiarization session occurred 48–72 h before the data collection. Several restrictions were imposed on the volunteers: no food 3–4 h before and no stimulants or intense physical activity 12 h before the experimentation.

Familiarization. In the first session, the subjects were familiarized with the testing activities that would be performed on the day of data collection. Subjects practiced the exercises typically 1–3 times each until the subject felt confident and the researcher was satisfied that proper form was achieved. Moreover, height, body mass, and body fat percentage using bioelectric impedance (Tanita model BF-350, Arlington Heights, Illinois, USA) were obtained according to the protocols used in previous studies [22].

Data collection. The protocol started with the preparation of the subjects' skin and followed by electrode placement, maximal isometric voluntary contraction (MIVC) collection and exercise performance.

Hair was removed from the skin surface overlying the muscles of interest. The skin was then cleaned by rubbing with cotton wool dipped in alcohol for the subsequent placement of the electrodes on the peroneus longus (PL), tibialis anterior (TA) and soleus (SOL) [23,24]. Pre-gelled bipolar silver/silver chloride surface electrodes (Blue Sensor M-00-S, Medicotest, Olstykke, DNK) were placed with an inter-electrode distance of 2 cm on the following muscle groups:

- PL: 3 fingerbreadths below the fibular head directed toward the lateral aspect of the fibula [24].
- TA: placed parallel to and just lateral to the medial shaft of the tibia (shin), at approximately one-quarter to one-third the distance between the knee and the ankle [23].
- SOL: placed parallel to the muscle fibers on the inferior and lateral aspects of the leg, clearly below the belly of the gastrocnemius [23].

These muscles were chosen for investigation as they help control anteroposterior and lateral movement of the ankles.

The reference electrode for each muscle was placed perpendicular to the axis of the other 2 active electrodes, at 10 cm from the midpoint of the 2 active electrodes, according to the manufacturer's specifications. The assessment of muscle activity was performed on the dominant leg with the subjects barefoot in all exercises.

MIVC. A 5 s MIVC was performed for each involved joint to estimate the maximal electromyographic (EMG) amplitude for each muscle (PL, TA, SOL). For normalization of the EMG activity the MIVC were performed according to the techniques described by Kendall et al. [25].

Equipment. The different exercises were performed on stable (Thera-Band® Exercise Station, Hadamar, Germany) or unstable (Exercise Ball, Rocker Board and Soft Stability Trainer: Thera-Band®, Hadamar, Germany) surfaces with or without external resistance (Elastic tubing, Thera-Band®, Hadamar, Germany). The exercise station was a stable platform, the Rocker Board was unstable in the anteroposterior direction and the Exercise Ball and Soft Stability Trainer were unstable in a multi-axial direction. Furthermore, men used green exercise tubing and women used red exercise tubing, based on pilot studies to ensure the given position for each exercise could be maintained for 20 s. A Cross Line Auto Laser Level was fixated with a tripod (Black & Decker LZR6TP, New Britain, CT, USA) and used as visual feedback for subjects in connection to requested hip and knee joint positioning during exercises.

2.3. Exercise performance

Each subject completed the 12 exercises in a random order that was assigned to subjects employing Matlab software (Version 7.0, Mathworks Inc, Natick, MA, USA). Each exercise was performed for

Table 1
Subject characteristics (means ± standard deviations).

Sex	*N*	Age (yrs)	Weight (kg)	Body fat (%)	Height (cm)
Male	24	22.63 ± 2.4	72.1 ± 7.6	8.7 ± 3.0	176.5 ± 5.4
Female	20	23.6 ± 3.1	58.8 ± 6.3	21.9 ± 5.4	163.7 ± 5.6
All	44	23.1 ± 2.8	66.1 ± 9.7	14.7 ± 7.9	170.7 ± 8.4