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Review article

Instability resistance training for health and performance

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A B S T R A C T

Recently, resistance exercises performed on an unstable surface have become part of athletic training and rehabilitation. Accordingly, their role in performance and health-oriented strength training has increasingly emerged as a matter of interest to researchers and conditioning specialists. A more pronounced activation of stabilizing muscles is assumed to be the main feature of instability resistance exercises. This assumption has been proven by EMG studies, which have highlighted significantly greater electromyographic activity of trunk-stabilizing muscles during exercises under unstable as compared to stable conditions. Intervention studies also demonstrated an enhanced improvement of trunk stability after training programs utilizing unstable devices as compared to floor exercises. Findings indicate that instability resistance training may facilitate the neural adaptation of trunk-stabilizing muscles, resulting in an improvement in trunk stability. However, both acute and long-term responses of primarily activated muscles to exercises performed on an unstable surface remain a matter of debate. It has been established that there is a significantly lower peak isometric force and rate of force development during resistance exercises under unstable as compared to stable conditions. In addition, the power output was compromised when exercises were performed on unstable surfaces. However, we have demonstrated that this effect depends on the type of exercise, instability device used, weight lifted, subject's training background, and so forth. Our findings on muscular power in the concentric phase of resistance exercises with different weights under stable and unstable conditions complement this review. Applications of instability resistance exercises for the improvement of neuromuscular functions in the physically active, plus for those following anterior cruciate ligament reconstructions, are also presented.

1. Introduction

Most studies support the application of resistance exercises for the prevention and rehabilitation of injuries; however their utilization for improving strength and power remains a matter of debate. The main reason for this is that an unstable support base compromises the power output in the concentric phase of resistance exercise.[1–3] This may be ascribed to the delayed amortization phase of stretch-shortening cycle (SSC). It has been established that the activation of SSC enhances the power output in the concentric phase of the lifting exercise. The mechanism of power production using SSC employs the energy storage capabilities of a series of elastic components and the stimulation of stretch reflex to facilitate the muscle contraction over a minimal amount of time. If a concentric muscle action does not occur immediately following the eccentric one, the stored energy dissipates and is lost as a heat and also the potentiating stretch reflex fails to be activated. Instability resistance exercises, such as chest presses, may compromise all three phases of SSC, namely the amortization phase. Around this turning point, where the eccentric phase changes into the concentric one, maximal force is produced. At the same time, subjects must stabilize their torso on an unstable surface in order to provide firm support for contracting muscles. This additional task may compromise the contraction of muscles acting on the barbell. Their less intensive contraction not only prolongs the change of movement direction, but because of lower peak force, negatively impairs accumulation of elastic energy. The consequence is lower power in the subsequent concentric phase of lifting.

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Understanding the physiological mechanisms and biomechanical factors that influence muscle strength and power during instability resistance exercises is a basis for the design of training and rehabilitation programs. In order to provide more information in this field of research, several experiments were conducted in our department.

In general, subjects performed a) barbell chest presses on a bench and on a Swiss ball and b) barbell squats on a stable support base and on a BOSU ball. The weight lifted was calculated as a percentage of their previously established 1 repetition maximum (1RM) under stable conditions. According to Goodman et al,[4] there is no significant difference in 1RM strength or muscle EMG activity for the barbell chest press exercise on an unstable exercise ball and a stable flat surface.

Chest presses involved the subjects lowering the barbell to the chest without touching it when transitioning from the eccentric to the concentric phase. Any repetitions that contacted the chest or failed to come within ~0.05 m of the chest were disregarded and repeated after 1 min of rest. The distance of the barbell movement was controlled in graphic and digital forms using the FiTRO Dyne Premium system. Subjects were required to keep the same grip width for the entire testing protocol, and to ensure that contact was maintained with the bench between their hips and back. Under unstable conditions, the chest presses were performed with the Swiss ball placed in the thoracic area and with the feet placed on the floor.

Squats were performed while holding a barbell on the back from full extension to a knee angle of 90°, followed immediately by an upward movement. Subjects were required to keep the same foot position for the entire testing protocol. In order to ensure similar unstable conditions as the chest presses on a Swiss ball, subjects stood on the bladder side of a BOSU ball during squats. According to Laudner and Koschnitzky,[5] there were no significant differences in EMG data for any muscle (tibialis anterior, peroneus longus, medial gastrocnemius) when standing on a single-leg on either side of the BOSU balance trainer, which demonstrates no benefit to the amount of ankle muscle activity resulting from flipping the BOSU balance trainer onto the bladder side. A laboratory assistant stood behind the subject to prevent a possible fall.

Basic biomechanical parameters involved in the lifting exercises were monitored using the computer-based system FiTRO Dyne Premium (FiTRONiC, Slovakia). For this system, Gažovič[6] reported test–retest correlation coefficient and measurement error of 0.89 and 13.5% respectively for peak power, and 0.87 and 7.28% respectively for mean power in the concentric phase of bench presses with weight of 60 kg. The study of Jennings et al[7] showed intraclass correlation coefficients of 0.97 (95% CI, 0.95–0.98) for maximal power during squat jumps and 0.97 (95% CI, 0.95–0.98) for bicep curls with the limits of agreement of −17 ± 96 W and 0.11 ± 13.90 W, respectively. In addition, we have reported ICC and SEM% values in range 0.97–0.98 and 7.6–7.7% respectively for mean power over the entire concentric phase, 0.96–0.98 and 9.1–9.6% respectively for mean power in the acceleration phase, and 0.94–0.97 and 9.2–10.0% respectively for peak power, when chest presses were performed on the bench.[8] The ICC and SEM% values during chest presses on a Swiss ball ranged from 0.93 to 0.96 and 8.4 to 9.1% respectively for mean power over the entire concentric phase, from 0.87 to 0.90 and 11.7 to 12.2% respectively for mean power in the acceleration phase, and from 0.79 to 0.82 and 12.1 to 13.4% respectively for peak power at weights of 40 and 60% 1RM, and from 0.70 to 0.76 and 17.6 to 19.8% respectively at weight of 80% 1RM. These findings indicate that measurement of peak and mean power during unstable chest presses provides reliable data, comparable to those obtained during bench presses under all conditions tested, excluding peak values of power measured during unstable chest presses with weights ≥80% 1RM.

The FiTRO Dyne Premium system consists of a sensor unit based on a precise encoder mechanically coupled to a reel. While pulling out the tether (connected by means of small hook to the barbell axis) the reel rotates and measures velocity. The rewinding of the reel is guaranteed by a string which produces a force of approximately 2 N. Signals from the sensor unit are conveyed to the personal computer by means of a USB cable.

The system operates on Newton's law of universal gravitation (force equals mass multiplied by the gravitational constant) and Newton's law of motion (force equals mass multiplied by acceleration). Instantaneous force while moving a barbell of a mass in the vertical direction is calculated as the sum of the gravitational force (mass multiplied by gravitational constant) and the acceleration force (mass multiplied by acceleration). The acceleration of the vertical motion (positive or negative) is obtained by derivation of vertical velocity, measured by a highly precise device mechanically coupled to the barbell. Power is calculated as the product of force and velocity and the actual position by the integration of velocity. Comprehensive software allows the collection, calculation, and on-line display of the basic biomechanical parameters involved in resistance exercises.

The device was placed on the floor and anchored to the bar by a nylon tether. Subjects performed exercises while pulling on the nylon tether of the device (Fig. 1a–d). Peak and mean values of power were obtained from the entire concentric phase of lifting, as well as from its acceleration segment.

2. Acute and adaptive changes in muscular power during resistance exercises with different weights lifted under stable and unstable conditions

2.1. *Utilization of elastic energy during resistance exercises under stable and unstable conditions*

This study[9] compared power outputs in the concentric phase of chest presses and squats, performed with and without countermovement (CM), both on stable and unstable support surfaces. On alternative days, a group of 16 physically active young men randomly performed 3 repetitions of (a) barbell chest presses on a bench and a Swiss ball, and (b) barbell squats on a stable support base and a BOSU ball. The initial weight of 20 kg was increased by 10 kg or 5 kg (at higher loads) up to at least 85% of previously established 1RM under stable conditions. As a parameter of the capability to utilize elastic energy, the difference in mean power in the concentric phase of resistance exercises performed both with and without CM (ΔP) was calculated. Results revealed higher power outputs in the concentric phase of CM chest presses, as compared to those performed from a position on the chest under both stable and unstable conditions. This enhancement of power due to CM was rather modest at lower weights but become more pronounced with increasing weights, reaching a maximum at 57.1% 1RM on a stable support surface and at 47.6% 1RM on an unstable support surface. Lifting heavier weights not only failed to increase the enhancing effect, but actually led to its decline. A similar trend was observed during squats with maximal enhancement of power in the concentric phase of lifting at about 80% 1RM under both conditions. The ΔP was significantly lower during chest presses performed on the Swiss ball as compared to those on the bench; but this was only evident for higher weights (≥60% 1RM). On the other hand, the ΔP during squats performed on the BOSU ball and on the stable support base did not differ significantly across all weights lifted. These findings indicate that the ability to utilize elastic energy during CM chest presses is more profoundly compromised under unstable as