Effect of work-load exercise on the compensatory muscle hypertrophy in the hypophysectomized rat

Shigeru Yamada

Department of Sports Sciences, College of Arts and Sciences, the University of Tokyo,
3-8-1 Komaba, Meguro-ku, Tokyo 153

Summary

To study the role of growth hormone in the work-induced hypertrophy in skeletal muscle, effects of work-load exercise on skeletal muscles of hypophysectomized rat was compared with those of normal rats. The work-induced muscle hypertrophy was observed with hypophysectomized rat. The development of compensatory muscle hypertrophy and the accumulation of albumin in the work-loaded muscle took place in the hypophysectomized rat.

Key Words: Albumin, Skeletal muscle, Compensatory hypertrophy, Growth hormone.

Introduction

We have been studying the mechanisms bringing about the work-induced hypetrophy in the rat skeletal muscle and found that the tenotomy-induced hypertrophy in the skeletal muscle accompanies a significant increase in concentration of albumin in the hypertrophied muscle (1). The observation that the mutant rat defective in albumin synthesis failed to develop the work-induced muscle hypertrophy strongly suggested the possible correlation between the muscle albumin concentration and hypetrophy (2). However, the albumin deficient rat is also known to exhibit the lowered in born levels of testosterone and growth hormone (3). To rule out the possibility that the lowered tostosterone level might affect the development of the work-induced muscle hypertrophy, we studied the effect of work-load exercise on the skeletal muscle of the castrated male rats (4). This paper deals with the experiments on the work-load exercise in the skeletal muscle of the hypophysectomized rat and shows that neither growth hormone nor testosterone are primarily involved in the workinduced enlargement of the rat skeltal muscle.

Materials and Methods

Animals

Sprague-Dawley rats were obtained from the stock of CLEA Japan, Kanagawa.

Tenotomy

Rats of the same developmental stages were divided into control and experimental groups by weight-matching. Tenotomy and sham-operation of the hind legs were performed in the same manner as described previously (1). The plantaris and soleus muscles in both operated and contralateral limbs were removed for examination 7 days after operation.

Hypophysectomy

Rats weighing 70 to 95 g were anesthetized as above and hypophysectomized. The hypophysecto-mized rats were maintained for 3 to 4 weeks before use, at which time they weighed 100 to 120 g.

Assay of growth hormone

Blood samples were centrifuged and growth hormone in plasma was determined by a double-antibody radioimmunoassay method using materials supplied by NIADDK (5).

Preparation of antibody

Anti-64KDa protein antibody was prepared as described previously (1).

Polyacrylamide gel electrophoresis and immunoblotting

Methods for polyacrylamide gel electrophoresis and immunoblotting were performed in the same manner as described previously (1, 4).

Results

The effect of growth hormone on compensatory muscle hypertrophy was studied. Figure 1 shows that the growth hormone concentration in the hypophysectomized rats was negligible as compared to that in the sham-operated rats. To study the effect of work-load exercise on the muscle hypertrophy in hypophysectomized rat, the soleus and the plantaris muscles of one limb were work-loaded by tenotomy of the synergistic gastrocnemius muscle. The contralateral limb which received only sham-operation served as control. During the week following tenotomy, the work-loaded muscles of the tenotomized limb of hypophysectomized exhibited statistically significant increase in wet weight as compared to those of control muscles (Fig. 2). Total protein from the work-loaded and the control muscle were analyzed by means of SDS polyacrylamide gel electrophoresis (Fig. 3A). Changes in muscle albumin levels were compared between hypertrophied and control muscles of the hormone-depleted rats by means of Western-blotting (Fig. 3B). As observed in the case of normal rats, the amount of albumin significantly increased in the work-loaded muscles of the hormone-depleted animals.

These results strongly suggest that the possible correlation between albumin and exercise-induced muscle hypertrophy and that growth hormone is not essential for the development of muscle hypertrophy.

Discussion

Among biochemical parameters which may influence the rate of muscle hypertrophy, serum level growth hormone is known to exert pronounced effects (6, 7, 8, 9, 10, 11, 12, 13, 14,). Pituitary growth hormone is essential for normal growth of most body tissues in mammals. (17). Thus hypophysectomy prevents normal growth of mammals, while administration of excess growth hormone leads to gigantism (8, 11, 13, 15, 16). Although the response of different tissues to treatment with these hormones is not uniform and the mechanisms by which these hormones affect muscle mass and muscle protein composition remain only poorly understood, the accumulated facts raise the possibility that the observed inability of the NAR skeletal muscle to respond to work load training might be the consequence of the lowered inborn levels of testosterone and growth hormone in this mutant rat (3). Therefore, the effect of hypophysectomy on compensatory muscle hypertrophy was examined in normal rats as respects muscle enlargement and albumin accumulation. The results show that compensatory muscle hypertrophy is inducible in the hypophysectomized rats. Moreover, muscle hypertrophy observed with this organ-ectomized rats also accompanied albumin accumulation in the hypertrophied muscle. Successful induction of the compensatory muscle hypertrophy in the hypophysectomized rats is well in agreement with the Goldberg's statement that growth hormone has no effect on tenotomy-induced muscle hypertrophy (17). Taken together, the present results, suggest that growth hormone is not essential for the induction of muscle hypertrophy.
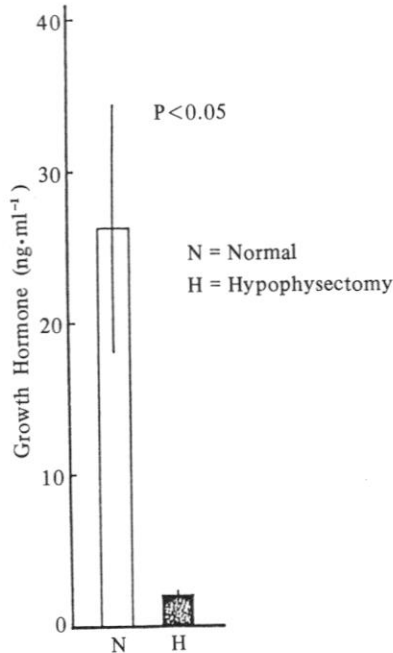

Fig. 1. Effect of hypophysectomy on the serum growth hormone concentration. Normal male rats were hypophysectomized and level of serum growth hormone was determined by radioimmunoassay as described in "Materials and Methods", N and H indicate the growth hormone concentration in serum of normal and hypophysectomized rats, respectively. Blood was drawn from the abdominal aorta at 15–20 min after sodium pentobarbital injection.
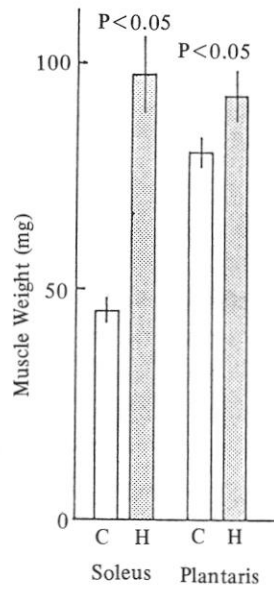
Fig. 2. Effects of tenotomy and training on the weight of the plantaris and soleus muscles in the hypophysectomized rats. Experimental conditions are described in "Materials and Methods". H and C indicate the muscle weight of the tenotomized and sham-operated limbs after training, respectively. The muscle weights are represented as a mean value.
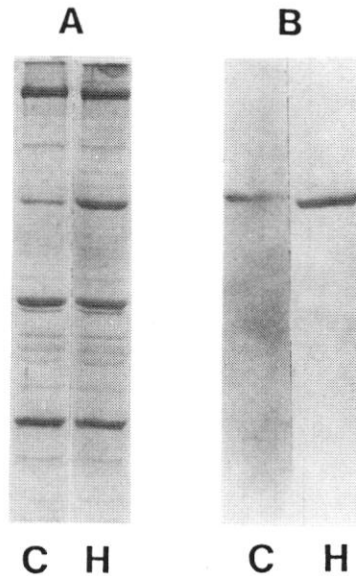

Fig. 3. SDS-polyacrylamide gel electrophoresis and Western blot analysis of the hypertrophied and control muscles of the hypophysectomized rat. Conditions for hypophysectomy and tenotomy were as described in "Materials and Methods". After tenotomy and training for 7 days, the plantaris muscle of the tenotomized (H) and control (C) limbs were dissected and solubilized in SDS sample buffer. Each 12 μl of solution (25 μg protein) was subjected to SDS-polyacrylamide gel electrophoresis and stained for protein with Coomassie blue (A). Proteins in the gel was electrophoretically transfered to nitrocellulose filter. The filter was treated with anti-rat albumin antibody and peroxidase-conjugated anti-rabbit IgG, and stained for peroxidase activity as described in "Materials and Methods" (B).

References

1) Yamada, S., Tomino, S., Izumi, S and Akino, M: (1984) B.B.A 798, 260–267.
2) Yamada, S.: (1989) 東京大学教養学部体育学紀要 23, 83–86.
3) Takahashi, M., Wakabayashi, K. and Nagase, S.: (1980) J. Sports. Med., 20, 13–22.
4) Yamada, S.: (1989) 東京大学教養学部体育学紀要 23, 87–92.
5) Kato, M., Suzuki, M., and Kakegawa T.: (1985) Endocrinology 116, 382–388.
6) Goldberg, A.L.: (1967) Am. J. Physiol 213, 1193–1198.
7) Mackova, E.V. and Hnik, P.: (1976) Physiol. Bohemoslov. 25, 325–332.
8) Marchetti, M., Figura, F., Candeloro, R., and Favilli, S.: (1980) J. Sports. Med., 20, 13–22.
9) Nimni, M.E. and Bavetta, L.A.: (1961) P. S. E. B. M. 106, 738–740.
10) Kochakia, C.D. and Tillotson, C.: (1957) Am. J. Physiol. 189 (3) 425–427.
11) Evans, H.M., Simpton, M.E. and Li, C.H.: (1962) Growth 12, 15.
12) Arvill, A. and Hjalmarson, A.: (1967) Acta Endocrinol. 56 uppl. 122.
13) Knobil, E.: (1960) in: Growth in Living System, ed. Zarrow, M.X., Basic Books, New York.
14) McManus, M.B., Lamb, S.R., Judis, J.J. and Scala, J.: (1975) Europ. J. Physiol. 34, 149–156.
15) Bigland, R. and Jehring, R.J.: (1952) J. Physiol. 166, 129.
16) O'Malley, B.: (1969) Trans. N.Y. Acad. Sci. 31, 478–484.
17) Goldberg, A.L., Etlinger, J.D., Goldspink, D.F. and Jablecki, C.: (1975) Med. Sci. Sports Exercise 7, 248–261.