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POWER PRODUCTION DURING BENCH PRESS WITH DIFFERENT RANGES OF MOTION ON STABLE AND UNSTABLE SURFACES

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ABSTRACT

Purpose. The study compared power during concentric-only and countermovement (CM) bench press with different ranges of motion (ROM) on a stable and unstable surface. **Methods.** A group of 22 fit men performed three repetitions of 1) full ROM concentric-only bench press, 2) full ROM CM bench press, 3) half ROM concentric-only bench press, and 4) half ROM CM bench press, on a bench (stable) and Swiss ball (unstable) at 60% 1RM. The FiTRO Dyne Premium system was used to monitor force and velocity and calculate power. Mean values of power during the acceleration and the entire concentric phases were analyzed. **Results.** No significant differences were found in mean power during concentric-only bench press on the bench and Swiss ball performed at half ROM and full ROM. Likewise, mean power during the concentric phase of half-range CM bench press on the bench and Swiss ball did not differ significantly. However, power values during full-range CM bench press were significantly higher on the bench than on Swiss ball. These differences were even more pronounced for mean power during the acceleration phase of full-range CM bench press on the bench compared with the Swiss ball. Contrary to this, these values did not differ significantly when the barbell was lifted during half ROM bench press on the bench and Swiss ball. **Conclusions.** Power was significantly lower during full-range CM bench press on the Swiss ball than on the bench, however, values did not differ significantly during stable and unstable half-range CM bench press.

Key words: bench press, stable support base, Swiss ball, utilization of elastic energy

Introduction

Resistance exercises on unstable surfaces have recently grown in popularity. Though being suitable for rehabilitation purposes, their use in sports training remains a matter of debate. More pronounced activation of stabilizing muscles has been assumed as the main advantage of resistance exercises performed on unstable surfaces. This assumption was proven by electromyographic (EMG) studies showing significantly greater EMG activity of trunk-stabilizing muscles in unstable than stable conditions during exercises such as the curl-up [1], bridge [2, 3], dumbbell bench press [4], and squat [5, 6]. Intervention studies have also documented more effective improvements in trunk stability after short-term training programs using the Swiss ball compared with floor exercises [7, 8]. These findings indicate that instability resistance training may facilitate neural adaptation of the trunk-stabilizing muscles resulting in improved trunk stability.

Alternatively, other studies have shown significantly lower peak isometric force in unstable conditions when compared with stable conditions during dumbbell bench press (60%) [9], isometric knee extension (70%), plantar flexion (30%) [10], and squat (46%) [6] and also the rate of force development during the squat (40.5%) [6]. However, when dynamic bench presses were performed on an unstable surface, the reductions were found to be smaller (approximately 6% in force and 10% in velocity and power outputs) [11]. Similar findings have been reported after resistance exercises performed as a mode of interval training on stable and unstable surfaces [12]. Here, in the initial set, mean power in the concentric phase of the lift decreased more intensely in unstable (Swiss ball) than in stable conditions both during bench press (13.2% and 7.7% decrease, respectively) and squat (10.3% and 7.2% decrease, respectively) exercises. In the final sixth set of eight repetitions, the rates of reduction of mean power in the concentric phase of the bench press were significantly greater in unstable than stable conditions (19.9% and 11.8%, respectively). On the other hand, there were no significant differences in the decline of power in the concentric phase of squat exercise performed on an unstable Bosu ball and a stable support base (11.4% and 9.6%, respectively). These findings [12] indicate that power outputs during resistance exercises are more compromised in unstable than in stable conditions and that this effect is more evident for the barbell bench press performed on a Swiss ball than for barbell squats on a Bosu ball.

However, significant differences in mean power in the concentric phase of unstable compared with stable resistance exercises were only found when lifting heavier weights (≥ 60% 1RM) [13]. Video analysis showed that concentric muscle action did not occur immediately after the eccentric phase as participants had to stabilize their own body on the unstable support surface [13]. It

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was hypothesized that most of the stored energy dissipates and is lost as heat and the stretch reflex fails to be activated. However, whether this effect is indeed due to the compromised ability to reuse elastic energy during countermovement (CM) resistance exercise on unstable surface needs to be proven. This effect was assumed to be evident only during CM resistance exercises performed throughout the full range of motion (ROM). Verification of this hypothesis was performed by comparing mean power during concentric-only and CM bench press with different ranges of motion on stable and unstable surfaces.

Material and methods

A group of 22 fit men (age 22.7 ± 2.7 years, height 178.1 ± 7.8 cm, weight 79.0 ± 9.2 kg) volunteered to participate in the study. All had at least 4 years' experience with resistance training although none had any experience with instability resistance training. All participants were informed about the procedures and main purpose of the study. They were asked to refrain from any strenuous exercises during the duration of the study. The study was performed in accordance with the ethical standards on human experimentation outlined in the Declaration of Helsinki.

Participants underwent a familiarization session during which the test protocol was explained and trial resistance exercises were performed. Emphasis was placed on proper technique especially when performed on the unstable surface. The exercises were performed without and with countermovement using maximal effort during the concentric phase.

For the experimental protocol, the participants randomly performed on different days one set of three repetitions of 1) full range of motion (ROM) concentric-only bench press, 2) full ROM countermovement bench press, 3) half ROM concentric-only bench press, and 4) half ROM countermovement bench press. Each set was performed once on the bench and once on a Swiss ball at 60% of 1 repetition maximum (1RM), which was calculated prior to the study for each participant in stable conditions. A rest interval of 2 min was provided between reps. The best result of the three repetitions for each exercise was selected for analysis.

The CM bench press involved the participants lowering the barbell to the chest without making contact when transitioning from the eccentric to concentric phase. Any repetitions that made contact with the chest or failed to come within 0.05 m of the chest were disregarded and repeated after 1 min of rest. Bench press performed without CM started from an initial position on the chest (barbell positioned about 0.05 m from the chest). The participant then held the position for approximately 2 s before the tester gave the command that they were to perform the lift. Each participant was observed during the test to ensure that no countermovement was implemented. Real-time analysis allowed for the monitoring of all possible movement with the barbell. Participants were required to maintain the same grip width throughout the entire testing protocol. Emphasis was placed on maintaing contact between the hips and back with the bench. During unstable condition testing, the bench press was performed with the Swiss ball placed under the thoracic area and with both feet placed flat on the floor.

For the half ROM bench press, boxes were placed on each side of the bench or Swiss ball limiting the range of motion to half of the entire movement (approx. 90°). The distance of the barbell movement was set up using a computer system described below. Each participant was observed during the test to ensure that the triceps did not touch the boxes. The distance of the barbell movement was controlled in graphic and digital form to be in the range of ± 5 cm. Only data which met the specified criteria were included for analysis.

Basic biomechanical parameters during the tests were monitored using the FiTRO Dyne Premium system (FiTRONiC, Slovakia). The system consists of a precise analogue rotary sensor coupled to a reel. When pulling the tether, the reel is wound and a sensor measures velocity. Rewinding of the reel is guaranteed by string producing force of about 2 N. The signal is passed through a 12-bit analogue-to-digital convertor and sent to a PC by USB cable. Included comprehensive software was used to collect, calculate, and display real-time basic biomechanical parameters involved in exercise. The device was placed on the floor and attached to the barbell by a nylon tether (Fig. 1). Mean values of power during the entire concentric phase of lifting ($P_{\text{mean total}}$) and during the acceleration phase ($P_{\text{mean acc}}$) were selected for analysis.

The system operates on Newton's law of universal gravitation (force equals mass multiplied by the gravitational constant) and the Newton´s law of motion (force equals mass multiplied by acceleration). Instant force when moving the barbell in the vertical direction is calculated as a sum of gravitational force (mass multiplied by the gravitational constant) and acceleration force (mass multiplied by acceleration). Acceleration of the vertical movement (positive or negative) is obtained as a derivation of vertical velocity. Power is calculated as a product of force and velocity and the actual position by integration of velocity.

Statistical analysis of the collected data was performed using SPSS ver. 18.0 for Windows (IBM, USA). The Kolmogorov–Smirnov test for normality and Levenne's test for equality of error variances were performed on all variables, finding that the data were normally distributed and no significant differences in sample variance were detected. Statistical power was determined to be > 0.80 at the 0.05 alpha level. Data were then analyzed using a three-way analysis of variance (ANOVA) with repeated measures. Factors included surface type (stable, unstable) × contraction type (concentric-only,

Figure 1. Measurement of strength parameters during full and half ROM bench press on the bench (above) and Swiss ball (below) using the FiTRO Dyne Premium system

eccentric-concentric) × range of motion (full, half). Where significant differences were detected at $p \le 0.05$, post hoc analysis was performed using Tukey's honest significance test. Descriptive statistics include means and standard deviations.

Results

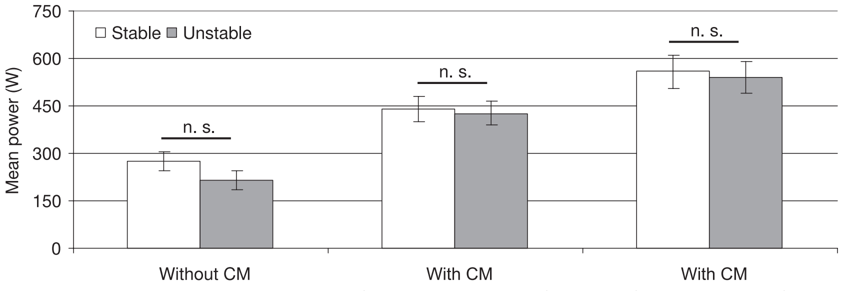
The results are presented in Figures 2 and 3. No significant differences were found in mean power in concentric-only bench press on the bench and Swiss ball performed at half ROM (275.6 ± 28.7 W and 215.3 ± 29.8 W, respectively) and full ROM (286.1 ± 30.2 W and 237.1 ± 31.0 W, respectively).

Likewise, mean power in the concentric phase of half-range CM bench press on the bench and Swiss ball did not differ significantly (440.5 ± 39.8 W and 427.1 ± 37.7 W, respectively). However, significant interactions were found for full-range CM bench press, $F(1, 20) = 4.4$, $p = 0.028$, where values of $P_{\text{mean total}}$ were significantly higher on the bench than on the Swiss ball (479.7 ± 44.7 W and 397.5 ± 34.3 W, respectively). These differences were even more pronounced, $F(1, 20) = 6.4$, $p = 0.008$, for mean power during the acceleration phase of full-range CM bench press on the bench when compared to those on the Swiss ball (600.5 ± 58.1 W and 488.2 ± 43.3 W, respectively). However, the values did not differ significantly when the barbell was lifted at half ROM on the bench and Swiss ball (558.0 ± 54.2 W and 538.7 ± 49.1 W, respectively).

Discussion

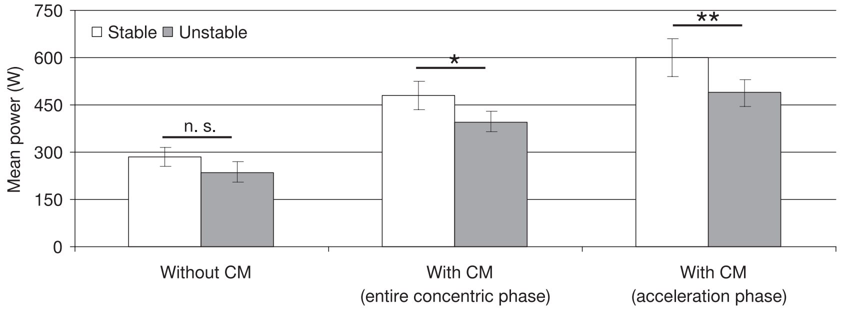
It is known that concentric contraction using the stretch-shortening cycle (SSC) produces greater power output than a simple concentric contraction by itself [14–16]. An effective SSC requires three critical elements, including a well-timed preactivation of the muscle(s) before the eccentric phase, a short and fast eccentric phase, and an immediate transition (short delay) between the stretch (eccentric) and shortening (concentric) phase.

The mechanisms underlying this enhancement of power are usually ascribed to the utilization of elastic energy stored in the elastic components of the muscles in combination with reflexively induced neural input [15, 17–20]. Alternative explanations propose that the prestretch of an active muscle alters the properties of the contractile machinery and that prior stretch allows the muscle to build up a maximum active state before the concentric contraction begins [21–23]. However, no differences were found in EMG activity between SSC and isometric condition in the concentric phase of a vertical jump, indicating that reflex activity was not involved in the observed increase of torque values [24]. These



n.s. – not significant

Figure 2. Mean power in the concentric phase of half ROM bench press performed without and with countermovement (CM) on the bench and Swiss ball



* $p \leq 0.05$, ** $p \leq 0.01$, n.s. – not significant

Figure 3. Mean power in the concentric phase of full ROM bench press performed without and with countermovement on the bench and Swiss ball

findings have led a number of scientists to suggest that reflex activity is not involved in increased force output during SSC [25]. It may be therefore assumed that the utilization of elastic energy can explain the enhancement of power during countermovement weight exercises.

However, the ability to utilize elastic energy during resistance exercises may significantly differ when performed in stable vs. unstable conditions. This assumption may be corroborated by findings of significant differences in the physiological and biomechanical variables of stable and unstable resistance exercises. Marshall and Murphy [4] showed greater EMG activity of trunk-stabilizing muscles in unstable than in stable conditions during the dumbbell bench press. The high muscle activation during exercises performed on unstable surface can be attributed to their increased stabilization function. This is due to additional stresses imposed on the synergistic and stabilizing muscles of the trunk during bench press with the back supported by the unstable Swiss ball [26].

Preliminary analysis of the position of the barbell and its movement distance showed a sort of plateau between the eccentric and concentric phases of bench press performed on the Swiss ball. The duration of this phase depends on the stiffness of the ball as well as the weight lifted. On a less stiff ball or while lifting heavier weights, the participant is required to generate greater muscular effort to quickly change from the eccentric to concentric phase. On the other hand, when lifting lighter weights, the participant can utilize the elastic properties of the ball to accelerate the upward movement. The magnitude is proportional to the applied force (or weight lifted) and the induced deformation in the ball. Though it is possible to estimate the extent to which the ball is depressed by knowing the weight of the participant and barbell weights, the tangible stiffness of the ball is unknown and may vary across its surface. Therefore, the use of video analysis instead of calculating the force exerted by the ball may be more appropriate in this context.

As shown in the present study, there were no significant differences in mean power in the concentric phase of full- and half-range bench press initiated from a static position on stable and unstable surfaces. Similarly, these values did not differ significantly during half-range CM bench press performed on the bench and Swiss ball. During such exercise, with a considerably lower contribution of elastic energy, it is likely that other factors such as greater muscle tension during unstable surface exercise contributed to similar production of power as in stable conditions. However, during full-range CM bench press on the Swiss ball, a presumably lower amount of energy was accumulated in the involved elastic tissues of muscles and tendons that could consequently be utilized for subsequent concentric contraction. This is mainly due to the delayed and prolonged amortization phase of the stretch-shortening cycle. The reasoning is that maximal force is produced around the turning point when the eccentric phase changes into the concentric phase. At the same time, the torso must be stabilized on the unstable surface in order to provide firm support for the contracting muscles. This additional task may compromise the contraction of the 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. Consequently, this leads to lower power output in the concentric phase of full-range CM bench press on unstable than on stable surfaces.

Indeed, significantly lower peak force values around the transition point from the eccentric to the concentric phase weere found in unstable than stable bench press [27], although only at 80% and 60% 1RM but not at 40% 1RM. Because of lower force production during instability resistance exercises, some authors [4, 6] have recommended performing resistance exercises on stable surfaces in order to improve muscular strength and athletic performance. The main reasoning is that 80% of the maximum muscular strength required for its enhancement in trained individuals [28] is not met during instability resistance exercises.

Taken altogether, lower peak force in the transition point from the eccentric to the concentric phase and the delayed and prolonged amortization phase of the stretch-shortening cycle are most likely responsible for lower power production in the acceleration and entire concentric phase of lifting.

Conclusions

There were no significant differences in mean power of concentric-only bench press on the bench and Swiss ball performed at half ROM and full ROM. Likewise, mean power in the concentric phase of half-range CM bench press on the bench and Swiss ball did not differ significantly. However, power during full-range CM bench press was significantly higher on the bench than on the Swiss ball. These differences were even more pronounced in mean power produced during the acceleration phase of full-range CM bench press on the bench than on the Swiss ball. Contrary to this, these values did not differ significantly when the barbell was lifted during half ROM bench press on the bench and Swiss ball.

Taking into account that no significant differences in power output during half-range CM bench press on the bench and Swiss ball were found and that significantly lower values were recorded during full-range CM bench press on the Swiss ball than on the bench, it is likely that unstable conditions compromise the ability to utilize elastic energy stored during the eccentric phase of lifting. These findings need to be taken into account when instability resistance exercises are implemented into a training program especially for sports requiring maximal force production in a short amount of time. Future research should be directed toward intervention studies evaluating the effects of instability resistance training on explosive strength and other related variables of athletic performance.

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