pate in any additional exercise throughout the study. However, it is unlikely that the subjects exercised outside our sessions based on self-reports and our results. It is possible that these sedentary subjects did increase caloric intake or change eating habits in some way, since body composition did not change even with initiation of an exercise program.

Regardless, it appears that SS strength training is no better at enhancing strength development than TR strength training. In fact, we found that TR strength training is more effective at improving strength in many of the exercises in the absence of changes in percentage of body fat, BMI, lean body mass, and body weight. In addition, strength training alone has no significant effect on aerobic capacity, but our study suggests that it is capable of improving short-term endurance.

Practical Applications

The results of the present investigation have practical applications when recommending resistance training to sedentary individuals to improve strength and endurance. Our current study implies that the TR protocol of one set to fatigue will significantly improve strength during a 10-week period. Although SS strength training does improve strength, the TR protocol produces greater improvements, is less time consuming, and will most likely lead to better exercise adherence. However, further research is required. Until such time, we recommend the TR protocol to produce greater improvements in strength and endurance. Additionally, since strength training alone does not appear to improve aerobic capacity, some form of aerobic activity would be beneficial.

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Specificity of Sprint and Agility Training Methods

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ABSTRACT

The purpose of this study was to determine if straight sprint training transferred to agility performance tests that involved various change-of-direction complexities and if agility training transferred to straight sprinting speed. Thirty-six males were tested on a 30-m straight sprint and 6 agility tests with 2–5 changes of direction at various angles. The subjects participated in 2 training sessions per week for 6 weeks using 20–40-m straight sprints (speed) or 20–40-m change-of-direction sprints (3–5 changes of 100°) (agility). After the training period, the subjects were retested, and the speed training resulted in significant improvements ($p < 0.05$) in straight sprinting speed but limited gains in the agility tests. Generally, the more complex the agility task, the less the transfer from the speed training to the agility task. Conversely, the agility training resulted in significant improvements in the change-of-direction tests ($p < 0.05$) but no significant improvement ($p > 0.05$) in straight sprint performance. We concluded that straight speed and agility training methods are specific and produce limited transfer to the other. These findings have implications for the design of speed and agility training and testing protocols.

Key Words: transfer of training, change of direction, sprinting

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Introduction

Straight sprinting speed and agility are considered important qualities in many sports. Sprinting in a straight line is a relatively closed skill involving predictable and planned movements and is used in sports such as track and field and gymnastics. Agility is difficult to define, but is often described as a quality possessing the ability to change direction and start and stop quickly (1, 9, 13, 14). In a sporting situation, changes of direction may be initiated to either pursue or evade an opponent or react to a moving ball. Therefore, it has been recognized that a component of agility performance is the response to a stimulus (3). It has been shown that up-and-back sprint time of 2.4-m increased as a light stimulus became less predictable in terms of timing and location, presumably because of increased information processing (5). Further, Chelladurai and Yuhasz (4) demonstrated that a change-of-direction task with a simple stimulus shared only 31% common variance with a more complex task in which the timing and location of the stimulus were not known. This suggests that having to react to a stimulus such as an opponent's movement on the field may significantly influence the nature of the change-of-direction movement task.

Several studies have reported correlations between straight sprint tests and various agility tests. When a correlation coefficient (r) is less than 0.71, the shared or common variance between the 2 variables is less than 50%, indicating that they are specific or somewhat independent in nature (15). For example, Hortobagyi et al. (11) used this statistical approach to demonstrate that various modes of strength testing indicated more generality ($r > 0.71$) of strength than specificity ($r < 0.71$). Common variances of 11% and 22% have been reported, respectively, for straight sprints and a soccer agility test (2) and the Illinois agility test (7). Mayhew et al. (12) reported a common variance of 21% for 40-yd time and an agility test containing 5 changes of direction and forward, sideways, and backward running. Further, these investigators conducted a factor analysis on several fitness test results and found the speed and agility tests to be represented by different factors. This meant that speed and agility had little in common statistically, leading the authors to conclude that they were relatively independent qualities.

A common variance of only 7% was reported for a straight 20-m sprint and a 20-m sprint involving 3 changes of direction of 90° in Australian footballers (16). When the players were required to bounce a football twice while performing these changes of direction, the correlation with the straight sprint dropped to nearly 0. Corvo (6) suggested that speed training has limited benefit for improving agility in rugby league players, and Gambetta (8) suggested that because of the need to change direction in American football, the importance of straight sprinting speed is diminished. Collectively, these findings and views indicate that straight sprinting and relatively complex agility maneuvers have little in common and are independent or specific qualities.

It would therefore follow that the training of straight sprinting speed would have little transfer to agility performance and vice versa. In 1969, a study was conducted (10) that compared the effects of speed and agility training on various fitness parameters. The study reported that agility training was superior to speed training for performance in the Illinois agility run and a "zig-zag run," but the speed training was not significantly better for improving 50-yd sprint time. Unfortunately, the authors failed to describe the training that was implemented, making it difficult to evaluate the effects. Since the potential specificity of speed and agility training has not yet been clearly established, the purpose of the present study was to determine if straight sprint training transferred to change-of-direction tests of varying complexities. Another objective was to determine if agility training could enhance straight sprinting speed.

Methods

Subjects

Thirty-six men volunteered to participate in the study and provided informed consent. The project was approved by the Human Research Ethics Committee of the University of Ballarat. The subjects had a mean ± *SD* age, height, and body mass of 24.0 ± 5.7 years, 180.1 ± 4.4-cm, and 81.1 ± 8.4-kg, respectively. To be eligible for participation, the subjects were required to have prior experience of at least one season participating in activities involving sprinting and/or change-of-direction maneuvers, such as the activities performed in many team sports. During the study some of the subjects wanted to continue participating in various physical activities of a noncompetitive recreational nature. These individuals were allowed to participate in one such session per week because this represented their baseline level of activity. However, people who wanted to perform more than one additional training session per week were not selected as subjects because of the potential to mask the effects of the imposed training.

Testing

All subjects were assessed on 7 different 30-m tests. Test 1 was a straight sprint, and tests 2–7 involved multiple changes of direction (Figure 1). Tests 2–7 were designed to involve progressively greater change-of-direction complexity by increasing either the angle of directional change and/or the number of changes of direction. Therefore, test 2 was considered the simplest and test 7 the most complex change-of-direction task. Poles about 1-m high were placed on

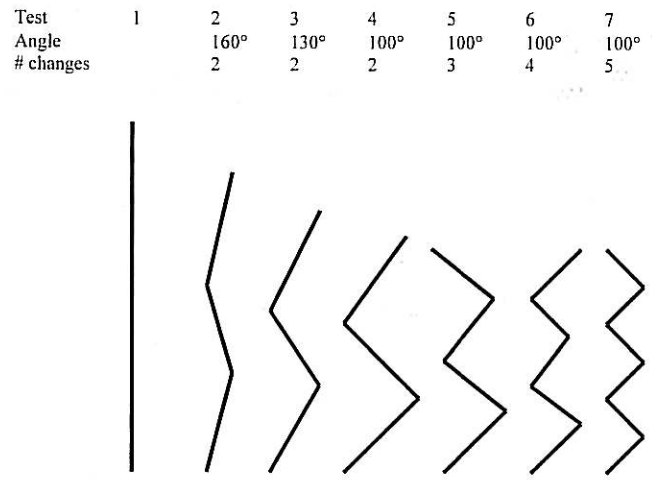

Figure 1. Description of the seven 30-m tests.

the floor to indicate the change of direction. The subjects were not permitted to touch these as they sprinted around them. When this did occur (fewer than 5 occasions), the trial was repeated after a complete recovery of at least 3 minutes.

Performance in the 7 tests was assessed by the time to cover the 30-m distance as measured by a dual-beam infrared timing system (Swift Performance Equipment, Lismore, Australia). The system requires both beams to be broken simultaneously to trigger the start or finish of timing and is designed to capture the trunk movement rather than a false trigger from a limb. All times were recorded to a resolution of 0.01 second.

The participants were tested in small groups (3–4), with half the subjects performing the 7 tests in ascending order and half in descending order. A randomized order was not used because of the time required to precisely set the 7 tests. Two trials were allowed for each test, with the best one being retained. A rest of at least 3 minutes between trials and tests was administered to minimize the effects of fatigue. Before testing, each subject performed a warm-up consisting of 3 minutes of jogging, stretching of the muscles of the lower extremity, and 3–4 submaximum efforts of the test about to be conducted.

The sprints were performed from a standing start with the toe of the preferred foot 0.3-m behind the starting gate. This was intended to allow some forward lean and cause triggering of the timing system as soon as the subject moved. The subjects were not permitted to use a "rolling" start and were instructed to sprint with maximum effort when they were ready. The sprint tests were performed in an indoor stadium on a wooden floor, and the subjects wore running shoes, which they were instructed to wear for both pretesting and posttesting occasions.

Table 1. Summary of the training programs for the speed and agility groups.

Week	Repetition number × distance (m)	Rest between repetitions	Intensity (% of maximum)	Angle of directional change (°)*	No. of changes of direction*
1	6 × 40	Complete	95	100	3
2	8 × 30	Complete	98	100	3
3	8 × 20	Complete	100	100	4
4	5 × 40	Complete	100	100	4
5	6 × 30	Complete	100	100	5
6	5 × 30	Complete	100	100	5

* Applies to agility group only.

Training

Following the testing, the subjects were randomly divided into 1 of 3 groups: a speed training group (n = 13), an agility training group (n = 13), and a control group (n = 10). The control group was instructed to continue with daily activities but not to undertake any new training. Both training groups were required to participate in 2 training sessions per week, 3–4 days apart, for a 6-week period. All training sessions were supervised by one of the investigators, and all sprint efforts were timed with a stopwatch with feedback given to enhance motivation. A minimum of 10 sessions needed to be completed during the training period for the data to be retained. The speed and agility training programs were designed to be equivalent with respect to the distances run, the total training volume, and the intensity of the efforts. The only difference between the programs was that the speed group performed only straight sprints, whereas the agility group performed only change-of-direction sprints (Table 1). The agility training consisted of 3–5 changes of direction of 100° (similar to tests 5–7) and was intended to be relatively complex to differentiate it from the speed training.

The subjects were instructed to use a "complete" recovery between sprints (typically 2–4 minutes) and to avoid any worsening of times as the session progressed. The length of each interval varied from 20–40 m to provide variety and allow a slightly different training emphasis. For example, 20-m efforts emphasized acceleration, whereas 40-m efforts allowed greater speeds to be attained. The intensity was slightly below maximum speed for the first 2 weeks to allow progression and to reduce the risk of injury (Table 1). The intensity of the submaximum efforts was monitored by providing feedback to each subject on how his interval time (recorded by stopwatch) compared with the times achieved during the pretesting. Within 2–3 days of completion of the training program, the subjects were again assessed on the 7 tests, using the same order as the pretests.

Statistical Analyses

An analysis of variance (ANOVA) with repeated measures was conducted to determine if the training responses for the experimental groups differed significantly from each other and the control group for each test. Pearson correlation coefficients were also computed to determine the interrelationships among the tests. The level of significance for both statistical tests was set at $p \leq 0.05$.

Results

Nine subjects did not complete the study because of illness, injury, or failure to complete all the tests or the minimum number of training sessions. One subject was required to withdraw because of a slight hamstring muscle strain during an agility training session. The number of subjects in each group who completed the entire study were 11 (speed), 9 (agility), and 7 (control).

Descriptive data are shown in Table 2, and the mean times for each test for all subjects are illustrated in Figure 2. The ANOVAs revealed significant ($p < 0.05$) group-by-time interactions for tests 1, 3, 5, 6, and 7. These results indicate that the changes over time (before to after training) were significantly different between the groups for these tests. To clarify the within-group changes, paired t-tests were conducted for each group on each test. The mean changes for all groups and tests are indicated in Figure 3.

There were no significant improvements in any of the tests for the control group. The speed group improved significantly in test 1 (straight sprint) and test 2 only. The agility group improved significantly in tests 2–7 (change-of-direction tasks) but not test 1. Generally, the speed group improved most in the straight sprint, and the gains in performance decayed from test 2–7 as the change-in-direction task became more complex. The reverse trend was apparent for the agility group; that is, the gains were greatest for the tests that were similar to the training (5–7) and dimin-

Table 2. Mean ± *SD* times (in seconds) for all groups before and after training.

	Speed		Agility		Control	
Week	Before	After	Before	After	Before	After
1	4.47 ± 0.18	4.34 ± 0.18	4.74 ± 0.30	4.72 ± 0.24	4.52 ± 0.21	4.53 ± 0.16
2	4.76 ± 0.19	4.65 ± 0.23	5.04 ± 0.23	4.93 ± 0.24	4.82 ± 0.24	4.77 ± 0.18
3	5.79 ± 0.26	5.71 ± 0.25	6.00 ± 0.28	5.78 ± 0.24	5.74 ± 0.26	5.82 ± 0.20
4	6.67 ± 0.32	6.59 ± 0.29	6.91 ± 0.27	6.73 ± 0.23	6.71 ± 0.27	6.70 ± 0.27
5	7.65 ± 0.40	7.65 ± 0.42	7.93 ± 0.37	7.68 ± 0.29	7.83 ± 0.42	7.83 ± 0.40
6	8.60 ± 0.41	8.63 ± 0.43	8.83 ± 0.35	8.55 ± 0.37	8.83 ± 0.53	8.78 ± 0.52
7	9.51 ± 0.52	9.51 ± 0.52	9.78 ± 0.31	9.52 ± 0.30	9.68 ± 0.67	9.78 ± 0.66

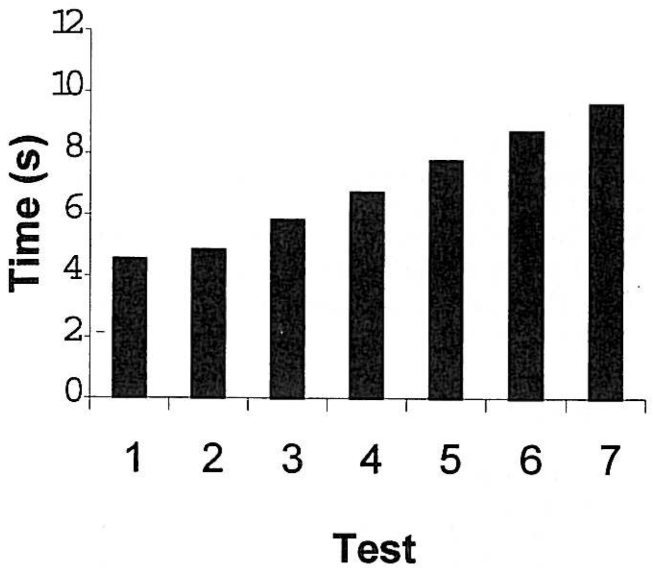

Figure 2. Mean times for each test from pretraining data ($n = 36$).

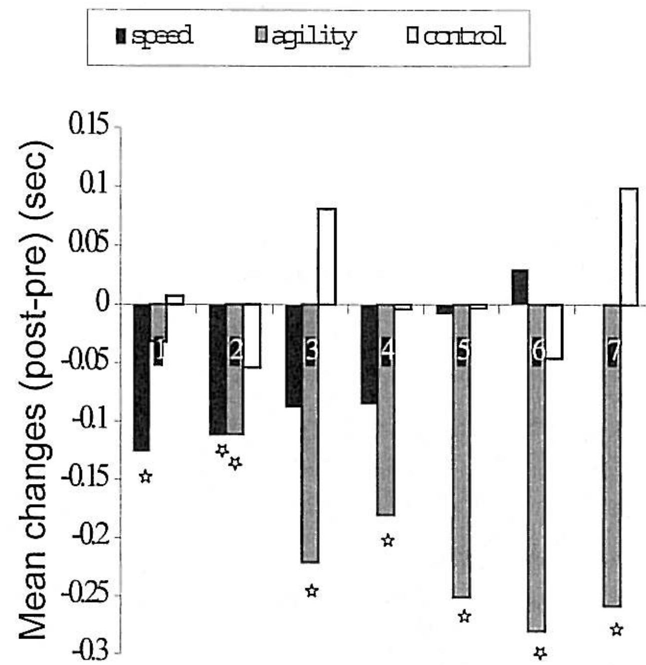

Figure 3. Mean changes for all groups in each test. Asterisk denotes significant change ($p < 0.05$) before and after training.

ished as the sprint task became less complex (Figure 3).

Discussion

The progressively increasing sprint times from tests 1–7 (Figure 2) support the notion that systematically increasing the angle of directional change and the number of changes of direction increased the complexity of the agility tasks. The longer times are likely to be due to the need to apply greater lateral forces and to produce more decelerations and accelerations.

An important finding from this research was that straight sprint training enhanced speed in a straight line (test 1) with limited transfer to the agility tasks. Although there was a significant improvement in test 2, this test only involved 2 changes of direction with a relatively small directional change (20° deviation). The correlation between tests 1 and 2 was relatively high before the training ($r = 0.92$, $p < 0.01$), indicating the tests had much in common. However, the speed training resulted in no improvement in the most complex agility task (test 7) and only minor, nonsignificant gains in tests 3–6. The correlation between tests 1 and 7 was 0.64 (pretraining data) and 0.47 (posttraining data), which indicate respective common variances of 41% and 22%. This relatively small common variance indicates that the speed and agility tests assessed specific qualities, a finding that is consistent with previous research (2, 7, 12, 16). The 5 relatively sharp changes of direction in test 7 required the subjects to adopt a sideways leaning posture in an effort to apply enough lateral force to the ground to successfully change direction at high speed. They also required significant adjustments to the stride pattern to decelerate and then accelerate around each marker. The complexity of this task made the running motion dissimilar to the mechanics of straight running. Therefore, the lack of transfer from the speed training to the more complex agility maneuvers was expected.

The agility training induced significant gains in all agility tests but produced little change (nonsignificant) in straight sprinting speed. In general, both training groups experienced the biggest gains in the tests related to their training, and the training-induced improvements diminished as the tests became more different to the training. Therefore, the results of this research strongly support the specificity of training. In summary, sprinting in a straight line and sprinting with changes of direction are specific tasks that do not readily transfer to the other.

Practical Applications

The findings of this research indicate that straight sprint training has limited ability to transfer to agility performance involving fast changes of direction. Therefore, the interval training and supplementary exercises that are typically performed to enhance straight sprinting speed (for example, in track and field) can be expected to be of limited value for the agility component of many sports. Coaches are advised to implement specific agility drills to develop this component. Since running mechanics are likely to vary according to the sporting situation, analysis of movement patterns typically used at high speed should be conducted. These patterns can then be incorporated into any training or testing protocols to enhance specificity.

The present research also suggests that agility training may not improve straight sprinting speed, and therefore speed and agility methods should be included in a training program according to the needs of each sport. Although this study focused on the running component of agility performance, the role of perceptual skills, such as reacting to surrounding players and decision making, should also be considered in the design and testing of agility.

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