Improving Running Economy Through Strength Training

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HEAVY RESISTANCE TRAINING is known to improve both upper and lower body muscle strength. However, less is known as to whether this strength development enhances running economy in distance runners, thus resulting in improved performance. Many distance runners feel that heavy resistance training, particularly for the lower body, can be detrimental to performance, even though there is no evidence of this.

We recently investigated the effects of a 10-week weight training program on selected physiological variables associated with running performance. The subjects were endurance-trained female distance runners (Figure 1) who had no prior strength training experience.

The strength training program resulted in significant increases in strength: 24% for upper body lifts and 34% for lower body lifts. There were no changes in body mass, fat free mass, % body fat, or body circumference measurements. No significant differences were found in maximal aerobic capacity (VO₂max) or blood lactate accumulation following the 10-week program, which involved heavy resistance training and endurance training. However, the results did suggest that weight training improved running economy by 4%.

Running economy is defined as the steady-state oxygen consumption (ml·kg⁻¹·min⁻¹) for a standardized running speed (3). By improving running economy, a runner should be able to run

Figure 1 University of New Hampshire Women's Cross-Country Team. Photo by Mark Bolton
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Table 1
10-Week Strength Training Program

<table>
<thead>
<tr>
<th></th>
<th>Weeks 1-3</th>
<th>Weeks 4-8</th>
<th>Weeks 9-10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group A</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel squat</td>
<td>$3 \times 10$-RM</td>
<td>$3 \times 6$-RM</td>
<td>$3 \times 4$- to $5$-RM</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>$3 \times 10$-RM</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 6$-RM</td>
</tr>
<tr>
<td>Straight-leg heel raise</td>
<td>$3 \times 12$-RM</td>
<td>$3 \times 12$-RM</td>
<td>$3 \times 8$-RM</td>
</tr>
<tr>
<td>Seated press</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 6$-RM</td>
<td>$3 \times 4$- to $5$-RM</td>
</tr>
<tr>
<td>Rear lat pulldown</td>
<td>$3 \times 10$-RM</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 6$-RM</td>
</tr>
<tr>
<td>Hammer curl</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 6$-RM</td>
<td>$3 \times 4$- to $5$-RM</td>
</tr>
<tr>
<td>Weighted sit-up</td>
<td>$2 \times 15$-RM</td>
<td>$2 \times 15$-RM</td>
<td>$2 \times 15$-RM</td>
</tr>
<tr>
<td><strong>Group B</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunge</td>
<td>$3 \times 10$-RM</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 5$-RM</td>
</tr>
<tr>
<td>Knee extension</td>
<td>$3 \times 10$-RM</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 6$-RM</td>
</tr>
<tr>
<td>Bent-leg heel raise</td>
<td>$2 \times 20$-RM</td>
<td>$2 \times 20$-RM</td>
<td>$2 \times 20$-RM</td>
</tr>
<tr>
<td>Bench press</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 6$-RM</td>
<td>$3 \times 4$- to $5$-RM</td>
</tr>
<tr>
<td>Seated row</td>
<td>$3 \times 10$-RM</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 6$-RM</td>
</tr>
<tr>
<td>Front lat pulldown</td>
<td>$3 \times 10$-RM</td>
<td>$3 \times 8$-RM</td>
<td>$3 \times 6$-RM</td>
</tr>
<tr>
<td>Abdominal curl</td>
<td>$2 \times \text{max}$</td>
<td>$2 \times \text{max}$</td>
<td>$2 \times \text{max}$</td>
</tr>
</tbody>
</table>

Faster over the same distance, or run longer at the same running speed, due to a decrease in oxygen consumption.

**Program Design**

Twelve women distance runners, ages 23 to 36 years, took part in this study. They had been running 20 to 30 miles a week, 4 to 5 days a week for at least 1 year. None of them had ever engaged in a regular weight training program. All runners maintained a steady-state level of endurance training at least 12 weeks prior to and throughout the study. Each one was expected to continue with her individual training, running at the same frequency, intensity, and distance as she had been doing prior to the study.

Six of the women were randomly assigned to a strength training program that consisted of weight training 3 days a week for 10 weeks. The other 6 women continued their steady-state endurance training without weight training. All strength training sessions were preceded by a 5-min easy run, followed by 5 min of light, static stretching for the major muscle groups of the arms, back, and legs.

During the first three strength training sessions the runners performed all exercises with very light weight in order to learn good lifting technique and to minimize muscle soreness. Afterward, they performed repetitions to maximum in each set (i.e., 10-RM) and took a 2-min rest between sets. The repetitions and sets varied depending on the exercise and week of training (Table 1).

As the runners' strength increased, or when they were able to do more than the required number of repetitions, additional weight was added to maintain the same relative resistance. Regardless of the exercise, the weight load being lifted was demanding and the program was clearly designed to build muscular strength as opposed to muscular endurance in these aero-bically trained women. Strength training was undertaken on Monday, Wednesday, and Friday mornings, with at least a 5-hr interval between strength sessions and afternoon running sessions.

The following exercises were done with free weights: parallel squat, seated press, hammer curl (holding a dumbbell in a thumbs-up position), weighted sit-up, lunge, bent-leg heel raise, and bench press (Figures 2, 3, and 4). Adonis machines were used for the front and rear lat pulldown, knee flexion, knee extension, straight-leg heel raise, and seated row. The 14 exercises were divided into two groups, A and B, which were alternated with each strength session (Table 1). In other words, during Week 1 the women did Group A lifts on Monday, Group B lifts on Wednesday, and Group A lifts on Friday. During Week 2 they did Group B lifts on Monday, Group A lifts on Wednesday, and Group B lifts on Friday.

Strength was assessed by determining the maximum amount of weight that could be lifted for one repetition (1-RM) in the parallel squat, knee flexion, seated press, hammer curl, bench press, and rear lat pulldown. The runners were tested for strength before and 3 days after the strength training program. All were tested for VO$_2$-max, running economy, blood lactate accumulation, and body composition before and 1 week after the strength training program.

**Discussion**

There is little information about the effects of weight training on running economy and distance running performance. But many researchers have studied the effects of strength training programs on variables associated
Members of the UNH cross-country and track & field teams are shown here demonstrating the lunge (above) and hammer curl (upper and lower right). Proper technique and full range of motion, along with progressive increases in resistance, are instrumental in the program's success.
with cardiovascular fitness (1, 4, 5, 6, 8, 9, 13, 16). Some have found improved endurance without a change in VO₂max (5, 6, 9); others have found no improvement in cardiovascular function (1, 8). Hickson et al. (5, 6) reported improved treadmill running times to exhaustion without changes in blood lactate accumulation or VO₂max following a weight training program.

The body composition data reported in past investigations is variable. Hickson et al. (6) and Sale et al. (13) reported an increase in leg strength, muscle size, and body mass following a strength training program. Results from Hickson et al. (5) and Marcink et al. (9) suggest that strength can increase without changes in muscle girth, body mass, or % body fat. Other research suggests an increase in strength and muscle girth can occur with an accompanying decrease in % body fat and no change in body mass (7, 16).

In a recent investigation, Staron et al. (14) found no significant changes in body mass, fat free mass, % body fat, or girth measurements—despite significant increases in strength following an 8-week heavy resistance training program. However, there were gradual increases in cross-sectional areas of fiber types I, Ila, and IIb, and a significant decrease in the percentage of type Iib fibers, with a concomitant increase in type Ila fibers. The strength improvements during the early stages of training may have been due to neural factors (12), but it appears that significant changes contributing to strength gains are also taking place in the muscle (14).

As for the women in our study, after 10 weeks the running economy improved significantly in the 6 distance runners who added strength training to their endurance training program. Their relative oxygen uptake (milliliters of oxygen per kilogram of body weight per minute) decreased significantly (4%) while running at all three submaximal treadmill speeds: 7:30 per-mile pace, 7:00 per-mile pace, and 6:30 per-mile pace. These changes were not evident in the other 6 distance runners, who only performed endurance training. There were no significant changes in maximal aerobic capacity, blood lactate accumulation, body mass, fat free mass, fat mass, or % body fat in either group of runners following the 10-week training programs.

One explanation for the improved running economy may be that greater leg strength enhances mechanical efficiency and motor unit recruitment patterns (12, 15). If a more efficient pattern is induced by an increase in leg strength, it may allow for a decreased oxygen cost at each running speed (2, 11).

We are not sure whether the strength gains in our study occurred at the neural level, at the muscular level, or both. Strength training can induce changes within the nervous system that will allow the individual to more fully activate prime movers and better coordinate the activation of all relevant muscles. These changes will produce a greater net force in the intended direction of movement (12). If hypertrophy of muscle fibers does occur with strength training, there is a reduction in the number of motor units and in the firing rates required to produce a given force (12).

Another explanation for improved running economy could be that greater overall strength leads to changes in running style, thus allowing a runner to do less work at a given submaximal running speed. Williams and Cavanagh (15) have identified several biomechanical aspects of running style that seem to be related to running economy and that may influence the energy demand of running. Nelson and Gregor (10) demonstrated that running mechanics can change over time, leading to faster race times.

The different and sometimes conflicting results from research on strength training should not be surprising; they can be attributed primarily to the variation in training protocols and in individual fitness levels. Progressive resistance exercise programs differ in the kinds of exercises performed and types of resistance used, the number of sets and amount of rest taken between sets, the number of repetitions per set, and the % 1-RM performed in each set.
Certainly one strength training program may produce different results when compared to another strength training program. Likewise, results may well differ between previously strength trained, untrained, and aerobically trained subjects who participate in the same strength training program.

The results of our study suggest that a low volume, moderate to high intensity weight training program, when added to an endurance training program, significantly improves upper and lower body strength as well as running economy, and has little or no impact on VO$_2_{\text{max}},$ blood lactate accumulation, or body composition in trained female distance runners.

### Application

It appears that combining a weight training program with an endurance training program can benefit distance runners. However, many coaches use an endurance protocol (3 x 15-20) and restrict strength training to the upper body. This may be a big mistake in that it may hinder an endurance runner from attaining maximal performance. Runners, regardless of the distance they run, benefit from increased upper and lower body strength, especially near the end of a race when fatigue can interfere with performance.

Upper body strength helps delay fatigue in the arms and postural muscles during a race. As these muscles become fatigued, they could compromise the efficiency of movement and increase the oxygen demand for running. For its part, lower body strength is vital for maintaining proper knee and hip lift as well as stride length. We want our distance runners to gain strength and lean body weight without increasing their muscle girth and total body weight. Therefore, our strength training program emphasizes low volume and moderate to high intensity.

When strength training distance runners, especially those who have never strength trained before, one of our first concerns is to minimize the initial muscle soreness associated with beginning a weight training program, and to prevent injury. Therefore, during the first 2 weeks of a strength training program it is important to begin with a light weight of, say, 50% of 1-RM, in order to emphasize proper lifting technique.

Working with a partner, coach, or trainer is important. Partners can spot for each other, help with correct lifting technique, and offer encouragement. The coach should supervise all strength training ses-

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**Figure 5** On the home course, scoring members of the UNH team improved race times by 1 minute when compared to last year's performances. *Photo by Mark Bolton*
sions and provide feedback to each runner concerning his or her lifting technique, effort, and improvement. Runners have a tendency to lift light. They seldom add enough weight to maintain the same intensity. This causes strength to plateau, particularly with the parallel squat and lunge, which are difficult lifts to execute with good form; constant supervision is a necessity.

We prefer a strength training program that is short (45-min sessions or less), prevents boredom and staleness, and is somewhat specific to running. This can be accomplished by alternating two groups of exercises during each session (Table 1). The strength training program can be divided into 4-week cycles during the season: Cycle 1, early season: perform 3 sets of 10-12 RM for all exercises 3 days a week; Cycle 2, midseason: perform 3 sets of 6-8 RM for all exercises 2 days a week; Cycle 3, late season: perform 2 or 3 sets of 4-5 RM 1 day a week for only 4 core exercises. The core exercises are the parallel squat, lunge, bench press, and seated row.

The 4-week cycles can be used during off-season training too. However, the runners should do all the exercises 3 days a week during each 4-week cycle.

During the off-season the emphasis should be on maximizing strength while continuing to run base mileage. Running can interfere with optimal strength gains, therefore weight training should be performed before running, with at least a 5-hr interval between sessions if at all possible. This will minimize muscle fatigue. During preseason and in-season training, the emphasis changes to running. Weight training now follows the running program, and at least a 1-hr interval between sessions is recommended. When working with a high school team, however, it is more likely that the weight training session will immediately follow the running session.

All high-intensity running workouts should be scheduled on non-lifting days. After the race season ends, the emphasis can change from running to strength training, with strength training sessions now preceding running sessions once again.

The women's cross-country team at the University of New Hampshire is currently using this strength training program with great success. We have had fewer running injuries this season, and the women have been improving their race times (Figure 5). It appears that the strength training program is one reason for the team's success, therefore it will be continued throughout the off-season as well as during the indoor and outdoor track seasons.

**References**


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