Changes in myosin heavy chain composition with heavy resistance training in 60- to 75-year-old men and women

Abstract The purpose of this investigation was to assess the myosin heavy chain (MHC) expression in the vastus lateralis muscle from elderly men and women, and to determine whether heavy resistance training influences its expression. Twenty healthy, mildly physically active subjects gave their informed consent to participate in the study. The experimental group consisted of seven men and seven women [mean (SD) age 65.5 (4.1) years] and the control group consisted of three men and three women [mean (SD) age 62.3 (3.6) years]. The 6-month resistance training program was divided into two phases with weeks 1–12 consisting of high-intensity resistance training, and weeks 13–24 involving power training. Muscle biopsy samples were taken from the vastus lateralis muscle at week 0 and week 24 using the needle biopsy technique. The male and female experimental groups both exhibited a significant decrease ($P \leq 0.05$) in the percentage of MHC IIb, while the experimental female group also demonstrated a significant increase ($P \leq 0.05$) in the expression of MHC IIa, after 24 weeks of heavy resistance training. There was no change in MHC expression within the control group. The male [130.4 (25.3) kg vs 171.1 (30.5) kg] and female [58.2 (8.3) kg vs 77.9 (11.1) kg] experimental groups exhibited a significant increase ($P \leq 0.05$) in the maximal strength values for the 1 repetition maximum (1RM) squat exercise. The control group showed no change in strength for the 1RM squat exercise for either the male [115.8 (35.10 kg vs 123.8 (47.2) kg] or female [57.5 (99.0) kg vs 58.3 (2.9) kg] groups. The results clearly show that elderly subjects undergoing heavy resistance training have the ability to produce a similar shift in the expression of MHC isoforms from MHC IIb to MHC IIa, as has been shown to occur in younger subjects. This highlights the plasticity of human skeletal muscle in response to heavy resistance training, even at older ages.

Key words Aging · Myosin · SDS-PAGE · Strength

Introduction

While examining the plasticity of skeletal muscle to chronic changes in the amount of neuromuscular activity, adaptations have been seen at the level of the myosin heavy chains (MHCs; Talmadge and Roy 1993). Changes in the expression of these MHC isoforms have also been observed with aging (Klitgaard et al. 1990b; Larsson et al. 1993). Analysis of myosin expression in skeletal muscle has attracted a great deal of attention because changes in the phenotypic expression appear to be related to muscle function and adaptations to a variety of physiological stimuli (Periasamy et al. 1989; Pette and Staron 1990).

There have been no long-term studies that have examined the use of very heavy resistance training protocols in inducing changes in the expression of MHC isoforms in aged skeletal muscle. A recent study by Williamson et al. (2000) using a lower-intensity resistance training program found that there was a reduction in the coexpression of hybrid MHCs (i.e., MHC I/IIa,
I/IIa/IIx, IIa/IIx), while favoring a significant increase in MHC I (10.4%) and a non-significant increase in MHC IIa (8.7%) in single fibers from older men (mean age 74 years) following 12 weeks of training. In another study, Willoughby and Pelsue (1998) looked at the MHC mRNA expression after moderate- and high-intensity resistance training in a group of elderly subjects (mean age 69 years). However, they did not report the specific expression of the MHC isoforms. In a cross-sectional study by Klitgaard et al. (1990a), the MHC composition was compared across five groups; three of trained elderly men (around 69 years of age), and a young and aged-matched control group. The trained elderly subjects were swimmers, runners or were strength-trained. It was found that the elderly control subjects had a 27% higher content of MHC I and correspondingly lower content of MHC IIa and MHC IIb. The swimmers and runners had nearly identical values to those in the age-matched control group, while the strength-trained subjects had a MHC composition similar to those observed in the young control group.

Previous studies involving both humans and rodents have shown that heavy resistance training induces adaptations in MHC isoforms. These shifts predominantly involve a rearrangement in the pattern of expression involving the fast MHC isoforms, from MHC IIb to MHC IIa in humans and MHC IIb to MHC IIx in rodents (Adams et al. 1993; Bamman et al. 1998; Staron et al. 1991, 1994). It was first proposed by Goldspink et al. (1991) that the gene responsible for encoding for MHC IIb may be a default gene that provides a readily available pool of fibers that transform into IIa fibers with increases in activity, regardless of the type. We hypothesized that a transformation from MHC IIb toward MHC IIa would also occur in the elderly, although this relationship has not yet been verified with long-term heavy resistance training. Therefore, the purpose of this investigation was to determine the changes in MHC expression in the vastus lateralis muscle of elderly men and women in response to heavy resistance training.

**Methods**

**Subjects**

Twenty healthy, mildly physically active subjects gave their informed consent to participate in the study. The subject characteristics are given in Table 1. Approval for this study was granted by the Southern Cross University Ethics Committee on Human Experimentation.

**Experimental strength training**

The 6-month resistance training program was divided into two phases and was designed to promote muscle hypertrophy, strength and power. Weeks 1–12 consisted of high-intensity resistance training, and weeks 13–24 involved power training. The power training aspect of the program for weeks 13–24 was included to promote the activation of high-threshold motor units. Training consisted of two sessions per week of three sets of Smith-machine squat, leg press, leg extension, leg curl and deadlift, as well as a number of upper body exercises, thus making it a total-body training program. Only six exercises were performed per workout. The load intensity for the high-intensity resistance training (weeks 1–12) began at 10–12 repetitions maximum (RM) for the first 4 weeks, then 6–8RM for the next 4 weeks, and 3–5RM for the last 4 weeks. The power-training phase (weeks 13–24) involved 3–6 repetitions at 30–50% 1RM only for the Smith-machine squat, leg press and leg curl exercises. The remainder of the exercises were performed non-explosively and involved a repeat of the periodization cycle for weeks 1–12. To maintain strength levels during weeks 13–24, every sixth workout performed was heavy (4–6RM). A warm-up of 3–5 min on an exercise bike was performed prior to each workout. Warm-up sets of increasing percentages were also used for the Smith-machine squat, leg press, leg extension, leg curl, deadlift and upper body exercises.

**Measurement of I RM**

The measurement of maximal strength values was performed with the aid of the Smith-machine during the squat exercise to a knee angle of 110°. In the testing of the maximal load, separate I RM contractions were performed, allowing 1.5 min for recovery between the trials. After each repetition the load was increased until the subject was unable to squat to the required knee angle. The last acceptable squat with the highest possible load was determined as the I RM (Häkkinen et al. 2000).

**Muscle biopsy sampling**

Two muscle biopsy samples (week 0 and week 24) were obtained using the percutaneous needle biopsy technique of Bergström (1962), as modified by Evans et al. (1982). Tissue samples were taken from a site one-third of the length from the proximal lateral edge of the patella to the anterior superior iliac spine of the vastus lateralis muscle. Approximately 60–75 mg of skeletal muscle was removed and frozen in isopentane that had been precooled in liquid nitrogen, and stored at −80 °C for later analysis. The analyses performed during this investigation were part of a larger study, and the histochemical fiber data will be reported in detail elsewhere. However, it should be noted that both type I and II fibers exhibited a significant increase in size for the experimental group, but no changes were observed for the control group.

**MHC analysis**

Muscle samples were sectioned using a cryostat at −20 °C to a thickness of 40 μm. Three to five of these sections were placed into 0.5–1 ml of a lysing buffer containing 36.25% glycerol, 6.25% 2-mercaptoethanol and 2% sodium dodecyl sulfate (SDS) in Tris-HCl buffer (pH 6.8). Small amounts of the extracts (8 μl) were loaded on 6% SDS-polyacrylamide gels with 4% stacking gels and run using a Mini-Protein II electrophoresis system (Bio-Rad, Regents Park, NSW, Australia).

The running conditions consisted of 70 V (constant voltage) for 30 min followed by 150 V (constant voltage) for 6 h using a Bio-Rad PowerPac (model 300) power supply. Gels were stained using Bio-Safe Coomassie Blue (Bio-Rad). This procedure was based on the SDS-polyacrylamide gel electrophoresis protocol described by Talmadge and Roy (1993) and Humphries et al. (1997).

The gels were scanned electronically and the identification of MHC protein bands was conducted using Scion Image software beta version 3b. The bands were identified as MHC I, MHC IIa and MHC IIb isoforms from a myosin molecular weight standard (Kaleidoscope Prestained Standards, Bio-Rad) and on the basis of previously determined migration patterns, using densitometric and image processing techniques (Klitgaard et al. 1990b; Talmadge and Roy 1993). The integrated peak areas corresponding to each band were summed and are expressed relative to the total area. Results