レジスタンス・トレーニングによる筋肥大（英文）

安部　孝、児島康介、Charles F. Kearns、銕平名博、福田　純

Whole body muscle hypertrophy from resistance training: distribution and total mass

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SHORT REPORT

Whole body muscle hypertrophy from resistance training: distribution and total mass

T Abe, K Kojima, C F Kearns, H Yohena, J Fukuda

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Objective: To examine the absolute and relative changes in skeletal muscle (SM) size using whole body magnetic resonance imaging (MRI) in response to heavy resistance training (RT).
Method: Three young men trained three days a week for 16 weeks.
Results: MRI measured total SM mass and fat free mass (FFM) had increased by 4.2 kg and 2.6 kg respectively after resistance training.
Conclusions: RT induces larger increases in SM mass than in FFM. RT induced muscle hypertrophy does not occur uniformly throughout each individual muscle or region of the body. Therefore the distribution of muscle hypertrophy and total SM mass are important for evaluating the effects of total body RT on muscle size.

Accurate measurements of skeletal muscle (SM) mass and distribution in humans are important for studies of SM hypertrophy response to heavy resistance training (RT). Currently, the most accurate in vivo methods of measuring SM mass are multiscan magnetic resonance imaging (MRI) and computed tomography.[1] Despite its safety, most MRI studies have only evaluated regional—for example, arms, trunk, and legs—SM mass.[1] We recently reported whole body MRI using a contiguous slice by slice (no interslice gap) method to evaluate total SM mass and its distribution.[2] Using this approach, the distribution of RT induced whole body SM hypertrophy can be investigated.

To date, most studies[3 4] have only evaluated limb muscle hypertrophy, and very few have reported RT induced muscle hypertrophy in the trunk region.[5] More importantly, the distribution of the relative increases in RT induced muscle hypertrophy has not been reported. Thus the purpose of this pilot study was to examine the absolute and relative changes in SM size using contiguous whole body MRI scans in response to RT.

METHODS

Three healthy young men (age 20–21 years) volunteered for the study. All were physically active, but none had participated in RT before the start of the programme. All subjects signed informed consent documents. The department's ethical commission approved the study.

RT was carried out three days a week for 16 weeks. Three lower body (squat, knee extension, and knee flexion) and two upper body (bench press and latissimus dorsi pull down) exercises were performed. Workouts consisted of a warm up set followed by three sets to failure of 8–12 repetitions for each of the five exercises. The loads were progressively increased to maintain this range of repetitions per set. One repetition maximum (1RM) strength was determined by progressively increasing the weight lifted until the subject failed to lift the weight through a full rage of motion. Strength of the squat was assessed using the 3RM test.

Table 1 Body composition and strength before and after training

	Subject	Before	After	Difference	Change (%)
Body mass (kg)	A	62.9	65.0	2.1	3.3
	B	59.1	61.3	2.2	3.7
	C	65.2	67.9	2.7	4.1
	Mean	62.4	64.7	2.3	3.7
FFM (kg)	A	55.1	57.2	2.1	3.8
	B	53.5	55.6	2.1	3.9
	C	59.9	63.4	3.5	5.8
	Mean	56.1	58.7	2.6	4.5
Total SM mass (kg)	A	20.5	24.6	4.1	20.0
	B	19.6	24.7	5.1	26.0
	C	25.1	28.6	3.5	13.9
	Mean	21.7	26.0	4.2	19.4
BP strength (kg)	A	42.5	57.5	15.0	35.3
	B	40.0	55.0	15.0	37.5
	C	60.0	70.0	10.0	16.7
	Mean	47.5	60.8	13.3	29.8

BP, Bench press; FFM, fat free mass; SM, skeletal muscle.

Total body SM distribution and mass were measured using an MRI 1.5-T scanner (GE Signa, Milwaukee, Wisconsin, USA) with spin echo sequence (TR, 1500 milliseconds; TE, 17 milliseconds).[2] Contiguous transverse images with 1.0 cm slice thickness (no interslice gap) were obtained from the first cervical vertebra to the ankle joints for each subject. Four sets extended from the first cervical vertebra to the femoral head during breath holding (about 20 seconds). The other three sets of acquisitions were obtained from the femoral head to the ankle joints during normal breathing. In each slice, the cross sectional area (CSA) was digitised, and the muscle tissue volume (cm^3) per slice was calculated by multiplying the CSA (cm^2) by slice thickness (cm). SM volume units (litres) were converted into mass units (kg) by multiplying the volumes by the assumed constant density for SM (1.041 kg/l).[6]

Body density was measured by hydrostatic weighing with simultaneous measurement of residual lung volume by oxygen dilution. Body fat percentage was calculated from body density using the equation of Brozek *et al*.[7] Fat free mass (FFM) was estimated as body mass minus fat mass.

RESULTS

Mean relative increases in upper body and lower body strength (1RM or 3RM) after RT were 30% and 16% respectively. Body fat decreased by 0.6% on average, and

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Abbreviations: CSA, cross sectional area; MRI, magnetic resonance imaging; RT, resistance training; SM, skeletal muscle; FFM, fat free mass

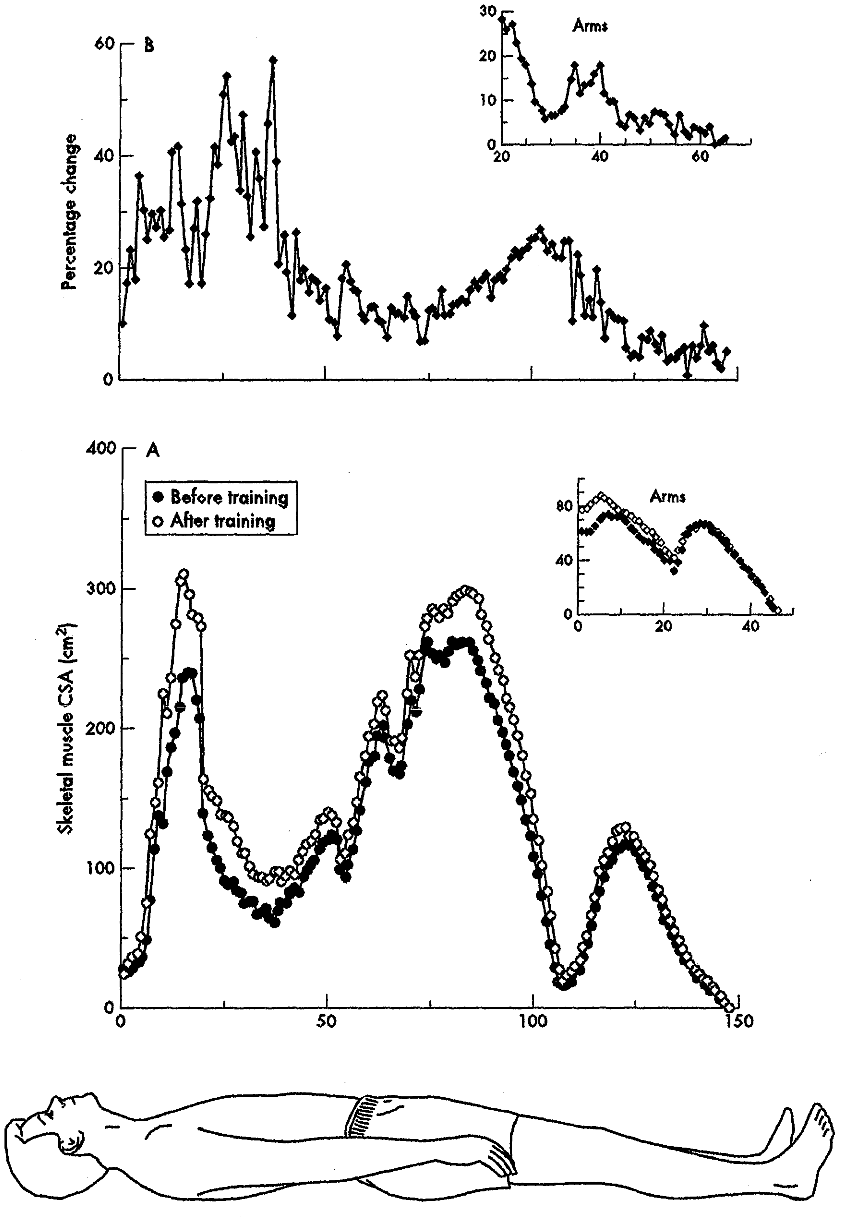

Figure 1 Absolute and relative changes in skeletal muscle size distribution in response to total body resistance training. CSA, Cross sectional area.

FFM increased by 2.6 kg after RT. The mean increase in total SM mass after RT was 4.2 kg (table 1).

The greatest absolute increases in muscle CSA were seen at the level of the shoulder, chest, upper thigh, and upper portion of the upper arm (fig 1A; subject A). Relative changes in muscle hypertrophy were greater at the level of the shoulder, chest, and upper portion of the upper arm (+25–40%) compared with the waist, hip, forearm, thigh, and lower leg (+10–20%) (fig 1B). The relative increase in muscle CSA of all three subjects was 26% at the shoulder (peak CSA level) and 18% and 9% at the mid-thigh and lower leg respectively.

DISCUSSION

It has been reported that FFM increases by about 2.0 kg after 10–16 weeks of total body RT.[3 4] However, very little is known about the degree of SM increase after RT. The mean increase in SM in this study was 4.2 kg. Nelson and coworkers[8] reported a 1.4 kg (24 hour urinary creatinine) and 1.6 kg (in vivo neutron activation) increase in total SM in postmenopausal women after 52 weeks of randomised controlled RT. Although the SM gain in our study was threefold higher than in other reports,[8] the relative increases in limb muscle CSA were consistent with the literature (5–10% increase in lower body and 15–30% increase in upper body muscle CSA after 12–16 weeks of RT).[3 4] Nelson *et al*,[8] on the other hand, only reported a 6–8% increase in arm and thigh muscle CSA. The differences in RT induced SM gain between our data and other reports are probably due to differences in the training programmes—for example, training frequency.

The novel finding of this study was that the RT induced increase in total SM mass measured by MRI was larger than the increase in FFM. Another study[8] showed decreases in non-SM lean tissue (as measured by in vivo neutron activation) and increases[8] or decreases[9] in total body water

Take home message

Resistance training induces larger increases in skeletal muscle mass than in fat free mass. Muscle hypertrophy does not occur uniformly throughout each individual muscle or region of the body.

after RT. In our study, there were no differences in total body water (bioelectrical impedance analysis method) after training (63.6–69.3% before *v* 63.4–67.5% after). One possible explanation is that non-SM lean tissue may decrease after RT. Clearly, more work is needed to determine if there are changes in organ or non-SM lean tissue after RT.

If changes in muscle hypertrophy were constant across every muscle, then a single anatomical CSA would reflect changes in SM mass. However, our data show that muscle hypertrophy did not occur uniformly throughout each individual muscle or region—for example, trunk, arm, and leg—of the body. Therefore the distribution of muscle hypertrophy and SM mass are important for evaluating the effects of total body RT because there are differences between relative changes in individual muscle CSA and SM mass.

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Authors' affiliations
T Abe, K Kojima, Tokyo Metropolitan University, Exercise and Sport Science, Minami-Ohsawa, Hachioji, Tokyo 192-0397, Japan
C F Kearns, Schering-Plough Research Institute, Kenilworth, NJ 07033-1300, USA
H Yohena, J Fukuda, Fujisawa-Shonandai Hospital, Fujisawa, Kanagawa, Japan

Correspondence to: Dr Abe, Tokyo Metropolitan University, Exercise and Sport Science, Minami-Ohsawa, Hachioji, Tokyo 192-0397, Japan; abebe@comp.metro-u.ac.jp

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How valid is a self reported 12 month sports injury history?

B J Gabbe, C F Finch, K L Bennell, H Wajswelner

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Background: A past injury history is one of the most commonly cited risk factors for sports injury. Often, injury history data are collected by self report surveys, with the potential for recall bias.
Objective: To assess the accuracy of a 12 month injury history recall in a population of 70 community level Australian football players.
Methods: The retrospective, self reported injury histories of 70 community level Australian football players were compared with prospective injury surveillance records for the same 12 month period. The accuracy of the players' recall of the number of injuries, injured body regions, and injury diagnosis was assessed.
Results: Recall accuracy declined as the level of detail requested increased. All players could recall whether or not they were injured during the previous year. Almost 80% were able to accurately recall the number of injuries and body regions injured, but not the diagnoses, whereas only 61% were able to record the exact number, body region, and diagnosis of each injury sustained.
Discussion: The findings of this study highlight the difficulty of using retrospectively collected injury data for research purposes. Any injury research relying on self reported injury history data to establish the relation between injury history and injury risk should consider the validity of the self report injury histories.

One of the most commonly reported risk factors for sports injury is the presence of a positive past injury history.[1–6] However, often this is based on self reported data, relying on the participants' correct memory of events. This reliance on memory can introduce recall bias,[7,8] potentially leading to incorrect conclusions about the epidemiology of sports injuries sustained and the relation between past and future injury.

The potential for recall bias can be avoided altogether if self reported injury data are avoided. For example, information could be extracted from a participant's medical record or from prior injury surveillance records.[7] However, difficulties arise with respect to accessing medical record data for establishing an injury history. Sports participants can seek treatment from more than one type of health professional and in more than one location, increasing the difficulty of collecting the relevant information. In addition, continuing sports injury surveillance systems using prospective methods are relatively uncommon, particularly in Australia. Prospective studies are often time consuming and can be expensive to undertake because of the length of data collection and the degree of monitoring involved.[9,10] Therefore, studies designed to evaluate the relation between an injury history and a subsequent injury must often rely on self reported data.

Minimisation of recall bias is a prerequisite when the collection of self reported data cannot be avoided.[7] Providing