Incompatibility of endurance- and strength-training modes of exercise

GARY A. DUDLEY AND RUSDAN DJAMIL
Department of Zoological and Biomedical Sciences, Program of Physiology and Pharmacology, and College of Osteopathic Medicine, Ohio University, Athens, Ohio 45701

DUDLEY, GARY A., AND RUSDAN DJAMIL. *Incompatibility of endurance- and strength-training modes of exercise.* J. Appl. Physiol. 59(5): 1446–1451, 1985.—Twenty-two male and female subjects trained for 7 wk for endurance (*group E*), for strength (*group IS*), or for both strength and endurance (*group C*) to evaluate the effect of concurrent performance of both modes of training on the in vivo force-velocity relationship of human muscle and on aerobic power. Endurance training consisted of five 5-min sessions three times a week on cycle ergometer with a work load that approached the subject's peak cycle-ergometer O_2 uptake (peak CE $\dot{V}O_2$). Strength training consisted of two 30-s sets of maximal knee extensions per day performed on an isokinetic dynamometer three times a week at a velocity of 4.19 $rad \cdot s^{-1}$. *Group C* performed the same training as *groups IS* and *E*, alternating days of strength and endurance training. Subjects (*groups C* and *IS*) were tested pre- and posttraining for maximal knee-extension torque at a specific joint angle (0.52 rad below horizontal) for seven specific angular velocities (0, 0.84, 1.68, 2.81, 3.35, 4.19, and 5.03 $rad \cdot s^{-1}$). *Groups C* and *E* were tested for peak CE $\dot{V}O_2$ pretraining, at 14-day intervals, and posttraining. *Group IS* showed significant increases in angle-specific maximal torque at velocities up to and including the training speed (4.19 $rad \cdot s^{-1}$). *Group C* showed increases ($P < 0.05$) at velocities of 0, 0.84, and 1.68 $rad \cdot s^{-1}$ only. Peak CE $\dot{V}O_2$, when expressed in relative or absolute terms, increased ($P < 0.05$) ~18% for both *groups E* and *C*. This response was linear for *group E* ($r = 0.98$, $P < 0.01$) and for *group C* ($r = 0.99$, $P < 0.01$). The results indicate that concurrent training for strength and endurance does not alter the increase in aerobic power induced by endurance training only. In contrast, concurrent training reduces the magnitude of increase in angle-specific maximal torque at fast, but not slow, velocities of contraction.

muscle force-velocity relationship; aerobic power

CONVENTIONAL STRENGTH and endurance modes of exercise training induce distinctly different adaptive responses when performed independently. Typically, strength-training programs involve large muscle group performance of high-resistance low-repetition exercises to increase the force output ability of skeletal muscle (1, 23). In contrast, endurance-training programs utilize low-resistance high-repetition exercises such as bicycling or running to increase maximum O_2 uptake ($\dot{V}O_{2\,max}$) (18, 21). Endurance training does not increase the force output ability of muscle (9), and training for strength induces little or no increase in $\dot{V}O_{2\,max}$ (9, 11, 14). Obviously the nature of the adaptive response to training is specific to the training stimulus.

In contrast to the wealth of information describing the physiological responses to strength (1, 7) or endurance training (7, 12), data describing their compatibility are sparse. Recently, Hickson (9) found that concurrent training for strength and endurance reduced the ability for strength development but did not compromise gains in $\dot{V}O_{2\,max}$. It is not known whether this altered adaptive response was dependent on contraction velocity as velocity-specific measurements of muscle strength were not made. This is important because the velocity of contraction has a substantial impact on the force output ability of human skeletal muscle (2, 17, 24). In addition, the compatibility of strength training at high velocities where maximal power output occurs and of endurance training remains undetermined. The purpose of the present study, therefore, was to evaluate the influence of concurrent high-velocity isokinetic strength and endurance training on the in vivo force-velocity relationship of human muscle and on aerobic power. This was accomplished by assessing the influence of training essentially the same major muscle group (knee extensors) with a cycle ergometer and an isokinetic loading dynamometer on maximal knee-extension torque at a specific angle for seven angular velocities. Alterations in cycle-ergometer (CE) $\dot{V}O_{2\,max}$ were also examined.

METHODS

Testing procedures. Twenty-two volunteers (14 females and 8 males) participated in this study (Table 1). They were university students or staff who had not trained regularly for 3 mo prior to this study. Informed consent was obtained from each subject before the study. No attempt was made to alter their physical activity beyond the training sessions. Prior to testing and training each subject was familiarized with equipment to be used. They were also instructed in the procedure of obtaining carotid pulse rate, which would serve as an index of endurance-training intensity (19).

For each subject performing endurance-type training, $\dot{V}O_{2\,max}$ was determined during exercise on a cycle ergometer as described previously (6, 16). Briefly, an incremental load test was performed 1 day before and 2 days after training. The initial work load of 60 W (60 rpm) was performed for a duration of 1 min. Thereafter, the exer-

0161-7567/85 $1.50 Copyright © 1985 the American Physiological Society