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Editorial

The "*Journal of Functional Morphology and Kinesiology*" Journal Club Series: Highlights on Recent Papers in Strength and Conditioning

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Abstract: We are pleased to introduce the sixth Journal Club. This edition is focused on several relevant studies published in the last years in the field of Strength and Conditioning, chosen by our Editorial Board members and their colleagues. We hope to stimulate your curiosity in this field and to share with you the passion for sport and exercise seen from a scientific point of view. The Editorial Board members wish you an inspiring read.

Keywords: strength; conditioning; eccentric; concentric; ergometry; neural adaptation

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1. Introduction

Muscle strength is a fundamental physiological requirement in order to produce movement and complete many activities of daily living. The acquisition of strength above, and the recovery to, baseline levels has been the focus of considerable scientific endeavour. The outcomes of such work have yielded a substantial understanding of how humans develop force and control muscles to perform many activities. While early research using early scientific techniques focused more on the muscle, recent advances in technology and techniques now allows us the opportunity to investigate the entire system from the cortex to the muscle, under a variety of conditions and activities.

2. Recent Papers Regarding Strength and Conditioning

2.1. Improving Muscle Strength Using Eccentric Ergometry Training

Highlight by Joel A. Walsh

Neuromuscular adaptation to eccentric resistance training, compared to traditional resistance training, that translates to improvements in muscle strength, power and force development have been well documented [1]. The majority of previous research in this area has been carried out under tightly controlled clinical settings, specifically looking at single-joint eccentric resistance training that could be considered to lack applicability to more general aspects of human movement. One key element of eccentric training that has lacked attention is the reduced metabolic cost of performing eccentric exercise for the same mechanical work required to perform similar concentric exercise [2]. This outcome may be attractive to clinicians and physiologists as eccentric training would likely offer an efficient alternative to traditional rehabilitation practices. It is only recently that researchers have adopted the use of eccentric ergometer training (EET) to enhance muscle strength and fatigue resistance among patients whose functional rehabilitation is limited by cardiovascular and pulmonary constraints [3]. These authors have shown that in patients with severe COPD, 10 weeks of EET led to increases in muscle strength and hypertrophy, at progressively lower levels of perceived fatigue and dyspnea. Similar applications of EET have led to increased lower limb strength in patients with spinal cord injuries [4] and EET is as successful as traditional rehabilitation when addressing fall risks in elderly subjects [5]. The physiological adaptation stimulated by EET in clinical populations has the potential to extend to healthy subjects and in particular to competitive sport, where the continuous search for training methods to enhance performance is paramount. Recent work has reported increases in lean muscle mass and a 6.5% improvement in muscle power in elite alpine skiers following six weeks of moderate intensity EET [6]. Similarly, increases in quadriceps muscle mass and maximal power output (5–9%) have been documented in young healthy subjects following eight weeks of EET at between 20–55% of maximal concentric cycling power output [7]. These findings support the case for the inclusion of EET into athletic training, specifically during pre-or early season training where development of muscle strength is a primary focus. It would be feasible for physiologists and coaches to include EET, supplementary to regular strength training, due to being able to overload the muscle system at low metabolic cost [8] and thereby increasing muscle strength without accumulating fatigue. Specifically, the use of EET in cycling populations would be of particular benefit and is an area yet to be explored. Although EET has received little attention until recently, adaptive effects reported among patient, healthy and elite athlete populations is enough to indicate the benefits of EET as an effective rehabilitation or training modality that could be used as an alternative to more traditional training methods where physical condition or time impacts training attrition. Nevertheless, additional research into the effects of EET should be encouraged in order to achieve a greater understanding of its potential application.

2.2. Probing the Early Neural Adaptations to Strength Training

Highlight by Darryl J. McAndrew

Increased muscle strength in response to strength training has long been attributed to adaptive changes in both the muscle tissue and the central nervous system. These early phase increases in strength have been shown to occur without morphological changes [9,10] and without increases in muscle twitch torque [11,12]. While latter phase morphological changes such as increased myofibrillar size and number [13,14], hyperplasia, muscle architecture and connective tissue structure [15,16] are well reported, the mechanisms underlying early neural adaptation are less clear. Over the past 35 years, research in the field has continually focused on neural adaptations primarily utilising 'indirect' methods such as motor unit recordings to illustrate changes in maximal motor unit discharge rates [17,18], reduction in the variability of motor unit discharge rate [19,20] and increases in correlated motor unit activity [21]. However, recent technological advances in 'direct' neurophysiological techniques such as transcranial magnetic stimulation (TMS) have really expanded our understanding of these adaptations. Transcranial magnetic stimulation is a non-invasive method of studying 'corticospinal excitability', i.e., the transmission of neural commands from the motor cortex to the target muscle. When stimulating the brain, the evoked responses recorded in the muscle are a reflection of the entire communication pathway (cortex, spinal cord and peripheral nerve), whereas stimulating the cervicomedullary junction reflects activity within the spinal cord circuitry. Using these two approaches, observed increases in voluntary activation, but not cervicomedullary-evoked potentials or motorneuron excitability, indicate that cortical changes may play a major role in the early neural adaptation to strength training [22]. Given the emerging identification of these early neural changes, one might ask the question of whether it is possible to exploit and to manipulate the cortical response to training, in order to accelerate and enhance strength gains [23–27].

2.3. What Does the Study of Different Modes of Muscle Contraction Tell Us about the Neural Control?

Highlight by Paul J. Stapley

Walsh and McAndrew (2.1 and 2.2, respectively) have elegantly outlined the potential clinical and high performance advantages of eccentric muscular training, and the possibility that magnetic stimulation of the central nervous system may be used in combination with traditional strength training methods to yield greater gains in strength. The theoretical background given in both of these highlights also provides a basis for asking more fundamental questions around the underlying neural control of eccentric vs. concentric muscle contraction, for example; *How do the two modes of muscular contraction (eccentric* vs. *concentric) differ in terms of their central or peripheral (spinal) control, and can neural plasticity be induced through strength training or conditioning?* The first of these questions has been discussed previously by a number of topical reviews [28–30]. These authors suggested that spinal and cortical excitability is reduced during eccentric compared to concentric contractions, and that muscle activity is modulated during eccentric contractions by inhibitory spinal mechanisms. However, others have noted greater cortical excitability associated with eccentric contractions to counteract spinal inhibition [31,32]. Perhaps the discrepancies recorded are also due to the type of exercise (single joint vs. whole body, aerobic exercises) used to study the type of muscle contraction? Indeed, in a recent study, Garnier, et al. [33] demonstrated that cortico-spinal excitability is increased some 30 mins after the end of downhill walking, an activity requiring significant eccentric contractions of the leg muscles. This form of neural plasticity, recorded via increases in the amplitudes of motor evoked potentials, could be indicative of possible therapeutic effects of eccentric physical activity, which could possibly lead to a greater enhancement of the neuromuscular system at a lower metabolic cost compared to concentric exercise. Our group is currently exploring the neural basis for eccentric and concentric muscle contractions and possible positive effects of strength training on central (cortico-spinal) and peripheral mechanisms.

2.4. Eccentric Training Effects on Biceps Femoris (Long Head) Architecture

Highlight by Eleftherios Kellis

Hamstring injury is a frequent sport injury with a high recurrent rate. Injured athletes display peak knee flexion torque at a shorter muscle length, possibly due to shorter fascicles of the biceps femoris long head (BFlh) [34]. Consequently, examination of the effects of various exercise protocols on the arrangement of fascicles within a muscle is particularly useful for hamstring injury prevention and rehabilitation.

Eccentric strengthening exercise is considered an effective method for improving muscle strength but its precise effect on hamstring architecture has only recently been investigated. In one of the first studies, Potier et al. [35] reported a significant increase (34%) in fascicle length and a non-significant change in pennation angle of BFlh after 8 weeks of eccentric training. More recently, Timmins et al. [36] found that BFlh fascicle length was longer after eccentric training and shorter after concentric training for 4 weeks. This effect, however, was lost after 28 days. Similar results were obtained by Alonso-Fernadez et al. [37] after 8 weeks of eccentric training with Nordic exercises. Additional useful information was reported by Bourne et al. [38] who reported that 10 weeks of eccentric training increased BFlh fascicle length and muscle size. However, eccentric hip extension training had a higher impact on BFlh size and architecture than Nordic Hamstring exercises. In contrast to all previous findings, Seymore et al. [39] reported an increase in cross-sectional area but no systematic changes in FL and stiffness of BFlh following 6 weeks of Nordic exercise training.

In conclusion, most studies favor the use of eccentric training protocols for improving muscle strength and size and for increasing the length of BFlh fascicles. Understanding the physiological mechanisms responsible for increases in BFlh fascicle length after eccentric training but not after concentric training is an important future task. In this respect, future research on the training effects on tendinous tissue properties of hamstrings is essential. The finding that hip extension exercises are more beneficial than Nordic exercises may stimulate additional research in our search for exercises that have a greater effect on BFlh architecture. Further study is required to examine whether the observed changes in BFlh morphology following eccentric training can reduce injury risk.

2.5. Resistance Training in Children and Adolescents

Highlight by Christoph Mickel

Several (inter)national associations and numerous reviews have reported the efficacy and safety of strength training for children and adolescents. However, differences in youth strength training programs and their effect on power measures have been unclear [40]. Power training has been presented as more effective than strength training for improving jump height, but for sprint measures, strength training was more effective than power training with youth. Furthermore, consistently large magnitude changes to lower body strength measures through strength training were reported, while the effects of power training on lower body strength, sprint and jump measures were trivial, small and moderate [40]. Therefore, the authors conclude: "Based on this meta-analysis, strength training should be incorporated prior to power training in order to establish an adequate foundation of strength for power training activities." [40].

Besides significant training-induced increases in force and speed-strength measures, effects on muscle morphology, bones, ligaments and tendons have been postulated [41]. This is already the case before the beginning of puberty. Therefore, even with low serum concentrations in testosterone, which is still regarded as a primary stimulator of anabolic processes in skeletal muscle [42], morphological adaptations are possible. Most probably, the effects are mediated via the "growth hormone—Insulin-like growth factor-1—axis" [43]. However, solely for bone structure, the effects can be regarded as evidence-based: Physical activities with high mechanical demands have a pronounced effect on bone structure development compared to activities which induce less mechanical stress. Beyond bone structure, the scientific knowledge on morphological tissues in children and adolescents is still insufficient and further research on this crucial period in athlete development should be encouraged.

Resistance training focusing on perfect movement technique and slowly progressive additional loads must be regarded as essential for up-and-coming athletes as it increases the level of force production and seems to have positive effects on other tissues than muscle, too.

2.6. Responders and Nonresponders in Resistance Training

Highlight by Antonio Paoli

Resistance training (RT) exerts many of its positive health effects through increases in strength and muscle mass [44]. Although these two variables are classically considered together (increase of muscle mass leads to an increase of strength, after the first period of neuromuscular adaptation [45,46]) recently this assumption has been called into question [47]. Regardless of their reciprocal influences, both of these adaptations (increase of muscle strength and cross-sectional area, also known as hypertrophy) are induced by RT but they could be of different magnitude in different individuals, thus one other critical issue in the field of RT research is the existence of responders and nonresponders. In recent years, this aspect has been highlighted by several studies [48], e.g., Ahtiainen et al. who demonstrated a great heterogeneity in muscle mass and strength responses to RT regardless of sex and age [49] whilst an earlier study showed high responders and low responders in terms of muscle fiber CSA after a period of RT [50]. Alternatively, Barbalho and colleagues [51] recently analysed data from older women, and found that there are no nonresponders both to low- or high-volume RT. The question is intriguing and probably involves both individual/genetic specificity [52] and the numerous variables of RT [53,54]. The existence or not of responders and nonresponders in RT is a topic worthy of further investigations. One example could be the research performed on the effects of endurance training volume on cardiorespiratory fitness. It has been shown that the individual cardiorespiratory fitness non-response to endurance training is abolished by increasing the dose (volume) of exercise [55]. It would be interesting to investigate whether, in RT, changing one of the many variables could transform a nonresponder into a responder. Therefore, I would like to invite researchers to investigate this complex but interesting aspect of resistance training.

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