Journal of Electromyography and Kinesiology 25 (2015) 773–781

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Characterization of ankle dorsiflexors performance in healthy subjects following maximal-intensity isokinetic resistance training

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ARTICLE INFO

Article history:
Received 12 March 2015
Received in revised form 3 June 2015
Accepted 4 June 2015

Keywords:
Resistance exercise
Muscle strength
Isokinetic parameters

ABSTRACT

The purpose of this randomized trial was to examine, in healthy subjects, the effect of unilateral isokinetic–concentric training of the dominant ankle dorsiflexors (DF) on the peak moment (PM), mean PM (MPM), maximal work and mean work (meanW).

Thirty volunteers (26.7 ± 4.6 years old) underwent bilateral isokinetic testing of ankle DF at 45 and 90°/s. Participants were randomly assigned to a control or a training group. The training lasted 4 weeks (4-day/week).

All dynamometric parameters increased significantly only in the training group for the trained leg ($p < 0.05$), with greater gains in work (32–47% at 45°/s and 31–41% at 90°/s) than moment variables (14–18% at 45°/s and 14–28% at 90°/s). Similar increases in strength were also noted at both angular velocities in the untrained leg ($p < 0.01$) for both work and moment parameters, depicting a cross-training effect. Correlations between 'moments' and 'works' increased in both legs after training from 0.59–0.77 to 0.79–0.95. Principal component analysis indicated that, at baseline, PM showed the highest weight on DF performance; after training, meanW at 90°/s and MPM at 45°/s exhibited the highest loadings.

High-intensity training of ankle DF increase the ability in generating energy throughout the entire range of motion rather than maximizing the PM.

1. Introduction

Isokinetic dynamometry is considered the reference method for evaluating muscle performance (Dvir, 2004) which can be described in terms of several outcome parameters (Woodson et al., 1995) such as the peak moment (PM), mean peak moment (MPM), maximal work (maxW) and the mean work (meanW). Based strictly on linear correlation analysis, past research has indicated that the PM, also known as peak torque, was highly correlated with the other outcome variables and could efficiently serve as the only representative parameter required for the interpretation of isokinetic data (Woodson et al., 1995; Bandy and Timm, 1992; Morrissey, 1987; Kannus, 1994). However, using principal component analysis (PCA) a recent study has indicated that PM, MPM, maxW and meanW contributed with different weights to ankle dorsiflexors (DF) performance, depending on the angular velocity employed (Manca et al., 2015a). The authors have further suggested that in ankle DF, the critical role of PM as the gold standard in isokinetic analysis was well maintained at intermediate angular velocities. However, at lower angular velocities, work measures could complement PM in providing a more comprehensive picture of DF performance. This assumption of complementarity rather than interchangeability of the PM and work supports previous arguments arguing that these parameters were not identical (Kramer and MacDermid, 1989) despite being highly correlated (Dvir and David, 1995).

However, whether the notion of complementarity may be extended to cover different experimental conditions has not been subjected to scientific scrutiny so far. Indeed, past research focused merely on baseline conditions through observational studies (Morrissey, 1987; Kramer and MacDermid, 1989; Bandy and Timm, 1992; Kannus, 1994; Woodson et al., 1995; Dvir and David, 1995; Manca et al., 2015a) while none had analyzed variations following the administration of a training protocol.

In the light of the above, clinicians should be encouraged to question the independence of these parameters by analyzing their

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http://dx.doi.org/10.1016/j.jelekin.2015.06.002
1050-6411/

inter-relationships both in physiological and pathological conditions.

Therefore, the objectives of this study were: to bilaterally characterize the performance of ankle dorsiflexion muscles (DF) in terms of PM, MPM, maxW and meanW, before and after a unilateral 4-week isokinetic–concentric training of the dominant DF; to examine the inter-relationships among these isokinetic measures using linear correlation and principal component analysis (PCA), a multivariate statistical technique which allows the retention of the most informative features in data without losing valuable information in the process of reduction analysis (Jolliffe, 2009).

2. Methods

2.1. Participants

Thirty healthy untrained subjects were recruited among university staff (21 males, 9 females; 26.7 ± 4.6 years old; 70.5 ± 12.0 kg). The demographic characteristics of the participants are reported in Table 1. All participants were requested to avoid any regular sporting or recreational activity during the study. Participants signed an informed consent form. This study (ClinicalTrials.gov identifier: NCT02010398) was conducted in accordance with the Declaration of Helsinki and approved by the local Bioethics Committee of the Local Health Authority (ASL) n.1-Sassari, Italy (ID: Prot. 1160/L).

2.2. Study design

This was a parallel-group case-control study in a randomized 1:1 allocation ratio. After baseline evaluation, 30 envelopes were numbered consecutively and randomly assigned to an intervention (Training; $n = 15$) or to a no-intervention (Control; $n = 15$) group, with a blocking procedure employing Research Randomizer 3.0 software. Testing procedures were performed before (PRE) and after (POST) the experimental period by the same operator at the same time of the day. Both outcome assessors and statistician were blinded to the allocation group. Data were collected in the Department of Biomedical Sciences, University of Sassari (January–December 2014).

2.3. Muscle performance testing

The primary outcomes, PM, MPM, maxW and meanW, were bilaterally assessed from the ankle DF on an isokinetic dynamometer (Biodex System 3 PRO, Biodex Medical Systems, Shirley, NY, USA) at baseline and within 1 week from the completion of the 4-week intervention. For each subject lower limb dominance was determined according to Hoffman et al. (1998). Before the actual testing participants were familiarized with the dynamometer in a separate session to abate the potential practice-based improvements associated with strength-testing procedures (Dvir and David, 1995). The device was calibrated and assembled with the ankle attachment positioned according to the manufacturer's specifications. The subject was seated with the knee flexed at 30° and the ankle in full plantar flexion as starting position. Gravity compensation was performed. Extraneous body movements were minimized by restraining each subject with shoulder harnesses, hip belts and mid-thigh straps. During the tests subjects' arms were placed across the chest with hands holding on to the straps. Before testing, participants underwent a 5-min warm-up realized by performing 1 set of 6–8 submaximal repetitions at 45 and 90°/s, with a 3-min rest between the 2 angular velocities. After a 5-min rest the criterion test took place and consisted of 4 maximal repetitions at 45°/s and 6 repetitions at 90°/s. The dominant leg was tested first with a 6-min rest between dominant and non-dominant side. No visual feedback or verbal encouragements were provided during testing (Gandevia, 2001). For reproducibility purposes, a retest procedure was executed within 1 week from the initial evaluation.

Table 1
Demographic characteristics of the participants at baseline.

Demographic features	Training group ($n = 15$)	Control group ($n = 15$)	Statistics
Age (years) *95% CI*	25.7 ± 5.4 (*22.7 – 28.7*)	27.7 ± 3.7 (*25.6 – 29.7*)	$F_{1,29} = 1.42$; $p = 0.24$
Gender (%)	*F*: 5 (33.3%) *M*: 10 (66.7%)	*F*: 4 (36.4%) *M*: 11 (63.6%)	Pearson's χ^2: $p = 0.5$
Weight (kg) *95% CI*	67.1 ± 13.0 (*59.9 – 74.3*)	73.9 ± 10.2 (*68.3 – 79.5*)	$F_{1,29} = 2.58$; $p = 0.12$

CI = Confidence Interval; F = Females; M = Males.

2.4. Intervention protocol

The DF of the dominant leg were arbitrarily chosen to be trained in the intervention group. The training protocol consisted of a 4-week unilateral isokinetic/concentric training, 4 days/week (Monday–Tuesday–Thursday–Friday), with an overall 25-min duration per session. After a light warm-up subjects performed 3×4 and 3×6 maximal concentric repetitions at 45°/s and 90°/s, respectively, with a 2-min rest between sets. Participants were verbally encouraged during exercise and provided with a visual feedback displaying the real-time moment-angular position curve to motivate the achievement of maximal performance.

2.5. Data analysis

STATA 12 (StataCorp, College Station, Texas) was used for the statistical analysis. An *a priori* sample power analysis was performed assuming an expected effect size (Cohen's d) of 0.6 and a statistical power of 0.80 at a 0.05 alpha level. For assessing test–retest relative reliability the 2-way random intra-class correlation coefficient for single measures ($ICC_{2,1}$) was performed (Shrout and Fleiss, 1979). Absolute reliability was also estimated with the standard error of measurement (SEM) (Weir, 2005). ICC and SEM scores were assessed separately in women and men to avoid gender-related bias deriving from between-gender strength differences (Almosnino et al., 2012). Sixty measures obtained from the 2 limbs of the 30 subjects were pooled since the coefficient of variation was not different between sides.

Demographic variables were analyzed at baseline with Student t-test or Chi-Square test, when appropriate. The Shapiro–Wilk test was used to assess normality. PRE to POST changes at each angular velocity were analyzed with a repeated-measures analysis of variance (ANOVA) with GROUP (training, control) and TIME (PRE, POST) as factors. When significance was achieved, pairwise comparisons with Bonferroni adjustment were used. The smallest real difference (SRD) was calculated to obtain a cut-off value for meaningful training-based gains (Lexell and Downham, 2005). Any training-based gain less than the cut-off value was attributed to a measurement error and discarded even if statistically significant. Cohen's d effect size magnitudes (small $\leqslant 0.5$; moderate 0.51–0.79; large $\geqslant 0.8$) were also used to quantify differences in the data after intervention.

Linear correlation coefficients (Pearson's r) were used to evaluate the degree of linear relationship between all variables with respect to both the PRE- and POST assessments.

The PCA was performed at PRE and POST to find the eigenvectors (factors) and eigenvalues. Sampling adequacy was established employing the Kaiser–Meyer–Olkin (KMO) measure (Kaiser, 1970).