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Original research

Progressive resistance, whole body long-axis rotational training improves kicking motion motor performance

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A B S T R A C T

Objectives: To evaluate lower extremity muscle activation, peak resultant ground reaction force (GRF) production and quickness during performance of a kicking motion following progressive resistance, whole body long-axis rotational training.
Design: Randomized, controlled study.
Setting: Kinesiological research laboratory.
Participants: Thirty-six healthy subjects were assigned to a training (Group 1) or to a control (Group 2) group.
Main outcome measures: Time-synchronized EMG (1000 Hz), peak resultant GRF (1000 Hz) and two-dimensional kinematic (60 Hz) data were collected as subjects responded to an audio cue by kicking a cone. Group mean change differences (MCD) were compared using independent sample *t*-tests. Fisher's exact tests were used to determine group differences in the proportion of subjects that displayed earlier activation responses post-training.
Results: Group 1 MCD revealed earlier gluteus maximus, gluteus medius, rectus femoris, medial hamstrings, and biceps femoris activation timing than Group 2 ($P \le 0.006$) and more Group 1 subjects displayed earlier activation of these muscles post-training ($P \le 0.041$). Group 1 MCD also revealed earlier peak resultant GRF timing and improved "kick quickness" than Group 2 ($P \le 0.014$) and more Group 1 subjects displayed earlier response timing for these variables post-training ($P = 0.035$).
Conclusion: Progressive resistance, whole body long-axis rotational training may improve performance during sports movements that require quick, integrated trunk-lower extremity function.

1. Introduction

The ability to quickly activate lower extremity muscles and generate peak ground reaction forces is essential to sports performance (Neptune, McGowan, & Fiandt, 2009). Neuromuscular training can decrease the processing time needed for muscle activation and movement initiation (Kwon, Chang, Lee, Kim, Hyouk, Nam, et al., 2010), enhancing anaerobic power, acceleration, and sports movement speed (Bangsbo, Nooregard, & Thorsoe, 1991). Athletes adapt to their neuromuscular training environment and the stimulation therein to solve movement dilemmas more quickly, more accurately, and with less variability (Barcelos, Morales, Maciel, Azevedo, & Silva, 2009; Kwon et al., 2010). Successful complex movement task performance requires more automated function, relying less on conscious awareness (Hurd, Chmielewski, & Snyder-Mackler, 2006; Powers & Fisher, 2010; Wu, Chan, & Hallett, 2008). The time period between an athlete's detection of a stimulus and activation of a corresponding movement response represents reaction time. This response is the composite influence of divergent afferent information, central processing of this information and the efferent response (DeMont & Lephart, 2004; Gracovetsky, 1997; Seidler, Noll, & Thiers, 2004).

The Ground Force 360 device (Center of Rotational Exercise Inc., Clearwater, FL, USA) was designed to develop integrated trunk and lower extremity neuromuscular function (Fig. 1). This occurs as progressive pneumatic resistance is applied during whole body, long-axis rotations that simulate sport movements that require quickly coordinated and integrated trunk and lower extremity function such as soccer ball kicking. During upright, weightbearing function, trunk and lower extremity movements, load transfer, anaerobic power production, and proprioceptive awareness, are synchronously coupled (Gracovetsky, 1997; Hewett & Myer, 2011; van Wingerden, Vleeming, Snijders, & Stoeckart, 1993; Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007a; Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007b). Gluteus maximus and

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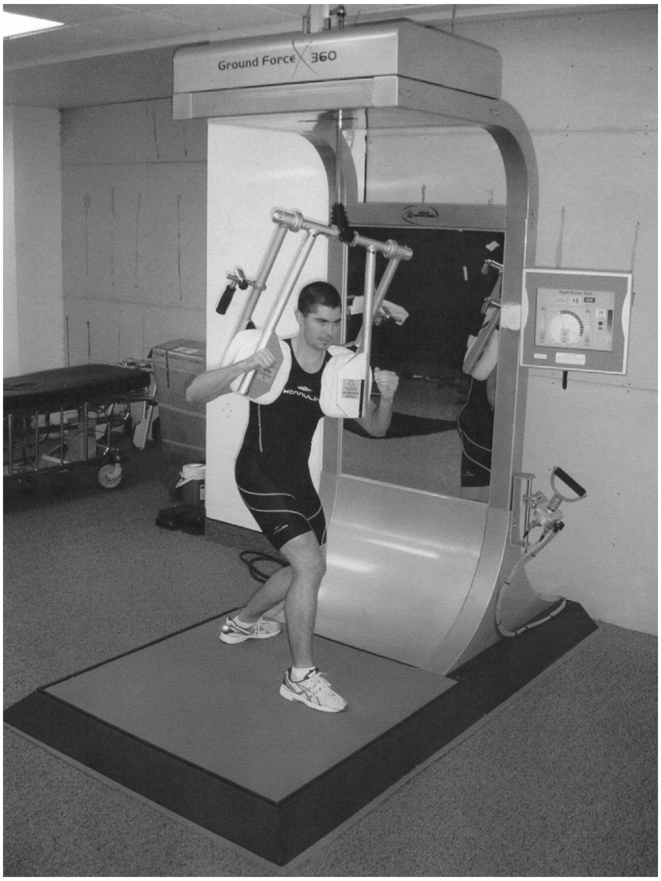

Fig. 1. Progressive resistance, whole body long-axis rotational training in the Ground Force 360 device (Center of Rotational Exercise, Inc., Clearwater, FL, USA).

hamstring neuromuscular activation in particular is known to help control lower extremity position and absorb energy during jump landings. The dynamic knee stabilization provided by this activation is highly integrated with trunk position (Hewett & Myer, 2011; van Wingerden et al., 1993). The close association between trunk and lower extremity function during progressive resistance, whole body long-axis rotation training may facilitate coordinated trunk and lower extremity functional integration during kicking-type movements. Maximal effort kick velocity is directly related to the linear and angular velocities of the foot, knee, and hip of the kicking lower extremity (De Witt & Hinrichs, 2012). Increased kinetic energy results from well-coordinated intra-segmental energy transfer between the proximal trunk and thigh and the accelerating shank and foot. Improved coordination between the trunk, proximal thigh, and distal shank and foot at the kicking lower extremity enables a more efficient intra-segmental kinetic energy exchange (Naito, Fukui, & Maruyama, 2012). Since it requires highly integrated trunk-lower extremity function, kicking movement performance may be enhanced following progressive resistance, whole body long-axis rotational training.

Previous studies have shown how progressive resistance, whole body long-axis rotational training provides an effective, non-impact method for improving the lower extremity neuromuscular control that enhances dynamic knee stability during single leg jump propulsion and landing (Nyland, Burden, Krupp, & Caborn, 2010a; Nyland, Burden, Krupp, & Caborn, 2010b). The purpose of this component of the larger study was to evaluate the effect of progressive resistance, whole body long-axis rotational training on lower extremity activation timing and duration, peak resultant ground reaction force timing and magnitude, and the time required to kick a cone ("kick quickness") following an audio cue. The study hypothesis was that the progressive resistance, whole body long-axis rotational training group would display earlier lower extremity neuromuscular activation and peak resultant ground reaction force timing, higher magnitude peak resultant ground reaction forces, and superior "kick quickness" compared to the control group.

2. Methods

2.1. Study design

A randomized controlled study using a pre-test, post-test design was performed with comparison of group mean change differences (MCD) between data collection sessions (Portney, L.G., & Watkins, M.P., 2000). By comparing mean change differences between two groups of healthy subjects the individual subject serves as the basic measurement unit (Sutton, Muir, & Jones, 1997). The time period between pre-test and post-test data collection was 4.0 ± 0.5 weeks (range = 3.5–5 weeks) for both study groups.

2.2. Subject recruitment and randomization

Following institutional review board approval, written informed consent was obtained. Inclusion criteria required that subjects were between 18 and 50 years of age, and were regular participants in sports at least twice weekly. Potential subjects were excluded if they had a history of low back injury or current back pain, had a current lower extremity injury, had a history of lower extremity surgery other than partial meniscectomy (and were more than 2 years post-surgery), or if they planned on increasing volume (intensity and/or frequency) or otherwise changing their existing exercise or sports activity program. A total of 46 subjects responded to campus flier advertisements. Ten potential subjects were rejected from study participation because of previous knee ligament reconstruction ($n = 2$), low back injury history ($n = 2$), the desire to increase existing exercise program or sports activity volume during the study period ($n = 4$), or because of an inability to comply with the study time commitment ($n = 2$). Using a random numbers table and block randomization to ensure equal gender representation, 36 subjects were assigned to a training group (Group 1) or to a control group (Group 2). Group 2 (control) did not perform progressive resistance, whole body long-axis rotational training. Each group consisted of 9 men and 9 women. Subject perceived sports activity level was determined using the International Knee Documentation Committee (IKDC) Physical Activity Scale (1 = highly competitive sports person, 2 = well-trained and frequently sporting, 3 = sporting sometimes, and 4 = non-sporting). Both groups continued regular athletic activities without increasing intensity, frequency, or volume. The institutional review board required that all female subjects provide a negative pregnancy test at study initiation. The rationale for this was their perception that intense exercise might induce spontaneous miscarriage if the female subject was pregnant and was not aware of it. Based on allocated time requirements, training group subjects were reimbursed $120 for study participation, and control group subjects were reimbursed $20.

2.3. Training group subjects (Group 1)

Nine of 18 (50%) subjects in Group 1 regularly participated in recreational running or weight training, and 9 of 18 (50%) regularly participated in basketball, volleyball, soccer, tennis, flag football, or swimming. Training group subjects were 22.3 ± 2.3 years of age, 173.6 ± 10.5 cm tall, had a pre- and post-test weight of 70.0 ± 9.4 kg and 70.8 ± 10 kg, respectively, and had an IKDC Physical Activity Scale (median) score of 3 (range = 2–4).