Review article

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MUSCLE STRENGTH IN UNSTABLE CONDITIONS

Marjan Marinković

The use of various exercises in unstable conditions aiming to improve balance and coordination has attracted much attention in the recent years. However, the impact of such exercises on strength has been poorly studied, partly because of the problematic reliability of the current methods of muscle strength assessment during such movements, limiting thus their practical use. Movement production in unstable conditions results in the reduction of maximum muscle strength since the total muscle force is diminished, co-contractions are increased, and muscle coordination is altered. The use of unstable platforms in resistance training should result in the development of higher levels of muscle activation via increased reliance on their stabilizing functions. Since this higher level of muscle activation is achieved with less resistance, such trainings could have a positive impact on muscle and joint rehabilitation after injuries, as well as in sport-specific trainings. However, the researches performed in the field of rehabilitation cannot be directly translated into the field od sports training due to different demands for muscle strength exercise in everyday activity (low loads, slow movements) and in sports activities (large loads, highly dynamic movements). *Acta Medica Medianae 2011;50(2):53-56.*

Key words: *muscle strength, unstable conditions, training, power*

Military Academy Belgrade

Contact: Marjan Marinković
Military Academy
Belgrade, Pavla Jurišića Šturma 33
e-mail: marinkovicvr@gmail.com

Introduction

Posture maintenance is a continual process of minimal adjustments above the existing base or support. With progressively smaller support/base, the adjustments have to be more precise in maintaining the balance of the body. Postural adjustment of the trunk or legs, in some situations can be initiated before the onset of voluntary movements of the trunk or upper extremities (1). It is believed that such postural adjustments are aimed to minimize balance disturbances induced by movements. With unstable base, the change of muscle potentials precedes the moment of force application, which is termed „muscle anticipation" (2). These facts can be explained by the fact that supporting structures have to be first stabilized before the motoric movement is effectively actuated. Moreover, the measurements of postural adjustments have shown that stabilizing muscles are activated approximately 30 ms before the muscular activation of a movement (3).

When a man moves, he is most commonly unaware of the complex neuromuscular processes controlling the posture of the body. In stable conditions, the demands for posture stabilization under the action of transient, movement-associated disturbances are reduced. On the other hand, in a very unstable situation, anticipatory postural adjustments, by themselves, can be viewed as the sources of disturbances, if the center of gravity is moved outside the desired area of support. This anticipatory increase of synergistic muscle activity is documented by way of inverted pendulum inducing arm instability (4).

The utilizitation of external forces in an attempt to maintain dynamic balance is a key factor of success in most sports and a necessity in everyday activities (e.g. carrying shopping bags, carrying of a baby etc.). This stabilization movement consists of the establishment of active muscle controls in minimizing the degree of freedom in one or a sequence of joints, resulting in the stabilization of excess movement of external objects. A training of motor skills, including balance training, increases the sensitivity of feedback mechanisms and reduces time to activation of selected muscles, improving the sensitivity of position sense and agonist and antagonist muscles (5). The muscles, as the terminal parts of the mechanism of sensorimotor system, especially contribute to balance maintenance.

The use of various exercises in unstable conditions aiming to improve balance and coordination has attracted much attention in the recent years. However, the impact of such exercises on strength has been poorly studied, partly because of the problematic reliability of the current methods of muscle strength assessment during such movements, limiting thus their practical use.

Stretch-shortening cycle of the skeletal muscles in stable conditions

The combination of eccentric and concentric muscle action makes up the natural state of muscle function, termed stretch-shortening cycle - SSC (6). This type of muscle function also involves the phase of preactivation. The SSC is characterized by an apparent function of increased production during the final phase (of concentric contraction) compared to isolated concentric contraction.

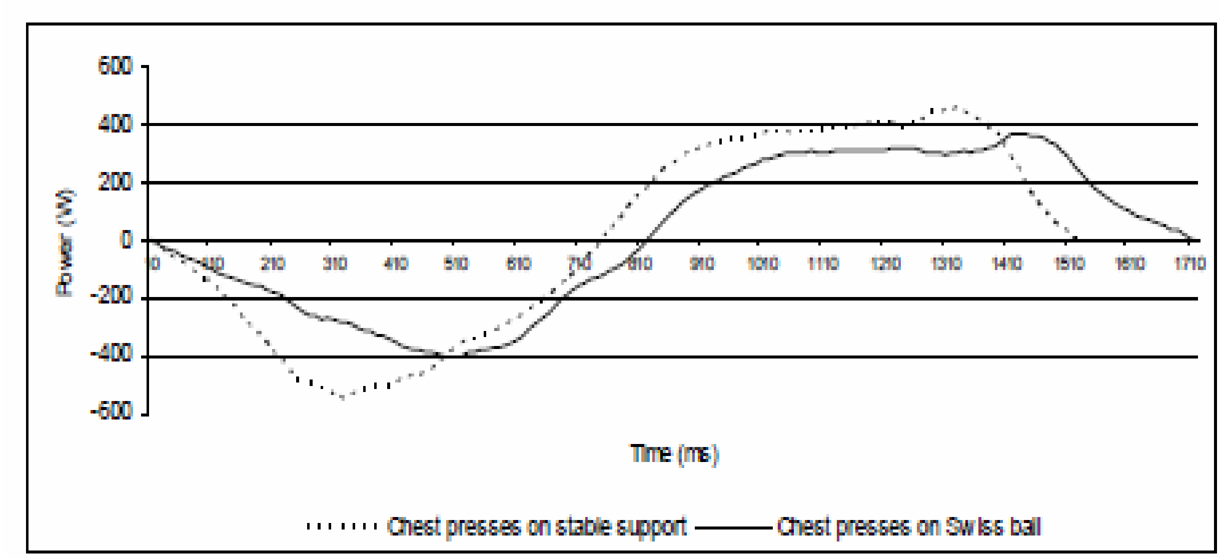
Significant efforts have been made to explain the mechanism of increased production of force during SSC. Eccentric muscle lengthening induces inner tension, similar to a rubber band. Elastic energy is produced in the tendons, other connective tissues, but also in myosin cross bridges. Although there is a possibility os storing elastic energy at the level of myosin cross bridges, due to a very short period of binding (around 30 ms) which is insufficient for the transition from eccentric to concentric contraction, most of the elastic energy is nevertheless made in the connective tissue (7). Thus created and stored energy is able to increase the force of the imminent concentric contraction. However, the contraction is to take place immediately after stretching or else the stored energy created by tension could be lost in the form of heat (8). The amount of tension created by muscle lengthening depends on the angle and velocity of muscle lengthening.

Effects of training in unstable conditions on muscle strength

Recently, load-bearing exercises performed in unstable conditions have become the part of training and rehabilitation programs. Accordingly, their impact on physical abilities and health attracted the attention of both trainers and researchers. Absence of stability may originate from the base or platform on which the exercise is taking place (e.g., ball or wobble plate) or from the position in which certain body segments are placed outside the base of support of the body (e.g., dumbbells). However, one must bear in mind that when a person tries to apply the force in unstable conditions, the maximum forces achieved in stable conditions are not possible because of the significant functions of muscle stabilization. That requires the adjustment of the number of maximum repetitions in order to compensate for unstable conditions. The studies performed so far have shown a significantly higher electromyographic activity of the trunk stabilizer muscles during load-bearing exercises in unstable compared to stable conditions (9,10). These findings indicate that unstable conditions in load-bearing training can facilitate naurologic adaptations of the trunk stabilizer muscles, producing overall improved stability of the body.

Movement production in unstable conditions results in the reduction of maximum muscle strength since the total muscle force is diminished, co-contractions are increased, and muscle coordination is altered (11). Although the exercise of maximum muscle strength is diminished in unstable conditions, balance changes during the training on unstable base can activate the muscles of the trunk and extremities, providing greater joint stability. The use of unstable platforms in resistance training should result in the development of higher levels of muscle activation via increased reliance on their stabilizing functions. Since this higher level of muscle activation is achieved with less resistance, such trainings could have a positive impact on muscle and joint rehabilitation after injuries, as well as in sport-specific trainings. Most sports involve the combination of stabilizing and force-producing functions, and resistance training in unstable conditions provides similar stimuli to the nerve and muscle systems, producing physiologic adaptations through adequate repetition. Resistance training in unstable conditions can reduce the probability of injury to the lower extremities due to increased sensibility of muscle spindles and better postural control.

The first targeted studies have shown that Swiss ball provides a wide range of movements in unstable conditions, with optimal starting position of several degrees of active extension of the trunk (12). Swiss ball (also known as fitness ball, exercise ball, pilates ball, therapeutic ball, yoga ball, etc.) is an elastic inflatable ball made of soft polyvinyl chloride (PVC). Air inflation is performed with a specially designed air pump through the inflation valve, to be then closed with a safety cap. The importance of Swiss ball in rehabilitation has been documented in the re-education of postural muscles, as well as in the facilitation of movements and postural reactions in patients with neurologic damage (13). The most common exercises with Swiss ball are characterized by isometric muscle activity, light loads, and longer periods of muscle contraction, leading to the development of central endurance (14,15). A study with subjects performing various typical exercises for trunk strengthening in stable and unstable conditions (Swiss ball) has shown that the activation of lumbosacral and upper lumbar spine erector, as well as deep abdominal stabilizers, was significantly greater in unstable conditions (16). A significantly greater instability of the base or platform compared to usual stable conditions, causes in addition the activation of other mechanisms of neurologic and neuro-muscular adaptation, resulting in increased muscle strength (17).



***Graph 1**. Power during single barbell chest press performed on stable and unstable surface (Retrieved from: Zemkova, 2010)*

Stretch-shortening cycle in unstable conditions

Although the results of several completed studies support the introduction of exercise programs in unstable conditions into rehabilitation programs, the reports to describe their use in sports training are scarce. However, the researches performed in the field of rehabilitation cannot be directly translated into the field od sports training due to different demands for muscle strength exercise in everyday activity (low loads, slow movements) and in sports activities (large loads, highly dynamic movements).

Significantly lower values of maximum strength have been measured with resistance exercises performed in unstable compared to stable conditions (18). The analysis of muscle contraction for one bench press shows a different character of the curves in stable compared to unstable conditions. Maximum values of strength during the exercises on a stable surface were not only higher, but they were achieved earlier compared to bench press in unstable conditions (Graph 1).

Lower values of maximum strength during the concentric phase of resistance exercises, with the movement in opposite direction, can be ascribed to a delayed ammortization phase of SSC. In the moment when maximum values of force are achieved in the transition of eccentric into concentric phase of muscle contraction, the subjects have to keep their balance on an unstable surface in order to accelerate the movement of external load (barbells) upwards, i.e. against the gravity. Therefore, this SSC phase can last longer compared to the exercise performed in stable conditions. The consequences of reduced value of force and lower velocity of performance are reduced values of maximum strength in the following concentric phase (19,20). More precisely, the strength in the acceleration phase of bench press is most compromised. It can be supposed that Swiss ball causes a higher degree of instability and makes the task more difficult. The above can be documented through a significantly higher EMG activity of trunk stabilizers in unstable compared to stable conditions during barbell bench press (21). It is the consequence of additional stresses to the muscles acting as trunk stabilizers during bench press on a Swiss ball placed in the region of upper chest and with feet on the ground (22).

Conclusion

The contribution of resistance training in unstable conditions can be more evident in individuals aiming to maintain their health or in convalescents, i.e. those who are not involved in strenuous sports training programs and competions. All the above observations indicate that numerous unresolved issues in the field demand an explanation. It is necessary to devise a study in which the parameters of muscle contraction during different types of training in unstable conditions would be investigated, as well as the long-lasting physiologic adaptations as the consequence of such training programs. The knowledge thus acquired can serve as the basis in the formulation of methods of testing and training to be utilized both in sports and in rehabilitation.

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ISPOLJAVANJE MIŠIĆNE SNAGE PRI NESTABILNIM USLOVIMA

Marjan Marinković

Upotreba različitih vežbi pri nestabilnim uslovima u cilju poboljšanja ravnoteže i koordinacije privlači pažnju poslednjih nekoliko godina. Njihov uticaj na poboljšanje snage je u velikoj meri neproučen, što ograničava njihovu praktičnu primenu. Izvođenje pokreta pri nestabilnim uslovima rezultuje smanjenjem maksimalne mišićne snage zbog smanjenja ukupne sile mišića, povećanja ko-kontrakcija i izmene mišićne koordinacije. Korišćenje nestabilnih platformi u treningu snage trebalo bi da omogući razvoj viših nivoa aktivacije mišića, preko povećanog oslanjanja na njihove stabilizirajuće funkcije. Kako se ovaj viši nivo aktivacije mišića postiže sa manjim otporom, ovakva vrsta treninga može imati pozitivne učinke u rehabilitaciji mišića i zglobova nakon povreda, kao i u treningu specifičnom za određene sportove. Međutim, istraživanja sprovedena u periodu rehabilitacije ne mogu se primeniti na oblast sportskog treninga, zbog različitih zahteva za ispoljavanje mišićne snage tokom svakodnevnih aktivnosti (mala opterećenja, spori pokreti) i sportskih aktivnosti (veliko opterećenje, dinamički pokreti). *Acta Medica Medianae 2011;50(2):53-56.*

***Ključne reči**: mišićna snaga, nestabilni uslovi, trening, mišićna sila.*