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A Comparison of the Technique of the 180° Cutting Maneuver Performed on Grass and on a Hardwood Floor

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Abstract: The 180º cutting maneuver (also known as the 505 drill) is commonly seen in field and court sports, and it consists of a 15 m run up to a turning point, followed by a timed stop and 180º change of direction for 5 m. The purpose of this study was to determine the most effective joint movements, limb velocities and body positions to perform the 180º cutting maneuver. Additionally, the study compared the kinematics of the 505 drill performed indoors while wearing running shoes and outdoors while wearing cleats. For this study, twelve athletes executed the 505 drill indoors while wearing running shoes, and twelve executed the 505 drill outdoors while wearing cleats. Fifty nine independent variables were measured for each athlete and compared to the athlete's time to complete the test. Mean test time was 2.27 seconds for the indoor group and a significantly lower 2.47 s for the outdoor group. Correlation analysis and forward stepwise multiple regression analysis was performed on both groups to determine which variables were significantly related to test time. Trunk forward lean at push off of the jab leg was most highly correlated to test time for the indoor athletes (r= -0.887), however, flexion at maximum flexion of the jab knee was most highly correlated to test time for the outdoor group (r= -0.748). Outdoor athletes could benefit from assuming a lower and more flexed body position similar to the indoor athletes and attain a greater degree of trunk lean at jab leg touchdown.

Key Words: 505 agility drill, change of direction, 180 degree cut.

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Introduction

Most team sports require the athlete to make rapid and skillful change of direction movements, which require exceptional strength and coordination. The ability to perform the cut at exactly the right instant in sports often leads to substantial rewards for the athlete. A cut can be used to either evade a defender, follow the path of an object such as a football or a baseball or in reaction to the motions of an opponent. The 180º cutting maneuver is different from all other changes in direction as it involves a complete deceleration of the athlete's velocity to zero meters per second before turning and accelerating again. This makes it the most complicated and difficult cut in sports and is therefore an agility move like no other. This 180º cutting maneuver is often called the 505 agility drill [1]. Agility can be defined as the component of fitness that involves changing the direction of a body's velocity quickly, efficiently and accurately [2-3]. This requires speed, strength, and coordination, abilities which are prevalent in every court and field sport. Speed, a scalar quantity defined as the distance covered divided by the time taken to cover it, is required going into and coming out of the cut or direction change. Strength refers to the total amount of force that can be effectively produced and is required during the cut itself as the muscles of the legs must create large eccentric contractions to decelerate an athlete in full sprint. The athlete must then produce large concentric contractions to accelerate the athlete in the new direction. Previous studies have suggested that peak ankle plantar flexor moment and vertical jump peak power are related to success in change of direction ability [3].

A common test of athletic ability is the timing of a change of direction movement over several metres. The most basic of these tests is the 505 agility test (Figure 1) [1]. It is described as basic, as it only involves one change of direction. The athlete starts at the first cone, the second cone is 10 m away, and 5 m from that is the third cone, all in a straight line. The athlete accelerates down the line of cones passing the second. When the athlete reaches the third cone they make a 180º turn and accelerate back to the initial starting point. The 5 m zone between the second and third cones is known as the testing zone. It is the goal of the athlete to travel through this area as fast as possible. In this way the athlete's deceleration, 180º turning ability and acceleration are all tested. These are all key components of the athlete's overall agility [1].

The purpose of the study was to determine the most effective movements used by athletes to execute the 505 agility drill performed in two different settings. The first test was conducted on grass and the athletes wore cleats. The second test was conducted on a hardwood floor and the athletes wore running shoes (Figure 2). A secondary purpose was to determine differences in the movement pattern used when the drill is executed on grass and when the drill is executed on a gym floor. Many athletes compete in more than one sport resulting in the need to adapt their technique to different situations. Additionally, many outdoor athletes spend much of their off season training time indoors when outdoor facilities are not available.

The 180º cutting maneuver is a crucial element in many sports. It involves running forward at a high speed, decelerating and stopping, and then running in the opposite direction as fast as possible (Figure 3). In American football it is known as the button hook. In cricket the runners execute this cut as they run between the wickets. It is also common in sports such as Ultimate frisbee, soccer, handball, basketball, and netball. Variations of the cut are used in court sports like tennis, squash, and badminton. More importantly, this change of direction maneuver is a critical aspect of many fitness and agility tests. The multistage shuttle run test, also known as the beep test, is widely used to test athlete's VO2 max and the results can often make the difference between making an elite team and being eliminated. The beep test involves running 20 m, making a 180º cut and running back.

During the NFL testing camps, athletes are put through a grueling battery of interviews, drills, and fitness tests. Of the four agility tests used during the NFL testing camps, three incorporate a 180º cut: the 20 yard shuttle, the 60 yard shuttle, and the three cone drill [4]. These tests highlight an athlete's ability to make a 180º turn efficiently and effectively. The NBA also uses agility tests with 180º turns to test their athletes at the start of every season.

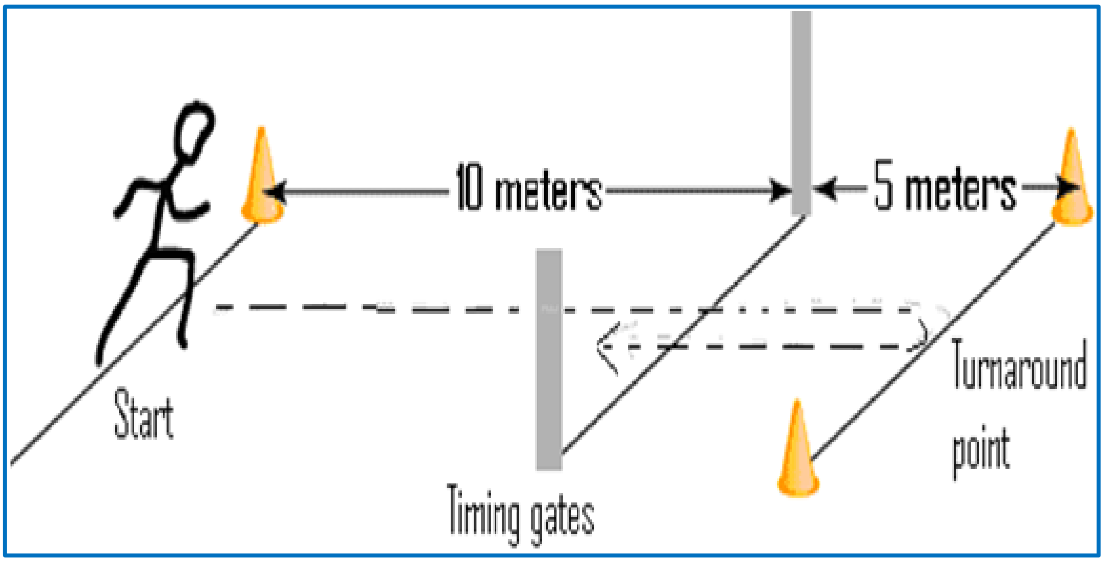

Figure 1. A schematic representation of the 180º cutting test.

Figure 2. Different footwear and different styles of performing the 180 º cutting test.

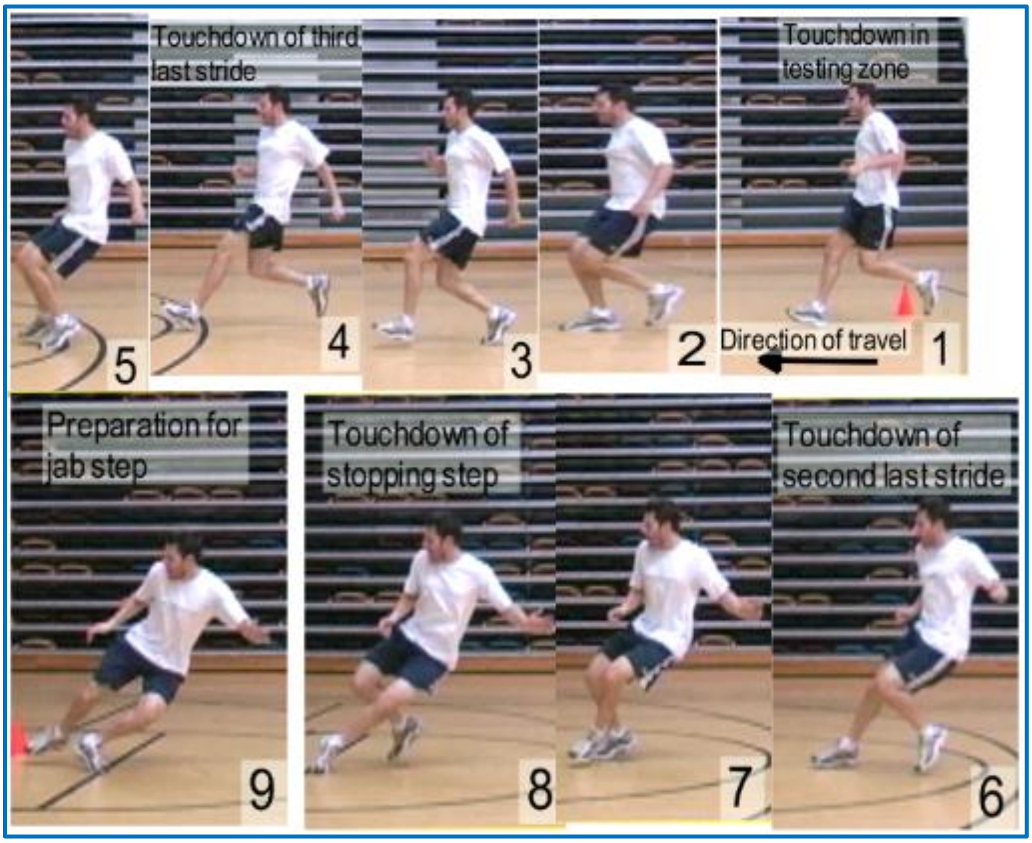

Figure 3. Run up into last step of change of direction

2. Materials and Methods

2.1 Design and Participants

Twelve (12) athletes executed the 505 drill indoors while wearing running shoes and twelve (12) athletes executed the 505 drill outdoors while wearing cleats. All participants provided written informed consent prior to the filming session. The informed consent form was approved by the Education and Nursing Review panel of the University of Manitoba. The participants in the study were instructed to perform the 180º cut as they would normally in practice or during a game, at the fastest speed possible [5]. Each participant was given 2-3 practice attempts to become familiar with the test protocol and to practice placing his jab foot on the desired turnaround location. Each athlete performed the test three times, and the fastest trial was subjected to further analysis.

The athletes were removed out of regular practice in groups of two to complete the test or a separate filming session was scheduled. Adequate rest was given in between trials to ensure fatigue did not affect the test results. Athletes began at the 15 meter mark and, at the investigator's command, ran to the zero mark (the turnaround point) and accelerated through the testing zone as fast as possible.

The footage obtained for the best trial from all of the cameras was imported into a Toshiba laptop computer using the Dartfish "In the Action" feature [6]. Video analysis was used to collect quantitative data from the video comparing the techniques employed between the 180º cut outdoors wearing cleats and indoors wearing court shoes. The primary variables of interest were the time the athlete spent in the testing zone as well as instantaneous velocities of the athletes at 1, 2 and 3 meters from the turnaround point. The data gathered from the timing gates provided an accurate account of the athletes' time in the testing zone (Figure 4). Dartfish [6] software was used to determine the athletes' velocity at 1, 2 and 3 meters from the turnaround point.

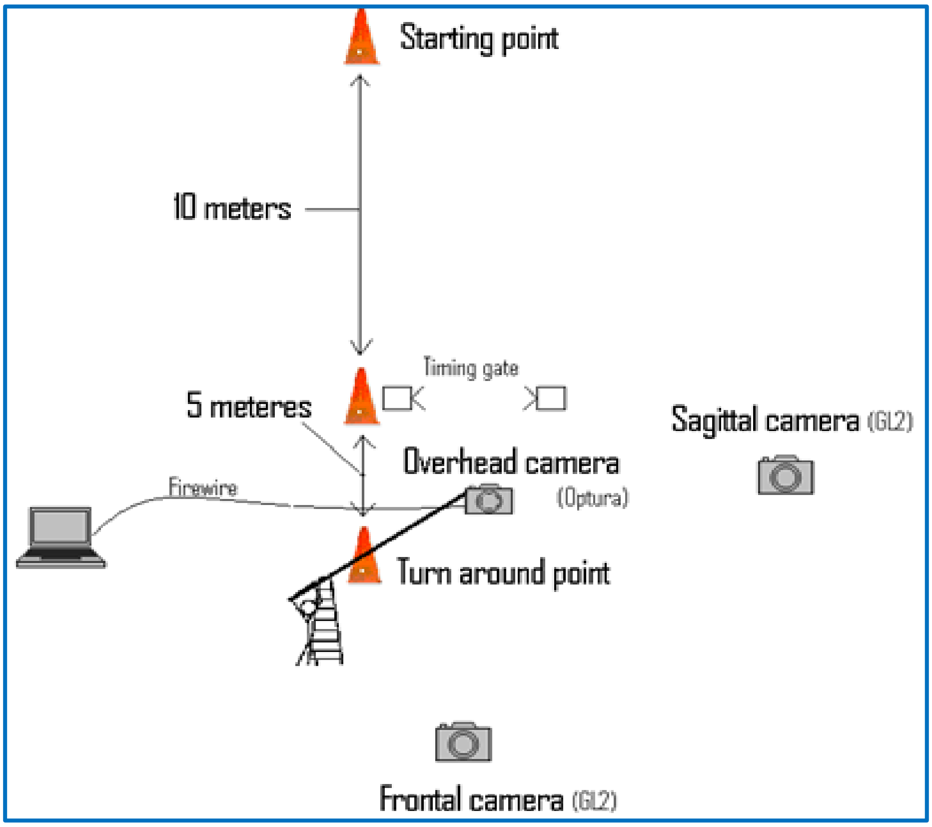

Figure 4. Positioning of cameras and cones for filming sessions.

2.2 Kinematic Variables Analyzed

The key variables that were measured were taken from the beginning of the last step prior to placement of the jab step until the end of the push off phase of the 1st step after the jab step (Table 1). This was to ensure that the kinematic data of the athlete's final deceleration and initial acceleration through the skill was captured. Analysis of the footage revealed the joint angles of the hip and knee of the touch down leg as well as the hip and knee extension of the push off leg for the last step leading up to the jab step and the first step following the jab step could be measured. The degrees of trunk and shoulder rotation at various points of the skill were also measured.

Using the 180-degree system, all joint angles were measured using the Dartfish Team Pro 4.5.9 Analyzer angle tool [6]. In anatomical position, according to the 180-degree system for measuring joint angles, all joints are in a position of zero degrees and any deviation from anatomical position was measured. Deviation from anatomical position in the posterior direction was referred to as hyperextension and labeled as negative flexion, i.e. 14.5º of shoulder hyperextension was labeled as -14.5º of shoulder flexion. For the one categorical variable, ground/hand contact during the jab step, a "1" was assigned to the athlete if contact was made, and a "0" was assigned to the athlete if no contact was made. This is in keeping with methods outlined in Hassard [7] in regards to categorical variables.

Variables measured from maximum flexion of the stance phase until the end of the push off phase determine the range of motion experienced at each joint through the force producing phase of the skill. The Dartfish "data table" allowed for the calculation of angular velocities of the hip and knee during extension of the first two push off phases following the jab step. Angular velocities were measured by taking the range of angular displacement and dividing by the elapsed time: $\omega=\theta/t$.

Table 1. List of variables measured

Phase of the Skill	Variables Measured
Dependent Variable	➢ Time in testing zone (seconds)
Touchdown of last step	➢ Trunk lean relative to vertical (degrees) ➢ Front hip flexion (degrees) ➢ Front knee flexion (degrees) ➢ Length of step (meters)
Jab step touch down	➢ Trunk lean relative to vertical (degrees) ➢ Trunk lateral flexion (degrees) ➢ Back knee flexion (degrees) ➢ Jab knee flexion (degrees) ➢ Jab hip flexion (degrees) ➢ Foot plant relative to direction of travel (degrees) ➢ Abduction of jab hip (degrees) ➢ Shoulder rotation relative to the direction of travel (degrees) * ➢ Length of last step (meters) ➢ Contralateral shoulder flexion (degrees) ➢ Contralateral shoulder abduction (degrees) ➢ Ipsilateral shoulder flexion(degrees) ➢ Ipsilateral shoulder abduction (degrees)
Max flexion of jab step	➢ Trunk lean relative to vertical (degrees) ➢ Trunk lateral flexion (degrees) ➢ Back knee flexion (degrees) ➢ Jab knee flexion (degrees) ➢ Jab hip flexion (degrees)
Jab step push off	➢ Trunk lean relative to vertical (degrees) ➢ Back knee flexion (degrees) ➢ Jab knee flexion (degrees) ➢ Back hip flexion (degrees) ➢ Jab hip flexion (degrees) ➢ Shoulder rotation relative to the direction of travel (degrees) * ➢ Shoulder range of motion during jab support time (degrees) * ➢ Support stance time (seconds) ➢ Contralateral shoulder flexion (degrees)

	➢ Contralateral shoulder abduction (degrees)*** ➢ Ipsilateral shoulder flexion(degrees) ➢ Ipsilateral shoulder abduction (degrees)
Max flexion of 1st step	➢ Trunk lean relative to the vertical (degrees) ➢ Length of step(meters) ➢ Lateral distance of first step (meters) ➢ Support knee flexion(degrees) ➢ Support hip flexion (degrees)
End of 1st step push	➢ Support hip flexion/extension (degrees) ➢ Support knee extension (degrees) ➢ Support ankle plantarflexion (degrees) ➢ Support stance time (seconds)
Angular Velocity	➢ Hip ext. velocity of jab push (degrees/s) ➢ Knee ext. velocity of jab push (degrees/s) ➢ Hip ext. velocity of first push (degrees/s) ➢ Knee ext. velocity of first push (degrees/s) ➢ Hip ext. velocity of second push (degrees/s) ➢ Knee ext. velocity of second push (degrees/s)
Additional variables	➢ Number of approach strides prior to jab step ➢ Hand / Ground contact during the cut ** ➢ Velocity 3 meters before turnaround point (m/s) ➢ Velocity 2 meters before turnaround point (m/s) ➢ Velocity 1 meter before turnaround point (m/s) ➢ Velocity 1 meter after turnaround point (m/s) ➢ Velocity 2 meters after turnaround point (m/s) ➢ Velocity 3 meters after turnaround point (m/s)

2.3 Statistical Analysis

Means and standard deviations for each of the variables were calculated for the twelve subjects in each group. The variables for the two groups were compared using t-tests to determine if significant differences existed. T-tests were used to compare each individual variable to the specific variable of the other group. Since 56 t-tests were performed the risk of a Type I error was high. Using a p value of 0.05, one test out 20 will be significant simply by chance. To combat this risk, a False Discovery Rate (FDR) correction was used to decrease the chance of finding significance when no significance existed [8] (Equation 3.1). By using the FDR correction, the p value is decreased in order to provide a more stringent test.

$\alpha / \sum_{i=1}^{k} (1/i)$	Equation 3.1.
α = 0.05 ***k*** = number of comparisons ***i*** = the interval steps	

The main goal of the study was to determine the technique variables that produce the best test time for the 505 drill indoors and outdoors. A forward stepwise multiple regression analysis was conducted in order to eliminate any variables that were not found to be significant predictors of test time. The forward stepwise multiple regression analysis provided a list of variables that were considered to be significant contributors to the dependent variable, test time [7].

3. Results

The height, age and weight of the participants in the study are outlined in Table 2. There were no significant differences between the values for each of the groups. The differences between the times of the two groups to complete the test are reported in Table 3. The mean time for the indoor athletes to complete the test was 2.27 seconds while the mean for the outdoor group to complete the test was 2.49 seconds. Also highlighted is the time to reach maximum flexion during the jab step. This variable was chosen as it coincided with the furthest distance the athlete's centre of gravity traveled into the testing zone. Additionally, it also coincided with the time during which the athlete's velocity reaches 0 m/s. The mean time for the indoor athletes to reach this point was 1.01 seconds whereas the mean time for the outdoor athletes was 1.18 seconds. This time was then translated into a percentage of the athlete's total time to complete the test. If the percentage had been 50%, it would indicate that the athletes spent exactly the same amount of time decelerating into the cut as they did accelerating out of the cut. The mean value for the indoor athletes was 44.57% and the mean value for the outdoor athletes was 47.47%. This indicates that athletes in both groups reached the zero point, or halfway location in the test prior to 50% of their total test time.

At touchdown of the jab step, thirteen variables were measured. Comparisons of the means for the measured variables are presented in Table 4. The variables which were calculated to be significantly different between the two groups were: trunk lean relative to the vertical, abduction of jab hip, lateral distance from jab hip to jab heel and ipsilateral shoulder flexion. The mean angle of trunk lean from the vertical for the indoor group was 50.58º while the mean angle of trunk lean for the outdoor group was only 27.85º.

The athlete's abduction of their jab hip was also found to be significantly different with a p-value of 0.002. The mean hip abduction angle for the indoor group was 18.88º and the mean hip abduction angle for the outdoor group was 38.02º. Similarly, the next significant variable was the lateral distance from the jab hip to the jab heel that had a p-value of 0.0002. The mean distance for the indoor group was 0.64 m whereas the mean distance for the outdoor group was only 0.55 m. Finally, the last variable that was significantly different between the two groups at touchdown of the jab step was shoulder flexion on the ipsilateral side as the jab. The indoor group had a mean shoulder flexion angle of 26.17º while the outdoor group had a mean flexion angle of -23.48º. The negative value indicates that the outdoor athletes generally hyperextended their shoulder back behind their body as opposed to flexing it forward in front of their body as was common for the indoor athletes.

Five variables were measured during maximum flexion of the jab step: forward trunk lean, trunk lateral flexion, stopping knee flexion, jab knee flexion and jab hip flexion. Of these five variables, only one was found to be significantly different between the indoor and outdoor groups.

Indoor athletes had a mean lateral flexion angle of -29.42º and outdoor athletes had a mean lateral flexion angle of -6.39º. The negative values recorded for lateral trunk flexion indicate that the faster athletes flexed away from the direction of the turn.

Table 2. Descriptive characteristics of subjects.

	Indoor Athletes				Outdoor Athletes			
	N = 12				N = 12			
	Mean ± SD		Range		Mean ± SD		Range	
Age (years)	21.50	1.56	19.00	24.00	24.60	3.90	20.00	30.00
Height (m)	1.85	0.03	1.80	1.90	1.80	0.05	1.70	1.90
Weight (kg)	82.23	3.99	75.00	88.60	79.30	6.84	70.40	93.40

Table 3. T-test comparison of means and standard deviations of the test times for indoor and outdoor athletes (*p ≤ 0.00108).

	Indoor Athletes		**Outdoor Athletes**			
Variable	**n = 12**		**n = 12**		**t-value**	**p-value**
	Mean	**SD**	**Mean**	**SD**		
Test time (s)	2.27	0.05	2.49	0.14	-4.78	**0.0001***
Time to max flexion of jab step (s)	1.01	0.07	1.18	0.09	4.99	**0.0001***
Percent of total time (%)	44.57	1.24	47.47	0.66	2.65	**0.01***

Table 4. T-test comparisons of means and standard deviations of the measured variables at touchdown of the jab step (*p ≤ 0.0108).

	Indoor Athletes		**Outdoor Athletes**			
Variable	**n = 12**		**n = 12**		**t-value**	**p-value**
	Mean	**SD**	**Mean**	**SD**		
Trunk lean relative to the vertical (deg)	50.58	19.25	27.85	14.36	3.28	**0.003***
Trunk lateral flexion (deg)	-24.52	19.46	-16.32	12.75	-1.22	0.24
Stopping knee flexion (deg)	107.95	12.54	95.03	18.59	1.10	0.28

Jab knee flexion (deg)	50.57	21.53	41.45	10.89	1.31	0.20
Jab hip flexion (deg)	78.89	18.88	63.10	18.07	2.10	0.047
Foot plant relative to the direction of travel (deg)	86.93	13.72	76.36	19.52	1.54	0.14
Abduction of jab hip (deg)	18.88	13.93	38.02	12.21	-3.58	**0.002***
Length of step (m)	0.69	0.14	0.70	0.20	-0.04	0.97
Contralateral shoulder abduction (deg)	37.09	26.67	33.20	33.70	0.31	0.76
Contralateral shoulder flex (deg)	26.44	27.87	36.68	27.79	-0.90	.38
Ipsilateral shoulder abduction (deg)	16.45	15.67	34.41	38.52	-1.50	0.15
Ipsilateral shoulder flexion (deg)	26.17	43.61	-23.48	42.26	2.83	**0.001***

Ten variables were selected and compared at the push off of the jab step. Of these ten variables two were found to be significantly different between the indoor and outdoor trials. Trunk lean relative to the vertical and contralateral shoulder abduction and were significantly different with a $p \leq 0.0108$. Indoor athletes had a mean forward trunk lean of 57.3º whereas outdoor athletes had a mean forward trunk lean of only 38.7º. Shoulder abduction of the contralateral limb to the jab step was seen to be significantly different with a p-value of 0.00015. Indoor athletes had a mean abduction angle of 19.84º while outdoor athletes demonstrated 29.37º of abduction in their shoulder.

The linear velocity of the athletes in both groups was measured at one meter intervals prior to and after the turn in order to evaluate the athlete's deceleration and acceleration. None of the measured velocities were found to be significantly different between the indoor and outdoor groups.

The number of ground contacts prior to the jab step was measured for the indoor and outdoor trials, with no difference found between the groups. Hand/ground contact was also evaluated during the cut. The athletes were not instructed to touch or not touch the ground as they cut. Instead they were told to perform the cut as well as possible. In keeping with the style outlined in Hassard [7] when dealing with categorical variables, a "1" was assigned to the athletes who contacted the ground with their hand and a "0" was assigned to the athletes who did not contact the ground with their hand. A Chi square test with a Yates correction was performed on the resulting data. Seven out of the indoor athletes touched the ground during the cut whereas only 2 of the outdoor athletes touched the ground during the cut. This was not a significant difference.

The variable which showed the highest correlation to test time in indoor athletes was trunk forward lean during jab push off. This variable was found to have a negative correlation (-0.887) with the athlete's test time, meaning that the greater the athlete leans forward from the vertical as he pushes off with his jab leg, the less time it will take to complete the test. Stopping knee flexion during jab touchdown was also shown to have a strong, negative correlation to test time (-0.719). This indicates that greater knee flexion of the stopping or contralateral knee was associated with a decreased test time. Trunk lateral flexion in the ipsilateral direction to the jab during the last step before the jab step (side flexion away from the turn) was found to be significantly correlated to test time ($r = +0.696$) at a level of $p \leq .01$. This means that those athletes who turned left and had a high amount of lateral trunk lean to the left generally performed well in the test.

Following the correlation analysis of the indoor athletes, a correlation analysis was performed on the variables from the outdoor athletes in order to determine which variables were strongly correlated with the athlete's test time. Ten variables were shown to be significantly correlated to the athlete's test time. The variable with the most significant relationship to test time was knee flexion of the jab leg at touchdown of the jab step.

The second most highly correlated variable with time for the outdoor athletes was their linear velocity one meter before the turnaround point. This was positively correlated with test time ($r = +.703$) and significant at a level of $p<.01$. This suggests the athletes that were able to decelerate most efficiently prior to the jab step were generally able to complete the test in the shortest amount of time.

The next step in the statistical analysis was performing two separate stepwise multiple regression analyses on the indoor athletes and outdoor athletes in order to determine the effect of each variable on test time. Only 11 variables were entered into the regression analysis as it was recommended [7] that fewer variables be entered into the analysis than there were subjects in the study. The indoor regression equation does not account for the variables relating to trunk rotation relative to the direction of travel (as measured by the overhead camera).

It was found that subjects in the study displayed considerably more trunk lean than those in the pilot study and therefore the measurements could not be performed accurately from the overhead camera video.

Regression analysis of the indoor athletes identified four variables, trunk lean relative to the vertical at push off the jab step, hip extension velocity of the jab step push, jab knee flexion at maximum flexion of the jab knee and trunk lateral flexion during the last step before the jab step. These variables could account for 95.7% of the variation in test time.

This equation was found to be accurate in predicting test time for indoor athletes. Indoor athlete #1 had a test time of 2.25 s. When the selected variables were entered into the equation for indoor athlete #1 the resulting test time was found to be 2.21 s.

Regression analysis of the outdoor athletes also identified four variables, linear velocity of the athlete one meter before the turnaround point, linear velocity of the athlete one meter after the turn around point, hip extension velocity of the jab step and support stance time of the jab step. However, only 88.8% of the variation in test time in the outdoor athletes is accounted for.

This regression equation was found to be an accurate equation for the prediction of outdoor athletes test times. Outdoor athlete #1 had a test time of 2.31 s. When the selected variables for outdoor athlete #1 were entered into the equation the predicted test time was also 2.31 s.

Regression equation for indoor athletes:

$y = 2.311 - 0.001x1 - 0.00016x2 + 0.001x3 + 0.002x4$

Where: y = test time

Intercept = 2.311

x1 = Trunk lean relative to the vertical (jab step push off)

x2 = Hip extension velocity (jab step push off)

x3 = Jab knee flexion (maximum flexion of the jab knee)

x4 = Trunk lateral flexion (last step before jab step TD)

Regression equation for outdoor athletes:

$y = 2.036 + 0.092x_1 + 0.124x_2 - 0.001x_3 + 0.349x_4$

Where: y = test time

Intercept = 2.036

x_1 = Linear velocity one meter before the turn.

x_2 = Linear velocity one meter after the turn.

x_3 = Hip extension velocity of the jab push.

x_4 = Support stance time of the jab step.

4. Discussion

The difference in average test time between the indoor group and the outdoor group was 0.22 seconds. This was a significant difference, especially when the range of test times is examined, 0.2 seconds for the indoor group and 0.4 seconds for the outdoor group. Based on the increased coefficient of friction between grass and cleats, the assumption was that the outdoor group would be able to perform the test faster than the indoor group as they would have been able to apply more lateral force to the ground without the risk of slipping. The indoor group however, made use of the decreased coefficient of friction by allowing their jab foot to skid across the turnaround point in a controlled manner. They were, therefore, able to keep their center of gravity further from the turnaround point than the indoor group by increasing their trunk lean away from the jab foot. This served to decrease the total linear distance covered by their centre of gravity, so that despite similar linear velocities between the groups, the indoor groups traveled a shorter distance and therefore completed the drill in a shorter time.

By the time the athlete reached the last step prior to the jab step he will have already begun to rotate his hips and shoulders up to about 90º away from the direction of travel [9]. In turn, foot plant of the last step before the jab step is placed almost 90º from the direction of travel which is not an ideal position from which the athlete can apply force to the ground. It is likely that much of the eccentric force will come from the hip abductors with minimal contribution coming from the hip and knee extensors. Additionally, more of the force will be taken up by the ligaments of the hip and knee [9].

Calahan et al. [10] reports that young men can generally produce a maximum concentric muscle torque in hip extension of about 151 Nm whereas only 93 Nm can be produced during hip adduction. Cheng and Rice [11] reported knee extensor torque could reach as high as 267 Nm in young men, further supporting the idea that leaning away from the cut and utilizing greater hip and knee flexion will activate stronger muscles to eccentrically control the deceleration.

The importance of a sideways lean is emphasized as the regression analysis highlighted trunk lateral flexion during the last step before the jab step as a key indicator of test time for the indoor group. For every 1 degree increase in the angle lateral trunk flexion there was a 0.002 second decrease in the athlete's test time. At first glance, this may appear to be quite a small difference. However, the range of trunk lateral flexion values for the indoor group was over 50°, so the differences can become significant. Additionally, the range of test times is also quite small. All of the indoor athletes had a test score between 2.14 seconds and 2.34 seconds yielding a range of 0.2 seconds.

The indoor group was able to attain a slightly greater position of forward trunk lean than the outdoor group at this point. The indoor group had a mean trunk lean angle of 39.2º whereas the outdoor group had a mean trunk lean angle of 24.2°. These values were not found to be significantly different at the adjusted p value of 0.0108 but were significantly different at the more commonly used p value of 0.05.

The technique of keeping the athlete's centre of gravity low is the most common theme in agility related literature. This topic has been widely described by Jeffreys [12] Sayers [13-14] and Sheppard [15]. These studies reiterate the fact that a low centre of gravity places the athlete in a more controlled position as well as allow the athlete to apply forces to the ground in a lateral direction rather than primarily vertical as would be the result of a more upright body position. An athlete may be fast, but if they cannot move under control, their effectiveness will be limited in a game situation [16].

The comparison of trunk lateral flexion between the two groups was approaching significance with a p value of 0.0122. The mean lateral trunk flexion for the indoor group was -29.4º whereas the outdoor group had a mean angle of -2.7º. The negative value refers to the fact that they were leaning away from their jab foot. The increased lateral lean of the indoor group will help keep their centre of gravity further from the turnaround point. The lean is facilitated by the predictable slide across the hardwood floor. The combination of cleats on grass does not offer the ability to slide as the two surfaces are form locked to each other rather than force locked as is the situation indoors [17]. Initially, it was believed that the small amount of slide in the indoor trials would hamper the athletes in completing the test. Instead, this slide turned out to allow them to utilize a more efficient stopping position because they had a greater trunk lean away from the cut

Following jab step push off, the jab leg is forcefully flexed forward at the hip. To mimic the motions of a sprinter, the contralateral shoulder should then forcefully flex in order to increase the ground reaction forces applied to the ground by the push off leg. It is recommended that further research into the role of the arms during a 180° cutting maneuver is undertaken as many of the athletes appeared to stop any type of conscious arm movements as they approached the cut. Additionally, there was no mention of the role of the arms while performing a 180° cut in any of the literature reviewed. Bezodis et al. [18] outlines the role of the non-kicking side arm in the place kick in rugby athletes and its contribution to controlling total angular momentum of the body during the kick. Elite athletes tended to display a more consistent motion of the non-kicking side arm. Research on optimal arm motions should be conducted on athletes as they rotate through a cut as well as to further understand the relationship of the arms in a 180° cut and how they contribute to both linear and angular momentum of the athlete as well as ground reaction forces.

An additional variable that was identified in the regression formula was the hip extension velocity for both indoor and outdoor groups. It is understandable that it is the one variable the groups had in common in their regression formulas. Powerful hip extension is a key factor in the success of almost every sport [19] and the execution of the 180° cut is no exception.

The average angle of hip flexion for the indoor group was 76.4º and the average angle of hip flexion for the outdoor group was 55.4º. It is advantageous to have a greater amount of hip flexion as this will place the hip extensor muscles under additional stretch. Consequently, they will contract with greater force due to the stretch shortening cycle as mentioned earlier [20]. Similarly, the average knee flexion angle for the indoor group was 86.3º whereas the average angle of knee flexion for the outdoor group was 70.6º. Here, too, more knee flexion would be advantageous as it would provide for a larger range of motion with which to apply force to the ground as well as increase the stretch on the knee extensor muscles.

5. Practical Applications

The research presented here is of some value to the rapid start and stop and change of direction skills involved in several team sports, including football, soccer, basketball, Ultimate Frisbee and any other sport that requires rapid change of direction maneuvers as there currently is a lack of published research on the topic of the 180° cutting maneuver. This cut is performed by countless athletes in testing situations and in the case of the NFL combine, can sometimes make the difference between gaining or losing a multimillion dollar contract. It appears that further research is required on the specific role of the arms during the cut and this study would suggest that a larger sample size be recruited to conduct such a project.

The indoor athletes examined in the present study exhibited greater skill and a more effective body position than the outdoor athletes filmed. This was due in part to the difference in the coefficient of friction between the ground and the athletes in each setting. The indoor athletes had a greater degree of trunk forward lean that kept the center of gravity further from the turnaround point. This enhanced position increased the balance of the indoor athletes as well as increasing the range of motion in the push off leg. The indoor athletes also exhibited a greater amount of lateral trunk flexion and a lesser amount of flexion in the jab knee. The greater trunk flexion also facilitated contact of one or both of the athlete's hands with the ground. Since this 180º cutting maneuver is used as a screening test in several professional and amateur sports teams, skill in performing the drill could be useful in scoring well in the test. Emphasis on the skill seen in performing the indoor version of the test appear to be more closely related to better timed scores on the test. These aspects of the skill should be practiced by the athletes being evaluated by the 180 º cutting maneuver.

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The authors declare that they have no competing interests.