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The impact of strength training on the prevention of orthopedic injuries in sports: a literature review

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Abstract:

Introduction: The perception of physical activity has evolved, influenced by urbanization, media, and public health initiatives. While regular physical activity offers health benefits, musculoskeletal injuries in athletes remain a concern, often going unnoticed due to subtle symptoms. Preventing these injuries is crucial, with strength training (ST) emerging as a strategy to enhance stability and reduce injury risk.

Purpose of the Study: This review examines the impact of strength training on preventing orthopedic injuries in athletes, focusing on mechanisms like muscle strengthening, joint stabilization, improved endurance, and correcting imbalances. It evaluates research on ST's effectiveness in preventing knee, ankle, hip, back, and upper limb injuries.

Methodology: A comprehensive search of databases, including PubMed, Scopus, and Google Scholar, was conducted using keywords such as "strength training," "orthopedic injury prevention," "musculoskeletal stability," "injury risk reduction," and "sports injuries."

Results: Strength training plays a key role in preventing sports injuries by enhancing muscle strength, joint stability, and endurance, addressing musculoskeletal weaknesses and imbalances. Studies show ST significantly reduces knee, ankle, hip, and back injuries. For instance, knee injuries are prevented by strengthening the hip abductors and quadriceps, while ankle injuries are mitigated by improving core and lower limb strength. ST also prevents injuries in "overhead sports" by enhancing shoulder stability.

Keywords: strength training, orthopedic injury prevention, musculoskeletal stability, sports injuries, injury risk reduction.

Introduction:

The perception of physical activity has undergone significant changes in recent years, influenced by various factors including urbanization, media portrayals, and public health initiatives [1]. Regular physical activity offers numerous health benefits, such as improved cardiovascular function, reduced body mass index (BMI), and lower blood pressure [2,3].

However, engaging in sports carries inherent risks, most notably the potential for musculoskeletal injuries. Sports injuries are often overlooked due to factors such as the subtle nature of certain injuries, the context in which evaluations occur, and the limitations of current diagnostic and reporting systems. For instance, many fractures in athletes are missed not because they are difficult to identify on imaging tests, but because they occur less frequently and often without significant symptoms, making diagnosis challenging, particularly in high-pressure environments like during a game [4-7].

1.1. The Importance of Preventing Orthopedic Injuries in Sports

The prevention of orthopedic injuries in sports is crucial due to its significant health, performance, and economic benefits [8]. Effective prevention strategies, including pre-participation screening, neuromuscular training, and equipment modifications, have been shown to significantly reduce injury rates, thereby promoting safer and prolonged participation in sports [9,10].

Despite the proven effectiveness of these strategies, their real-world implementation remains suboptimal, particularly among youth athletes. This gap in practice contributes to high injury rates and subsequent withdrawal from sports, which may lead to a more sedentary lifestyle and an increased burden on public health [11].

Resistance training (RT) has also been identified as a potential method for reducing the incidence of sports injuries. Studies suggest that regular participation in well-structured resistance training programs can increase muscle strength, power, and bone mineral density, all of which are critical for reducing the risk of sports-related injuries [12,13].

1.2. Definition and Importance of Resistance Training

Resistance training is a specialized physical conditioning method involving the progressive use of resistive loads, varying muscle activation rates, and different movement speeds to enhance muscular strength, power, and endurance [14].

Its role in injury prevention is significant, as it strengthens muscles, tendons, and ligaments, thereby increasing joint stability and reducing the risk of injury [15,16]. Additionally, resistance training can mitigate the occurrence of overuse injuries by promoting balanced muscle development and improving neuromuscular coordination [17].

1.3. Purpose of the Literature Review

The purpose of this review is to evaluate the existing literature on the impact of resistance training on the incidence of musculoskeletal injuries in athletes and to determine whether it can serve as an effective preventive measure against such injuries.

2. Mechanisms of the Impact of Strength Training on Injury Prevention

Strength training plays a critical role in injury prevention through various mechanisms, which will be discussed in the following sections.

2.1. Muscle Strengthening and Joint Stabilization

Buehler (2021) observed that increased training loads lead to significant improvements in muscle strength, which directly contributes to enhanced joint stability. For instance, in the case of the hip joint, stronger muscles help distribute forces more evenly, reducing the translation of the femoral head, and thus decreasing joint contact forces. This, in turn, leads to greater joint stability [18]. In sports like swimming, strength training is crucial for preventing degenerative changes in both the active and passive musculoskeletal systems and improving various strength parameters, including maximum strength and rate of force development. Enhanced joint stability, particularly in the knee, hip, and shoulder joints, reduces joint irritation and the likelihood of injury [19].

2.2. Improving Muscle Endurance and Reducing Fatigue

Strength training not only enhances muscle strength but also improves muscle endurance, which is particularly beneficial in sports such as swimming, where increased propulsion during starts, turns, and general swimming motion is crucial. By increasing overall propulsive force, athletes can improve their performance [19]. Additionally, strength training enhances physical capacity and endurance, which not only improves sports performance but also delays the onset of age-related diseases, contributing to a higher quality of life [20,21]. Vorup's research highlighted that incorporating strength training into a training regimen improves long-term performance and running economy by positively affecting ion transport proteins in muscles [22].

2.3. Correction of Muscle Imbalances

Resistance training is highly effective in correcting muscle imbalances, which are often the root cause of musculoskeletal problems. Regular strength training can improve muscle strength, balance, and flexibility, which are essential for addressing muscle imbalances. By ensuring a symmetrical distribution of load across different muscle groups, strength training helps reduce these imbalances [21]. A balanced agonist-to-antagonist ratio, such as between knee flexors and extensors, is crucial in reducing the incidence of musculoskeletal issues caused by muscle imbalances [23].

2.4. Strengthening Tendon and Ligament Structures

Strength training contributes significantly to the stabilization of joints, including the knee, hip, and shoulder joints, by improving the mechanical properties of tendons and ligaments. McMahon et al. observed that strength training leads to an increase in growth factors that positively affect tendon structure and adaptation, such as TGFβ-1 and local type I collagen synthesis [19,24]. Strengthening tendons is particularly important in sports that involve rapid, high-impact movements, as it reduces the risk of tendon injuries, which are common among athletes like sprinters [25]. Increased tendon stiffness resulting from strength training further decreases the likelihood of injury [24,26].

2.5. Increasing Range of Motion and Flexibility

A study by Syed-Abdul (2021) demonstrated that regular strength training significantly improves both flexibility and balance, which are critical for performance in various motor skills, such as jumping, running, and throwing [27]. Properly prescribed and supervised strength training not only enhances sports performance in children and youth but also supports the development of motor skills [28].

2.6. Strengthening the Musculoskeletal System

Athletes engaged in strength-based and weight-bearing sports typically exhibit higher bone mineral density, which significantly enhances bone structure and strength, making bones more resilient to mechanical injuries [19]. The mechanical strength of bones is increased through deposition and mineralization by osteoblasts, processes that are most active during growth years. Evidence suggests that peak bone density is reached shortly after the cessation of linear growth [28]. Regular physical activity, particularly during adolescence, serves as a potent stimulus for bone mineralization and growth, as evidenced by studies on young soccer players who show greater height and bone density compared to their non-athletic peers [23].

3. Review of Empirical Studies

3.1. Studies on the Impact of Strength Training on Knee Injuries

Knee injuries, particularly anterior cruciate ligament (ACL) tears, are among the most common sports injuries, especially in sports that involve rotation and contact, such as football, basketball, and rugby. Majewski et al. documented that 39.8% of sports injuries involved the knee joint, with ACL lesions being the most prevalent [29]. The complications of such injuries can lead to limited mobility, long-term rehabilitation, and an increased risk of developing degenerative diseases at a younger age [30].

A 2021 study by Jeong et al. examined how 10 weeks of core training affected motor control and joint kinematics in the trunk and lower extremities.

The study showed that such training can alter the biomechanics associated with ACL injuries, suggesting its potential use in preventive programs to reduce the risk of ACL injuries [31].
A 2020 study by Moffit et al. explored the effects of knee and hip extensor strength on knee biochemistry in distance runners. The results indicated that increased strength in the barbell squat positively influenced knee kinematics, increasing peak knee flexion angle while maintaining a lower peak angle and knee internal rotation moment. This may significantly reduce knee joint stiffness, thereby lowering the risk of injury. The authors suggest that exercises increasing maximum barbell squat load should be included in resistance training regimens for distance runners [32].
In the context of ACL injuries, exercise therapy has been consistently shown to be effective in functional recovery after reconstruction, facilitating the return to daily and sporting activities [33]. Additionally, pelvic and core strength training (PCST) programs have demonstrated a reduction in biomechanical risk factors for ACL injuries and improved vertical jump performance in athletes, indicating dual benefits of injury prevention and performance enhancement [34].

3.2. Studies on the Impact of Strength Training on Ankle Injuries

Ankle injuries are among the most common sports injuries, particularly in activities such as climbing, volleyball, and track and field. The most frequent injury to the ankle is a sprain [35]. Research indicates that strength training can improve ankle muscle strength, enhance basic athletic ability, and reduce the likelihood of joint injuries, thereby contributing to better athletic performance [36]. In soccer, specifically, strength training has shown potential in reducing injury risk and improving athletic performance, although some studies have not found statistically significant differences in injury rates between training and control groups, highlighting a high risk of bias and low quality of evidence [37]. Core muscle strength, which stabilizes the lower limbs and ankle joints, is also crucial in reducing ankle injury risk, as demonstrated by the correlation between core muscle strength and a decreased injury risk in young football players [38].
Strength and resistance exercises are also effective in the rehabilitation of patients with chronic ankle instability (CAI). A study by Jeon et al. (2015) involving 22 men with CAI, who participated in an 8-week strength training program, showed significant improvements in muscle strength, reduced swelling, and pain, as well as enhanced function and daily activity performance. The researchers suggest that strength and resistance training programs offer additional benefits, including preventing further injuries to the ankle area [39].

3.3. Studies on the Impact of Strength Training on Hip Injuries

Strength training has a significant impact on preventing hip injuries across various sports. Research indicates that strength training, particularly targeting the hip abductors and quadriceps, is effective in reducing running-related injuries among runners, including first-time marathoners [40]. A 6-week study by Snyder et al. showed that strengthening the hip abductors and external rotators led to changes in load distribution on the lower limb joints, potentially reducing the risk of injury [41].

In professional and semi-professional women's football, strength training has demonstrated beneficial effects in reducing injuries, including those affecting the hip region, by addressing musculoskeletal limitations and enhancing motor function [42]. A systematic review of randomized controlled trials (RCTs) supports that increasing the volume and intensity of strength training can reduce the risk of both acute and overuse injuries, including those involving the hip, by more than four percentage points for every 10% increase in training volume [43]. Specific strength training programs focusing on the gluteal muscles, such as the Strength Training Injury-Prevention Program (STIPP) for handball players, have shown a meaningful reduction in lumbar injuries, which are often related to hip muscle weakness, thereby indirectly preventing hip injuries [44]. Additionally, targeted exercises like loaded split squats, single-leg Romanian deadlifts (RDL), and single-leg hip thrusts have been identified as highly effective in maximizing gluteal muscle forces, which are crucial for hip stability and injury prevention [45]. The positive impact of regular strength training on reducing exercise injuries has also been observed in martial arts and aerobic gymnastics, where structured strength training protocols significantly improved athletes' physical capabilities and reduced injury rates [15,46]. Overall, the evidence consistently supports that well-designed strength training programs are essential for preventing hip injuries by enhancing muscle strength, stability, and overall athletic performance.

3.4. Studies on the Impact of Strength Training on Back Injuries

Research indicates that strength training, particularly when focused on core and lumbar muscles, can significantly reduce the incidence of back injuries. A systematic review found that strength training decreased the number of injuries and absence days per 1000 hours of exposure among soccer players, although the lack of standardized protocols limits the reliability of these findings [47]. In aerobic gymnastics, a dedicated strength training program significantly improved various physical performance metrics, suggesting its effectiveness in injury prevention [46]. Similarly, regular strength training in Kung Fu athletes led to significant improvements in physical quality and a reduction in exercise-induced injuries [15]. A meta-analysis of randomized controlled trials also supports the conclusion that increased strength training volume and intensity are associated with a reduced risk of both acute and overuse injuries, including those affecting the back [43].

3.5. Other Relevant Studies

A separate group of injuries involves the upper limb girdle, particularly the shoulder. These injuries are most common among athletes engaged in "overhead sports," such as volleyball, swimming, and handball [48].

A 2020 study by Batalha et al. examined the effectiveness of a training program aimed at preventing shoulder rotator cuff injuries in swimmers. The program included exercises targeting the activation of the rotator cuff muscles. The results did not show clear benefits of such training on shoulder endurance or balance. However, the study suggests that the program is a safe tool for strengthening the rotator cuff muscles, though further research is needed to confirm its effectiveness in preventing shoulder injuries [49].

A 2022 study by Shitara et al. compared shoulder stretching with shoulder strength training in preventing baseball-related shoulder injuries.

The researchers concluded that strength training is an effective tool for preventing baseball injuries, primarily by improving the external rotation strength of the shoulders, which reduces the risk of shoulder injuries. This finding suggests that incorporating strength training into baseball preparation programs could be beneficial [50].

4. Practical application of strength training in injury prevention

Resistance training, especially in the training programs of elite soccer players, is crucial. Given the significant training loads these athletes endure, they must be properly prepared to handle such demands. Resistance training strengthens muscles, making them more resilient to forces that could lead to injury. Improved motor control and coordination also enhance balance and joint stability.

A study by Zouita et al. observed that structural adaptations from resistance training can reduce injury risk, particularly in adolescent soccer players. These benefits include increased bone density and tensile strength, which are especially advantageous in contact sports like soccer. Additionally, resistance training strengthens supporting connective tissues and enhances passive joint stability. An analysis of injuries occurring during training indicated that many were linked to improper exercise techniques and inappropriate loading [23].

The proportion of strength training relative to total training volume must be adjusted to match the athlete's performance level and the demands of the competition [19]. Depending on the sport, the specific movements that need improvement, and the muscles and joints requiring strengthening and stabilization, appropriate training exercises should be selected. While isolated exercises can target individual muscle groups, multi-muscle group exercises may offer a more effective approach for developing overall strength and power.

It is also essential to consider the limitations some athletes may have in strength training, such as restrictions in knee and hip movement due to mechanical issues. These factors should be accounted for when designing a training plan [28]. Therefore, customizing resistance training programs to meet the specific needs and capabilities of each athlete is vital for optimizing performance and minimizing injury risk.

5. Conclusions

Strength training plays a key role in preventing orthopedic injuries in athletes, contributing to improved muscle strength, joint stability, and overall endurance. Regular participation in training programs leads to strengthening of muscles and supporting tissues, which in turn reduces the risk of injury. Improving muscle strength and neuromotor coordination affects better control of movements, which is important in injury prevention.

The mechanisms of action of strength training are multi-faceted. It strengthens muscles, tendons, and ligaments, which increases joint stability and reduces the risk of injury. Increased muscle strength improves biomechanical control, which is crucial in reducing the risk of injuries caused by overload and incorrect movements. Improving joint stability, especially in the hips, knees, and back, contributes to reducing the risk of injuries and overloads.

Studies indicate that strength training is particularly effective in reducing the risk of knee, ankle, hip, and back injuries.

For example, strengthening the adductors and hip extensors is beneficial in preventing knee injuries, while improving core strength helps stabilize the spine and prevent back injuries. Such training also reduces the risk of ankle injuries by improving lower extremity and core strength. Implementing appropriately designed strength training programs into a sports training routine can significantly impact injury prevention. These programs should be tailored to the specific needs of the athlete and the type of sport they play. Training should be individually tailored, taking into account differences in body mechanics and the specific requirements of the sport. These programs should include both isolated and multi-muscle group exercises to effectively develop muscle strength and power.

Despite the numerous benefits of strength training, the effectiveness of these programs can be limited by improper exercise techniques and incorrect load adjustments. Injuries are often caused by incorrect exercise execution or excessive loads. Therefore, it is important for coaches and specialists to carefully monitor exercise technique and adjust loads in a way that allows for safe and effective strength development.

Future research should focus on optimizing training programs to better meet the individual needs of athletes. The effectiveness of different types of strength training and their effects on different types of injuries should be studied according to the age, gender, and level of the athlete. There is also a need for research on the long-term effects of strength training on the health and performance of athletes, including the impact of training on reducing injuries in the context of different sports.

Coaches and rehabilitation specialists should include strength training as an integral part of preventive programs. It is imperative that training programs are regularly evaluated and adapted to the changing needs of athletes. It is worth investing in training coaches in safe and effective strength training techniques to maximize health and sport benefits and minimize the risk of injury.

Disclosure

Authors' contribution:

Conceptualization: Julia Szewczyk, Michał Świta
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