STRENGTH AND HYPERTROPHY IN FORCE TRAINING: an explanatory research

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RESUMO

O treinamento de força é uma modalidade que envolve muitas variáveis e aspectos metodológicos em sua prática e que desenvolve a força e hipertrofia. Para esses efeitos, faz-se necessário a ativação de fibras musculares e fibras nervosas. Assim, o estudo neurofisiológico é essencial para o entendimento das respostas geradas no organismo pelo treinamento de força. O objetivo deste estudo foi realizar uma ampla explicação dos fatores que influenciam no treinamento de força envolvendo os componentes de força e hipertrofia por meio de uma abordagem neurofisiológica. A metodologia se caracterizou por ser uma pesquisa qualitativa explicativa. Artigos relacionados aos termos “treinamento de força”, “Fisiologia” e “neurofisiologia” foram selecionados. Além disso, esse material deveria conter informações sobre força e hipertrofia. Os resultados explanaram sobre importância da intensidade do exercício para o treinamento de força, os tipos de fibras musculares, aspectos sobre a inervação e ativação neuromuscular, força, hipertrofia e benefícios dessa modalidade. A conclusão deste trabalho ressaltou a importância do conhecimento neurofisiológico no treinamento de força, assim como da necessidade que pesquisas relacionadas a este tema abordem conceitos de neurofisiologia.

Palavras- chave: Treinamento de força. Neurofisiologia. Força. Hipertrofia.

ABSTRACT

Strength training is a modality that involves many variables and methodological aspects in its practice and that develops strength and hypertrophy. For these effects, it is necessary the activation of muscle fibers and nerve fibers. Thus, the neurophysiological study is essential for understanding the responses generated in the body by strength training. The objective of this study was to perform a broad explanation of the factors influencing strength training involving the components of strength and hypertrophy through a neurophysiological approach. The methodology was characterized as an explanatory qualitative research. Articles related to the terms "strength training", "Physiology" and "neurophysiology" were selected. In addition, this material should contain information about strength and hypertrophy. The results explained the importance of exercise intensity for strength training, types of muscle fibers, aspects regarding innervation and neuromuscular activation, strength, hypertrophy and benefits of this modality. The conclusion of this study emphasized the importance of neurophysiological knowledge in strength training, as well as the need for research related to this topic to address concepts of neurophysiology.

Keywords: Strength training. Neurophysiology. Force. Hypertrophy.

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INTRODUCTION

Currently, the relationship of bodybuilding with health maintenance, prevention, treatment and / or rehabilitation of diseases, and esthetics is being studied and reported in the literature. However, this practice contains few neurophysiological information regarding strength training and hypertrophy (GENTIL, 2015).

Strength training (ST) consists of the execution of exercises that aim to generate morphological and physiological adaptations in its practitioners (GENTIL, 2015; FLECK; KRAEMER, 2006; MCARDLE; KATCH; KATCH, 2008). This is due to the metabolic imbalance and muscular stress developed in the body by the application of overloads, such as free weights, barbells, dumbbells, weight, elastic fitness band, body weight or some external resistance that opposes movement.

According with Tubino and Moreira (2003), the training consists of a program of exercises with scientific background linked to references that constitute in principles, among them can be cited: principle of biological individuality, principle of adaptation; overload principle; principle of continuity; principle of volume-intensity interdependence; principle of specificity.

In this perspective scientific researches performed numerous studies of the effects of physical exercise and its health benefits in the population, but still few works that address the interaction of ST with neurophysiology from the point of view of strength and hypertrophy.

Thus, the objective of this study was to perform a broad explanation of the factors that participate in strength training involving the components of strength and hypertrophy with a neurophysiological approach.

MATERIALS AND METHODS

This work is about a qualitative and explanatory research about strength training regarding the literature review and the neurophysiological approach of these studies about the strength and hypertrophy component. According to Gil (2008), the explanatory research provides deeper knowledge of a topic and identifies the greater number of factors influencing it.

RESULTS AND DISCUSSION

The intensity of the ST prescription generates positive results based on the ratio of the effort that the muscle needs to perform against the resistance that will be imposed. This will also determine the characteristic of exercises, such as aerobic or anaerobic. In this way, the intensity becomes a fundamental variable for the prescription of the exercises, because in order to obtain the increase of muscular strength and hypertrophy the intensity must be measured between moderate and high being influenced by the stimulation of certain muscular fibers with specificity for the development of force (FLECK; KRAEMER, 2006; UCHIDA et *al.,* 2010).

For determine the predominance of the anaerobic stimulus, the correct activation of the muscle fibers is fundamental for the correct prescription of the exercises. The objective is to recruit as many anaerobic muscle fibers as possible in which there is segmental displacement and perform work with the performance of the force (FLECK; KRAEMER, 2006; UCHIDA et *al.,* 2010).

The muscle fibers are divided into type I and type II. Type I fibers have oxidative metabolic characteristics, red fiber coloration, slow muscle contraction and small diameter. Type II fibers use the glycolytic metabolic pathway, have white coloration, have rapid muscle contraction and a larger diameter when compared to type I fibers (Table 1). There is a division within the glycolytic fibers: IIa, IIb and IIc, in which the IIa fibers have glycolytic-oxidative characteristics and type IIb, have more glycolytic characteristics in relation to the others. Type IIc fibers are not very present in humans, but have mixed characteristics of both types of fibers I and IIb, and can develop and assume predominant characteristics of one of these fibers depending on the stimulus external to the exercise acting on this tissue (MCARDLE; KATCH; KATCH, 2008; POWERS; HOWLEY, 2005).

Table 1 - Characteristics of types of muscular fibers

Types of fibers	Prevailing energy system	Contraction's Velocity	Color of fibers	Diameter Size
Type I	Oxidative	Slow	Red	Small
Type II	Glycolytic	Fast	White	Large

During the ST all fibers are recruited, however type IIb fibers are the most activated for this type of exercise, because they have specific enzymes that activate metabolic pathways that respond to specific stimuli, such as in acute response to weight (external resistance) to be expired. These enzymes have glycolytic or oxidative characteristics, depending on the type of muscle fibers (AIRES, 2012; FLECK; KRAEMER, 2006).

Type I fibers are activated by oxidative enzymes and have a greater amount of mitochondria in their myoplasm than glycolytic fibers. They have a high number of mitochondria that will produce sufficient energy for the aerobic work, consequently, the amount of myoglobin in these fibers should be greater to supply the oxygen demand necessary for this type of muscular contraction (AIRES, 2012; POWERS; HOWLEY, 2005).

However, in type II fibers there is a predominance of the extensive sarcoplasmic reticulum in comparison to type I fibers, so this fiber can capture a greater amount of Ca^{2+} in a shorter time due to a more rapid activation in muscle relaxation and thus the recovery in the actin-myosin interaction for a subsequent contraction that also occurs faster than type I fibers (BERNE; LEVY, 2008; FLECK; KRAEMER, 2006).

Another factor that differentiates the muscle relaxation between the fibers is the myosin-ATPase isoforms which is an enzyme responsible for the hydrolysis of ATP in myosin to allow the cross-bridge to be disengaged, thus allowing the myosin to return to its initial state and can again interact with actin by performing a new muscle contraction. For each type of muscle fiber there is a myosin-ATPase isoform that acts at different speeds, determining distinct characteristics in muscle contractility (BERNE; LEVY, 2008).

The innervation of type I fibers is characterized by having a small diameter, rapid conduction velocity and high excitability. However, type II fibers have a larger diameter, very rapid conduction velocity and low excitability (POWERS; HOWLEY, 2005).

According to the literature, a muscle contraction in ST activates all muscle fibers, but type I fibers are recruited first than type II fibers. This phenomenon is quite interesting because type II fibers have a diameter and conduction velocity greater than type I, so they should be activated first. This does not occur because the level of excitability of these fibers is different because the type I fibers are more excitable. In this way, the fibers with the highest excitability are recruited first, regardless of their diameter (MANZANO; GIULIANO; NÓBREGA, 2008).

This relationship between the recruitment of muscle fibers and their neurophysiological control is poorly explained in the literature, causing a deficit in the understanding of this physiological phenomenon. This failure in the teaching process impairs the understanding of such an important subject for health professionals who use this knowledge in their work. Therefore, a better explanation is needed about how the motor units function and why this mechanism exists, thus facilitating an understanding of the physiological processes involved.

The motor unit is the main and initial factor to be analyzed during the voluntary action of muscle, as it is responsible for the segmental movement, support by static actions, locomotion, due to the development of different neuromuscular contractions (isometric, isokinetic or isotonic) (FLECK; KRAEMER, 2006). This motor unit consists of an alpha motor neuron that innervates several muscle fibers, being responsible for the activation of the action potential in the muscular membrane in order to generate muscle contraction. (BERNE; LEVY, 2008).

The cell membrane has an internal electricity of around -70mV and the outside positive due to the existing difference of the concentration gradient of Potassium (K^+) and Sodium (Na^+), in which there is a high level of K^+ in intracellular liquids with respect to the medium external and for Na^+ the highest concentration is in the extracellular fluids. This electrical potential is called the membrane potential (GUYTON, 1988; BERNE; LEVY, 2008).

The membrane upon receiving a depolarized neural stimulus generates an action potential that leads to the activation of the mechanisms responsible for the muscular contraction that involves the interaction of actin and myosin (BERNE; LEVY, 2008).

The **sliding filament model** explains muscle contraction in which two contractile proteins - actin and myosin - interact with each other. Ca^{2+} release occurs from the sarcoplasmic reticulum (calcium-dependent metabolic pathway) in which this ion binds to another protein present in the actin filament, troponin, activating the action of actin moving on the myosin, performing muscle contraction (SILVERTHORN, 2010; POWERS; HOWLEY,2005).

Studies demonstrate that the neuromuscular junction (NMJ) has the capacity to undergo morphological remodeling with the increase of the ST. As an example of this situation we can mention that in ST there is an increase in the total length of the branch of the nervous terminal (WAERHAUG, 1992), of the area occupied by vesicles containing acetylcholine (ACh) (DESCHENES, 1993), and the area occupied by ACh receptors (GYORKOS & SPITSBERGEN, 2014). However, it is still unclear whether the neuromuscular system of older individuals responds to stimuli through ST similar to the neurons and muscle fibers of young individuals.

Deschenes (2015) compared NMJ activity in two distinct muscles: soleus and plantar. The soleus is composed primarily of muscle fibers of type I (fibers of slow conduction) characterized by a high duty cycle, meaning that this muscle is regularly recruited since its main function is related to the posture. However, the plantar muscle consists mainly of type II muscle fibers (fast conducting fibers) and functions primarily as a locomotor muscle in which its fibers are less recruited for this action than the soleus muscle (LAUGHLIN & ARMSTRONG, 1982).

This study demonstrated that among the muscles examined, the soleus showed a greater adaptation of NMJ to the ST, but these adaptations were evident only among NMJ that were expressed in fast contracting muscle fibers. A ST-induced increase in post-synaptic end-plate size, ie, NMJ perimeter length and area in the soleus, especially in fast-contracting but not slow-contracting muscle fibers (DESCHENES, 2015) . This can probably be attributed to the fact that, under normal conditions, fast-twitch muscle fibers in the soleus are rarely recruited, but during ST they are more activated.

The strength can be defined as the ability of the muscle, or muscle group, to exert tension against a resistance (FLECK; KRAMER, 2006). Weineck (2003) points to strength as a work generated by the neuromuscular system able to perform movement or not after a voluntary contraction. Campos and Gomes (2014) argue that strength development improves neuromuscular performance through neural and structural adaptations.

According to Weineck (2003), there are three types of force: maximum or pure force, rapid force and force resistance. The maximum force represents the ability of the muscle to generate force through a maximal voluntary contraction against an external resistance, and this contraction may be isometric or isotonic. For fast force, the neuromuscular system must be able to move the body, or some body segment, at the highest possible speed. Under the term "strength resistance" is meant the tension exerted by the muscle capable of withstanding a prolonged voluntary muscular contraction.

The increase of force is initially due to adaptive neural changes of the involved musculature and later by the increase of the cross section of the muscle, that is, the hypertrophy (MORINATE; DeVRIES, 1979).

In the execution of ST there is a range of physiological responses with the purpose of promoting adaptations to the organism. These initial adaptations are due to neural factors such as a recruitment of a larger number of motor units. Each motor unit has the function of providing the muscular contraction and consequently will contribute to the increase of force in order to overcome the imposed overload. This process was termed by Kraemer and Hakkinen (2002) "Neural Adaptation Window," which is the power capacity that exists in unused muscle work (because there is no recruitment), but that there is this "window of strength" on this fabric for when you need to use it.

In addition to the recruitment of new muscle fibers, there is also a higher frequency in the activation of these fibers causing a more pronounced and more uniform contraction, synchronizing the activation of the fibers of a certain motor plaque (FLECK; KRAEMER, 2006).

Another factor that contributes to the increase of the acute force of the ST is the synchronism of the voluntary muscular action in a certain movement, so the active motor units initiate a coordinated process of muscular contraction. It can be inferred that the increase of force and the organized motor control occurred due to a motor learning of the neural system (FLECK; KRAEMER, 2006).

Intermuscular changes occur in two important aspects during neural adaptation: decreased inhibition of the Golgi tendon organ and increased motor plate excitation. The Golgi tendon organ is a structure found close to the junction of muscles to tendons and is part of the proprioception system that are terminal organs specialized in sensory reception of muscles and tendons (McARDLE; KATCH; KATCH, 2008).

This receiver has as a function to perform a continuous monitoring of the dynamics performed by the muscles and to inhibit the force produced during a muscle contraction beyond the safety limits for the integrity of the muscle tissue and the connective tissue to which the muscle (McARDLE; KATCH; KATCH, 2008). This inhibition of the contraction generated by the Golgi tendon organ occurs by an inhibitory neuron located between a sensory fiber and a motor fiber.

"It has been proposed that this lower activation is linked to some mechanism of neural inhibition, specifically coming from the Golgi tendon organs" (BARROSO; TRICOLI; UGRINOWITSCH, 2005, p. 4). In this way the ST generates a change in the activation of the Golgi tendon organ, causing it to occur with increasing intensity, so in the muscle it may increase tension without there being an earlier interruption of both the mechanism and the adaptation in the muscle.

Hypertrophy is the increase in the number of contractile units within the muscle fiber, specifically in the sarcomer that makes myofibril. Physical exercise stimuli promote the synthesis of new sarcomers distributed in parallel in myofibril.

ST leads to hypertrophy of type II fibers (MERO, 2013). Type II fibers exhibit a greater plasticity in size in response to stimuli when compared to type I fibers. This is evident in a short period (6-10 weeks) where ST leads to hypertrophy of type II fibers (CLAFLIN, 2011).

Type II muscle fibers have a larger cross-sectional area than type I muscle fibers in humans (STARON, 1994), while they also have a greater amount of Na^+/K^+-ATPase pump isoforms than is required also associated with the faster propagation of action potentials in this type of muscle fiber (CLAUSEN, 1986).

Hyperplasia is a less frequent mechanism within the physiological responses to exercise and occurs with duplication of the muscle fiber and thereby also increasing the cross-sectional area of the muscle.

In relation to hypertrophy and ST, there are two distinct methods in which resisted exercises can generate hypertrophic physiological responses: a) sarcoplasmic or metabolic hypertrophy, in which increases muscle mass in response to acute training, with accumulation of intracellular substances as creatine, glucose, lipids, water, as well as an increase in the number of some organelles, such as mitochondria that supply the metabolic demands of ST, and b) myofibrillar or tensional hypertrophy, where myofibrillar increases due to mechanical stimuli caused by microleaf which activate cell regeneration mechanisms in which the number of actin and myosin filaments increases with the addition of sarcomeres to myofibrils (FLECK; KRAEMER, 2006; UCHIDA et al, 2010).

Metabolic hypertrophy presents responses to training after a high number of repetitions, light loads and short intervals. On the other hand, myofibrillar hypertrophy requires training to occur with few repetitions, heavy loads and longer intervals. However, there is no way to dissociate these two methods, both function concurrently, but the effects generated by the ST will depend on the manipulation of the training variables.

The ST generates some adaptations like alteration of the corporal composition through the decrease of the fat mass and increase of the lean mass; muscular hypertrophy due to the increase in the number of fibers and the diameter of these muscle fibers; improvement in motor performance, important for both sports and daily activities; increased strength; increased localized muscle resistance; increase in cardiac output due to the acute and chronic response generated by cardiac contractility in which it decreases the flow (FLECK; KRAEMER, 2006; UCHIDA et al, 2010).

CONCLUSION

The analyzes of strength and hypertrophy in this study resulted from the concepts of intensity, types of muscle fibers, neuromuscular activation and neural adaptation that aid in understanding the process of ST. This understanding about the relationship between muscle contraction and its neurophysiological control was addressed in this study in order to emphasize its importance in ST. In addition, to emphasize that this theme is still little explained in the literature, thus harming the understanding of several physiological processes in which this current relationship. It is important to show that the organism is quite complex, so for an excellent approach to its processes it is necessary to understand each phenomenon involved and the relation between them.

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