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Review article

Instability resistance training for health and performance

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ABSTRACT

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 online 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

Fig. 1. Measurement of strength parameters during barbell chest presses on a bench and a Swiss ball (above) and squats on a stable support base and a BOSU ball (below).

compared to stable conditions when higher weights are lifted. On the other hand, there is similar enhancement of power in the concentric phase of CM squats on the stable and unstable support surface regardless of the weight lifted. In addition to the type of exercise, this may also be ascribed to the differing degree of instability of the devices utilized (Swiss ball versus BOSU ball).

2.2. Power production during chest presses with different ranges of motion on stable and unstable surfaces

This study[10] compared power during concentric-only and countermovement (CM) chest presses with different ranges of motion (ROM) on a stable and an unstable surface. A group of 22 physically active young men performed three repetitions of a) full ROM concentric-only chest presses, b) full ROM CM chest presses, c) half ROM concentric-only chest presses, and d) half ROM CM chest presses, on a bench and a Swiss ball at 60% 1RM. Results revealed no significant differences in mean power during concentric-only chest presses on the bench and the Swiss ball performed at half ROM and full ROM. Similarly, mean power during the concentric phase of half-range CM chest presses on the bench and the Swiss ball did not differ significantly. However, the values during full-range CM chest presses were significantly higher on the bench than on the Swiss ball. These differences were even more pronounced for mean power during the acceleration phase of full-range CM chest presses on the bench compared to the Swiss ball. In contrary, the values did not differ significantly when the barbell was lifted during half ROM chest presses on the bench and the Swiss ball. Therefore, it was concluded that power is significantly lower during full-range CM chest presses on the Swiss ball as compared to the bench, however, the values do not differ significantly during stable and unstable half-range CM chest presses.

2.3. Weight lifted and countermovement potentiation of power in the concentric phase of instability and traditional resistance exercises

This study[11] evaluated the effect of weight lifted on power in the concentric phase of resistance exercises on stable and unstable surfaces. On alternative days, a group of 19 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 base and a BOSU ball. Exercises were performed both with and without countermovement (CM) using maximal effort in the concentric phase of lifting. The initial weight of 20 kg was increased by 10 or 5 kg (at higher loads) up to at least 85% of the previously established 1RM under stable conditions. Results revealed no significant differences in mean power in the concentric phase of stable and unstable CM chest presses at the lower weights lifted (from 20 to 50 kg). However, the values were significantly higher during chest presses on the bench, as compared to the Swiss ball while lifting higher weights (from 60 to 90 kg). Similarly, mean power in the concentric phase of squats was significantly higher on the stable base as compared to the BOSU ball at higher weights lifted (from 60 to 90 kg). Therefore, it was concluded that an unstable base compromises the power in the concentric phase of resistance exercises, but only when higher weights are lifted.

2.4. Power output in the concentric phase of chest presses in athletes with different experience with instability resistance training

As shown above,[11] an unstable support base compromises power in the concentric phase of chest presses, namely at higher weights lifted. However, this has only been documented in physically active subjects without instability resistance training experience. On the other hand, there is a lack of studies which deal with athletes incorporating instability devices, such as exercise balls or wobble boards, into the training routine. Preliminary results indicate that these subjects are able to utilize the spring properties of the ball and enhance the power in the concentric phase of lifting. In order to prove this observation, we compared peak and mean power in the concentric phase of chest presses at varied weights lifted and with the back supported by an unstable Swiss ball, in athletes with varied experience in instability resistance training.[12] Two groups of experienced lifters participated in the study. While group 1 ($n = 17$) had experience only with conventional resistance training, group 2 ($n = 16$) had experience with resistance exercises on unstable support surfaces. In random order, they performed barbell chest presses on a Swiss ball with weights of 40%, 60%, and 80% 1RM, respectively. Exercises were performed with countermovement using maximal effort in the concentric phase. While there were no significant differences in mean power over the entire concentric phase of chest presses performed on the Swiss ball in groups 1 and 2 when lifting weights of 40% and 60% 1RM, values were significantly lower at 80% 1RM in group 1 as compared to group 2. However, peak power and mean power in the acceleration phase of lifting were significantly lower in group 1 as compared to group 2 at all weights lifted. Therefore, it was concluded that power output in the concentric phase of chest presses performed on the Swiss ball is lower in subjects without experience in instability resistance exercises, as compared to those with experience. These differences are mainly evident in peak and mean power in the acceleration phase of lifting with higher weights ($\geq$60% 1RM). These findings indicate that the ability to produce power during weight exercises on an unstable support surface depends on the training background.

2.5. The effect of stable and unstable lifting conditions on power output and fatigue rate during resistance exercises

This study[13] evaluated the effect of fatigue on mean power in the acceleration and throughout the entire concentric phase of resistance exercises on both stable and unstable surfaces. A group of 24 physically active young men performed a set of 25 repetitions of chest presses on a bench or on a Swiss ball, and squats on a stable support base or on a BOSU ball (both with 70% 1RM). Results revealed that mean power during both exercises was significantly higher on the stable as compared to the unstable surface. However, mean power in the acceleration (46.1% and 29.3%, $p = 0.009$) and during the entire concentric phase of chest presses (44.9% and 33.1%, $p = 0.012$) decreased more profoundly under stable as compared to unstable conditions. However, mean power in the acceleration (35.8% and 39.2%, $p = 0.73$) and throughout the entire concentric phase of squats (35.1% and 38.4%, $p = 0.78$) decreased similarly under both stable and unstable conditions. Therefore, it was concluded that in the final repetitions of a set of chest presses, fatigue impairs the ability to produce power more profoundly when performed on the bench as compared to the Swiss ball, whereas values during squats decrease similarly on both the stable support base and the BOSU ball.

2.6. Power output in the concentric phase of resistance exercises performed in the interval mode on stable and unstable surfaces

This study[14] compared power outputs in the concentric phase of chest presses and squats performed in the interval mode on both stable and unstable surfaces. On alternative days, a group of 16 physically active young men randomly performed 6 sets of 8 repetitions of a) chest presses on a bench and on a Swiss ball, and b) squats on a stable support base and on a BOSU ball, with 2 min of rest period between sets. The exercises were performed with previously established 70% 1RM under stable conditions. Results revealed significantly lower power outputs when resistance exercises were performed on an unstable as compared to a stable support base. In the initial set, mean power in the concentric phase of lifting decreased more profoundly under unstable as compared to stable conditions during both chest presses (13.2% and 7.7%, respectively) and squats (10.3% and 7.2%, respectively). In the final set, the reduction rates of mean power in the concentric phase of chest presses were significantly greater on the Swiss ball as compared to the bench (19.9% and 11.8%, respectively). On the other hand, there were no significant differences in decline of mean power in the concentric phase of squats on the BOSU ball and on the stable support base (11.4% and 9.6%, respectively). Therefore, it was concluded that power output during resistance exercises is more profoundly compromised under unstable as compared to stable conditions, and this effect is more evident for barbell chest presses on the Swiss ball as opposed to the barbell squats on the BOSU ball.

2.7. Cardiorespiratory response to traditional and instability resistance exercises

This study[15] compared the cardiorespiratory parameters during and after upper and lower body resistance exercises performed under both stable and unstable conditions. On alternative days, a group of 16 physically active young men randomly performed 6 sets of 8 repetitions (with 2 min of rest period in-between) of a) barbell chest presses on either a bench or a Swiss ball, and b) barbell squats on either a stable surface or a BOSU ball (both with 70% 1RM). Cardiorespiratory parameters were monitored by means of the breath-by-breath system Spiroergometry CS 200. The kinetics of most of the cardiorespiratory parameters revealed only slight changes during the active lifting period, compensated by a rather pronounced increase in the early phase of recovery. More specifically, oxygen uptake after both stability and instability resistance exercises increased, and only after about 30–40 s a gradual decrease back to the resting level set in. On the other hand, the heart rate reached the maximum at the end of exercising and began to decline immediately in the recovery phase. The response of oxygen pulse was even more delayed, though it had remained relatively unchanged during exercise, but began to increase in recovery, reaching the maximum after approximately 40–50 s. However, the values obtained during the upper-limb exercises were significantly higher under unstable versus stable conditions, whereas no significant differences were observed for the lower-limb exercises. Moreover, there was a gradual increase in cardiorespiratory parameters from the 1st to the 6th set during both exercises performed on a stable as well as an unstable surface (about 10–20%). These findings indicate that instability chest presses represent a more intensive stimulus for cardiorespiratory functions than those performed on a stable surface. In contrast, cardiorespiratory response to squats is similar under both stable and unstable conditions.

Moreover, we estimated the energy demands of these upper and lower body resistance exercises when performed on both stable and unstable surfaces.[16] Results indicated a higher oxygen uptake (VO_2) during active intervals of chest presses performed on a Swiss ball as compared to a bench (0.96 l/min and 0.81 l/min, respectively), representing 20.3 kJ and 17.1 kJ, respectively. Further, an increase of VO_2 was observed in post-exercise phase after both instability and stability chest presses (0.09 l/min and 0.08 l/min, respectively), representing 1.8 kJ and 1.6 kJ, respectively. Similarly, oxygen uptake was higher during active intervals of squats performed on a BOSU ball as compared to a stable support base (1.19 l/

min and 1.08 l/min, respectively), representing 25.1 kJ and 22.8 kJ, respectively. Further an increase of VO_2 occurred in the recovery period (0.12 l/min and 0.11 l/min, respectively), representing 2.4 kJ and 2.2 kJ, respectively. Overall, the energy expenditure was only slightly higher during instability versus stability chest presses (22.1 kJ and 18.7 kJ, respectively) and squats (27.5 kJ and 25.0 kJ, respectively). Taking into account the only slightly higher energy demands of instability versus stability resistance exercises, one can hardly expect that weight exercises performed on an unstable surface would be superior in amount of calories burned.

2.8. The effect of instability resistance training on neuromuscular performance

There are some contradictory findings in the studies evaluating the effect of instability resistance training on neuromuscular performance. This is mainly due to the varied unstable devices utilized and the exercises incorporated into the training. To date, there are no scientific guidelines concerning the optimal intensity and duration of these exercises, thus there is a large deviation in study results. A few examples of dissertation theses in this field of research conducted under my supervision are listed below.

The study by Macko[17] evaluated the effects on balance following 12 weeks of training, which consisted of varied forms of exercises eliciting greater instability of either upper or lower body in karate competitors. Results indicated that the center of pressure (CoP) velocity under various standing positions (Heiko-dachi, Neko-ashi-dachi, and one-legged stance) decreased more profoundly in group 2 (G2) which utilized an Aquahit bag, as compared to Group 1 (G1) which exercised on a BOSU ball. On the other hand, there was a greater improvement in dynamic balance measured by the MFT S3 diagnostic system in G1 which exercised on the BOSU ball as compared to G2 who utilized the Aquahit bag, in both antero-posterior (A-P) and medio-lateral (M-L) planes during Heiko-dachi and Sanchin-dachi stances. However, mean CoP distance from the horizontally flowing curve (regulating the CoM movement in A-P plane) decreased significantly in G2 which utilized the Aquahit bag, whereas from the vertically flowing curve (regulating the CoM movement in M-L plane) in G1 exercising on the BOSU ball. Furthermore, sway trajectory distance between the appearance of stimuli on the screen and their hit by horizontal shifting the CoM, decreased more profoundly in the G1 exercising on the BOSU ball as compared to G2 utilizing the Aquahit bag. This study demonstrates that both regimens significantly improved postural stability but the gains were task-specific in terms of an improved static balance when utilizing the Aquahit bag and more enhanced dynamic balance when exercising on the BOSU ball. This effect was also evident in the accuracy of the visual feedback control of the CoP movement in A-P and M-L directions (the Aquahit bag and the BOSU ball, respectively) and a more precise perception of the CoM position and an improved regulation of its movement in the required direction (the BOSU ball).

Another study by Bauer,[18] compared the effects of 12 weeks of stable-unstable resistance training and 12 weeks of unstable-stable resistance training on 42 parameters of neuromuscular performance in handball players. While group 1 began on a stable surface for 6 weeks and progressed to an unstable surface for the following 6 weeks, group 2 began on an unstable surface for 6 weeks and progressed to a stable surface for the following 6 weeks. Both groups performed chest presses and squats on stable and unstable surfaces, i.e. a Swiss ball and a BOSU ball respectively (twice a week, 3 sets of 8 repetitions with 70% 1RM). The gains in height of push-ups were significantly higher in the unstable-stable group compared to the stable-unstable group. On the other hand, the gains in ground contact time, drop jump index, and average speed during shuttle run, were significantly enhanced in the stable-unstable group as compared to the unstable–stable group. However, there were no significant changes in the remaining parameters following either training program. These findings indicate that neither the stable-unstable training order nor the unstable–stable order can be regarded as superior for players who also follow a daily handball training routine.

Similarly, Ferková[19] compared 16 weeks of resistance training both on unstable and stable surfaces on parameters of strength and balance in tennis players. While group 1 (G1) first performed resistance exercises on unstable surfaces (1–8. weeks) and then on a stable surface (9–16. weeks), group 2 (G2) performed the same exercises in reverse order, i.e. on a stable surface and then on unstable surfaces i.e. Swiss ball and a BOSU ball (3-times a week, 6 sets of 6 repetitions with 60% 1RM). Results revealed that the G1 improved in body balance in terms of a decrease in velocity of the center of pressure (CoP) during the stance on a foam surface and an accuracy of regulation of CoP movement in medio-lateral direction. Also, G2 improved in dynamic balance and in an accuracy of regulation of CoP movement in antero-posterior direction. However, pre–post training changes in balance parameters did not differ significantly between groups. In contrary, there were no significant changes in strength parameters in either group. The author concluded that neither training program was more effective for the improvement of strength and balance in tennis players.

Contrary to these studies, the study by Vlašič[20] evaluated the effect of 12 weeks of training on balance boards on parameters of balance and strength in athletes (mainly soccer players) after anterior cruciate ligament (ACL) injuries. While group 1 (G1) utilized balance boards, group 2 (G2) performed the same training on a stable surface. Results revealed a significant improvement in postural stability in G1 during the stance on an injured leg and on both legs, both with eyes open and closed. On the other hand, there were no significant changes in parameters of balance under the same conditions in G2. Mean power during exercise bouts on the isokinetic cycle ergometer increased significantly in both groups, however while in the case of G1 this was evident during all revolution rates (60, 80, 100, and 120 per minute), in G2 this occurred only during 100 and 120 rpm, which in both cases resulted in decreased laterality. It should be pointed out however, that assessment of muscle power during resistance exercises revealed greater strength deficits than the test on the isokinetic cycle ergometer. For instance, there was a 32% between-leg difference in power during one-legged squat performed with maximal effort in the concentric phase, with an additional load of 40 kg on a multi-press machine in an athlete after ACL reconstruction, whereas the difference in power during short-term bouts on the isokinetic cycle ergometer was less than 10%. Another example is the less than 10% difference in power during short-term bouts on the isokinetic cycle ergometer in two subjects after ACL reconstruction, in which the between-leg difference in height of the jump (h) and power in the concentric phase of take-off (P_{con}) during countermovement jump was 30.9% and 11.5% respectively in subject 1, and 21.3% and 4.1% respectively in subject 2. A similar result was identified during a drop jump from a height of 23 cm in subject 1 (Δh 41.8% and ΔP_{con} 28.0%) as well as for subject 2 (Δh 38.0% and ΔP_{con} 27.5%). The author concluded that training on balance boards is more efficient in terms of improvement of postural stability and muscle power, which was also corroborated by gains in these parameters, as compared to training on a stable surface.

More information on other forms of intervention (e.g. serial mechanical proprioceptive stimulation, task-oriented balance exercises, combined agility-balance exercises, etc.) is located in the book chapter entitled "*Sensorimotor exercises in sports training and rehabilitation*".[21]

3. Conclusion

The findings of the above-mentioned studies showed that the power output is compromised during resistance exercises performed on unstable support surfaces. However, this effect depends on the type of exercise (chest presses, squats), instability device used (Swiss ball, BOSU ball), weight lifted, subject's training background, number of repetitions and sets, rest intervals, and so forth. This fact has to be taken into account when instability resistance exercises are implemented into the training program, namely for sports that require production of maximal force in a short time. Indeed, there are rarely any significant changes in parameters of body balance and muscle strength and power after resistance training on unstable surfaces in elite athletes. On the other hand, such training is more effective for the improvement of postural stability and power outputs than traditional training on a stable surface in individuals after lower-limb injuries. Therefore, instability exercises should be included into the post-rehabilitation program in order to increase the athlete's return to competition.

Conflicts of interest

The author has no conflicts of interest to declare.

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