The Effects of Combined Strength and Endurance Training.

The levels of strength and endurance needed for sport vary depending on the particular sport chosen. Some are predominantly strength based, while others are more endurance based, with most others requiring intermediate combination of the two. Physiological adaptations of the body are specific to the type of training undertaken.

Adaptations to Endurance Training

There are several marked adaptations associated with the regular performance of endurance training. Aerobic endurance training produces increases in \( \text{VO}_2 \) max (13, 7, 8), but has no hypertrophy effect on muscle (6). Muscle fibre size has actually been shown to decrease (15, 11). Capillary supply to the muscles has been shown to change in response to endurance training through an increase in the capillary to muscle fibre ratio (16, 9). There is an increase in the number as well as the size of mitochondria, the latter of which is associated with an increase in certain enzymes (8). These increases are most apparent in the type I fibres as they have the highest content of mitochondria. Smaller increases in muscle and blood lactate levels are produced at the same relative exercise intensity after completing an endurance training program (8, 7). Glycogen is depleted less rapidly when trained than when untrained (8). The decreased use of carbohydrate during submaximal exercise is compensated for by a proportional increase in fat oxidation (8, 9). There is also a decrease in heart rate response during submaximal exercise (7). Several of these adaptations are in direct contrast to those associated with strength training.

Strength Training Adaptations

Effective strength training programs create muscle hypertrophy which is due to an increase in myofibrillar protein content (16). This hypertrophy is often associated significantly with that of the fast twitch (FT) and slow twitch (ST) fibre types. Strength training produces certain neuromuscular adaptations (14). These adaptive changes are associated with the coordination of the agonist, synergists, and antagonists (14). It has also been shown that mitochondrial volume density decreases as muscle mass increases (12). In contrast to aerobic endurance training there is a decrease in capillary density, within muscle, from
strength training which emphasises high-load, low-repetition exercises (16). Strength training at moderately high loads with greater repetitions may cause an increase in absolute capillarisation but increases in hypertrophy will result in a maintained or decreased capillary density (16). There has been some evidence from studies on animals that suggests an increase in the number of vesicles which store acetylcholine in the neuron's terminal (10). A greater force production by the associated motor unit would result if the increases in the number vesicles also corresponds to an increase in the secretion of acetylcholine (10).

Simultaneous Strength and Endurance Training Adaptations

As shown previously there are distinct, and in some cases opposite, differences in adaptive responses to both strength and endurance training. What are the resultant effects of training when both methods are used simultaneously? And what are the causes of these effects?

A study by Kraemer et al (11) was done to examine the physiological adaptations to simultaneous high-intensity strength and endurance training in physically active men. This study had two groups training for strength and endurance simultaneously. One used the muscles of the lower body for endurance and full body for strength (Group C) while the other performed strength training on the upper body and endurance training on the lower body (Group UC). There were also groups that trained independently for strength (ST group) and endurance (E group). Thirty five men were assigned to one of the four groups. The high-intensity strength training work outs consisted of 10 RM and 5 RM load schemes using a combination of universal weight machines and free weights. The high-intensity endurance running work outs consisted of long distance runs of maximum distance in 40 minutes and sprint intervals from 200-800m with exercise to rest ratios progressing from 1:4 to 1:0.5. The C and ST groups significantly increased 1 RM strength for all exercises. Only the C, UC, and E groups demonstrated significant increases in treadmill maximal oxygen consumption. The ST group showed significant increases in power output. There were the following significant changes in muscle fibre areas: types I, IIa, and IIc increased in the ST group; types I and IIc decreased in the E group; type IIa increased in the C group; and there were no changes in the UC group. Significant shifts in percentages from type IIb to type IIa were observed in all training groups, with the greatest shifts in the groups which resistance trained
the thigh musculature. From the data it was suggested that type IIb muscle fibres are not recruited to the same extent during high intensity endurance training as they are during heavy resistance training. It appears that only the quantity and not the quality of contractile proteins are affected by simultaneous training. It was concluded that simultaneous training appears to be more detrimental to potential strength and power gains than to VO2 max.

Dudley and Djamil (3) examined the effects of simultaneous strength and endurance training or, torque at a specific joint angle for seven angular velocities; 0.00, 0.84, 1.68, 2.51, 3.35, 4.19, 5.03 rad/sec using an isokinetic dynamometer on peak VO2 measured on a cycle ergometer. Twenty two males and females were trained for seven weeks. Strength training consisted of two 30 second bouts of maximal voluntary knee extensions on an isokinetic dynamometer at a velocity of 4.19 rad/sec, three times per week. Endurance training consisted of five, five minute sessions three times a week on a cycle ergometer with 5 minutes rest between bouts. The combined strength and endurance group alternated their training for each of the six days. The increases in peak VO2 for the endurance trained and combination trained groups were not significantly different. The strength trained group had increases in angle specific torque at angular velocities from 0.00 to 4.19 rad/sec. The combination trained group increased torque only at the lower angular velocities 0.00 to 1.68. It was concluded that concurrent training for strength and endurance does not affect gains in peak VO2 but compromises the ability to produce force at the high-velocity low-frequency region of the force-velocity curve.

Bell et al (1) examined the effects of concurrent endurance and low velocity resistance training (LVR) on measures of strength and aerobic endurance. Thirty one males were assigned to the two groups. One group trained for six days a week, alternating endurance and LVR training each day. The endurance sessions consisted of 40 minute bouts on rowing exercise machines and was progressively increased by five minutes every three weeks up to 55 minutes of training. LVR training was performed on variable resistance hydraulic equipment three times a week. The resistance training velocity was approximately 1.05 rad/sec. A second group completed only the three resistance training sessions a week. This group was allowed a maximum of one 30 minute continuous exercise session of moderate intensity per week. Training for both groups lasted for twelve weeks. There was no significant difference
between the groups of either peak torque, total work and cross-sectional area of knee extensions. During the last three weeks the combined group showed <1% increase for the increase for the three factors despite an increase in the volume of resistance training. In contrast the resistance trained group experienced 4.5, 4.6 and 2.5% increases in the three factors respectively. It was concluded that descriptively, the study exhibited adaptations with concurrent strength and low velocity resistance training.

Hickson et al (6) found that the addition of heavy resistance training to the training routines of well trained cyclists and runners improved endurance performance. Strength training consisted of five sets of five repetitions for the squat, three sets of five repetitions for knee extensions and flexions and three sets of 25 repetitions for toe raises. Subjects strength trained three days per week using as much weight as possible for each exercise. After ten weeks of strength training 1 RM squat was increased an average of 27%. VO2 max during cycling and treadmill running was unchanged by the heavy resistance training. Short term endurance was increased during cycling and running by 11 and 12% respectively. Cycling time to exhaustion at 80% of VO2 max increased by 20%, while performance times for the 10km run were unchanged. The authors stated that there were no changes in total body mass, thigh girth or muscle fibre size and that therefore any potential negative influences on performance did not represent limiting factors to the results. It was determined that the strength gains likely reflect learning specific activation and motor unit recruitment patterns rather than intramuscular adaptations. It was concluded that certain types of endurance performances, especially those requiring FT fibre recruitment could be improved by strength training.

Hennessy and Watson (5) conducted a study which compared the effects of 4 preseason training programs on endurance, strength, power, and speed. Fifty six subjects were divided into 4 groups: an endurance (E) group completed a running program 4 days/week; a strength (S) group trained 3 days/week; an (S+E) group combined the S and E training program 5 days/week; a control group did not train. After 8 weeks, the E and S+E groups had similar gains in endurance running performance, the S group had no change while the C group showed a decline. The S+E and S groups made gains in strength but the C and E groups did not. Power (vertical jump performance) and speed (20m sprint time) gains were only noted for the S group. It was concluded that training for strength alone results in gains in strength, power, and speed while maintaining
endurance but while S+E training produces gains in endurance and upper body strength, it compromises gains in lower body strength and does not improve power or speed.

Conclusion

In most studies the subjects training for strength and endurance performed greater volumes of work than either the strength or endurance only groups. The compromise in strength found by most of the previous studies has been hypothesised by several authors to be due to overtraining. When results of VO2max tests for strength and endurance and endurance only groups were compared, most studies found no significant differences (3, 5, 1, 11), though many also noted that the endurance gains in combination groups were similarly, slightly lower than those of endurance only groups. It has been suggested that if compromises were due to overtraining, that this effect selectively targeted only the adaptations associated with strength(4). It appears that overtraining is not likely the cause of the incompatibility, as it has been pointed out (4) that similar results were obtained with differing total training volumes. One of the studies found, instead of a compromise, that for well trained endurance athletes strength training actually improved their performance (6). This may suggest that interference is limited if strength training is performed only when endurance has been trained to high levels. This may only be of use to athletes who need to attain a high level of endurance for their sport.

One of the interference characteristics of the combined training is a lack of muscle hypertrophy (1, 11, 2, 3, 4). As previously explained this is a training response typically associated with improvements in endurance. The adaptations to strength, and endurance training show different neural responses in terms of muscle fibre recruitment. It appears that concurrent strength and endurance training may hinder the organisation of efficient motor unit recruitment patterns necessary for forceful muscular contractions at the level of the peripheral or central nervous system (2). The hypertrophy of certain muscle fibres is likely to be limited by the lack of neural stimulation which is associated with the training of strength only. One of the more recent studies (11) compared the fibre types across the different groups and found that in the E and UC groups there was an increase in type IIc muscle fibres which was not found in the C group. It was concluded that this may point to a possible incompatibility for optimising endurance mechanisms when training for both strength and endurance. Several
of the studies showed compromises in strength (5, 11, 3), though it is not exactly clear what the mechanism(s) are which cause the compromises. From the studies reviewed, the impact of combined training appears to be more detrimental to potential strength and power gains and not to VO2max.


