The Interference Effects of Training for Strength and Endurance Simultaneously

Liam C. Hennessy and Anthony W.S. Watson

Sports Injuries Research Centre, University of Limerick, Limerick, Ireland.

Reference Data

ABSTRACT
This study compared the effects of three preseason training programs on endurance, strength, power, and speed. Subjects were divided into four groups: the endurance (E) group completed a running endurance program 4 days · week⁻¹; the strength (S) group trained 3 days · week⁻¹; the S+E group combined S and E training programs 5 days · week⁻¹; the control (C) 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. No strength gains were noted in the C or E groups, but strength gains were made in the S+E and S groups. Power (vertical jump performance) and speed (20-m sprint time) gains were noted only for the S group. These findings show that training for strength alone results in gains in strength, power, and speed while maintaining endurance. S+E training, while producing gains in endurance and upper body strength, compromises gains in lower body strength and does not improve power or speed.

Key Words: power, speed, team games, preseason

Introduction
Team games such as Gaelic football, hurling, soccer, and rugby require the expression of several components of physical fitness. Speed, strength, endurance, and power are, among other fitness components, demanded in varying degrees. Frequently players train to develop several components of fitness simultaneously during the preseason. Additionally, published guides and training programs advise players to train for strength, power, and endurance simultaneously (19, 40). Also, athletes participating in high intensity, short recovery activities generally combine resistance exercises and endurance training in their physical preparation (12, 29, 31, 48).

There is conflicting scientific evidence regarding the development of the components of strength and endurance concurrently (3, 11, 16, 22, 23, 28, 37). Hickson reported that endurance training inhibited strength gains during 10 weeks of simultaneously training for strength and endurance (22). Strength acquisition was inhibited in previously untrained subjects when both strength and endurance training were combined (28).

Hunter and associates (28) also found that strength was not compromised in a previously endurance trained group that combined strength and endurance training. Nelson et al. (37) found that the development of strength was not compromised by endurance training and strength training concurrently in a previously untrained group, but an inhibition in aerobic development occurred during the latter part of a 20-week study.

Furthermore, other authors report no interference for force and endurance development with simultaneous strength and endurance training (3, 16). Anecdotal evidence and comments from players who do combination training suggest that speed and power may be compromised with endurance training.

Clearly, there is a lack of agreement in the research as to whether training for strength and endurance negatively affects the development of one component or the other. Furthermore, few studies have addressed the influence of concurrent strength and endurance training on the components of power and speed, which are important requirements in team games. Differences in subject training status may affect the results achieved. Also, variations in study design in the papers already cited make training guidelines difficult to formulate.

Therefore the purpose of this study was to examine the effects of training for strength and endurance concurrently on the development of strength, speed, power, and endurance in team sport players during an 8-week period. To reflect relevance to the practical situation found in preseason team preparation, it was important to select players who had been actively involved in competitive games and training during the previous season but who had completed a rest/recovery period of approximately 4 weeks. To help interpret these findings, the effects of strength training alone and endurance training alone were also examined. Additionally, a control group was included for comparison.
Methods

Subjects
Fifty-six subjects were recruited from senior Rugby and Gaelic Athletic Association (GAA) teams. All players had experience with weight training, and all had participated in competition and training with their respective teams during the previous season. Players were not involved in any formal team or individual training for at least 4 weeks prior to the start of this study.

Descriptive data are presented in Table 1. All subjects were fully informed of the requirements and possible risks of the study, and all gave written informed consent to participate. Subjects were randomly assigned to one of four groups, each consisting of 14 players. Seven individuals withdrew from the study due to work and social commitments, 2 others due to injury sustained during work, and 6 due to other sporting commitments. The final breakdown of the four groups was as follows: control group (C), n = 10; strength and endurance training (S+E), n = 10; endurance training only (E), n = 12; and strength training only (S), n = 9.

Strength Group. The strength training group trained 3 days a week for 8 weeks. Two training days consisted of a high intensity workout using a percentage greater than 70% of their one repetition maximum (1-RM) weight from Weeks 2 through 8. Also, 1-RM tests were completed in squat and bench press during Weeks 3 and 5 to calculate subsequent training loads in these exercises. Table 2 outlines the details of the exercises completed and resistances used.

On the 3rd day, a workout consisting of three sets of 10-RM was completed using the following exercises: lunge, upright row, dumbbell flies, triceps press or pushdown, calf raise, and bent knee sit-ups. When the subjects completed three sets of 10 repetitions, the resistance was increased. The strength training program contained a degree of strength endurance training. This reflected the type of resistance training that Gaelic and Rugby players regularly engage in during the preseason.

Endurance Group. Subjects in this group ran 4 days a week, 2 of which involved a continuous low intensity run. Subjects ran at a heart rate corresponding to 70% of maximum heart rate, calculated as 220 – age. The duration of this run gradually increased from 20 min in the 1st week to 60 min in the 8th week.

On the 3rd day, subjects performed a fartlek run comprised of running at varying paces. Briefly, an easy 5-min jog was followed by fast striding for approximately 200 m, then a 200-m jog. This was repeated several times. Following this, subjects completed a series of fast strides for short distances (30–100m), each followed by a recovery jog. They finished the run with a slow continuous jog for 5 min. The duration of fartlek running was gradually increased from 15 min in the 1st week to 35 min in the 8th week.

The fourth training session consisted of a continuous run at 85% of max HR. The duration of this run was gradually increased from 20 min in the 1st week to 40 min in the 5th week, and was maintained at 40 min for the rest of the study. During all training sessions, heart rate was monitored by telemetry (Polar Electro, Finland). Following training runs, exercise heart rate recordings were examined regularly by the same investigator.

Strength Plus Endurance Group. Subjects in this group performed both the strength and endurance training programs 5 days a week: Monday, easy run (70% of max HR) and moderate intensity weights; Tuesday, fartlek; Wednesday, high intensity weights and easy run.

Table 1
Descriptive Data of Subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (yrs)</th>
<th>M</th>
<th>SD</th>
<th>Height (cm)</th>
<th>M</th>
<th>SD</th>
<th>Weight (kg)</th>
<th>M</th>
<th>SD</th>
<th>% Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10</td>
<td>24.0</td>
<td>3.0</td>
<td>181.2</td>
<td>2.9</td>
<td>79.5</td>
<td>8.5</td>
<td>17.9</td>
<td>5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Str. &amp; Endur.</td>
<td>10</td>
<td>23.4</td>
<td>3.6</td>
<td>180.3</td>
<td>3.9</td>
<td>80.6</td>
<td>8.6</td>
<td>17.9</td>
<td>4.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endurance</td>
<td>12</td>
<td>24.0</td>
<td>2.8</td>
<td>179.4</td>
<td>4.5</td>
<td>80.9</td>
<td>10.7</td>
<td>18.1</td>
<td>6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength</td>
<td>9</td>
<td>24.3</td>
<td>3.6</td>
<td>182.2</td>
<td>3.9</td>
<td>78.9</td>
<td>10.3</td>
<td>18.0</td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2
Resistance Training Completed 2 Days/Week

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S* R</td>
<td>%</td>
<td>S* R</td>
<td>%</td>
<td>S* R</td>
<td>%</td>
<td>S* R</td>
<td>%</td>
</tr>
<tr>
<td>Back squat</td>
<td>2*10</td>
<td>65</td>
<td>3*8</td>
<td>70</td>
<td>4*8</td>
<td>75</td>
<td>5*8</td>
<td>80</td>
</tr>
<tr>
<td>Bench press</td>
<td>2*10</td>
<td>65</td>
<td>3*8</td>
<td>70</td>
<td>4*8</td>
<td>75</td>
<td>5*8</td>
<td>80</td>
</tr>
</tbody>
</table>

Note. Sets (S) and repetitions (R) for all exercises are outlined; Percentages (%) of 1-RM loads for squat and bench press exercises are outlined.
(70% max HR); Thursday, rest; Friday, high intensity run (85% max HR); Saturday, high intensity weights.

All subjects in the running programs were instructed to run on grass whenever possible. Furthermore, they were not to train for 3 days prior to retesting at the end of Week 8. It was felt that any residual fatigue resulting from the training programs would be eliminated during this rest period.

**Testing**

The following variables were measured for each subject: age, height, body weight, percent fat (% fat), vertical jump, 20-meter (20-m) sprint time, and estimated maximum oxygen uptake (EVO₂ max). Height was measured to the nearest centimeter (cm) using a portable stadiometer. Weight was assessed using a beam balance scale (Seca) to the nearest 0.1 kg. Skinfold measurements were used to estimate % fat. The procedures of Lohman (34) were used to determine body density, and subsequent conversion to estimated body fat was calculated according to the method of Siri (44).

Vertical jump height was recorded using a vertical jump measuring apparatus (Cranea, Birmingham). Each subject was allowed to practice a double leg takeoff using a free-arm swing prior to measurement. The best of three trials was analyzed. Speed over 20 m was recorded using a high accuracy electronic digital timing device (Cranea, Birmingham). The subject stood behind the first line. Timing began when the subject crossed the infrared beam on the starting line 1 meter in front of the first line. Each subject performed three sprints and the best time was recorded. A multistage shuttle-run protocol (6) was used to estimate maximum oxygen uptake. In brief, the subjects ran back and forth between two lines on a 20-m course. The running pace was set by audio signals emitted at specific intervals from a tape recording. The running pace was progressively increased every minute throughout the test. Results with this test show high correlations with directly determined maximum oxygen uptake (r = 0.84 and 0.93) and a test and retest reliability coefficient of 0.97 (33, 41).

All subjects were asked to maintain their normal eating habits throughout the study, and they all did a dietary recall over a 2-day period during the study. Additionally, all subjects maintained an activity/training diary. Details of all recreational and training activities were recorded. Diaries were analyzed throughout the study to assess training compliance and to monitor training intensities and progressions.

Test order was established so that the subject was not fatigued when engaging in a test. The order of testing was as follows: height, weight, skinfold measurement, vertical jump, 20-m sprint, and multistage shuttle-run test. On another day, 1-RM lifts were recorded for the back squat and bench press according to the techniques previously described (14, 39).

### Table 3

| Variable test | Test | Retest | 95% Conf. limits | V* (%) | r**
|---------------|------|--------|-----------------|-------|------
| VJ (cm)       | 51.1 | 3.2    | 51.2            | 2.6   | 3.9  | 2.5  | 0.82 |
| % Fat         | 14.6 | 1.3    | 15.0            | 1.3   | 5.7  | 5.3  | 0.81 |
| 20-m sprint (s)| 3.20 | 0.11   | 3.22            | 0.15  | 2.7  | 2.0  | 0.80 |
| Shuttle run (levels) | 12.6 | 1.5    | 12.7            | 1.6   | 7.7  | 2.2  | 0.97 |
| 1-RM efforts: |       |        |                 |       |      |      |      |
| Bench press (kg) | 88.2 | 13.3   | 89.0            | 13.8  | 10.1 | 2.7  | 0.96 |
| Squat (kg)     | 104.0 | 14.7   | 105.5           | 13.5  | 8.4  | 2.3  | 0.97 |

*Method error coefficient of variation; **Reliability coefficient.

Test-retest determinations for the tests in this study are presented in Table 3, which gives reliability coefficients, means and standard deviations of both tests with 95% confidence limits, and method error coefficients of variation (43). A 48-hr period elapsed between test and retest determinations. No systematic difference was found between mean scores of both tests. The method error coefficient of variation indicates the variability of the standard deviation of the mean difference between tests. All method error coefficients are less than 6%, indicating acceptable reproducibility of the tests used in the study. Furthermore, all reliability coefficients are acceptable.

### Statistical Procedures

Differences in strength training volumes for squat and bench press exercises between the S and S+E groups were analyzed using two-tailed unrelated t tests. A one-way analysis of variance with post hoc Scheffé test was used to examine differences in dietary constituents and total energy intake between the four groups. A two-factor analysis of variance (Factor A = four levels) with repeated measures on Factor B (pretreatment and postraining) was used to analyze the training data. Since differences within groups were expected for certain variables, a one-tailed related t test was applied following initial analysis of variance to identify significant differences among mean values. Statistical significance was accepted at p < 0.05 for each test. However, as all dependent variables between pre- and postraining were significantly correlated, Bonferroni inequality test procedures (5) were applied to pairwise t tests for the dependent variables under study.

Six pairwise comparisons from the four groups were made and, following application of the Bonferroni procedure, the alpha level was adjusted to p < 0.0083. Such a procedure is recommended to reduce the chances of making a Type I error when several
dependent variables are being analyzed (5, 9). However, the conservative nature of this procedure risks making a Type 2 error. Therefore a nonparametric sign test was used to supplement the parametric tests. It was considered that such a test would make statistical analyses more meaningful. All statistical analyses were completed using the SPSS-X package (45).

**Results**

No differences (p > 0.05) were found between S and S+E groups in total training volume (load × sets × repetitions) for squat or bench press exercises over the period of study. When weekly training volumes for squat exercise were compared between groups, there was no difference (p > 0.05) between groups from Weeks 1 through 7. However, the S group completed a greater training volume (p < 0.05) in the squat compared to the S+E group during Week 8 (4,955 ± 638 kg vs. 4,340 ± 259 kg, respectively).

No differences (p > 0.05) were found between the four groups in amounts of protein, fat, carbohydrate, or total energy consumed over a 2-day dietary recall period.

No pretraining differences (p > 0.05) between groups were found in any anthropometric or performance variable under study. Significant differences (p < 0.05) were noted for all four groups between pre- and posttraining values in body weight (Table 4). Both E and S+E groups decreased in body weight, the former by 4 kg and the latter by 1.7 kg. This decrease was complemented by a 3.3% reduction in % fat for the S+E group and a 3.7% reduction for the E group (Table 4). In contrast, body weight increased in the C and S groups (p < 0.05). The S group gained 2.9 kg of weight, yet had a decrease of 1.4% in % fat (p < 0.05). The control group gained 1.0 kg of body weight including a significant (p < 0.05) increase in % fat. No differences in posttraining values for body weight or % fat were noted across groups.

No significant differences were found in pretraining values for either squat or bench press strength variables between groups (Table 5). Furthermore, no changes occurred in squat or bench press 1-RM performances in the C and E groups between pre- and posttraining tests. However, significant differences (p < 0.05) were found between pre- and posttraining values for both S+E and S groups in squat and bench press performances.

Percent increases in the S+E and S groups for squat and bench press tests were 5.4 versus 16.7% for squat, and 14.5 versus 20.9% for bench press in S+E and S groups, respectively. There was a significant difference (p < 0.05) between S+E and S groups in posttraining strength values for the squat. Further, a significant difference (p < 0.05) was noted between the S group and the C and E groups in posttraining values for both upper body and lower body strength performances (Table 5).

### Table 4

<table>
<thead>
<tr>
<th>Group</th>
<th>Weight</th>
<th>% Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td></td>
<td>M  SD</td>
<td>M  SD</td>
</tr>
<tr>
<td>Control</td>
<td>79.5  8.5</td>
<td>80.5  8.8</td>
</tr>
<tr>
<td>Str. &amp; Endur.</td>
<td>80.6  8.6</td>
<td>78.9  7.3</td>
</tr>
<tr>
<td>Endurance</td>
<td>80.9  10.7</td>
<td>76.9  9.1</td>
</tr>
<tr>
<td>Strength</td>
<td>78.9  10.3</td>
<td>81.8  9.8</td>
</tr>
</tbody>
</table>

*Significantly different from pre to posttraining, p < 0.05.

### Table 5

<table>
<thead>
<tr>
<th></th>
<th>Bench Press (kg)</th>
<th>Squat (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre  M  SD</td>
<td>Post M  SD</td>
</tr>
<tr>
<td>Control</td>
<td>89.0  11.9</td>
<td>88.0  11.4</td>
</tr>
<tr>
<td>Str. &amp; Endur.</td>
<td>86.0  11.3</td>
<td>98.5  9.1</td>
</tr>
<tr>
<td>Endurance</td>
<td>84.6  11.2</td>
<td>85.0  9.3</td>
</tr>
<tr>
<td>Strength</td>
<td>85.0  13.5</td>
<td>102.8  13.9</td>
</tr>
</tbody>
</table>

Significant difference, p < 0.05, *between pre and posttraining; †between S group and C and E groups; ‡between S group and C, E, and S+E groups.

No differences in pretraining values for vertical jump, 20-m sprint, or E\(\text{\textsubscript{VO}}\text{\textsubscript{2}}\) max were noted between groups (Table 6). Only the S group demonstrated a significant increase in vertical jumping performance from pre- to posttraining values (54.9 ± 4.9 vs. 57.9 ± 4.0 cm, p < 0.05).

No changes in 20-m sprint times were found from pre- to posttraining values for C, S+E, and E groups. However, the S group demonstrated an improvement in sprinting time (3.15 ± 0.09 sec vs. 3.11 ± 0.08 sec, p < 0.05) from pretraining to posttraining occasions (Table 6).

Significant changes (p < 0.05) in E\(\text{\textsubscript{\text{\textsubscript{VO}}}}\text{\textsubscript{2}}}\) max were found from pre- to posttraining values for the C, S+E, and E groups (Table 6). The C group declined in performance while the S+E and E groups improved in this fitness component as a result of training (7.3 and 10.8%, respectively). The S group showed a small nonsignificant increase (0.4%) in this aerobic fitness component from pre- to posttraining states. A significant difference (p < 0.05) between the S+E and C groups was noted after training (Table 6). There was also a significant difference between the E group and the C and S groups (p < 0.05). However, no difference was found after
Table 6
Variables for Groups Pre and Posttraining

<table>
<thead>
<tr>
<th>Group</th>
<th>Vertical jump (cm)</th>
<th>20-m sprint (s)</th>
<th>E\textsuperscript{\text{O}}\textsubscript{2}\text{max}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td></td>
<td>(M)</td>
<td>(SD)</td>
<td>(M)</td>
</tr>
<tr>
<td>Control</td>
<td>54.6</td>
<td>4.6</td>
<td>53.9</td>
</tr>
<tr>
<td>Str. &amp; Endur.</td>
<td>54.9</td>
<td>5.2</td>
<td>55.1</td>
</tr>
<tr>
<td>Endurance</td>
<td>52.4</td>
<td>3.6</td>
<td>53.0</td>
</tr>
<tr>
<td>Strength</td>
<td>54.9</td>
<td>4.9</td>
<td>57.9</td>
</tr>
</tbody>
</table>

Significant difference between \(^*\)pre and posttraining, \(p < 0.05\); \(^\dagger\) between S+E and C, between E and C, and between E and S, \(p < 0.05\).

Training between the E and S+E groups (59.3 ± 2.9 vs. 57.5 ± 2.9 ml · kg · min\(^{-1}\), respectively).

There was good agreement between the post hoc parametric \(t\) test and the nonparametric sign test for the 28 pre- to posttraining comparisons. There was agreement for statistical differences between methods, and agreement for comparisons where no differences were found.

Discussion

The results of this study show that training for strength alone resulted in improvements in strength, vertical jump, and speed while maintaining endurance. S+E training resulted in endurance and upper body strength gains, but it compromised gains in lower body strength and did not promote gains in vertical jump or speed.

Previous studies have shown an inverse relationship between aerobic endurance performance and \(\%\) fat (47). It has been estimated that a 1.0% increase in body weight would decrease endurance performance in a 12-min run test by approximately 1.5% (47). An increase of 1.25% in body weight was accompanied by a 0.8% increase in \(\%\) fat for control subjects in this study. This increase in body weight was due to the lack of physical training in the control group, as no difference was found in food constituents and total energy intake between groups. A slight decrease in \(E\textsuperscript{O}_2\text{max}\) is to be expected from a significant weight gain alone. A significant decrease of 2.3% occurred in endurance as measured by \(E\textsuperscript{O}_2\text{max}\) over the 8-week inactive period in the control group.

The pretraining values in \(E\textsuperscript{O}_2\text{max}\) for subjects in this study are lower than those observed in elite players reported in the literature (range = 54–64 ml · kg · min\(^{-1}\)) (1, 10, 13, 36, 42). However, \(E\textsuperscript{O}_2\text{max}\) values of the subjects in this study are slightly greater than values reported for recreational individuals (22, 37). Although no invasive measurements were taken in this study, the decline in \(E\textsuperscript{O}_2\text{max}\) may also be a consequence of the relatively fast reduction in oxidative enzyme activity after training has ceased (21).

Strength, speed, and vertical jump performance were unaltered by 8 weeks of inactivity in the control group, suggesting that these components are less likely to decline than \(E\textsuperscript{O}_2\text{max}\) over the same time period. Pretraining levels in strength compare favorably to values reported in other field games players (86 and 82 kg bench press) (10, 36). Subjects were instructed not to take part in weight training or endurance training over the 8-week period of the study. However, they were allowed to participate in recreational activities such as tennis and golf. Analysis of activity diaries showed that they complied fully to these instructions.

The E group demonstrated a 10.8% improvement in \(E\textsuperscript{O}_2\text{max}\). Such an improvement following 8 weeks of endurance training is consistent with other investigations (8, 37). The endurance regimen resulted in a decrease in body weight and \(\%\) fat. Performance enhancement of 1-RM strength efforts, vertical jump, and sprint time reduction would not be expected following endurance training.

The energy for low intensity steady running is generated predominately in the slow twitch fibers of the exercising muscles. Furthermore, endurance training causes specific biochemical, physiological, and morphological changes in skeletal muscle (24, 25, 30, 32), and such changes are not associated with strength, power, and speed training. No improvements were found in strength, vertical jump, and sprint time in the E trained group.

Strength training alone resulted in increases in body weight and improvements in squat, bench press, and vertical jump performances with decreased \(\%\) fat levels. Evidence of an improvement in 20-m sprint time was found, but no change occurred in \(E\textsuperscript{O}_2\text{max}\). Changes in strength were similar to previous findings reported in the literature (22, 27, 46).

Interestingly, vertical jump performance was found to improve as a consequence of strength training without any specific jump training. Strength training using the squat exercise as the main training stimulus has been shown to enhance vertical jump performance (2, 28). The improvement noted in the present study
for the S group is similar to that found by Adams and colleagues for a group of subjects with some background in resistance training and using a similar weight training regimen (2).

However, in the study by Hunter and colleagues (28) an increase in vertical jump performance was noted in a strength trained, an endurance and strength trained, and a previously endurance trained group that strength trained and maintained the gains in endurance. The subjects in that study had low vertical jump levels prior to training (all groups ≤44.3 cm), compared to values found in field games players in the present study and elsewhere (20). Therefore it is not surprising that strength training, even though accompanied by endurance training, resulted in an increase in vertical jump.

In contrast, the S+E trained group in the present study did not improve in vertical jump, though strength improvements were found in 1-RM measurements. While some investigators have not found an interference effect during concurrent strength and endurance training (3, 16), others have suggested an interference effect of endurance training on strength development (11, 22, 26, 28, 37). Evidence from the present study supports the latter findings. Although strength was shown to increase in the S+E group, the S group had a greater increase in lower body strength, as reflected by performance in the squat.

There was no difference in total training volume during the training program in squat or bench press between the S and S+E groups. However, the S group completed a 14% greater training volume in the squat as compared to the S+E group during Week 8. This suggests there was interference in the capacity of the S+E group to achieve the same training volume the S group had attained in the squat exercise by the 8th week.

Additionally, the gains in power may have been due to this proportionally greater lower body strength gain in the S group. Power output and vertical jump performance are positively correlated to the percentage of fast twitch fibers in the exercised muscle group (4, 17). Furthermore, the training effects of endurance and strength training regimens would seem to induce different if not opposite effects on skeletal muscle (15, 35). Thus, strength training seems to promote fast twitch muscle fiber hypertrophy (18), with an increase in vertical jump performance (2), while endurance effects can cause a decrease in fast twitch muscle fibers and perhaps a transition to slow twitch fibers (32) and a decrease in vertical jump performance (38). Therefore the dual demands placed on the exercising muscles from combined training may have produced conflicting physiological changes.

Further, the present study found a significant improvement in 20-m sprint time in the S group, which was not replicated in the S+E trained group. This suggests that the development of speed may be compromised by simultaneously training for strength and endurance. Therefore it is reasonable to assume some training effect for speed over 20 m as a consequence of strength training alone.

The possibility of overtraining as a result of concurrent S+E training has been noted by other investigators (37) and may explain the present results. A greater change in EVO₂ max in the E group would offer support for overtraining in the S+E group. However, the E group did not demonstrate a greater improvement in EVO₂ max over and above the S+E group, even though the E group showed a 3.5% greater improvement. Further, the subjects were regularly monitored for overtraining effects (7) and no signs of these were evident in the S+E group.

Summary
The results of this study indicate that concurrently training for strength and endurance over an 8-week preseason period yielded improvements in endurance and upper body strength. However, strength gains were compromised when combination training (endurance and strength) was carried out in the same muscle group. Additionally, combination training did not lead to vertical jump and speed gains. In contrast, strength training alone promoted gains in strength, vertical jump, and speed while maintaining a pretraining level of endurance. These results suggest that trainers or coaches should be careful when designing training programs for their players who require strength, power, speed, and endurance.

Practical Applications
Inactivity over an 8-week period for previously active athletes may lead to weight gain, mainly as a result of storing additional body fat. A reduction in EVO₂ max can be expected. However, there should be no change in strength, vertical jump, or speed as a result of not training for 8 weeks.

Endurance training alone for 8 weeks can be expected to result in a significant reduction in body weight and body fat. Gains in EVO₂ max will occur. However, there will be no changes in strength, vertical jump, or speed.

A strength training program similar to the one used in the present study will yield strength, vertical jump, and speed gains while maintaining EVO₂ max. Additionally, a reduction in body fat and a gain in weight can be expected.

The combination of endurance and strength training for 8 weeks is likely to yield significant improvements in strength and EVO₂ max. However, strength gains are compromised when the same muscle group is exercised by both methods of training, that is, combination training. Also, combination training will interfere with vertical jump and speed gains. Therefore it is important to realize the limitations of combination training when designing training programs for athletes who need to develop the components of strength, power, speed, and endurance.
References


