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Research Article

Review of the Role of Resistance Training and Musculoskeletal Injury Prevention and Rehabilitation

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Abstract

Many individuals perform Resistance Training (RT) as a part of their routine conditioning programs to increase muscular strength and/or hypertrophy. However, RT is often overlooked in its role in musculoskeletal injury prevention and rehabilitation. This is problematic in that RT results in many adaptations, such as an increased bone mass, lean mass and tensile strength that could aid in the prevention and rehabilitation of musculoskeletal injuries. The aim of this review is to demonstrate that RT should be considered an integral component, in any exercise program designed to prevent and rehabilitate musculoskeletal injuries. To date, most of the limited original studies, reviews and meta-analysis on RT and musculoskeletal injuries have focused on one particular intervention, injury type/location, sport or studied other relatively narrowly defined research questions, effectively not allowing for a full quantification of intervention effect estimates. This review demonstrated a dearth of literature regarding the role of RT in musculoskeletal injury prevention and rehabilitation. It also focuses on the preventive effect of several different forms of RT revealing novel and interesting information, enabling proposals for future directions in the field of musculoskeletal injury prevention and rehabilitation using RT. Findings of this review specifically indicate that while high-intensity strength-type resistance training plays an essential role in the prevention and rehabilitation of musculoskeletal injuries, more user-friendly forms of RT, such as hypertrophy RT and muscular endurance RT need to be examined. While this review advocates the role of RT in the prevention and rehabilitation of musculoskeletal injuries both for its safety and efficacy, further examination and quantification of specific RT exposures and a differentiation of acute and overuse outcome effect estimates is still lacking.

Keywords

Rehabilitation; Resistance training, Sports Injuries; Strength training; Weight training

Introduction

Resistance Training's (RT) beneficial relationship to health factors and chronic disease has been recognized only recently [1,2]. Prior to 1990, RT was not a part of the recommended guidelines for exercise training and/or rehabilitation for either the American Heart Association or the American College of Sports Medicine (ACSM) [3]. Many individuals now perform RT as a part of their routine conditioning programs to increase mainly muscular strength and hypertrophy [1,4]. Despite RT's proven ability to increase a multitude of physical parameters, such as muscular strength, power, hypertrophy, and muscular endurance, RT is often overlooked in its role in injury prevention and rehabilitation [5].

While the utilization of RT for injury prevention is not a new concept [6], many athletes, and health and fitness professionals still do not see RT as a necessary addition to an injury prevention and/or rehabilitation workout plan [5]. While some clinicians do understand and incorporate RT for its benefits relating to injury prevention and rehabilitation, this lack of emphasis on RT in a clinical setting has also resulted in limited scientific evidence for RT's effectiveness in injury prevention and/or rehabilitation workout plans [5]. However, those few studies that have examined RT's role in injury prevention and/or rehabilitation, have confirmed that the incorporation of RT in athletic training decreases the risk and severity of injury [5]. Although injuries are never completely unavoidable due to the physically demanding nature of sports, there are ways to reduce the risk and severity of such injuries by progressively increasing the tensile strength of connective tissue. This includes injuries that are sustained through contact situations such as tackles in American football and rugby, and non-contact injuries which are often more preventable. Studies reporting the direct effect of RT on injury prevention and/or rehabilitation are limited. However, the physiological adaptations on bone, connective tissue and muscle do imply enhanced protection against injury and re injury for individuals engaging in RT [6].

Physiological adaptations to resistance training

Several adaptations to RT could aid in the prevention and rehabilitation of musculoskeletal injuries. Specifically, RT may promote growth and/or increases in the structural integrity of ligaments, tendons, tendon to bone and ligament to bone junction strength, joint cartilage and the connective tissue sheaths within muscle [5].

Decreases in muscle mass and subsequent reductions in muscle strength not only results in a loss of functional ability, but also increases the risk for musculoskeletal injury [7]. RT programs may then reduce the risk for musculoskeletal injuries related to muscle imbalance, expressed as either as a bilateral comparison or an agonist to antagonist ratio. Correction of an existing imbalance through a RT program is important in reducing the individual's risk for muscle injury [6].This agonist to antagonist ratio constitutes an element of functional specificity of a joint, but is subject to numerous factors of variations such as the joint considered, dominance, sex, age, physical activity, and velocity of movement. This ratio has been supposed to constitute a clinical element in the functional analysis of the joint, and provide either an index of the risk of developing certain sports injuries, or a guide control in the modalities of rehabilitation [8].

To date, there has been little research conducted on the direct effect of RT on connective tissue adaptations. Those studies that have done so have reported increases in both the size and strength of tendons and ligaments [7]. In this regard, tendons and ligaments have been shown to respond to RT by increased metabolism, thickness, and strength [9]. In addition, research demonstrates that damaged tendons and ligaments regain strength at a faster rate when RT is performed after the damage has occurred [9]. Further, while collagen content increases with training, comparisons between untrained individuals and bodybuilders suggest that the increase in collagen content is proportional to the increases in muscle size. Thus, increases in muscle mass are likely met by increases in the size and strength of the connective tissue [7], leading to an increased tensile strength.

Studies involving humans and animal models have also demonstrated that RT can cause increased bone mineral content and therefore may aid in prevention of skeletal injuries. Bone tissue has the ability to remodel and adapt to the physical stresses imposed on it. In general, physically active individuals have been found to be at a reduced risk for osteoporosis, fractures or other ailments related to bone deterioration [7], possibly as a result of an increased bone density and turnover. Although bone will respond to many types of training programs, studies demonstrate that exercise, such as RT and those with high strain or impact such as running or jumping, provide the greatest osteogenic effect [7].

Rationale for resistance training

RT provides a multitude of benefits [10,11] and is particularly beneficial for improving the function of most cardiac, frail, and elderly patients, who benefit substantially from both upper- and lower-body exercise [10,12]. While the introduction of RT for athletic performance, and general health and fitness are well known, the effect and mechanisms of RT on musculoskeletal injury prevention and rehabilitation has not yet been well documented.

With regards to musculoskeletal injury prevention, many acute muscle strain injuries are thought to occur during the eccentric phase of sudden, forceful muscle actions [13]. In addition, repeated eccentric muscle actions during exercise are also thought to contribute to microscopic muscle and tendon damage, leading to chronic muscle strains, muscle rupture and tendinopathy [13]. In terms of musculoskeletal injury rehabilitation, trauma to the musculoskeletal system due to injury or surgery often leads to relative inactivity of the affected area. This disuse then results in muscular atrophy and weakness of the affected muscle groups [14], effectively necessitating the need for strength RT and hypertrophy RT. Previous studies suggest that a major benefit of RT is learning to coordinate the different muscle groups involved in the training movement rather than intrinsic increases in strength of the muscle group being trained [15], implying that coordinated muscles are capable of smoothly decelerating joint motions even if the muscles themselves are relatively weak. The most common cause of impaired neuromotor coordination is prior injury. As a protection against further injury, the central nervous system creates an alternate pattern of muscle recruitment, referred to as a motor engram, to avoid stressing the damaged soft tissues [16]. If adequate rehabilitation does not take place, this motor engram then persists long after the injury has healed predisposing an individual to re injury. In this regard, RT has been found to enhance motor neuron excitability and induce synaptogenesis, both of which assist in enhancing communication between the nervous system and the muscles [17].

Specially, a study was undertaken of injury rate and time lost to rehabilitation in a cohort of high-school athletes and determined that all athletes utilizing RT as part of their exercise program suffered an injury rate of 26.2% compared to 72.4% of those that did not [18]. In addition, the authors found that the rehabilitation ratio (time lost to rehabilitation due to injury per number of athletes performing in the studied group) was 2.02 days in those who utilized RT compared to 4.82 days for those not engaging in RT. As such, that study demonstrated fewer and less severe injuries in individuals engaging in RT. In addition, those individuals engaging in RT were able to return to sport much sooner.

Safety of resistance training

Several case study reports and retrospective questionnaires have demonstrated that in many clinical and educational contexts, RT is presumed to be dangerous [19]. However, there is no convincing evidence that RT is particularly perilous, with the majority of literature indicating that RT is markedly safer than many other sports and exercise modes, especially when supervised by qualified professionals [18]. Resistance training is even considered both safe and beneficial in the elderly [20], and in those with low- (younger individuals, asymptomatic with no more than 1 risk factor threshold) to moderate-disease (older individuals with 2 or more risk factors) risk [21].

Types of resistance training

It is typically believed that high loads and low repetitions are best to increase muscular strength, while lower loads and higher repetitions are best to increase muscle endurance [7]. However, this over implication of RT program design, by not only the general population but also by health professionals, limits optimal physiological and physical adaptations [1]. As RT encompasses a myriad of subtypes of exercise, it is essential for clients, patients, and health and fitness professionals to understand and differentiate between these subtypes as they have different impacts on injury prevention and/or rehabilitation [5]. In this regard, strength RT training requires training at a load of 85% or more of one Repetition Maximum (1RM) for 6 or less repetitions of 2-6 sets with rest periods of 2-5 minutes, power (single-effort) RT training requires training at a load of 80-90% 1RM performed at maximum speed for 1-2 repetitions of 3-5 sets with rest periods of 2-5 minutes, power (multiple-effort) RT training requires training at a load of 75-85% 1RM performed at maximum speed for 3-5 repetitions of 3-5 sets with rest periods of 2-5 minutes, hypertrophy RT training requires training at a load of 67-85% 1RM for 6-12 repetitions of 3-6 sets with rest periods of 30 seconds to 1.5 minutes, and muscular endurance RT training requires training at a load of 67% or less of 1RM for 12 or more repetitions of 2-3 sets with rest periods of 30 seconds or less [22].

Prescription for patients with musculoskeletal injury

While it appears that RT may have a significant role in the prevention and rehabilitation of musculoskeletal injuries, it is also clear from the literature that there is no single optimal design of RT for all populations and/or conditions [5]. Although RT programs using heavy weights yield high levels of muscle activation, there may be a need for alternative types of RT dependent on the individual, aims of the RT programme, type of musculoskeletal injury, disorder, surgery and/or agonist and antagonist muscle strength imbalances.

When designing musculoskeletal injury prevention and rehabilitation programs, RT program design should focus on all necessary RT subtypes. Muscle endurance RT training will enhance a muscles' ability to work repeatedly without fatiguing and becoming injured/reinjured. In addition, while heavy/strength RT exercises should be included in musculoskeletal rehabilitation programs to induce sufficient levels of neuromuscular activation to stimulate muscle growth and strength, even low-load (hypertrophy and muscle endurance) RT can increase the elasticity of tendon-aponeurosis structures [9]. Importantly, RT programs for the restoration of connective tissue, such as ligaments should focus on eccentric muscle actions [23], since eccentric actions generate more tension, less waste products (and less chemical irritation of nerves), and require lower oxygen consumption and lower energy requirements than concentric work [24]. In recent years, eccentric exercise has been used in rehabilitation to manage a host of conditions, such as tendinopathies, muscle strains, and in Anterior Cruciate Ligament (ACL) rehabilitation [24]. However, the collagen metabolism in healthy tendons seems not to be affected by eccentric training [23], possibly limiting eccentric training role in the prevention of connective tissue injuries. In addition, where significant muscle atrophy has occurred as a result of injury or surgery, conventional hypertrophy-RT should take place to restore muscle bulk [15]. Studies have also previously shown changes in muscle strength following RT to be specific to the length and speed at which the muscle has been trained [15].

Further, training isolated muscle groups may not be the most effective way of increasing functional performance in an attempt to prevent and rehabilitate musculoskeletal injuries as the major adaptations are task-specific [15]. As such, health and fitness professionals should also make use of sport, cross training and/or motion specific RT exercises as these may reduce the incidence and recurrence of various types of injuries, especially overuse injuries [6]. This is essential since RT has been found to be the only modifiable risk factor that significantly contributes to the incidence of sport injuries [25]. To further prevent injuries, health and fitness professionals should perform range of motion exercises to reduce muscle tightness [26]. Prior to the implementation of RT musculoskeletal injury and rehabilitation programs, it is essential to screen individuals for agonist and antagonist muscle strength imbalances. This may assist the professional in identifying those individuals possessing a predisposition for injury or re-injury. Resistance training may then be performed to correct the imbalance and therefore reduce the incidence of injury or the recurrence of an earlier injury [6]. Specifically, Askling et al., [27] found that just one to two days weekly of eccentric hamstring exercises for 10 weeks, works effectively, in maintaining muscle group balance.

Further, in the case of musculoskeletal injury rehabilitation, RT program design should be tailored to the appropriate stage/phase of rehabilitation, namely early-phase, mid-phase and late- or final-phase [28]. In early-phase rehabilitation, the aim is to progressively load the damaged tissue and restore its' tensile strength. As such, RT in this phase should take the form of gentle exercises, such as muscle endurance RT, which allows the damaged tissue to heal. Mid-phase rehabilitation should involve progressively increasing RT load, in the form of strength training, and difficulty (from machines to free weights) to progressively load the connective and bone tissue in an attempt to develop tensile strength. This increased tensile strength would then produce a healed tissue that will be able to better withstand the stresses and strains of daily life, exercise and sporting demands [28]. The Late- or final-phase of rehabilitation should focus on increasingly functional RT with appropriate volume and intensity, whether it be hypertrophy, strength or power RT, to ensure adequate tissue adaptation. The aim of this phase is to effectively and efficiently return to activities of daily living, occupational demands and/or the specific sport during which the injury occurred and it is essential to perform RT exercises that replicate activities and movements in that activity, occupation and/or sport [28].

Conclusion

To date most of the limited original studies, reviews and meta-analysis on RT and musculoskeletal injuries have focused on one particular intervention, injury type/location, sport or studied other relatively narrowly defined research questions. This is problematic in that although these studies demonstrate RT may have an effect on musculoskeletal injuries, these narrowly defined research studies do not allow for a full quantification of intervention effect estimates. As such, while this review advocates the role of RT in the prevention and rehabilitation of musculoskeletal injuries both for its safety and efficacy, further examination and quantification of specific RT exposures and a differentiation of acute and overuse outcome effect estimates is still lacking.

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