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The Effects of Traditional and Enforced Stopping Speed and Agility Training on Multidirectional Speed and Athletic Performance

Brief Running Head: Speed Training with Enforced Stopping

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Abstract

This study investigated the effects of a traditional speed and agility training program (TSA), and an enforced stopping program emphasizing deceleration (ESSA). Twenty college-aged team sport athletes (16 males, 4 females) were allocated into the training groups. Pre- and post-testing included: 0-10, 0-20, 0-40 m sprint intervals, change-of-direction and acceleration test (CODAT), T-test (multidirectional speed); vertical, standing broad, lateral, and drop jumps, medicine ball throw (power); Star Excursion Balance Test (posteromedial, medial, anteromedial reaches; dynamic stability); and concentric (240°/s) and eccentric (30°/s) knee extensor and flexor isokinetic testing (unilateral strength). Both groups completed a six-week speed and agility program. The ESSA subjects decelerated to a stop within a specified distance in each drill. A repeated measures analysis of variance determined significant ($p < 0.05$) within- and between-group changes. Effect sizes (Cohen's *d*) were calculated. The TSA group improved all speed tests (ES = 0.29-0.96), and most power tests (d = 0.57-1.10). The ESSA group improved the 40-m sprint, CODAT, T-test, and most power tests (d = 0.46-1.31), but did not significantly decrease 0-10 and 0-20 m times. The TSA group increased posteromedial and medial excursions (d = 0.97-1.89); the ESSA group increased medial excursions (d = 0.99-1.09). The ESSA group increased concentric knee extensor and flexor strength, but also increased between-leg knee flexor strength differences (d = 0.50-1.39). The loading associated with stopping can increase unilateral strength. Coaches should ensure deceleration drills allow for appropriate sprint distances before stopping, and athletes do not favor one leg for stopping following deceleration.

Key words: deceleration; change-of-direction speed; plyometrics; dynamic stability; unilateral strength

INTRODUCTION

Multidirectional speed, which encompasses linear and change-of-direction speed (i.e. planned agility), is an vital physical quality for many athletes (26). Linear and change-of-direction speed are essential components of court sports such as basketball, netball, and European handball, and field sports such as the football codes, field hockey, and lacrosse. The common characteristics between these sports is that they feature a pattern of random, reactive, and intermittent movements, as well as specific skill requirements (3). The reactive nature of movement patterns featured requires the capacity to reach high maximal running speeds, and to rapidly change direction (41). This can be a determining factor for performance in both field- and court-based team sports. For example, more than half of the sprints in Australian football contain at least one direction change (9), and elite basketball players will make more movements requiring a direction change when compared to sub-elite players (39).

A component of multidirectional speed is deceleration. Deceleration involves the athlete slowing down their movement and stopping, and finishing with a body position that allows for movement in a particular direction. Indeed, deceleration is required after any sprint performance in order to slow the athlete's center of mass, regardless of the relative speed of the run (14). The deceleration aspects of speed have not been widely analyzed, although there is available coaching theory (8, 14, 18, 22, 36). Kovacs et al. (18) stated that the four major components of deceleration are power, reactive strength, dynamic balance or stability, and eccentric strength. There is research documenting relationships between power and reactive strength to multidirectional speed (24, 35, 37). However, dynamic stability and unilateral eccentric strength have had far less analysis. Dynamic stability should aid the athlete in maintaining a stable center of gravity during sport-specific movements (4). Furthermore, dynamic stability, as measured within a modified version of the Star Excursion Balance Test (SEBT), has been related to faster multidirectional speed in male team sport athletes (23).

Eccentric strength in the leg muscles should assist in absorbing the forces associated with maximal running (21), as well as re-accelerating from a stationary position (24). A high level of eccentric strength has also been said to be an important contributor to effective deceleration (14). Indeed, Lockie et al. (26) demonstrated that a greater isokinetic eccentric between-leg strength balance related to faster multidirectional speed (measured by a 40-meter [m] sprint and T-test) in male athletes. Nevertheless, there is no research documenting whether multidirectional sprint training can enhance these capacities in team sport athletes.

In addition to dynamic balance, eccentric strength, power, and reactive strength (18), factors including sprint technique, concentric strength, and a between-leg balance in strength and power (41), have been said to contribute to multidirectional speed. As a result, multidirectional sprint training will often involve a range of activities, including technique drills, maximal sprints, specific movement drills, and plyometrics (3). Multidirectional speed training can improve numerous physical capacities, including linear sprint performance, change-of-direction speed as measured by the L-run and T-test, and leg power measured by jump performance in both males and females (3, 16, 38). However, none of these studies used training drills that emphasized deceleration or enforced stopping at the end of a sprint effort. In addition, neither Polman et al. (38), Bloomfield et al. (3), or Jovanovic et al. (16), assessed other aspects of performance important for multidirectional speed, including dynamic stability and unilateral leg strength, in particular eccentric strength.

Developing dynamic stability has fallen within neuromuscular training, with a view towards enhancing joint stability and preventing injury (45). Myer et al. (33) found that both plyometrics and balance training can improve dynamic stability as measured by a single-leg hop-and-hold task, as well as concentric hamstring strength, in high school-aged female team sport athletes. Also within female high school athletes, neuromuscular training, comprising functional strength exercises, plyometrics, agility, and balance training, improved lateral, anteromedial, and medial reach distances from the SEBT (45). However, Myer et al. (33) did not determine whether changes in dynamic stability or hamstring strength could affect multidirectional speed. Valovich McLeod et al. (45) further acknowledged that the influence of improving dynamic stability on athletic performance must be investigated, and collegiate-aged males and females also require further analysis in this area. Developing dynamic stability and unilateral strength should contribute to enhanced multidirectional speed, which could be especially true in training programs that emphasize deceleration.

If movement training places too great an emphasis on acceleration while ignoring deceleration, what will result are athletes who have faster initial velocities without the capacity to control the body or slow down (18). A specific emphasis on deceleration mechanics may also accentuate the eccentric components associated with change-of-direction speed, potentially train dynamic balance, all while providing a specific stimulus for multidirectional speed development. Therefore, this research determined the effects of emphasizing deceleration by enforcing stopping at the end of traditional speed and agility training drills in recreational male and female team sport athletes. The effects of this type of training on multidirectional sprint and power performance, in addition to dynamic stability and unilateral strength, were determined. It is hypothesized that both a traditional speed and agility program, and one that emphasizes deceleration, will improve multidirectional speed and power. However, the deceleration-based program will encourage greater gains in dynamic stability and unilateral leg strength. This study demonstrated if there is value in enforcing stopping during multidirectional sprint training.

METHODS

Experimental Approach to the Problem

This study determined the effects of traditional speed and agility training, and training that included enforced stopping in drills to emphasize deceleration, on multidirectional speed and athletic performance tests in team sport athletes. An additional goal was to determine the effects of these training programs on physical aspects of performance that are said to contribute to multidirectional speed, and whether either program was more beneficial. In pre- and post-testing, subjects completed a 40-m sprint, change-of-direction and acceleration test (CODAT), and T-test to assess multidirectional speed; vertical jump, standing broad jump, lateral jumps from each leg, drop jump for the calculation of the reactive strength index (RSI), and a backwards overhead medicine ball throw (BOMBT) for power analysis; a modified SEBT (mSEBT) to assess dynamic stability through functional reaching; and isokinetic strength testing to determine unilateral concentric and eccentric knee extensor and flexor strength. The dependent variables were: speed test times; jump heights and distances; RSI; medicine ball throw distance; excursion distances from the mSEBT (posteromedial, medial, and anteromedial); and concentric and eccentric peak torque, and bilateral asymmetries in peak torque, in knee extensor and flexor contractions.

Subjects

Twenty subjects (age = 23.60 ± 4.86 years; height = 1.75 ± 0.09 m; body mass = 76.12 ± 12.84 kilograms [kg]) were recruited for this study, including 16 males (age = 23.31 ± 5.34 years; height = 1.78 ± 0.07 m; body mass = 80.60 ± 9.89 kg), and four females (age = 24.75 ± 2.22 years; height = 1.64 ± 0.03 m; body mass = 58.19 ± 4.37 kg). Mixed-gender groups have been previously used when analyzing speed and agility training (3, 20). Subjects were recruited if they: were 18 years of age or older; were currently active in a team sport (e.g.

soccer, basketball, netball, rugby league, rugby union, Australian football, touch football); had a history of physical activity (≥two times per week) extending over the previous six months; were available for the duration of the study; did not have any existing medical conditions that would compromise participation; agreed to follow a pre-determined training program; and continued with their normal physical activity. The study occurred during the subjects' competition season (16, 25, 42), and their existing physical activity generally consisted of two field- and two gym-based sessions, and one game, per week. Although subjects would have different training backgrounds, by ensuring they maintained their normal physical activity, the researchers felt that any changes in athletic performance could be related to the applied training intervention. The procedures used in this study were approved by the institutional ethics committee. All subjects received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained prior to participation in the study.

As per previous research (25), sample size was determined by estimating the magnitude of differences between the effect sizes that would theoretically result from the training protocols. As effect size may be measured in relation to the principle assessment criterion, speed test times were used. Based on investigations of speed training (3, 25, 42), it was assumed that the effect size for this study would be large (0.80). An 80% confidence level was desired, and power was set at 0.80. As a consequence, with an expected effect size of 0.80 and alpha level of 0.05, the sample size used in the study was considered appropriate to determine athletic performance changes with sufficient statistical power (19).

Procedures

Testing was conducted over two days, separated by at least 48 hours, and no more than 72 hours. The first testing session was a field session, conducted across double indoor basketball courts with a sprung wooden floor. Due to the limited availability of the courts, all subjects were tested in the one session for both the pre- and post-tests, and rotated through each assessment in alphabetical order. Prior to data collection in session 1, the subject's age, height, and body mass were recorded. A standardized warm-up, consisting of 10 minutes of jogging, 10 minutes of dynamic stretching of the lower limbs, and progressive speed runs, was used in session 1. Due to the need to use the timing lights system for three different speed tests, all subjects completed the assessments in the following order: 40-m sprint; vertical jump; standing broad jump; CODAT; lateral jumps; T-test; and BOMBT. As subjects rotated through the assessments in order, at least three minutes recovery was provided between each trial. Three trials were completed for each test (three for each leg in the lateral jumps), and the best trial was used for analysis. Session 2 was laboratory-based, and subjects were scheduled dependent on their availabilities. The order for testing in this session was: mSEBT; drop jumps; and isokinetic strength testing. A specific warm-up was used for the mSEBT and isokinetic testing, which will be detailed later. Following pre-testing, subjects were randomly allocated into the two training groups. Training involved two one-hour sessions per week, on non-consecutive days, for six weeks. Post-testing was conducted within a week of the subject's final session, following the same procedures as pre-testing. Subjects refrained from intensive exercise in the 24 hours prior to each testing session.

40-m Sprint

Sprint time was recorded by a timing lights system (Fusion Sports, Coopers Plains, Australia). Gates were placed at 0 m, 10 m, 20 m, and 40 m, at a height of 1.2 m and width of 2 m, to measure time over the 0-10 m, 0-20 m, and 0-40 m intervals. Sprints over 10 m (16, 24), 20 m (10), and 40 m (15) have been used in the assessment of team sport athletes. Subjects began the sprint from a standing start 30 centimeters (cm) behind the start line to trigger the first gate, and were instructed to accelerate from the starting line and sprint through all gates. If the subject rocked backwards or forwards prior to starting, the trial was disregarded and repeated. Time for each interval was recorded to the nearest 0.001 s.

Vertical Jump

The vertical jump was used as an indirect measure of power in the vertical plane. A Vertec apparatus (Swift Performance Equipment, Wacol, Australia) was used to measure vertical jump performance. The subject initially stood side-on to the Vertec (on the subjects' dominant side), and while keeping their heels on the floor, reached upward as high as possible, fully elevating the shoulder to displace as many vanes as possible. The last vane moved became the zero reference. The subject then jumped as high as possible with no preparatory or jab step, and height was recorded in cm from highest vane moved. No restrictions were placed on the knee angle during the eccentric phase of the jump. Vertical jump height was calculated by subtracting the standing reach height from the jump height.

Standing Broad Jump

The standing broad jump was used as an indirect measure of horizontal power, and involved the subject placing the toes of both feet on the back of the starting line. With a simultaneous arm swing and crouch, the subject then jumped forward as far forward as possible, ensuring a two-footed landing. Subjects had to 'stick' the landing for the trial to be counted. If not, the trial was disregarded and another completed. No restrictions were placed on body angles attained during the preparatory phase of the jump. Distance was measured using a standard tape measure (HART Sport, Aspley, Australia), which was the perpendicular line from the front of the start line to the posterior surface of the back heel at the landing (37).

Change-of-Direction and Acceleration Test (CODAT)

The dimensions and movement direction for the CODAT is shown in Figure 1. The CODAT was used for this assessment as it contains movement patterns common to many team sports (i.e. sprinting forwards while completing lateral cuts), and has been shown to be a valid and reliable assessment of change-of-direction speed (27). Two timing gates (Fusion Sports, Coopers Plains, Australia) were used, also positioned at a 1.2-m height and 2-m width; one positioned at the start, and the other at the finish of the test. Subjects started 30 cm behind the start line, were required to face forwards at all times during the CODAT, and stayed outside the markers when running. If subjects cut across or over a marker, the trial was stopped and another attempted. Time was recorded to the nearest 0.001 s.

INSERT FIGURE 1 ABOUT HERE

Lateral Jump

The use of lateral jumps served as indirect assessments of lateral power. For the lateral jump, the subject started by standing on the testing leg with the medial aspect of the foot level with the start line (32). No restrictions were placed on the range of motion during the preparatory crouch, or the actions of the arms. Once ready, the subject jumped laterally to the inside (e.g. the right leg jump involved a displacement towards the left) as far as possible and landing on two feet. The perpendicular distance jumped was measured to the nearest 0.01 m, from the start line to the lateral margin of the take-off leg with a standard tape measure (HART Sport, Aspley, Australia). If subjects did not ‘stick’ the landing, the trial was disregarded and reattempted. The order in which leg was tested first for each subject was randomized.

T-Test

The T-test was assessed because it features anterior, posterior, and lateral movements, and the methodology was adapted from Semenick (40). Markers were positioned and taped to the floor as shown in Figure 2, with a start line indicated by tape on the floor. One 1.2-m high, 2-m wide timing gate (Fusion Sports, Coopers Plains, Australia) was used, and subjects were required to face forwards throughout the test. Subjects began the sprint from a standing start 30 cm behind the start line (Marker 1), before sprinting forwards 9.14 m to touch the top of the middle marker. They then side-shuffled 4.57 m to the left to touch the next marker, side-shuffled 9.14 m to the right to touch the next marker, side-shuffled 4.57 m to touch the middle marker again, before back pedaling (i.e. running backwards) through the start line to finish the test. The hand that was on the same side as the shuffle direction (i.e. the left hand when shuffling to the left, and the right hand when shuffling to the right) was used to touch the marker. Subjects were not to cross their feet when side-shuffling; if they did, the trial was stopped and reattempted. Due to time limitations during testing, all three trials involved an initial shuffle to the left. Time was recorded to the nearest 0.001 s from when the subject broke the gate the first time, until they returned through the gate following the back pedal.

INSERT FIGURE 2 ABOUT HERE

Backwards Overhead Medicine Ball Throw (BOMBT)

The BOMBT was used to assess combined upper- and lower-body power (43). Subjects stood with their backs to the throwing area, with their feet shoulder-width apart and heels on the zero line. To start the throw, the medicine ball was held in front of the body, with the arms extended at shoulder height. In one continuous movement, subjects flexed at the hips, knees and trunk, lowering the ball below the waist. They then extended their legs and thrust the hips forwards, while flexing the shoulders and elevating the ball above shoulder height as they threw it back over their head as far as possible. Following the throw, the subjects' feet could leave the ground, as would happen with a jump. A 3 kg medicine ball (HART Sport, Aspley, Australia) was used for all subjects (30), and three practice trials were completed for familiarization. The medicine ball was covered in chalk to assist with ball grip, and to mark the ground when the ball landed after the throw. Horizontal distance was measured by a standard tape measure (HART Sport, Aspley, Australia) from the zero line to the rearmost chalk-marking made by the ball. The BOMBT distance was also made relative to body mass via the formula: *Relative BOMBT = throw distance·body mass*$^{-1}$ (43).

Modified Star Excursion Balance Test (mSEBT)

Dynamic balance was assessed by using the mSEBT through three excursions; posteromedial, medial, and anteromedial. These excursions are the most representative of the SEBT (13), and are also reliable (12). The testing protocol used was adapted from the literature (23). Lockie et al. (23) also measured anterolateral, lateral, and posterolateral excursions; however these excursions were not considered in this study. The testing grid consisted of standard, 120-cm long, tape measures taped to the laboratory floor. Each tape measure extended from an origin at 45º increments, which was measured by a goniometer. The anteromedial directions required the subject to reach in front of their body. The medial reach involved the subject adducting their stance leg to a position behind the body, before extending the leg medially. The subject reached behind their body for the posteromedial excursion.

INSERT FIGURE 3 ABOUT HERE

Subjects stood on the center marker of the mSEBT, with the ankle malleoli aligned with the lateral tape measures, which was visually assessed by the researcher. Subjects then used their free leg to reach in this order: posteromedial, medial, anteromedial. With each attempt, the subject attempted to reach as far as possible along each line and make a light touch on the ground with the most distal part of the reaching leg. The subject then returned the reaching leg to a bilateral stance, without allowing contact to affect overall balance. A researcher noted the reach distance after each attempt. Subjects placed their hands on their hips during the mSEBT, and were required to keep them there throughout all reach attempts (Figure 3). A trial was disregarded if the researcher felt the subject used the reaching leg for an extended period of support, removed the stance leg from the center of the grid, removed their hands from their hips, or was unable to maintain balance. A minimum of three practice trials were used prior to data collection to familiarize subjects to the movements required, and to serve as a warm-up. The order of the stance leg used during testing was randomized across subjects. Reach distances were considered relative to leg length, and expressed as a percentage according to the formula *relative reach distance = reach distance/leg length x 100* (11). Reach differences between the legs were calculated through the formula: (*longer reach leg - lesser reach leg)/longer reach leg x 100*.

Drop Jump – Reactive Strength Index (RSI)

A 40-cm drop jump was used to determine the subject's RSI according to standard procedures (24). The drop jumps were performed on a force plate (Kistler, Winterthur, Switzerland), with data sampled at 1000 Hz. The starting position for the drop jump involved the subject standing upright on a 40-cm box. The subjects were instructed to step off from the height, and to jump up maximally from the force plate, attempting to minimize contact time. Contact time with the plate and the flight time of the jump were recorded. Jump height was calculated using the formula *Jump Height* = $(½a[t/2]^2)$ (a = acceleration due to gravity [i.e. 9.8 $m \cdot s^{-2}$], and t = total flight time). RSI was determined using the following equation: $RSI = JH \cdot CT^{-1}$ (JH = jump height in meters [$½at^2/2$], and CT = the length of the time in seconds the subject was in contact with the force plate following the drop) (24).

Isokinetic Strength Assessment

Knee extensor and flexor strength was assessed by an isokinetic dynamometer (CSMI Solutions, Stoughton, USA), with procedures adapted from previous research (26). Subjects completed 10 minutes of cycling on an ergometer at a self-selected pace as a warm-up. They then sat in the dynamometer, and were secured to the seat with shoulder straps fastened in the middle of the chest, and the thigh strap was secured 3 cm above the quadriceps-patella tendon junction. The knee joint axis of rotation was determined through palpation of the lateral femoral condyle, and aligned to the axis of the dynamometer. Subjects held onto the seat handles during testing. Two testing velocities were used; concentric torque at 240 degrees per second (°/s), and eccentric torque at 30°/s. The peak torque generated by the knee extensors and flexors at these speed has been related to multidirectional speed in team sport athletes (26). Contractions were performed through a range of 15-80°, with full extension defined as 0°. Subjects completed the concentric assessment first, before the eccentric assessment.

Once ready, subjects completed a warm-up of three submaximal repetitions at the testing velocities, with a 60-second rest interval between each set. Following this, subjects completed four maximal repetitions at each of the testing speeds, with a 60-second recovery between each velocity. The leg that was tested first was randomized. To ensure maximal effort, a visual display of each repetition on the computer screen was shown, and verbal encouragement was provided. For each angular velocity, the peak torque generated during each repetition was calculated within the software, and the highest value from each set was made relative to the subjects' body mass and used for analysis. Bilateral asymmetries in torque were calculated as the percentage difference between the stronger and weaker legs: (*stronger leg - weaker leg)/stronger leg x 100*. The stronger leg was defined as the leg that generated greater relative torque at a given testing speed (34).

Training Groups

After pre-testing, subjects were ranked by gender according to combined speed test times (0-40 m + CODAT + T-test), and randomly allocated into the two training groups: (1) traditional speed and agility training (TSA; n = 10); and (2) speed and agility with an enforced stop at the end of drills (ESSA; n = 10). As the study was designed to analyze the effects of each individual program, a non-training control group was not included (20, 25). A six-week training program has been shown to be a sufficient time period to induce changes in speed, agility, power, and dynamic balance (3, 25, 45). During the training period, subjects completed their assigned sessions on two non-consecutive days per week. All sessions were conducted on a football oval, where subjects wore their own athletic trainers or sporting cleats. If there was inclement weather, the training was completed on an indoor double basketball court, where subjects wore their own athletic trainers. The same dynamic warm-up, involving a low-intensity jog, followed by dynamic stretching, low-intensity technique drills, and progressive speed runs, was used before every session by all subjects. A cool-down involving low-intensity jogging and stretching was also used after every session.

Table 1 displays the training programs for each of the protocols. The programs featured training drills recommended for speed and agility development, and these were adapted from several different sources (3, 5, 8, 38). The drills were organized into four groups of exercises: speed and sprint technique; speed ladder drills; agility/change-of-direction speed; and total-body power using medicine ball throws. The training program was periodized appropriately by adjusting the technical complexity and intensity of the drills from week-to-week. The researchers supervised all training sessions, provided coaching and teaching advice, and ensured correct technique was used for each drill. Verbal encouragement was also provided by the researchers during each training session.

INSERT TABLE 1 ABOUT HERE

The TSA subjects completed each drill maximally, and decelerated at the end of a drill without restriction until they comfortably slowed down. Certain drills, indicated in Table 1, required subjects in the ESSA group to decelerate and stop at the end of the drill. The deceleration position was adapted from current coaching theory (8, 36), and required flexion of the knees and hips, such that the subject was in a sprint start position for drills that ended with a linear sprint (Figure 4A), or a quarter-squat position for sprints that finished with a lateral shuffle, or back pedal (Figure 4B). This position was held for 2 s to ensure the subject had completely stopped. The sprint start position allowed the lead leg to contact the ground ahead of the body to provide the necessary braking force to stop (14). Subjects were told to alternate which leg was the front, braking leg for the specific drills, in an attempt to balance the loading experienced by each leg. A degree of forward trunk lean was encouraged to minimize excessive eccentric braking forces being placed on the lead leg, which could occur if the subject was leaning backwards during deceleration (14). A red marker was placed at the end of certain drills, such that subjects had to stop level with this marker. These distances were provided so that subjects could safely decelerate and stop, and were dependent on the length the sprint efforts. Deceleration distances of 3 m were used for 10-20 m linear sprints, and 6 m for longer, 30-40 m linear sprints (22). Otherwise, subjects generally needed to stop at the end of a drill. Verbal instruction and feedback provided by the researchers during each drill ensured the ESSA subjects decelerated and stopped within each repetition.

INSERT FIGURE 4 ABOUT HERE

Statistical Analyses

Descriptive statistics (mean ± standard deviation) were calculated for all subjects. A one-way analysis of variance (ANOVA) was used to ensure there were no significant ($p < 0.05$) between-group differences in subject characteristics and mean pre-test multidirectional speed times (40-m sprint + T-test + CODAT) prior to the intervention. Following the training period, data was analyzed via a two-way ANOVA ($p < 0.05$), including groups as a between-subjects factor measured at two levels (TSA and ESSA) (3, 42). The within-subject factor (time) represented the pre- and post-training measures. As only two repeated measures were employed, the assumption of Mauchly's test of sphericity was not applicable. All other repeated measures ANOVA assumptions were considered, with the Levene statistic used to determine homogeneity of variance. If a significant F ratio was detected, post hoc tests were performed using the Bonferroni adjustment procedure. Effect sizes (Cohen's *d*) were calculated from the difference between the means divided by the pooled standard deviations for the pre- and post-test results. 0.50 and below was considered a low effect; 0.51-0.8 a medium effect; and 0.81 and above a large effect (6). All statistical analyses were computed using the Statistics Package for Social Sciences Version 20.0 (IBM, Armonk, USA).

RESULTS

Due to reasons unrelated to the study design, one male subject withdrew from the ESSA group, leaving nine subjects in this group. Nonetheless, there were no significant differences in age (TSA = 24.20 ± 5.92 years; ESSA = 23.33 ± 3.81 years; p = 0.713), height (TSA = 1.76 ± 0.09 m; ESSA = 1.74 ± 0.10; p = 0.576), or body mass (TSA = 77.64 ± 12.73 kg; ESSA = 73.50 ± 13.79 kg; p = 0.505), between the groups prior to the intervention. In addition, the total time for the TSA group (22.720 s) was not significantly (p = 0.794) different from that of the ESSA group (22.563 s). Therefore, it was assumed each group had similar physical characteristics. Neither group had a significant change in body mass from pre- to post-test (TSA = 77.64 ± 12.27 kg, p = 0.982; ESSA = 73.19 ± 13.79 kg, p = 0.145).

Table 2 displays the changes in speed test times for both the TSA and ESSA groups. The TSA significantly decreased time in all tests, by between 2-5% in the 40-m sprint intervals, 7% in the CODAT, and 4% in the T-test. The ESSA group significantly decreased 40-m time by 2%, CODAT time by 7%, and T-test time by 4%. However, the ESSA group did not significantly decrease 0-10 m or 0-20 m time. Nevertheless, there were no significant differences between the groups in any of the changes for the speed tests. The power test data is shown in Table 3. The TSA significantly improved in all tests except the vertical jump and RSI, while the ESSA group significantly improved in all but the right-leg lateral jump (Table 3). There were no significant between-group differences in the power adaptations.

INSERT TABLE 2 ABOUT HERE

INSERT TABLE 3 ABOUT HERE

The relative reach distances, and the between-leg difference in reach distance from the mSEBT, are shown in Table 4. When reaches were made with the left leg, and the right leg was used for stance, the TSA group significantly improved posteromedial and medial excursions. The ESSA group significantly improved the medial excursion. The same adaptations for both groups in these excursion directions also occurred when the right leg reached and the left leg was used for stance (Table 4). There were no significant differences for any of the changes in reach distance between the groups. The ESSA group significantly reduced the between-leg difference in medial reach, although this change was not significantly different to that of the TSA group. The increase in the between-leg difference in anteromedial reach for the TSA group had a large effect of 1.01, although the between-group difference to that of the ESSA group did not reach significance (p = 0.051).

INSERT TABLE 4 ABOUT HERE

Table 5 displays the data from the isokinetic strength tests. The TSA group had no significant changes in relative peak torque for the knee extensors or flexors at either the 240°/s concentric velocity, or the 30°/s eccentric velocity, and no significant changes in between-leg differences in relative peak torque. The ESSA group significantly increased relative concentric knee extensor torque for the left leg by 8%. There was a significant, 19% increase in eccentric knee flexor torque, which had a large effect (d = 1.03). The ESSA group had an increase in the between-leg difference in relative concentric peak torque at 240°/s for the knee flexors. This increase was significantly different to that of the TSA group (p = 0.020). There were no other significant between-group differences in unilateral strength.

INSERT TABLE 5 ABOUT HERE

DISCUSSION

This is the first study to investigate the effects of a traditional speed and agility training program, versus a program that emphasized deceleration by enforcing stopping at the end of drills, in team sport athletes. In addition, the effects of speed and agility training on dynamic stability as measured by three excursion distances from an mSEBT, and isokinetic unilateral strength of the knee extensors and flexors, was also investigated. The results reinforced that a well-designed speed and agility training program can improve multidirectional speed and power. Dynamic stability, as measured by functional reaching, can also be improved by this type of training. Generally, there were few between-group differences in adaptations induced by the interventions. There are, however, some important issues for strength and conditioning coaches to consider should they wish to implement enforced stopping during drills in an attempt to train deceleration, especially with regards to leg strength.

An appropriately designed training program can improve multidirectional speed as measured by a 15-m sprint and T-test in collegiate-aged males and females (3), and 5- and 10-m sprints as quickness measures in elite soccer players (16). The results from the TSA group supported these studies, as this group improved all 40-m sprint intervals, and the CODAT and T-test following the intervention (Table 2). The ESSA group significantly decreased 40-m, CODAT, and T-test time. Interestingly, the ESSA group did not significantly decrease 0-10 m and 0-20 m time, although the reduction in 10-m time did have a medium effect ($d = 0.66$). Within particular speed and agility drills, deceleration zones of 3-6 m were set (22). However, these distances may not have been long enough in some cases, especially for the agility drills which had shorter linear sprints (e.g. the T- and Z-drill). In a repeat-sprint exercise involving 40-m sprints in field hockey players, Lakomy and Haydon (22) found that deceleration distances of less than 6 m deterred players from sprinting maximally. Subjects in the ESSA group may have started decelerating before the end of the linear sprint, which meant the distances covered were shorter, potentially limiting 10-m and 20-m speed development. Nevertheless, 40-m sprint time still improved for the ESSA group. An avenue for future research is to determine the most appropriate deceleration zones for maximal sprint and agility drills. This could ensure appropriate linear sprint development, while still developing an athlete's capacity to decelerate as efficiently as possible.

Plyometrics can often be incorporated into programs designed to improve multidirectional speed (3, 38). This is because depending on the jumps used, leg power can be developed, which can then be expressed in sprint performance. For example, linear sprint training improved power as measured by vertical jump performance, which contributed to enhanced 15-m sprint velocity in male field sport athletes (42). Additionally, sprint training can reduce contact time following a drop jump (28), which would increase RSI, and linear speed improvements have been associated with increased horizontal leg power (3, 25). Total-body plyometric training can also improve medicine ball throw performance in female volleyball players (29), which shows power developments are not just restricted to the legs. There were a range of improvements in the power tests for both groups, most of which had medium effects (Table 3). When BOMBT distance was made relative to body mass, the improvements in power had large effects (TSA $d = 1.10$; ESSA $d = 1.05$). Furthermore, there were no between-group differences, which suggest any adaptations made were similar for both groups. This is not surprising, given that both groups completed the same plyometric exercises, and any influence of the enforced stopping training may not be seen in the explosive stretch-shortening capacities required in jumping or throwing. Nonetheless, speed and agility training that can improve multidirectional speed can also increase lower- and total-body power in team sport athletes.

Dynamic stability is stated to be an essential component of change-of-direction ability and multidirectional speed (4, 18). The SEBT is often used to assess dynamic stability through functional reaching, and the posteromedial, medial, and anteromedial directions best represent the challenges posed by this test (13). A modified version of the SEBT has been used to analyze this capacity in relation to multidirectional speed in male team sport athletes, and found that faster athletes could reach further in the posteromedial and medial directions (23). Indeed, further reaches in these directions related to faster T-test and CODAT times (23), and excursion distance can be improved through specific training (45). The results from this study indicated that TSA training improved posteromedial and medial reaches, while ESSA training improved medial reaching, as well as decreasing between-leg differences in excursions in this direction (Table 4). Nonetheless, as there were no significant differences in reach modifications between the groups, adaptations induced by the training protocols were relatively similar. A range of exercises used in the training program involved unilateral stance and lateral cutting movements (Table 1), which would stress an athlete's ability to maintain dynamic stability (23). This investigation suggests that speed and agility training, either traditionally-focused or with an emphasis on deceleration, can improve dynamic stability as measured by selected reaches from an mSEBT. These adaptations would likely contribute to the multidirectional speed improvements for both groups (Table 2).

Leg strength is viewed as a contributing factor to multidirectional speed (18, 41). Conceptually this is understandable, as acceleration from a near-stationary position, or reacceleration following a stop and direction change, requires the athlete to overcome the inertia of their body mass. Furthermore, bilateral maximum strength as measured by a squat has been related to both linear (31) and change-of-direction speed (35). Sprint training can increase isometric force development in male physical education students (28), and three-repetition maximum squat in field sport athletes (25). However, there is less research analyzing the unilateral strength of the knee muscles, and whether they are affected by speed and agility training. This is important, as greater knee flexor strength asymmetries measured eccentrically at 30°/s related to slower multidirectional speed in male athletes (26). There were no significant changes in unilateral strength for the TSA group (Table 5). In contrast, there were three significant changes for the ESSA group. These results may have been influenced by the loading that would be expected during a deceleration movement (1, 14). The peak relative 240°/s concentric torque for the left leg knee extensors significantly increased following the intervention in the ESSA group (Table 5). The quadriceps are said to be the primary leg muscles for deceleration (1, 14). Even through the actions required during deceleration are typically eccentric, the loading experienced during the enforced stops may have contributed to this change. The loading on the left leg can also be seen in the knee flexors, which had a significant increase in the peak relative 30°/s eccentric torque, which also had a large effect (d = 1.03). The knee flexion enforced in the deceleration position (Figure 4) would have placed great eccentric stress on the hamstrings (21), which provides an indication why there was a large effect for the increase in left leg knee flexor torque. These adaptations support current scientific theory about the stress experienced on the front leg during a deceleration following a sprint (14). Potentially, training that enforces stopping at the end of drills can contribute to increased strength of the knee extensors and flexors.

There was, however, an increase in the between-leg difference in knee flexor concentric torque in the ESSA group only following the intervention, suggesting a greater asymmetry in leg strength. Although concentric torque asymmetries have been found in team sport athletes, they may not adversely affect multidirectional speed (26). This would be particularly true if they are below the clinical significance standard of 15% (2, 17), which was the case in the current study (Table 5). Nonetheless, what these results do imply is that ESSA subjects may have favored a particular leg to use for braking, even though they were instructed to alternate the final stopping leg within drills. Given that positioning the preferred leg as the front leg in a sprint start can enhance acceleration (44), the preferred leg may also be more effective for braking. Practitioners wishing to implement deceleration training must ensure a balance of loading between the legs, as an over-emphasis on one leg may lead the development of knee flexor asymmetries between the legs. Due to the potential development of a leg strength imbalance, the overuse of a preferred leg for stopping could potentially contribute to an increased risk of injury (7, 17). There are also performance implications, because if an athlete that favors stopping on a certain leg, they may also change direction better from that leg, as opposed to the contralateral leg. The implications of favoring a preferred leg for deceleration movements should be investigated further.

There are certain limitations for this study. No control group was used, although this is in line with previous research (20, 25). While it appears that both traditional speed and agility training, and training with enforced stopping can improve aspects of performance relating to multidirectional speed, complete confirmation of this could be aided by using a control group. Additionally, multidirectional sprint technique was not directly analyzed. Indeed, the stopping distance used within the deceleration-emphasized drills, which would greatly affect sprint technique, was based on repeat-sprint research (22), rather than speed and agility training research. The loading associated with stopping within certain distances needs to be investigated. This could involve incorporating motion capture for kinematic analysis, and the use of a force plate at the end of the stop to quantify kinetics during an enforced deceleration. This information could not only be used to prescribe training, but also to avoid injury risk when using this type of protocol. Nonetheless, this research still provides valuable information about how drills that enforce stopping can affect multidirectional speed. Although this type of training generally did not induce changes different to that of traditional speed and agility training, there were certain isokinetic strength adaptations that indicate the applicability of using deceleration exercises in a team sport athlete's program.

PRACTICAL APPLICATIONS

This study confirms that an appropriate speed and agility training program in team sport athletes can improve multidirectional speed and power. A novel aspect to this study was that this type of training can improve dynamic stability, as measured by functional reaching. The practical applications are that a properly periodized speed and agility program will improve factors important for team sport athletes, including multidirectional speed, leg power, and dynamic stability. A training program that focuses entirely on deceleration is probably not necessary. There may be value in introducing certain deceleration-focused drills, as this could lead to increases in knee extensor and flexor strength. Nonetheless, there are several issues that strength and conditioning coaches should be cognizant of when using deceleration drills. Coaches should ensure that their athletes still have the opportunity to complete maximal sprints over distances important for match-play, and do not decelerate too soon. Indeed, future research should determine appropriate stopping distances following maximal sprints over team sport-specific distances (i.e. up to 40 m). Coaches should also ensure that athletes do not favor braking with one leg over the other. This could lead to the development of a between-leg strength asymmetry, which could eventually hinder multidirectional speed performance if the strength difference becomes too great. Furthermore, the biomechanics associated with a deceleration following a maximal sprint over a variety of distances should be determined. This would confirm the loading experienced during a stop that could affect knee extensor and flexor strength development, as well as the type of technique adaptations that may occur following speed and agility training that enforces stopping within drills.

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Figure Legend

Figure 1: The Change-of-Direction and Acceleration Test. m = meters.

Figure 2: The T-test. m = meters.

Figure 3: Modified Star Excursion Balance Test performance with a left stance leg and right reach leg for the (A) posteromedial; (B) medial; and (C) anteromedial excursions.

Figure 4: The stopping position required following a linear sprint (A), and following a lateral shuffle or back pedal (B) (8, 14, 36).

Table 1: The six-week speed and agility program used by the traditional and enforced stopping training groups. The * indicates that an exercise required a deceleration and stop at the end of the drill for the enforced stopping group. Reps = repetitions; m = meters.

	Speed and Sprint Technique		Speed Ladder		Agility/Change-of-Direction Speed		Total-Body Power	
Week	Drill	Sets x Reps	Drill	Sets x Reps	Drill	Sets x Reps	Drill	Sets x Reps
1	A-Skip*	4 x 15 m	One Foot In*	2 x 8 m	4-Point Pop-up*	2 x 3 each side	Overhead Medicine Ball Throw	3 x 5
	A-March*	3 x 10	Bunny Hops*	2 x 8 m	Wide Z-Drill*	4 x 40 m		
	Partnered Leg Recovery	3 x 10 per leg						
2	A-Skip*	4 x 15 m	Two Feet In*	3 x 8 m	Box Drill*	4 x 20 m	Medicine Ball Squat, Push, Pass	3 x 5
	Solo Leg Recovery	3 x 10 per leg	Two-Feet In Lateral*	2 x 8 m each direction	Compact Z-Drill*	4 x 30 m		
	In-place Double Ankle Jumps	3 x 10						
	Chute Acceleration Run*	4 x 30 m						
3	Straight-Leg Run*	4 x 20 m	Two In Two Out*	2 x 8 m	Y-Cuts*	4 x 10 m	Medicine Ball Lateral Pass	3 x 5 each side
	Countermovement Jumps	3 x 8	Two In Two Out Lateral*	2 x 8 m each direction	T-Drill*	4 x 30 m		
	Single Hurdle Run-Through*	4 x 8 hurdles						
	Chute Acceleration Run*	4 x 30 m						
4	Double Hurdle Run-Through*	4 x 8 hurdles each leg	Two Feet In*	3 x 8 m	Lateral Skater*	3 x 20 m	Overhead Medicine Ball Throw and Sprint*	3 x 5
	Split Jump	3 x 8	Side-step Run*	3 x 8 m	Step-out Drill*	4 x 20 m		
	Flying 30's*	4 x 30 m (with 30-m build-up)			W-Drill*	4 x 20 m		
5	Split Jump	3 x 8	One Foot In*	3 x 8 m	Lateral Skater*	3 x 20 m	Medicine Ball Squat, Push, Pass, and Sprint 10 m*	3 x 5
	Flying 30's*	4 x 30 m (with 30-m build-up)	Two Feet In*	3 x 8 m	Snake Run*	4 x 20 m		
			Two Feet In Lateral*	2 x 8 m each direction	Z-Drill with Poles*	4 x 40 m		
6	Tuck Jump	3 x 8	Two Feet In*	3 x 8 m	Line Drill*	3 x 20 m	Medicine Ball Squat, Push, Pass, and Sprint 10 m*	3 x 5
	Chute Flying 30's*	4 x 30 m (with 30-m build-up)	Tango Run*	3 x 8 m	Star Run*	4 x 20 m		
			Side-step Run*	3 x 8 m	Z-Drill with Poles*	4 x 40 m		

Table 2: Change in time (mean ± standard deviation) for the 0-40 m sprint (0-10 m, 0-20 m, and 0-40 m intervals), change-of-direction and acceleration test (CODAT) and T-test following six weeks of traditional speed and agility training, or speed and agility training with enforced stopping, in male and female team sport athletes. p = significance.

	Traditional Speed and Agility Training (n = 10)				Enforced Stopping Speed and Agility Training (n = 9)			
	Pre	Post	*p* value	Effect Size	Pre	Post	*p* value	Effect Size
0-10 m (s)	1.811 ± 0.136	1.729 ± 0.095	0.011*	0.70	1.815 ± 0.105	1.746 ± 0.103	0.126	0.66
0-20 m (s)	3.187 ± 0.231	3.064 ± 0.179	0.010*	0.60	3.154 ± 0.166	3.082 ± 0.178	0.078	0.42
0-40 m (s)	5.711 ± 0.458	5.590 ± 0.388	0.011*	0.29	5.695 ± 0.391	5.572 ± 0.378	0.026*	0.32
CODAT (s)	6.154 ± 0.480	5.720 ± 0.427	0.004*	0.96	6.100 ± 0.322	5.697 ± 0.292	0.001*	1.31
T-Test (s)	10.907 ± 1.036	10.435 ± 0.802	0.024*	0.51	10.767 ± 0.975	10.288 ± 0.864	0.032*	0.52

* Significant ($p < 0.05$) difference in within-subjects factor (pre- and post-test).

Table 3: Change in vertical jump (VJ), standing broad jump (SBJ), lateral jump (LJ) from the left and right legs, backwards overhead medicine ball throw (BOMBT), relative BOMBT (RBOMBT), and reactive strength index (RSI) as measured by a 40-centimeter (cm) drop jump (mean ± standard deviation), following six weeks of traditional speed and agility training, or speed and agility training with enforced stopping, in male and female team sport athletes. m = meters; $m \cdot BM^{-1}$ = meters per kilogram body mass; $JH \cdot CT^{-1}$ = jump height/contact time ratio; *p* = significance.

	Traditional Speed and Agility Training (n = 10)				Enforced Stopping Speed and Agility Training (n = 9)			
	Pre	Post	*p* value	Effect Size	Pre	Post	*p* value	Effect Size
VJ (cm)	48.40 ± 11.09	52.40 ± 8.90	0.095	0.40	50.44 ± 9.94	55.00 ± 9.73	0.008*	0.46
SBJ (m)	2.09 ± 0.23	2.23 ± 0.22	0.001*	0.62	2.08 ± 0.20	2.25 ± 0.18	0.001*	0.89
Left LJ (m)	1.77 ± 0.17	1.87 ± 0.18	0.026*	0.57	1.68 ± 0.21	1.83 ± 0.17	0.016*	0.79
Right LJ (m)	1.67 ± 0.17	1.77 ± 0.12	0.016*	0.68	1.60 ± 0.19	1.74 ± 0.16	0.083	0.80
BOMBT (m)	12.05 ± 2.27	13.87 ± 2.87	<0.001*	0.70	11.53 ± 1.95	13.94 ± 2.83	0.012*	0.99
RBOMBT ($m \cdot BM^{-1}$)	0.155 ± 0.018	0.179 ± 0.025	<0.001*	1.10	0.160 ± 0.031	0.190 ± 0.026	0.011*	1.05
RSI ($JH \cdot CT^{-1}$)	0.91 ± 0.35	0.95 ± 0.28	0.679	0.13	0.85 ± 0.25	0.99 ± 0.20	0.016*	0.62

* Significant ($p < 0.05$) difference in within-subjects factor (pre- and post-test).

Table 4: Change in left (right stance leg) and right (left stance leg) relative reach distance (reach distance/leg length x 100) as measured by the modified Star Excursion Balance Test, and the percentage (%) difference between the legs (mean ± standard deviation), following six weeks of traditional speed and agility training, or speed and agility training with enforced stopping, in male and female team sport athletes.

	Traditional Speed and Agility Training (n = 10)				Enforced Stopping Speed and Agility Training (n = 9)			
	Pre	Post	*p* value	Effect Size	Pre	Post	*p* value	Effect Size
Left Leg Reach (%)								
Posteromedial	79.24 ± 6.57	90.32 ± 7.68	0.001*	1.55	80.38 ± 6.89	85.96 ± 13.86	0.242	0.51
Medial	71.51 ± 4.42	85.02 ± 9.07	0.001*	1.89	74.19 ± 9.24	83.72 ± 10.05	0.012*	0.99
Anteromedial	72.21 ± 8.37	71.09 ± 6.89	0.577	0.15	71.43 ± 7.75	74.16 ± 8.40	0.080	0.34
Right Leg Reach (%)								
Posteromedial	78.91 ± 8.23	88.27 ± 8.26	0.001*	1.14	81.57 ± 7.61	88.17 ± 9.69	0.074	0.76
Medial	75.38 ± 7.65	83.51 ± 9.01	0.001*	0.97	71.68 ± 7.66	81.00 ± 9.29	0.009*	1.09
Anteromedial	71.41 ± 7.76	74.87 ± 7.03	0.110	0.47	73.41 ± 8.06	75.47 ± 8.38	0.367	0.25
Difference (%)								
Posteromedial	5.09 ± 3.59	4.41 ± 3.01	0.515	0.21	9.49 ± 8.26	7.27 ± 8.46	0.639	0.27
Medial	9.61 ± 7.10	7.90 ± 5.59	0.591	0.27	10.57 ± 7.55	4.06 ± 4.20	0.038*	1.07
Anteromedial	2.49 ± 2.42	7.80 ± 7.02	0.081	1.01	4.72 ± 3.30	3.62 ± 1.57	0.360	0.43

* Significant ($p < 0.05$) difference in within-subjects factor (pre- and post-test).

Table 5: Change in peak relative torque, and the percentage (%) difference between the legs (mean ± standard deviation), for the knee extensors (Ext) and flexors (Flex) of the left and right leg, during concentric (Con) contractions at 240 degrees per second (°/s), and eccentric (Ecc) contractions at 30°/s, following six weeks of traditional speed and agility training, or speed and agility training with enforced stopping, in male and female team sport athletes. $Nm \cdot BM^{-1}$ = Newton meters per kilogram body mass.

	Traditional Speed and Agility Training (n = 10)				Enforced Stopping Speed and Agility Training (n = 9)			
	Pre	Post	*p* value	Effect Size	Pre	Post	*p* value	Effect Size
Left Leg ($Nm \cdot BM^{1}$)								
Ext Con 240°/s	1.50 ± 0.23	1.48 ± 0.20	0.872	0.09	1.54 ± 0.24	1.66 ± 0.24	0.031*	0.50
Ext Ecc 30°/s	3.34 ± 1.47	3.21 ± 1.09	0.779	0.10	2.74 ± 0.85	3.08 ± 0.76	0.216	0.42
Flex Con 240°/s	1.34 ± 0.29	1.38 ± 0.25	0.380	0.15	1.19 ± 0.46	1.33 ± 0.16	0.320	0.41
Flex Ecc 30°/s	2.18 ± 0.37	2.29 ± 0.38	0.419	0.29	1.77 ± 0.36	2.29 ± 0.39	0.037*	1.39
Right Leg ($Nm \cdot BM^{1}$)								
Ext Con 240°/s	1.54 ± 0.26	1.55 ± 0.15	0.836	0.05	1.60 ± 0.28	1.65 ± 0.24	0.179	0.19
Ext Ecc 30°/s	3.40 ± 0.83	3.36 ± 1.07	0.863	0.04	3.21 ± 0.97	3.39 ± 0.84	0.550	0.20
Flex Con 240°/s	1.33 ± 0.25	1.37 ± 0.22	0.473	0.17	1.41 ± 0.15	1.47 ± 0.13	0.062	0.43
Flex Ecc 30°/s	2.25 ± 0.31	2.35 ± 0.48	0.382	0.25	2.12 ± 0.35	2.27 ± 0.50	0.334	0.35
Difference (%)								
Ext Con 240°/s	10.02 ± 11.43	11.76 ± 5.11	0.710	0.20	6.40 ± 5.80	6.54 ± 4.93	0.940	0.03
Ext Ecc 30°/s	26.29 ± 22.52	20.74 ± 10.67	0.462	0.31	19.44 ± 18.18	15.08 ± 12.21	0.618	0.28
Flex Con 240°/s	10.10 ± 6.51	5.27 ± 7.08	0.154	0.71	7.00 ± 6.65	11.61 ± 6.15	0.006*†	0.72
Flex Ecc 30°/s	12.11 ± 9.86	13.41 ± 9.49	0.625	0.13	10.23 ± 6.87	13.15 ± 16.31	0.659	0.23

* Significant ($p < 0.05$) difference in within-subjects factor (pre- and post-test).

† Significant ($p < 0.05$) difference in between-subjects factor (training group).

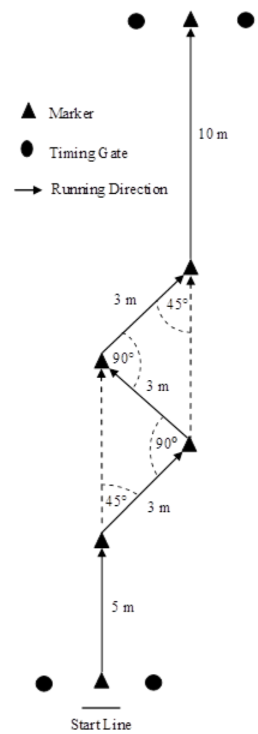

Figure 1: The Change-of-Direction and Acceleration Test. m = meters.

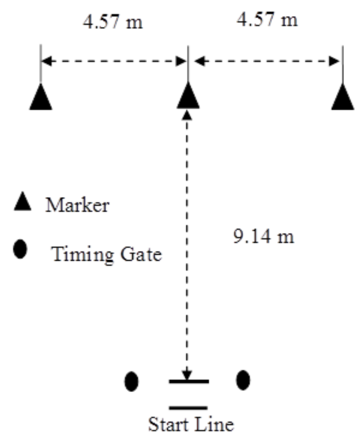

Figure 2: The T-test. m = meters.

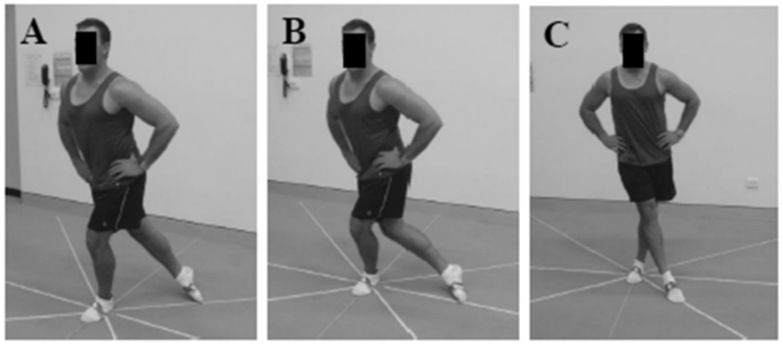

Figure 3: Modified Star Excursion Balance Test performance with a left stance leg and right reach leg for the (A) posteromedial; (B) medial; and (C) anteromedial excursions.

Figure 4: The stopping position required following a linear sprint (A), and following a lateral shuffle or back pedal (B) (8, 14, 36).