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Title: The Use and Efficacy of Unstable Surface Training: A Comprehensive Review

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Abstract. Unstable Surface Training (UST) has gained prominence in rehabilitation for its unique approach to enhancing proprioception, balance, and neuromuscular control. This review aims to synthesize the current understanding and applications of UST in the sport training, educational and rehabilitation context. Reviews the historical development of UST, its biomechanical principles, and its integration into modern rehabilitation practices. A comprehensive analysis of clinical studies and trials examining the efficacy of UST across various populations forms the core of this review. Studies demonstrate UST's role in enhancing rehabilitation outcomes, with particular emphasis on musculoskeletal rehabilitation and core stability making UST a valuable addition to rehabilitation programs, offering improved outcomes in terms of proprioception, muscle strength, and joint stability. However, its application must be tailored to individual needs, with careful consideration of safety and progression protocols.

Використання та ефективність вправ на нестійкій поверхні: всебічний огляд

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Резюме. Вправи на нестійкій поверхні (ВНП) набули популярності в реабілітації завдяки своєму унікальному підходу до покращення пропріоцепції, балансу та нервово-м'язового контролю. Мета цього огляду – узагальнити сучасне розуміння та застосування ВНП у тренуванні спортсменів, а також в контексті освіти та реабілітації. Розглянуто історичний розвиток ВНП, їхні біомеханічні принципи та інтеграцію в сучасні практики реабілітації. Основою цього огляду є всебічний аналіз клінічних досліджень і випробувань, присвячених вивченню ефективності використання ВНП різними групами населення. Дослідження свідчать про важливу роль ВНП у покращенні наслідків процесу реабілітації, зокрема реабілітації функції опорно-рухового апарату та стабільності постуральних м'язів тулуба, завдяки чому ВНП є цінним доповненням до реабілітаційних програм, яке дозволяє покращити її результати в плані пропріоцепції, м'язової сили та стабільності суглобів. Водночас її застосування має бути адаптоване до індивідуальних потреб з ретельним урахуванням принципів безпеки та прогресування.

History of Exercising on Unstable Surfaces.

Different forms of exercising on unstable surfaces are as old as exercise itself. Exercising on sand or snow can be considered as training on surfaces

that produce a certain degree of instability with each movement. The shifting of the ground under the influence of the exerciser's body weight leads to each movement being different, and thus, exer-

cise and activity on sand or snow can be regarded as exercising on unstable surfaces. The first organized systems of exercise in Europe, such as the German and Swedish systems that emerged in the early eighteenth century, extensively used exercises on ropes which, in some classifications, could be considered unstable. Performing supports, climbs, or any movement where the rope is attached and hangs freely produces a certain degree of instability and thus requires the engagement of additional musculature that is not considered agonistic for the given movement (1).

Such exercises targeted the entire musculature, with a special emphasis on the flexors and extensors of the spinal column. Over time, with the mass production of machines and equipment for exercising, a greater number of exercises included isolated movements, which eventually led to a lack of adequate activation of the trunk stabilizers (core muscles). This led to a renewed focus on exercises for the development of trunk stabilizer musculature. There is much disagreement in professional and scientific circles about precisely defining this term. This definition is broad and depends greatly on the author and interpretation of the literature (2). The mentioned authors define superficial and deep trunk stabilizers or as the lumbopelvic muscle complex, consisting of the lumbar part of the spinal column, pelvis, and hip joints, as well as the active and passive tissues that limit the movements of these segments. This represents one of the most common and widely accepted definitions. Also mentioned is the region from the pelvic girdle to the shoulder girdle with all associated tissues (joints, ligaments, tendons, muscles, and fasciae) with proximal muscle attachments in the described segment.

The first documented organized forms of exercise with equipment or props that cause instability during exercise are associated with physioballs, also known as Pilates balls or Swiss balls. Therapists used these balls even before World War II for exercise in rehabilitation. Sherrington (3) recorded an interest in this form of exercise among therapists as a supplement to then-conventional therapeutic exercises. These balls, which then had a different name — Pezzi balls — were used in therapeutic programs for newborns and children by Mary Quinton, a British physiotherapist working in Swiss clinics. It was the director of one of the Swiss clinics, Dr. Susanne Klein-Vogelbach, who included exercises with these balls. She developed the concept of “functional kinetics,” which advocated the use of balls for therapeutic applications in adults with orthopedic and medical problems.

The term “Swiss ball” later came into use, credited to therapists who came to Switzerland from America for training. In the professional literature, primarily published in North America, therapists later called these balls Swiss balls, and the name has remained to this day (3). The Swiss ball is actually an invention of the Italian toy trader Aquilino Cosani, who conceived, made, and patented these balls in the 1960s. Initially intended for children’s play and jumping, they are still used for these purposes today as jumping balls, kangaroo balls, and the like. However, they were first used for therapeutic purposes in Switzerland, hence the name Swiss balls. In recent decades, this ball has been the subject of numerous research studies in the fields of training, recreation, and rehabilitation.

This large inflatable ball, of various diameters, became a tool in therapy and organized exercise programs from being a toy. It allows for effective use of the advantages of multifunctional exercises targeting multiple different muscle groups. More recently, in 1999, David Weck devised a new fitness prop called the BOSU half-ball, which has become extremely popular and widely used in the preceding period. BOSU, or “Both Sides Up” in translation, can be positioned on both sides and used for exercising in unstable conditions. Numerous studies have focused on this sports prop (4).

Application and Controversies of Unstable Surface Exercises in sport training. The integration of unstable surface exercises across various domains such as recreation, sports training, rehabilitation, and educational activities has garnered significant interest debate within the scientific community. The utilization of diverse equipment, ranging from inflatable balls to BOSU balls and elastic boards, has been well established in modern sports and fitness centers (5). These tools offer a spectrum of benefits, notably in strengthening muscles responsible for spinal stabilization and in mitigating pain associated with spinal movements (6).

Despite their widespread application, exercises on unstable surfaces have ignited controversies, particularly regarding their suitability for athletes needing rapid and explosive muscle actions. Critics argue that such exercises are not conducive to the development of explosive strength and speed, which are essential in many sports disciplines (7). They assert that these exercises fail to replicate the specific conditions of activities like running or sprinting, where a firm and stable surface is indispensable for maximizing movement speed, power and efficiency (8). This was also confirmed with a study (9) where a stable condition resis-

tance exercises in a 90° tilted environment improve high-velocity muscle power more effectively than when combined with balance exercises, suggesting a specific application of UST in astronaut and for the functional rehabilitation of bed-ridden patients. However, for athletes requiring explosive power movements, this approach may not optimize performance enhancement.

However, the significant engagement of trunk-stabilizing muscles offered by these exercises cannot be overlooked (10). This aspect is crucial for daily motor tasks and is key in the prevention and rehabilitation of lumbar spine issues (11). This highlights the importance of these exercises, particularly in populations where heavy load training might be contraindicated or risky.

While discussions on the use of exercises on unstable surfaces in elite sports continue, their significance in activating muscles, aiding rehabilitation, and educational purposes is becoming more recognized. This highlights the importance of a well-rounded approach that tailors to the unique goals and needs of each individual.

Training with Load on Unstable and Stable Surfaces in Youth. The effectiveness of resistance training for young people and children has been widely recognized and supported by recent scientific findings. Resistance training for young individuals does not adversely affect the immature skeleton and, in fact, offers numerous health, performance, and psychological benefits. Also, it has been shown to enhance musculoskeletal health, improve body composition, and reduce cardiovascular risk factors, debunking previous concerns about potential harm to youth growing bodies (12). Research in the pediatric population has shown that appropriately prescribed and supervised weight training can have numerous benefits on health status. With an increasing number of children and young people involved in organized sports training and competition, young athletes, their parents, and coaches are seeking the best ways to achieve optimal sports results. Since muscle strength and power are key to success in many sports, it's clear that stronger and more powerful young athletes will be more successful and, more importantly, develop a quality foundation for future development. A meta-analysis (13) showed that weight training is an effective method for improving selected motor skills (e.g., jumping, running, and throwing) during childhood and adolescence. Weight training in young athletes can include a wide range of modalities including weightlifting machines (for both adults and children), free weights, hydraulic and pneumatic machines, medicine balls, elastic bands,

isometric contractions, and bodyweight exercises. In recent years, unstable surfaces have often been used in training as it is believed that an unstable environment creates an increased level of muscle activation, especially in antagonist or synergist muscles (14). Moderate instability is suggested to provide optimal results and allow adequate overload of many muscles (14), in line with recommendations for training in children and adolescents (low to moderate) (12). An additional advantage of training on unstable surfaces could be increasing the muscles' ability to stabilize joints, leading to protection of joint complexes (3).

A systematic literature review and meta-analysis (8) did not show significant advantages of training on unstable surfaces in children, adolescents, and younger individuals, suggesting that using exercises on unstable surfaces compared to stable surfaces during strength training will not improve performance on stable surfaces. The limited number of studies in adolescents (15-17) and the lack of research with children make it difficult to determine the effects of training on unstable surfaces in the child and adolescent population. Although scientific literature has shown that regular judo practice increases muscle strength in children and adolescents, the obtained results indicate that additional weight training could be included in training programs to improve maximal strength and other performance parameters of motor tasks. Namely, weight training on unstable surfaces can be recommended as an effective model for improving the strength of abdominal muscles. However, coaches should find an optimal combination of weight training exercises on an unstable surface for young judokas as they quickly adopt strategies for maintaining an unstable position in changed conditions. Recent studies contribute to this area of research.

The inclusion of weight training on unstable surfaces can be recommended as an effective model for improving abdominal muscle strength in young athletes, like judokas (18). However, finding an optimal combination of weight training exercises on unstable surfaces is crucial, as young athletes quickly adapt to maintaining stability in changed conditions.

The application of unstable surface exercises in educational settings offers a diverse range of stimuli for neuromuscular adaptations. This is beneficial for children, breaking the monotony of traditional exercises and elevating their motivation levels (19). While definitive evidence on their effectiveness in enhancing sports performance in young athletes is lacking, the prevailing view sup-

ports their potential long-term benefits on young bodies subjected to constant physical stress. For instance, the (20) explored the impact of a 12-week unstable surface program in a school setting on 14-year-old adolescents. This study compared UST with a traditional physical education program, focusing on upper-body strength, trunk strength, and skinfold thickness. It revealed the potential of UST in enhancing physical abilities and addressing obesity risk factors in adolescents.

The Role of UST in Modern Rehabilitation Applications. Several authors (21) and research studies (3, 22, 23) have shown that an unstable exercise program gives a greater effect on the strength of the muscles stabilizing the pelvic girdle and spinal column. With this in mind, UST has found a significant place in rehabilitation programs, particularly for patients recovering from musculoskeletal injuries and surgeries. The dynamic nature of unstable surfaces forces the body to engage multiple muscle groups simultaneously, enhancing proprioceptive feedback and neuromuscular control. This is particularly beneficial in post-operative rehabilitation where re-establishing joint stability and muscle coordination is paramount.

For instance, the use of Swiss balls in lower back rehabilitation exercises has shown to improve core strength and alleviate chronic back pain. This is important since a Low Back Pain (LBP) is a prevalent condition impacting a significant portion of the population, leading to considerable discomfort, disability, and healthcare costs globally. The World Health Organization (WHO) has identified LBP as a major cause of disability, affecting individuals' quality of life and work productivity (24).

Recent studies have highlighted the importance of incorporating UST in rehabilitation routines. One important application of Unstable Surface Training (UST) is its use in enhancing knee joint stability in

athletes following anterior cruciate ligament (ACL) reconstruction. The study by Fort-Vanmeerhaeghe, Arboix-Aliy, and Montalvo (25) underscores UST's significant role in improving recovery outcomes. Additionally, UST is valuable in prevention, particularly because most ACL injuries occur during the deceleration phase of jumping or direction changes. Eccentric overload training becomes crucial, with the control of dynamic knee valgus during deceleration relying on the athlete's capacity for eccentric force generation in the extensors and activation of stabilizing muscles, such as hip abductors.

Another significant area of UST application lies in geriatric rehabilitation. With aging populations, emphasizing exercises that enhance balance and reduce fall risk is essential. UST exercises, due to their inherent instability, challenge balance and stimulate the proprioceptive systems, crucial for maintaining mobility and independence in older adults. Research by Pirauć et al. (26) underscores UST's efficacy, demonstrating notable improvements in dynamic balance and functional mobility over a 24-week period. This study highlights UST's ability to not only improve physical attributes such as balance and mobility but also to reduce the fear of falling among seniors, thereby fostering a greater sense of independence and confidence in daily activities. Moreover, UST significantly enhances cognitive functions like working memory and processing speed in older adults, showcasing its comprehensive benefits for aging populations (27).

UST's benefits extend beyond musculoskeletal rehabilitation to neurological rehabilitation. For patients recovering from strokes or other neurological disorders, UST has demonstrated promising results in retraining balance and gait. The dynamic nature of unstable surfaces necessitates continuous sensory and motor adjustments, beneficial for re-establishing neural pathways and improving motor function (8).

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