Time course for arm and chest muscle thickness changes following bench press training

RIKI OGASAWARA[1], ROBERT S. THIEBAUD[2], JEREMY P. LOENNEKE[2], MARK LOFTIN[3], TAKASHI ABE[1,3]*

[1]Graduate School of Frontier Sciences, University of Tokyo, Kashiwa, Chiba, Japan
[2]Department of Health and Exercise Science, University of Oklahoma, Norman, OK, USA
[3]Department of Health, Exercise Science and Recreation Management, University of Mississippi, Oxford, MS, USA
*Corresponding author: Takashi Abe, PhD; Department of Health, Exercise Science and Recreation Management, University of Mississippi, 215 Turner Center, Oxford, MS 38677, USA; Phone: +1-662-915-5521; Fax: +1-662-915-5525; E-mail: t12abe@gmail.com

(Received: August 1, 2012; Accepted after revision: November 5, 2012)

Abstract: The purpose of this study was to investigate the time course of hypertrophic adaptations in both the upper arm and trunk muscles following high-intensity bench press training. Seven previously untrained young men (aged 25 ± 3 years) performed free-weight bench press training 3 days (Monday, Wednesday and Friday) per week for 24 weeks. Training intensity and volume were set at 75% of one repetition maximum (1-RM) and 30 repetitions (3 sets of 10 repetitions, with 2 – 3 min of rest between sets), respectively. Muscle thickness (MTH) was measured using B-mode ultrasound at three sites: the biceps and triceps brachii and the pectoralis major. Measurements were taken a week prior to the start of training, before the training session on every Monday and 3 days after the final training session. Pairwise comparisons from baseline revealed that pectoralis major MTH significantly increased after week-1 ($p = 0.002$), triceps MTH increased after week-5 ($p = 0.001$) and 1-RM strength increased after week-3 ($p = 0.001$) while no changes were observed in the biceps MTH from baseline. Significant muscle hypertrophy was observed earlier in the chest compared to that of the triceps. Our results indicate that the time course of the muscle hypertrophic response differs between the upper arm and chest.

Keywords: strength training, B-mode ultrasound, trunk muscle thickness, muscular strength, muscle hypertrophy

Introduction

Heavy resistance training consistently increases skeletal muscle size and strength in men and women regardless of age [1, 2]. Although most studies have evaluated muscle hypertrophy and increased strength at the beginning and end of the training, fewer studies have investigated the time course of the muscle hypertrophic adaptations to heavy resistance training. These studies demonstrated that heavy resistance training-induced muscle adaptations are greater during the early phase (i.e., first ~10 weeks) of training than during the later phase [3–6] and that a significant increase in muscle size had occurred ~4 weeks following the initiation of resistance training [3, 7, 8]. Most of these studies observed limb muscle hypertrophy; however, very few studies report on muscle size changes of the trunk following heavy resistance training [3, 9]. One study reported on the time course of chest muscle hypertrophy following whole body (4 upper body and 2 lower body exercises) resistance training (3); however, the muscle hypertrophy was influenced by multiple exercises during the training sessions. In general, it is thought that the muscle hypertrophic responses are almost identical between trunk and limb muscles. However, it is unknown whether the time course of hypertrophic adaptations is the same between trunk and limb muscles following a single mode of multi-joint heavy resistance training. The purpose of this study was to investigate the time course changes in muscle size in both the chest and upper arm following 24 weeks of heavy bench press training. We hypothesized that trunk and limb hypertrophic responses would differ after a single mode of multi-joint heavy resistance training.

Methods

Seven healthy young men volunteered to participate in this study (aged 25±3 years, height 1.73±0.08 m, body mass 65.4±6.2 kg). All subjects were informed of the procedures, risks, and benefits, and signed an informed consent document approved by the University of Tokyo. All subjects were considered untrained and had not participated in a regular resistance exercise program for at least 1 year prior to the start of the study.

The subjects performed supervised free-weight bench press training 3 days (Monday, Wednesday and Friday) per week for 24 weeks. Training intensity and volume were set at 75% of one repetition maximum (1-RM) and 30 repetitions (3 sets of 10 repetitions, with 2–3 min of rest between sets), respectively. The 1-RM was assessed using free-weight bench press a week prior to the start of the training (after two times of familiarization) and every 3 weeks during training. The training load for each subject was then adjusted to the new 1-RM. During training sessions as well as 1-RM testing, the pronated grip width was set at 200% of the biacromial breadth for standardization across subjects. The 1-RM was determined by progressively increasing (to the nearest 2.5 kg increment) the weight lifted until the subject failed to lift the weight through a full range of motion. Usually about five trials were required to complete a 1-RM test. Approximately a 1.5-min rest was taken between trials.

Muscle thickness (MTH) was measured using B-mode ultrasound (Aloka SSD-500, Tokyo, Japan) at three sites: the biceps and triceps brachii (at 60% distal between the lateral epicondyle of the humerus and the acromial process of the scapula), and the pectoralis major (at the site between third and fourth of costa under the clavicle midpoint), as described previously [10, 11]. Prior to the testing, measurement points on the biceps (BB), triceps (TB) and pectoralis major (PM) were marked by a felt pen, and the same measurement points were used for each testing session. The measurements were carried out while the subjects stood with their elbows extended and relaxed. A 5-MHz scanning head was placed on the measurement site without depressing the dermal surface. The subcutaneous adipose tissue–muscle interface and the muscle–bone interface were identified from the ultrasonic image, and the distance between two interfaces was taken as MTH. Previous studies have reported that MTH is strongly correlated ($r = 0.90$–0.97) with muscle cross-sectional area or muscle volume in upper arm and chest muscles [11, 12]. Measurements were taken a week prior to the start of training, before the training session on every Monday, and 3 days after the final training session. Pilot data from our laboratory suggest that the acute increase in MTH (~12%) following bench press returns to pre-exercise levels within 24 h and is maintained for up to 48 h after the session. This suggests that the measured MTH is unaffected by the exercise-induced acute inflammatory response although it is acknowledged that is an indirect marker of muscle damage. The test–retest reliability for this method was less than 1% for the biceps and triceps [10] and 1.7% for chest [11], as described previously.

Statistical analysis was performed by one-way repeated measures ANOVAs for strength and MTH. Statistical significance was set at $p \leq 0.05$. When a significant time effect was observed, paired sample *t*-tests determined differences in MTH from pre-values to 24 weeks (24 comparisons) with a Bonferroni corrected alpha of $p \leq 0.002$. When a significant time effect occurred for strength, paired sample *t*-tests were performed from pre-values to 24 weeks (9 comparisons) using a Bonferroni corrected alpha of $p \leq 0.006$. In addition, paired sample *t*-tests were performed for strength and MTH between pre vs. 3 and 6 weeks (Phase 1); 6 weeks vs. 9, 12 and 15 weeks (Phase 2); and 15 weeks vs. 18, 21 and 24 weeks (Phase 3) using a Bonferroni corrected alpha of $p \leq 0.006$. The rate of change in MTH and strength was determined with a logarithmic regression model.

Results

One-way repeated measures ANOVA analysis revealed a significant time effect for strength ($p = 0.001$) and MTH (PM, $p = 0.001$; TB, $p = 0.001$; and BB, $p = 0.035$). Pairwise comparisons from baseline revealed that PM MTH significantly increased after week-1 ($p = 0.002$), TB MTH significantly increased after week-5 ($p = 0.001$) and strength significantly increased after week-3 ($p = 0.001$) *(Fig. 1)*. No significant changes were observed in the BB MTH from baseline using the Bonferroni corrected alpha $p \leq 0.002$.

Table I shows changes in MTH and strength during different phases of training. PM MTH and strength significantly increased in all three phases of training. TB MTH increased in phases 1 and 2, and BB MTH did not significantly increase in any phase.

The logarithmic regression model equations examining the rate of change were $y = 21.597 + (2.542 * \ln(x))$ for PM ($r^2 = 0.960$), $y = 34.246 + (1.869 * \ln(x))$ for TB ($r^2 = 0.976$), and $y = 42.729 + (10.675 * \ln(x))$ for strength ($r^2 = 0.993$).

Discussion

The main findings of the present study were that the time course of muscle hypertrophy differs between the upper arm (triceps brachii) and trunk (pectoralis major) muscles; e.g. significant increase in muscle hypertrophy occurred earlier in the trunk compared to that of the upper arm. Furthermore, the trunk muscle increased gradually throughout the training period while the triceps muscle increased significantly in only early phases (~week 15).

Previous studies investigating limb muscle hypertrophy following heavy resistance training reported that a significant increase in limb muscle size had occurred after ~4 weeks of heavy resistance training [3, 7, 8]. However, it was unknown whether the time course of muscle hypertrophy was the same between trunk and limb muscles following multi-joint single exercise training. Our results suggest that trunk muscle hypertrophy occurs earlier and that the increases were observed throughout

Table I Changes in muscle thickness and maximal dynamic (1-RM) strength each 3 weeks period during 24 weeks of heavy bench press training

	PM (mm)	TB (mm)	BB (mm)	1-RM (kg)
Pre	21.1 (3.2)	34.2 (3.4)	25.1 (3.9)	51.0 (9.8)
3 weeks	24.5 (3.6)[a]	35.8 (3.4)[a]	25.0 (3.3)	55.3 (11.3)[a]
6 weeks	25.3 (3.8)[a]	37.7 (3.1)[a]	25.4 (2.7)	61.2 (12.6)[a]
9 weeks	27.0 (4.1)[b]	38.4 (3.0)	25.2 (2.8)	65.7 (13.9)[b]
12 weeks	27.7 (4.2)[b]	39.1 (2.9)	26.2 (2.8)	68.7 (14.0)[b]
15 weeks	28.4 (4.2)[b]	39.0 (2.6)[b]	26.5 (2.9)	71.2 (14.1)[b]
18 weeks	29.1 (4.3)	39.3 (3.0)	25.8 (2.6)	73.5 (15.7)
21 weeks	29.4 (4.5)	39.8 (3.2)	26.0 (2.7)	75.6 (16.4)[c]
24 weeks	30.2 (4.4)[c]	40.1 (3.1)	26.0 (2.6)	77.4 (16.9)[c]

[a] Pre vs. 3 and 6 weeks; [b] 6 vs. 9, 12, 15 weeks; [c] 15 vs. 18, 21, 24 weeks. Significance was set at a Bonferroni corrected alpha of $p \leq 0.006$. All values are represented as mean (SD)

the training period following heavy bench press exercise training.

In the present study, the grip width was set at 200% of the biacromial distance (BAD) for standardization across subjects. Previous studies using experienced weightlifters reported that moving from a narrow (100% of BAD) to a wider pronated grip (200% of BAD) width increased muscle activity in the sternoclavicular portion of the pectoralis major and decreased triceps brachii activity [13, 14]. However, grip width appeared to have no influence on muscle activity in the clavicular portion of the pectoralis major muscle [13, 14]. In this study, the MTH measurement site of the pectoralis major was between the third and fourth costa under the clavicle midpoint, where previous studies have found no differences in muscle activation. Therefore, the grip width in this study did not likely affect the results.

Our findings showed that the time course of muscle hypertrophy differs between upper arm and trunk muscles. The reasons for this phenomenon are unclear, but a couple of possibilities exist. First, the different time course of the two muscles may reflect differences in the load imposed on each individual muscle (pectoralis major, triceps brachii and deltoid) during the bench press exercise, ultimately affecting the degree of muscle activation. This is of importance because it has been hypothesized that levels of muscle activation are related to changes in muscle protein synthesis [15]. Second, although speculative, it is possible that the muscle protein synthetic capacity is greater in muscles of the trunk compared with that of the limbs. Unfortunately, the molecular mechanisms for upper body muscle hypertrophy are currently under studied when compared with what is known for the lower body. However, the results of the present study suggest that heavy resistance exercise induced activation of muscle protein metabolism may be more responsive in the chest muscle compared to the triceps brachii muscle. Further study is needed to clarify this issue.

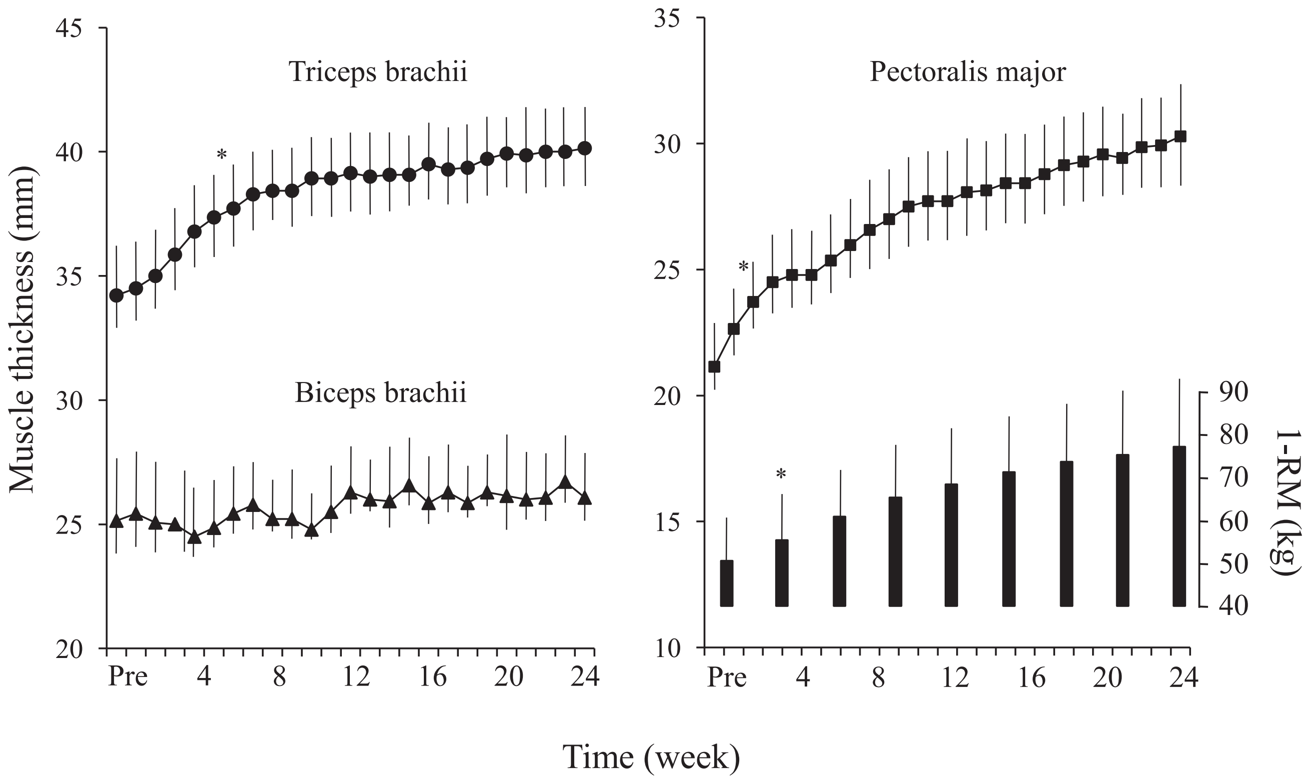

Fig. 1. Time course changes in muscle thickness of the upper arm and chest muscles and maximal dynamic (1-RM) strength during 24 weeks of heavy bench press training. Values are means ± SD. $*p < 0.05$, significant increase in muscle hypertrophy appeared from baseline

In conclusion, significant increases in muscle hypertrophy were observed earlier in the chest compared to that of the upper arm. Furthermore, the trunk muscle increased gradually throughout the training period while the triceps muscle increased in only early phases (~week 15). Our results indicate that the time-course of the muscle hypertrophic response differs between the upper arm and chest.

Conflict of Interest Statement

None of the authors had financial or personal conflict of interest with regard to this study.

References

1. American College of Sports Medicine: Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. Med Sci Sports Exerc 43, 1334–1359 (2011)
2. Pollock ML, Franklin BA, Balady GJ et al.: Resistance exercise in individuals with and without cardiovascular disease benefits, rationale, safety, and prescription. An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine. Circulation 101, 828–833 (2000)
3. Abe T, DeHoyos DV, Pollock ML, Garzarella L: Time course for strength and muscle thickness changes following upper and lower body resistance training in men and women. Eur J Appl Physiol 81, 174–180 (2000)
4. Ikai M, Fukunaga T: A study on training effect on strength per unit muscle cross-sectional area of muscle by means of ultrasonic measurement. Int Z Angew Physiol 28, 173–180 (1970)
5. Ogasawara R, Yasuda T, Sakamaki M, Ozaki H, Abe T: Effects of periodic and continued resistance training on muscle CSA and strength in previously untrained men. Clin Physiol Func Imaging 31, 399–404 (2011)
6. Sale DG: Neural adaptation to resistance training. Med Sci Sports Exerc 20, S135–S145 (1988)
7. Seynnes OR, de Boer M, Narici MV: Early skeletal muscle hypertrophy and architectural changes in response to high-intensity resistance training. J Appl Physiol 102, 368–373 (2007)
8. DeFreitas JM, Beck TW, Stock MS, Dillon MA, Kasishke PR 2nd: An examination of the time course of training-induced skeletal muscle hypertrophy. Eur J Appl Physiol 111, 2785–2790 (2011)
9. Yasuda T, Ogasawara R, Sakamaki M, Bemben MG, Abe T: Relationship between limb and trunk muscle hypertrophy following high-intensity resistance training and blood flow-restricted low-intensity resistance training. Clin Physiol Func Imaging 31, 347–351 (2011)
10. Abe T, Kondo M, Kawakami Y, Fukunaga T: Prediction equations for body composition of Japanese adults by B-mode ultrasound. Am J Hum Biol 6, 161–170 (1994)
11. Yasuda T, Fujita S, Ogasawara R, Sato Y, Abe T: Effects of low-intensity bench press training with restricted arm muscle blood flow on chest muscle hypertrophy: a pilot study. Clin Physiol Funct Imaging 30, 338–343 (2010)
12. Miyatani M, Kanehisa H, Ito M, Kawakami Y, Fukunaga T: The accuracy of volume estimates using ultrasound muscle thickness measurements in different muscle groups. Eur J Appl Physiol 91, 264–272 (2004)
13. Barnett C, Kippers V, Turner P: Effects of variation on the bench press exercise on the EMG activity of five shoulder muscles. J Strength Cond Res 9, 222–227 (1995)
14. Lehman GJ: The influence of grip width and forearm pronation/supination on upper-body myoelectric activity during the flat bench press. J Strength Cond Res 19, 587–591 (2005)
15. Burd NA, West DW, Staples AW, Atherton PJ, Baker JM, Moore DR, Holwerda AM, Parise G, Rennie MJ, Baker SK, Phillips SM: Low-load high volume resistance exercise stimulates muscle protein synthesis more than high-load low volume resistance exercise in young men. PLoS One 5, e12033 (2010)