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ANTROPHOMETRIC AND FUNCTIONAL CHANGES OF THIGH MUSCLES INDUCED BY STRENGTH TRAINING

ANTROPOMETRIJSKE IN FUNKCIONALNE SPREMEMBE STEGENSKIH MIŠIC PRI TRENINGU MOČI

Abstract

In muscle cells, physical activity leads to many changes, including metabolic ones or hypertrophy. As a result of these, a large increase in energy sources appears as well. During heavy resistant strength training, adaptation of many physiological processes in our body is in motion due to increased muscle activity. The purpose of this study was to follow up changes in thigh muscles' cross-sectional area and ergometric parameters during eight weeks of strength training. Forty five male subjects were included in the study (age 20.50 ± 1.32). After the eight-week period, a statistically significant increase in the cross-sectional area (CSA) of thigh muscles was recorded (left 9.26±0.32 cm^2, $p<0.01$; and right 9.07±0.57 cm^2, $p<0.01$). Parameter Peak Power obtained through the Wingate anaerobic test (WanT) has shown a statistically significant increase (before 719.36±104.92 W, $p<0.01$; after 790.68±112.72 W, $p<0.01$). In the eight-week period, significant metabolic changes followed the structural ones. There is a significant correlation between anthropometric and ergometric changes ($r = 3.21$; $p<0.05$).

Key words: strength training, anthropometry, metabolism

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Povzetek

Telesna dejavnost v mišičnih celicah povzroča veliko sprememb vključno s presnovnimi ali hipertrofičnimi spremembami. Posledica teh sprememb je tudi veliko povečanje energijskih virov. Med treningi moči z velikimi bremeni se v telesu zaradi povečane mišične dejavnosti sprožijo mnogi fiziološki procesi. Namen pričujoče študije je bila spremljava sprememb v prečnem prerezu stegenske mišice in ergometrijskih parametrov med osemtedenskim treningom moči. V študijo je bilo vključenih 45 moških (starih 20.5 let ± 1.32). Po osmih tednih je bilo mogoče opaziti statistično značilno povečanje prečnega prereza (CSA) stegenskih mišic (levo 9.26±0.32 cm^2, $p<0.01$; in desno 9.07±0.57 cm^2, $p<0.01$). Parameter Peak Power, ki smo ga izmerili s pomočjo Wingateovega anaerobnega testa (WanT) je pokazal na statistično značilno povečanje (prej 719.36±104.92 W, $p<0.01$; potem 790.68±112.72 W, $p<0.01$). V obdobju osmih tednov so presnovne spremembe sledile strukturnim, med antropometrijskimi in ergonomskimi spremembami pa obstaja statistično značilna povezanost ($r = 3.21$; $p<0.05$).

Ključne besede: trening moči, antropometrija, metabolizem

INTRODUCTION

In response to resistance training, changes within skeletal muscle are an important and perhaps the major adaptation. Increases in the volume of activity affect not only the skeletal muscles but many other physiological mechanisms, which all are trying to achieve the same goal: functional adaptation to newly established demands (McComas, 1996). Hypertrophy is followed by metabolic changes as well; they are manifested through significant increase in energy sources inside the myocytes (Costill, 1979).

Strength training includes active and dynamic processes in which functional changes affect the whole body due to a primary increase in muscle activity. In order to achieve this, careful planning is necessary. Training programs have to bring to balance many factors such as frequency of workouts, type of exercise, speed of movements, loads, number of repetitions etc. (Bompa, 1999).

Energy for high intensity short duration exercise (such as strength training) is mainly provided from anaerobic sources inside the muscle itself. They include the phosphagen pool (Phospho Creatine – PCr, ATP) and stored glycogen. Anaerobic capacity in humans may be determined with different test modalities, directly and indirectly. One of the direct approaches is muscle biopsy. This method is invasive, requires strict laboratory conditions and specialized medical staff. Routine indirect methods are much more commonly used. One of them is the Wingate anaerobic test (WAnT) for ergometric measurement of anaerobic power components. This test was first introduced in the late 1970s, and since then has undergone certain modifications. However, latest findings showed that this test can provide adequate and valuable data (Beneke, Pollmann, Bleif, Leithauser, & Hutler, 2002).

Many authors reported the influence of different training regimens on muscle fibre quality and performance. In this study, the strength training lasting eight weeks, and quantification of physiologic changes that occur in the muscles was attempted. Indirect but precise method to evaluate changes in cross-sectional area (CSA) of thigh muscles and metabolic changes in the trained muscles (via WAnT) were used. It was hypothesizes that metabolic changes in the working muscles follow the anatomic ones.

METHODS

Participants

A group of 45 healthy but untrained young men (age 20.5 ± 1.32 yr.) was formed, who were previously not engaged in any type of organized physical activity. Training sessions were conducted in the gym of the Faculty of Physical Education in Novi Sad, and all testing sessions took place in Laboratory for Functional Diagnostics of Medical Faculty in Novi Sad. All training sessions and test procedures were done by faculty staff. At the beginning and at the end of this research, body height (BH), body weight (BW), anthropometric measures of both thighs and ergometric testing were undertaken to evaluate the changes evoked by the training program.

Instruments

Functional test

Wingate test (WAnT) is "all-out" cycle-ergometer test, lasting for 30 s. Monitoring of the load was done directly via a PC through a module made for registering of wheel revolutions. Integrated software enabled numerical and graphical analysis of data gathered throughout the 30-second test. In such manner, basic parameters of anaerobic capacity were obtained (peak power (PP) and peak power/body weight (PP/BW)). Participants were thoroughly informed about the test and preliminary test was done to educate the subjects, since they were not aware of their maximal capabilities.

Anthropometric measurements

Muscle cross-sectional areas were obtained measuring total thigh circumference (C_T) (by tape), skin folds (S_Q) (with John-Bull calliper) and epicondylar distance – d_E (with anatomic calliper). With the subjects standing, the midpoint of the thigh was determined as the distance halfway between the greater trochanter and lateral epicondyle. A pen was used to make marks 4 cm distal to the midpoint over the quadriceps muscle group. Circumference and skin fold measurements were made over these marks. The remaining anthropometric measurements were carried out with the subjects lying on a table, with their feet on the table surface and the knee bent at an approximately 90˚ angle. Thigh cross-sectional area (A_T), and muscle cross-sectional area (A_M) were calculated based on anthropometric estimates and factor of correction according to Knapik (1996) as follows:

$$A_T = 0.826 \cdot C_T^2 / 4 \cdot \pi$$

$$A_M = 0.826 \cdot \pi/4 \cdot ((C_T/\pi - S_Q)^2 - (0.3 \cdot d_E)^2)$$

Procedures

The training program was based on dynamic strength training. Training sessions were at a frequency of three days/wk lasting for eight weeks. Each training session was designed in pyramidal manner, with five series per exercise. The three major exercises used: angled leg press, leg extensions, and lying leg curls. The level of weight was progressively increased with each series of exercise (60 %, 70 %, 80 %, 90 % 1RM (one repetition maximum)) and the number of repetitions inside the series was proportionally decreased (10, 8, 6, 4). At the end of exercise, where the load was 100-120 % 1RM 1-2 eccentric muscle actions were done.

RESULTS

Table 1 shows physical characteristics of the subjects. Normally, there were no changes in body height after eight weeks of the strength training program, but statistically significant changes of body mass were recorded (BW 2 – BW 1 = 2.35, $p<0.01$).

Table 1: Physical characteristics of the subjects

Variables	M±SD	MAX	MIN
Age (year)	20.50±1.32	23	19
BH (cm)	180.40±6.64	193	170
BW 1 (kg)	77.47±5.66	89	64
BW 2 (kg)	78.13±5.40	90	66

Legend:
BH – body height
BW 1 – body weight at the beginning of the eight-week training program
BW 2 – body weight at the end of the eight-week training program
M±SD – mean ± standard deviation

The obtained values of the anthropometric measurements of both thighs are shown in Table 2. After the training program, the increase in thigh circumference was significant for both legs (right leg 5.48±1.12%, left leg 5.81±1.03%; p<0.01). Thigh CSA (A_M) of the right and left leg increased by 5.58±1.22% and 6.45±1.03% after eight weeks, respectively. This increase was statistically significant (p<0.01). Muscle cross-sectional area for both right and left leg was increased (right 7.15±1.28%, left 7.53±1.20%) and was statistically significant (p<0.01). Significant correlation was established between the strength gain and the CSA increase of left and right thigh muscles after eight weeks of training (r = 3.21, p<0.05).

Table 2: Changes in thigh muscle cross-sectional area

Variables		At the beginning M±SD	After 8 weeks M±SD	t	p
Right leg	C_T (cm)	49.36±2.47	50.75±2.59	18.15	0.01
	A_T (cm²)	160.63±17.37	169.7±17.39	18.15	0.01
	A_M (cm²)	130.45±15.65	138.71±15.84	18.28	0.01
Left leg	C_T (cm)	49.47±2.45	50.94±2.57	19.76	0.01
	A_T (cm²)	157.83±16.49	167.09±17.16	19.16	0.01
	A_M (cm²)	131.7 ±14.68	139.59±14.84	18.15	0.01

Legend:
C_T – circumference of the thigh
A_T – thigh cross-sectional area
A_M – thigh muscle cross-sectional area
t – t test
p – p test

Comparing pre-exercise results with the results at the end of the strength training program, changes of the variables that define anaerobic capacity can be observed: peak power and peak power/body weight. The recorded increase of variable peak power was 9.91±1.42%, and is statistically significant (t=7.22, p<0.01). The gain of relative variable peak power/body weight at the end of the training program was also significant: 9.05±1.44% (t=8.42, p<0.01).

Table 3: Ergometer test results

Variables	M±SD	MAX	MIN
PP_1 (watt)	719.36±114.92	941	574
PP_1/BW_1	9.28±1.27	11.32	8.74
PP_2 (watt)	790.68±112.72	954	622
PP_2/BW_2	10.12±1.25	11.61	9.15

Legend:
PP_1 – peak power at the beginning of the training program
PP_1/BW_1 – peak power/body weight ratio at the beginning of the training program
PP_2 – peak power at the end of the training program
PP_2/BW_2 – peak power/body weight ratio at the end of the training program

DISCUSION

Strength, speed and endurance are important biomotor abilities for most physical movements. Their development is the key to successful performance. Sport training induces significant changes in skeletal muscles, such as hypertrophy. Hypertrophy as a mean of adaptation of skeletal muscle is usually seen in strength training. Overload as one of the basic principles is to blame according to many authors (Costill et al., 1979; McCall et al., 1996, Abe et al., 2000). The first signs of measurable hypertrophy could be seen after five to six weeks of intensive strength training (Moritani & DeVries, 1979). Primarily, this kind of adaptation inside working muscles appears due to increase of synthesis of contractile proteins. In addition to the increase in contractile proteins in the muscle cell, metabolic changes are also present. During high demanding activities amount of intracellular glycogen, phosphagen pool and amount of glycolytic enzymes are rising (Costill et al., 1979; Roberts et al., 1982; Nevill et al., 1989; Medbo et al, 1990).

Some other types of sport training will induce aerobic adaptation in the working muscles. Endurance training for example will provoke increase of oxidative enzymes and number of mitochondria in the muscles (Saltin & Astrand, 1967; Kayar et al., 1986).

It is necessary to say that alongside changes inside the muscles, there are adaptation reactions of surrounding tissues as well; increased capillarisation is one of them. During high intensity physical activity, the perfusion of working muscles increases 10 times or even more. Opinions on this subject are divided, but the majority of reports indicate that the ratio between the number of capillaries and the cross-sectional area of the muscle remain unchanged (McCall et al., 1996).

Applied strength training that lasted for eight weeks led to an increase in muscle CSA for both legs (left 7.89% and right 8.26%) Other authors reported similar findings for previously non trained individuals (Hakkinen et al., 1985; Higbie et al., 1996).

As stated earlier, metabolic changes follow an increase in muscle CSA. Our WAnT findings at the beginning and at the end of the training program support this theory. Variable PP and PP/BM were higher: 9.9%, 9.05%, respectively (for both variables $p<0.01$). Beneke et al. (2002) presented a paper in which they proved that aerobic component contribute up to 18% of total energy requirements for 30 second all-out test.

The alactic component of energy sources gives 31%, and high energy phosphates enable 50% of all energy output. The recorded gains in PP and PP/BM depict the changes of anaerobic capacities of the subjects after the applied strength training protocol.

After all authors of this study put into correlation the increase in variable PP and the increase in muscle CSA, and there was positive statistically significant correlation relationship ($p<0.05$). The underlying mechanisms of recorded adaptations are widely examined, but the exact nature of their influence on some aspects is still not completely understood. The variability in muscle CSA increase based on different reports could be a result of different training regimes, test modalities but can also be based on gender and age-related differences.

The results of the present study indicate that strength training lasting for eight weeks lead to a significant increase of muscle CSA. During this period, important metabolic changes inside working muscles also occur, which are recorded through variables obtained via WAnT. Furthermore, an important finding is that metabolic changes follow hypertrophic ones, and the foundation for this statement is the high correlation in increase of measured muscle CSA and PP variables.

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