

The Physiological Interactions of Concurrent Strength and Endurance Training: Implications for Athletes

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Introduction

It is of interest and benefit for competitive and recreational athletes to implement both strength and endurance training into their workout programs. Many perform these training programs concurrently in hopes of achieving the adaptations that are common to both forms of exercise. However, these two methods involve different levels of training volume, intensity and duration. Strength training is defined as a low number of repetitions performed on a load that is of high resistance, producing a maximal or near-maximal contraction. (Dudley et al., 1985; Sale et al. 1990) In contrast, endurance training is defined as repeated sub-maximal contractions with loads of low resistance. (Dudley et al., 1985; Sale et al., 1990) When performed independently, these two distinct forms of training induce for the most part, opposite physiological adaptations within the muscle. Therefore, the adaptation to training that the muscle endures is specific to the training stimulus.

Ultimately, strength training enhances force production of the skeletal muscles trained. (LaChance et al., 1987) The increased force production is accompanied by an increase in muscle cross-sectional area and fast-twitch fibre area (Costill et al., 1979), along with increases in muscle contractile protein. (McDonagh et al., 1976) In contrast, endurance training effectively increases the muscle's oxidative capacity. (Gollnick et al., 1973) This adaptation is accredited to increases in slow-twitch fibre area (Gollnick et

al., 1973), muscle mitochondria and aerobic enzyme activity. (Klausen et al., 1981) Moreover, it is important to note that strength training has little or no effect on increasing VO_{2max} (Hickson, 1980; Hickson et al., 1980) and endurance training has no effect on skeletal muscles ability to increase force production. (Hickson, 1980) These findings display that skeletal muscle adapts in a different and sometimes opposite manner to strength and endurance training. Furthermore, it is then hypothesized that skeletal muscle cannot adapt to the two different types of training stimuli simultaneously. For example, increases in the activity of aerobic enzymes have been shown with endurance training. (Gollnick et al., 1973) However, strength training can decrease the activity of these aerobic enzymes. (Tesch et al., 1987)

The hypothesis that skeletal muscle is unable to concurrently adapt to both strength and endurance training has been the topic of much research. Many studies have investigated the interference of strength training on endurance improvements, as well as the impeding effects of endurance training on strength improvements. Most investigations have concluded that interference is present when both strength and endurance training are performed simultaneously (Dudley et al., 1985; Hickson, 1980; Hortobagyi et al., 1991; Hunter et al., 1987; Kraemer et al., Nelson et al., 1990), with the development of strength being the main adaptation being affected. However, some studies (McCarthy et al., 1995; Sale et al., 1990) have shown no impairment in the development of strength or endurance. Furthermore, some research has suggested that strength development or force production is only impaired at high velocities. (Bell et al., 1991a; Bell et al., 1988; Dudley et al., 1985) While others have suggested that force

production at low velocities is not impaired by training for strength and endurance concurrently. (Bell et al., 1991b; Dudley et al., 1985; Kraemer et al., 1995)

This paper will review literature concerning the interaction of concurrent strength and endurance training. Specifically, the paper will review the effects of strength training on endurance improvements and the interference of endurance training in the process of strength enhancements. This will be done in hopes of providing the reader with a better understanding of the effects of such simultaneous training. This paper will also aim to address any factors involved in their interaction as well as the potential of strength training to improve endurance performance.

Interaction of Concurrent Strength and Endurance Training

Endurance Development

As previously stated increases in endurance capabilities, most commonly measured by increases in VO_{2max} , are accomplished by performing repeated sub-maximal contractions with loads of low resistance. (Dudley et al., 1985; Sale et al., 1990) Activities included in this form of training include running, biking, swimming, etc. Many studies have examined the possible interference of strength training on endurance improvements. The majority of which have concluded that there are no deleterious effects of strength training on endurance development. Hickson (1980) trained subjects who were previously not active for at least 3 months for 10 weeks. One group performed endurance training 6 days/wk, while the other performed strength training 5days/wk in addition to the endurance training. The endurance trained group

showed a 23% increase in VO_{2max} in $l\text{-min}^{-1}$, while the concurrent group showed an 18% increase. The result was that no significant difference in the increase of VO_{2max} was seen between the two groups. Similarly, Hunter et al. (1987) trained previously untrained subjects for 12 weeks. One group was trained for endurance and another trained concurrently for strength and endurance. The studies results showed near identical improvements in VO_{2max} for both groups, indicating that strength training has little effect on aerobic development. Moreover, Dudley et al. (1985) showed no significant differences in the development of endurance between one group that trained for endurance and another that trained simultaneously for strength and endurance. These results indicate that training for strength and endurance concurrently does not alter the ability to adapt to endurance training. Complementary results were also seen in studies done by Kraemer et al. (1995), McCarthy et al. (1995) and Sale et al. (1990).

All of the aforementioned studies showed no interference by strength training in the development of endurance abilities. However, the above results conflict with a study performed by Nelson et al. (1990). The study had one group perform endurance training 4 days/wk for 20 weeks, while another partook in strength and endurance training concurrently 4 days/wk for 20 weeks. The results showed that both groups showed significant increases in VO_{2max} over the first 11 weeks of training. However, after the 11th week the endurance group continued to show significant increases in VO_{2max} , while the concurrent group failed to show further increases. These results may have been seen because of specific parameters within the study's design. Nelson et al. (1990) had their groups' train for 20 weeks, whereas most other studies had subjects' train for less amounts of time. It should be noted though that Sale et al. (1990) had

subjects train for 22 weeks, yet the design consisted of two 11-week training sessions that was divided by a 3-week break. This difference in study design may account for the opposite findings. It can then be concluded that concurrent training does not impede the development of aerobic endurance.

Strength Development

Performing exercises that involve a low number of repetitions on a load that is of high resistance effectively increases strength. (Dudley et al., 1985; Sale et al., 1990) It is of importance that athletes have high levels of not only strength but also endurance. For this reason many athletes' training programs involve simultaneous strength and endurance training. A number of studies have been conducted to investigate the possible interference effects of performing strength training and endurance training concurrently. Most have shown that concurrent strength and endurance training does in fact have deleterious effects on the development of strength or force production. Nelson et al. (1990) conducted a study on previously untrained subjects in which one group, strength trained 4 days/wk for 20 weeks while another group performed the same routine but also performed endurance on the same days. The results indicated that although both groups showed increases in force production, yet the strength-training group showed greater improvements. The same results were found by Kraemer et al. (1995). Subjects in both the strength and concurrent group showed increases in muscle strength, however the strength only group showed significantly greater increases than that of the concurrent group. Moreover, in a 10-week study by Hickson et al. (1980), subjects in both the strength and concurrent groups showed increases in force production. However, while the strength group increased force

production for the entire 10 weeks, the concurrent group displayed a decrease in the last 2 weeks of the training program. These studies exhibit that training concurrently for strength and endurance has negative effects on the development of strength. Dudley et al. (1985), Hunter et al. (1987) and Hortobagyi et al. (1991) also saw similar results in their studies.

In contrast, several studies have shown no interference in strength development when training concurrently for strength and endurance. In a study by McCarthy et al. (1995), subjects trained for 3 days/wk on alternate days for a period of 10 weeks. A strength group performed strength-training exercises on each of the days, while another group performed the strength-training program in addition to an endurance-training program. The results showed that strength increases in the concurrent group were of the same magnitude of the increases in the strength-training only group. However, McCarthy et al. (1995) noted that performing the programs on alternate days allowed for rest and recuperation, possibly explaining the results of the study. Asfour et al. (1984) showed similar results to McCarthy et al. (1995). The results of Asfour et al. (1984) study, state that an individual's strength and endurance capacities can be improved concurrently. However, it is important to note that the study by Asfour et al. (1984) lasted only 6 weeks. When compared to other studies that were longer in duration, the results of Asfour et al. (1984) may seem less significant. For example, had the study been continued past the 6-week mark, Asfour et al. (1984) may have seen similar results to that of Hickson (1980), where strength development leveled off after 6 weeks and decreased in the final 2 weeks of training. Furthermore, a study conducted by Sale et al. (1990) divided subjects into two groups; one group endurance-trained both legs

and strength-trained one, while the other strength-trained both legs and endurance-trained only one leg. The results indicated that strength development was not impaired in either group. However, the design of the study may have contributed to the findings. Sale et al. (1990) state that the concurrent form of training used in the study may be considered more a “hybrid” than “pure” form of training, thus producing the dissimilar results to that of most concurrent training studies. Also, Sale et al. (1990) suggest that limitations are present in their study if the interference that occurs between concurrent training takes place at the central and not peripheral level. From the results of all of the above studies it can be conceived that training simultaneously for strength and endurance can impede strength development.

High- vs. Low-Velocity Movements

Several studies have suggested that the impairment of force development seen with concurrent training may only affect movements performed at a high velocity. Kraemer et al. (1995) hypothesized that slow-velocity movements may not be impaired by concurrent training to the same extent that high-velocity movements are after analyzing the results of their study. Dudley et al. (1985) made the same inquiry and concluded that concurrent training reduces the ability to increase strength at high-velocities, but the same effect may not occur at low-velocities. Research by Bell et al. (1988) also suggests that concurrent strength and endurance training impair high-velocity strength gains. Later research conducted by Bell et al. (1991) examined concurrent training, where endurance training was combined with low-velocity resistance training. The results showed that the concurrent training did not impair strength increases. The results of these studies suggest that concurrent training for

strength and endurance may not impair low-velocity movements. Further research detailing the differences experienced by high- and low-velocity movements with concurrent endurance training is needed.

Specificity of Muscle Impairment

It has also been suggested that the impairment to strength development that occurs from concurrent strength and endurance training is specific to the muscle groups involved in the endurance training. This suggestion has been confirmed with research by Hunter et al. (1987), where running was performed for the endurance component, while squats and bench press were two of the exercises performed for the strength component. The results showed that the strength group made significantly higher increases in squat 1RM, whereas there was no difference found in the increase of bench press 1RM between the strength and concurrent groups. Similar results were attained by Kraemer et al. (1995), where endurance training involved only the lower extremities. The results of Kraemer et al. (1995) showed increases in 1RM for leg press, military press and bench press for all groups. However, the increases in 1RM for leg press in the strength group were significantly higher than in the concurrent group. These findings, along with the fact that both groups had similar increases in bench press and military press, indicate that only muscles involved in the endurance-training component of concurrent training are affected by the associated strength decline. In conclusion, the findings of both Hunter et al. (1987) and Kraemer et al. (1995) express that the deleterious effects on strength improvements exhibited with concurrent training are limited to the muscle groups involved in the endurance component.

Factors Involved in Interaction

Sequencing of Training

It shows that the sequencing of the training may be of importance when investigating the antagonism of concurrent strength and endurance training. Sale et al. (1990) found that subjects who trained concurrently for strength and endurance on alternate days showed greater strength improvements when compared to subjects who trained concurrently on the same day. These results exhibit that concurrent strength and endurance training on the same day may cause more of an interference than does training for strength and endurance on separate days. Athletes and coaches alike should take note of this fact when developing training programs. Moreover, Collins et al. (1993) devised a study in which one group trained for endurance first and strength second on the same day. The other group performed the same exercises, but strength training was done first and endurance training was completed second. The results showed no differences in the development of strength or endurance between the two groups. Although it deserves mention that Collins et al. (1993) had subjects train on the same day. If compared to the study by Sale et al. (1990), the results of Collins et al. (1993) may be contributed to the fact that both groups trained concurrently on the same day. Further research detailing the differences between same day, opposite day and whether strength or endurance training is performed first is needed to draw further conclusions in this area.

Development vs. Maintenance Phase of Training

Antagonism between strength and endurance training has been seen when both forms of training are performed concurrently. An area that needs further investigation is whether developing strength or endurance first, and then maintaining either adaptation while developing the other is possible. A study by Hunter et al. (1987) compared the strength development of previously untrained subjects to that of prior endurance trained subjects. The untrained group trained concurrently for strength and endurance, while the endurance trained group trained for strength and maintained their endurance capacities. The results found that the concurrent training impaired the strength development of the untrained group, when compared to a strength training only group. Furthermore, the study found that strength development was not impaired in the previously endurance trained group, while the group trained for strength development and endurance maintenance. This fact should also be taken into account by athletes and coaches when devising training programs and attempting to avoid the antagonism of concurrent training. No studies were found in which previously strength trained subjects attempted to maintain strength while developing endurance. However, a study by Bell et al. (1991) investigating the sequencing of training for strength and endurance found that after 5 weeks of strength training followed by 5 weeks of endurance training, some maintenance of strength was present. When the opposite sequence was followed, that is endurance then strength training, the improvements in VO_{2max} were not maintained. An extension of the study of Bell et al. (1991) might be to add a maintenance phase of the first form of training to the second form of training and analyze the results. For example, 5 weeks of strength training would be followed by 5

weeks of endurance training with the addition of a strength maintenance program, and vice versa. The results of such a study might be useful in avoiding the interference effects of concurrent training.

Strength Training to Increase Endurance Performance

It has been shown that training concurrently for strength and endurance does not hinder improvements in VO₂max. (Dudley et al., 1985; Hickson, 1980; Hunter et al., Kraemer et al., 1995) Therefore, there seems to be a possibility that strength training can be utilized to improve endurance performance. Hickson (1980) investigated this possibility. The results found that following heavy resistance training on the muscles involved in the endurance performance, short-term endurance performance was enhanced. Marcinik et al. (1991) experienced similar results when strength training endurance athletes for 12 weeks. The results showed that endurance performance was increased and the improvement was related to increased leg strength as well as an elevated lactate threshold. Hickson et al. (1988) investigated further into the potential for strength training to raise endurance performance. Hickson et al. (1988) strength trained endurance athletes for 10 weeks. The results showed a 30% increase in leg strength and short-term endurance performance was also increased. Hickson et al. (1988) noted that this increase would be specifically helpful for endurance events requiring fast-twitch fibre recruitment. An example would be an endurance event that usually concludes with a sprinting component. These findings are in conflict with the results of Bishop et al. (1999), who found that endurance trained females (cyclists) who strength trained for 12 weeks, showed significant increases in squat 1RM. However this did not lead to improved cycle endurance performance in the group of female athletes.

These contrasting results, to the possibility of strength training improving endurance performance calls for further investigation or research on this topic.

Concluding Remarks

This paper has investigated the possible “interference” or “antagonism” experienced with concurrent strength and endurance training. It is concluded that strength training has no negative effects on endurance training, while both are performed concurrently. There is the possibility that strength training may improve endurance performance, yet further investigation is needed. In contrast, it seems that concurrent training for strength and endurance has deleterious effects on the development of strength. Furthermore, these negative effects seem to be exclusive to high-velocity movements as well as the muscles involved in the endurance performance. Seeing as both strength and endurance are required for most competitive sports, further research in the area of concurrent training for strength and endurance would be both valid and desired.

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