ABSTRACT

International Journal of Exercise Science 14(1): 211-221, 2021. Moderate angle cutting maneuvers (between 45° and 90°) are common and essential performance skills for success in multidirectional sports. Research addresses the injury risks of cutting but few studies have attempted to quantify the performance of the cut itself. PURPOSE: To identify any anthropometric, kinematic, and/or kinetic markers of a high-performance cut so they may be taught and lead to more effective training. METHODS: Ten college-aged male athletes (mass 73.97 ± 8.77 kg, height 1.81 ± 0.07 m) and ten non-athletes (mass 87.37 ± 13.93 kg, height 1.85 ± 0.04 m) completed five moderate angle cutting trials with a speed constraint of 4.03 m/s - 4.44 m/s through a 3 m in to and 3 m out of a 60° change in direction set-up. Kinetic and kinematic measurements were recorded through ground reaction forces and lower limb angles. RESULTS: A Bonferroni correction revealed that athletes spent significantly less time in the propulsion phase (52.0% ± 0.02%, p < 0.02) compared to non-athletes (55.4% ± 0.03%, p < 0.02). The propulsion phase was determined as the percentage of the contact phase the knee was extending (e.g. Green, et al, 2012). The athletes produced significantly greater instantaneous values of X GRF, Y GRF, and Z GRF during the propulsion phase (p < 0.05). CONCLUSION: Greater GRFs coupled with shorter propulsion phases by the athletes accounted for the lack of differences in the propulsion impulse between the two groups. Changing direction in a shorter time improves an athlete’s ability to evade an opponent, by decreasing the time an opponent has to react to a new direction.

KEY WORDS: Moderate angle cut, athletic performance, propulsion, agility, change of direction, athletes

INTRODUCTION

The ability to change direction, or cut, quickly and effectively while running is an essential performance skill for success in multidirectional sports (11). Cutting is used acutely in action, for example, when creating open space for a pass in soccer, evading a defender while going up for a layup in basketball, and maneuvering through a pile of defenders in football. For instance, during the active portion of a basketball game, it is estimated that 70% of the movements are cutting related, whether they be side to side shuffling movements or powerful movements to get open for a shot (28, 30). Further, during soccer matches, players make over 600 turns during
the match, with movements consisting of angular changes of up to 90 degrees (4). Literature in the realm of agility and multidirectional movement in sports, such as Nilsson, et al. (2014), have analyzed the components of a cut that may increase injury risk, or potential mechanisms for decreasing the risk of injury, but to our knowledge none have looked at the mechanism that make a cut more useful in the field of play (23).

It has been noted in the literature that better control over the increased forces on the lower limbs during a cut may lead to greater performance, but quantification of these variables has yet to be explored (17, 19, 26). The ability to effectively produce these changes in direction in a sporting event can allow players to change the outcome of a game (9). These movements require precision and familiarity with the immediate situation in order for them to be used effectively in a competitive setting. The athlete’s ability to stop and regain speed effectively allows them to complete the move faster in the hopes of evading their opponent or gaining open space which adds the tactic of deception to the movement (11). While previous research provides insight about the types of cutting maneuvers and their prevalence in sports, our study aims to take it a step further and quantify the characteristics of a high-performance cut. Understanding the mechanisms that contribute to a more effective cutting maneuver would allow players to further develop their multidirectional tactics and perform better in their sporting events.

The purpose of this study is to identify any anthropometric, kinematic, kinetic, or temporal markers of a high-performance cut. By utilizing a group of non-athletes as our control group, we will be able to compare the developed cutting maneuvers of athletes to the baseline cutting maneuvers of individuals with no prior experience. We hypothesize that there will be evident kinematic differences in the context of the technique of the cutting maneuver between the athletes and the non-athletes due to the varying athletic background of all of the participants. Additionally, we believe that the anthropometrics will not have a significant impact on the differences of the cutting maneuvers. There have been previous studies that note anthropometric differences in athletes performing cutting maneuvers from the same sport, but due to the inclusion of a variety of athletes and sports backgrounds, we believe anthropometrics will not drive the differences in the cuts (9). The information gained from this comparison will be crucial from a performance standpoint in competitive multidirectional sports since athletes will be able to better practice their directional changes. If any indicators of a high-performance cut are discovered in this study, they can be utilized by coaches and athletes alike in training to maximize the effectiveness of the maneuvers in a competitive setting.

METHODS

Participants
Twenty male college students, ages 18 to 22, were recruited: ten participants were athletes and ten were non-athletes. The athletes had at least three years of competitive exposure to varsity high-school athletics such as soccer, basketball or football, and had to be a skilled position in football such as a wide-receiver or running back. These athletes continued to play these sports competitively through intramurals at Gonzaga University from freshman year to their participation in the study. These sports were chosen due to the exposure to moderate angle side
cutting. The other ten were chosen due to their lack of experience in cutting sports or athletics in general. No participant had a major lower limb injury within the year prior to the study. Volunteers who had been previously diagnosed with a concussion were excluded from our study, due to the potential effects it may have on proprioception (15). All participants displayed dominance with their right leg. Leg dominance was determined by asking the subject to identify the leg they would use to kick a soccer ball at a target with (21). Right leg dominance was preferred because of the data collection set up. This project was approved by the Gonzaga University IRB and prior to data collection, written informed consent was provided by each participant. This project adhered to the principles and research ethics outlined in Navalta et al, 2019 (22).

Protocol

Anthropometric measurements collected were chosen based on their relevance in the literature, or they were thought to potentially impact the cutting mechanism (15). Height, leg length, foot length, foot width, Q-angle and ankle flexibility of the participants were measured using standard scales, tape measures and goniometers. Leg length was measured from the greater trochanter to the lateral malleolus. Foot length was measured from the posterior aspect of the participants heel to the tip of their big toe. Foot width was measured at the widest part of the foot. Flexibility of the ankle was measured with a goniometer to determine the range between maximum dorsiflexion and plantarflexion, as well as maximum inversion and eversion. Additionally, arch height was measured for each participant by having them wet their right foot and stand on a piece of cardboard. This was repeated with the participants sitting down to see if their arch collapsed. The footprint of each participant was assessed by the investigators to determine if their arch is low, normal or high (5). Center of pressure (CoP) of each participant was calculated by completing a ten second, right leg, balance trial on the force plate to determine how far the CoP moved throughout the ten seconds. A single leg (right) and double leg maximal squat jump on a force plate was used to determine an individual’s power.

Participants used their own preferred athletic shoe for the cutting trials. Participants started 4 meters away from the force plate (11), where they would perform a 60 degree cut (3, 10) then run 4 meters out of the cut (11) (Figure 1). Tape on the floor marked the path described. There were two timing gates, both 3 meters from the center of the force plate, and the trials were controlled with a required time of completion between 1.34 and 1.49 seconds, which would equate to a speed of approximately of 4.03 m/s - 4.44 m/s. Another requirement for a successful trial was the participant's entire foot landing on the force plate. Five successful trials were required.

Kinematics: Two cameras (210 Hz) were used to record kinematics (Figure 1). Camera 1 was 132 degrees from the -y direction, and was used to observe sagittal plane kinematics. Camera 2 was 60 degrees from the -y direction, and was used to observe frontal plane kinematics. The same trained investigator placed reflective markers on the participants acromion, greater trochanter, lateral epicondyle of the tibia, apex of the knee and lateral malleolus. Sagittal plane trunk, knee and ankle angles were obtained at touchdown and midstance (Kinovea®). Touchdown was the moment that the participant touched the force plate. Midstance was determined by observing
when the participants greater trochanter was directly over the lateral malleolus. Camera 2 was used for frontal plane torso lean at midstance. This angle was measured between the tip of the participants right shoe, to the midpoint of their torso between their shoulders. Footfall patterns were also recorded for each cut and were noted as forefoot, whole foot, or heel strike. In order for the foot strike to count, no portion of the foot could come into contact with any surface other than the force plate. A foot strike was considered forefoot when between the first (toe side) one-third of the foot strikes the ground first and a heel strike with the rear one-third (heel) of the foot and the ground (16). A strike was noted as whole foot when the entire foot struck the ground at the same time.

**Figure 1.** This figure shows the approach, take off, dimensions of the setup and location of the cameras and timing gates. “1” is the first timing gate, “2” is the second timing gate and “C1” and “C2” represents the cameras. This figure does not include the distance to slow down after the trial.

**Kinetic and Temporal Variables:** The X, Y, and Z-direction forces were used to calculate impulses in all three directions. Loading rates and peak GRF values were also determined for all three dimensions. Time spent in breaking and propulsive phases were determined from the breaking and propulsive forces in the Y-direction.

**Statistical Analysis**

All statistical analyses will be performed using SPSS Statistics Software (IBM, Armonk, NY) and Microsoft Office Excel Version 15.30. T-tests were conducted between the two groups for anthropometrics, kinematics, temporal and kinetic variables. To assess the statistical significance of the data, the variables were organized into anthropometric, kinematic, kinetic, and temporal variables wherein, Bonferroni corrections were applied. Bonferroni corrections were applied in order to reduce the likelihood of encountering type-1 and type-2 errors during analysis. The
Table 1. Comparison of mean ± standard deviation of measured variables

|                              | Body Mass (kg) | Q-angle (deg) | Contact time (s) | Time in the Braking Phase (%) | GRF X loading rate (kN/s) | Height (cm) | Right Leg Squat Jump Takeoff Velocity (m/s) | Full Body Angle (deg) | Time in the Propulsive Phase (%) | GRF Y loading rate (kN/s) | GRF Z loading rate (kN/s) | Right Leg Length (cm) | Right Leg Squat Jump Peak Power (W) | Upper Body Lean (deg) | Average Attempts for Five Successful Trials | Braking Impulse X (Ns) | Braking Impulse Y (Ns) | Right Shank to Thigh Length (cm) | Right Leg Squat Jump Average Power (W) | Leg Angle at Impact (deg) | Leg Angle at Midstance (deg) | Propulsion Impulse X (Ns) | Propulsion Impulse Y (Ns) | Right Foot Length (cm) | Double Leg Squat Jump Peak Average Power (W) | Thigh Angle at Impact (deg) | Thigh Angle at Midstance (deg) | Max GRF X (N) | Max GRF Y (N) | Right Ankle Dorsiflexion (deg) | Right Leg Balance CoP X range (m) | Knee Angle at Impact (deg) | Knee Angle at Midstance (deg) | Max GRF X (N) | Max GRF Y (N) | Right Ankle Plantarflexion (deg) | Right Leg Balance CoP Y range (m) | Hip Angle at Impact (deg) | Hip Angle at Midstance (deg) | Max GRF X (N) | Max GRF Y (N) | Right Ankle Inversion (deg) | Right Leg Balance CoP Total Distance (m) | Right Foot Arch Height Seated (Low: 1, High: 3) | Right Foot Arch Height Standing (Low: 1, High: 3) | Max GRF Z (N) | Max GRF Y (N) | Right Ankle Eversion (deg) | Right Leg Balance CoP Total Distance (m) | Right Foot Arch Height Seated (Low: 1, High: 3) | Right Foot Arch Height Standing (Low: 1, High: 3) | Max GRF Z (N) | Max GRF Y (N) |
|------------------------------|----------------|----------------|------------------|-------------------------------|--------------------------|---------------|---------------------------------|----------------------|-------------------------------|--------------------------|--------------------------|--------------------------|---------------------------------|------------------|---------------------------------|-------------------------------|---------------------------------|--------------------------|---------------------------------|-------------------------------|---------------------------------|--------------------------|---------------------------------|------------------|---------------------------------|--------------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|
| Athletes                    | 73.97 ± 8.77   | 13.6 ± 1.96   | 0.3 ± 0.04       | 47.9 ± 0.02*               | 11.87 ± 10.28            | 180.53 ± 6.89 | 2.05 ± 0.27                    | 162.32 ± 5.1        | 52.1 ± 0.02*                  | 5.27 ± 3.91              | 0.02 ± 0.00               | 87.37 ± 13.93       | 15.8 ± 1.81                    | 0.29 ± 0.02        | 44.6 ± 0.03*                    | 12.14 ± 9.79       | 0.03 ± 0.01                    | 120.57 ± 3.73  | 27.15 ± 1.67                   | 96.78 ± 4.6         | 53.76 ± 3.73                  | 5.27 ± 3.91              | 0.03 ± 0.01                    | 120.57 ± 3.73  | 27.15 ± 1.67                   | 96.78 ± 4.6         | 53.76 ± 3.73                  |
| Non-Athletes                | 87.37 ± 13.93  | 13.6 ± 1.96   | 0.3 ± 0.04       | 47.9 ± 0.02*               | 11.87 ± 10.28            | 180.53 ± 6.89 | 2.05 ± 0.27                    | 162.32 ± 5.1        | 52.1 ± 0.02*                  | 5.27 ± 3.91              | 0.02 ± 0.00               | 87.37 ± 13.93       | 15.8 ± 1.81                    | 0.29 ± 0.02        | 44.6 ± 0.03*                    | 12.14 ± 9.79       | 0.03 ± 0.01                    | 120.57 ± 3.73  | 27.15 ± 1.67                   | 96.78 ± 4.6         | 53.76 ± 3.73                  | 5.27 ± 3.91              | 0.03 ± 0.01                    | 120.57 ± 3.73  | 27.15 ± 1.67                   | 96.78 ± 4.6         | 53.76 ± 3.73                  |

Note: Anthropometrics, measures of power, kinematic, kinetic, and variables related to moderate angle cutting (60°) trials between college-aged male athletes (N = 10) and non-athletes (N = 10). Of the values, only percent time in the braking and propulsion phase, GRF Y loading rate (kN/s), right leg squat jump takeoff velocity (m/s), Q-angle (deg), and body mass (kg) were significantly different between the two groups. GRF = Ground Reaction Force; CoP = Center of Pressure; *Significance between Athletes and Non-athletes at the alpha level for each respective data group.
alpha values for each group to reach significance went as follows: anthropometrics = 0.002, kinematics = 0.004, kinetics = 0.005, temporal = 0.02. Ground reaction force time series were compared between the two groups using an independent t-test (alpha 0.05). Statistics were not used to analyze the foot strike data.

RESULTS

Anthropometrics: No anthropometric variables ($p > 0.002$) were found to be significantly different between the two groups.

Kinematics and Kinetics: No kinetic ($p > 0.005$) or kinematic ($p > 0.004$) variables were statistically different. However, there were periods of significant differences in the instantaneous GRF values in the X, Y and Z-directions (Figure 2). In all three dimensions of GRF there were significant differences during the latter half of the cut, and in X and Z there were significant differences following the initial contact with the force plate (Figure 2). In all cases, the athletes generated greater instantaneous GRF than the non-athletes.

Figure 2. Average ground reaction forces reported in body weights, GRF (BW), of college-aged male A (solid lines) and NA (dashed lines): GRF X (blue), GRF Y (red), GRF Z (green). X-axis represents the percent of contact time. Significance between the two groups depicted by black shaded line. Athletes produced significantly greater instantaneous values of X GRF, Y GRF, and Z GRF during the propulsion phase ($p < .05$).
Temporal Variables: Athletes spent a significantly greater time in the braking phase (48.1% ± 0.02%) than the non-athletes (44.6% ± 0.03%) \( (p < .05) \). Athletes also spent significantly less time in the propulsion phase (52.0% ± 0.02%) compared to the non-athletes (55.4% ± 0.03%) \( (p < .05) \). A univariate analysis of variance was run to determine the effect size and was reported as \( F(1,18) = 26.756, p = 0.000 \) with a fairly high effect size of 0.598. This test allowed us to use the effect size to calculate a G*Power (power = 1-\( \beta \) error prob) of 0.824 using G*Power 3.9.1.7 (8). The percentage of time spent in the breaking and propulsive phases was determined by analyzing the time pre-midstance and post-midstance, which was indicated by the procedure noted in our methods section. The times in the breaking and propulsive phases were interpreted as a percentage of the total time spent on the force plate.

Foot-Fall Patterns: Athletes exhibited forefoot striking 17 times, heel striking 25 times, and mid-foot striking 13 times where non-athletes only did each 15 times, with the remaining 20 cuts being mid-foot striking. Additionally, athletes were more consistent in their footfall patterns than non-athletes. Of the ten athletes, eight used the same footfall pattern for each successful cut during their five cutting trials, whereas non-athletes had eight participants using two to three different foot-fall patterns throughout their successful cuts. Athletes did not have any trials where all three foot-fall patterns were used, whereas the non-athletes had four participants use each foot-fall pattern at least once.

DISCUSSION

Moderate angle cutting maneuvers are essential movement techniques in multidirectional sports which can be utilized to evade opponents or obstacles (11). This change of direction technique is evident in sports such as, soccer, basketball, and football, making it an important aspect of game performance (14, 27). Importantly, we found that those with experience performing the cutting maneuver spent significantly less time during the propulsive phase of the cut and produced more force during this phase of the cut.

The only significant differences found between the cuts of the athletes and non-athletes were in the timing and instantaneous forces during both the deceleration and propulsion phases. Specifically, the athletes spent less time in and produced more force during the propulsion phase than the non-athletes, resulting in similar propulsive impulses (Table 1). Because all participants completed a trial within a short time window, we conclude the timing difference during the propulsion phase becomes an important defining characteristic in a high-performance cut. In the field of play, the propulsion phase is also the portion of the cut which the defender reads to determine the new direction the player is going. Since the propulsion phase is shorter with a greater ground reaction force, the athletes showed an ability to change direction more rapidly thus decreasing the time an opponent must react to a new direction (31).

There were many variables that were not found to be significantly different between the athletes and the non-athletes including all of the anthropometrics as well as the kinematics of the cut. The lack of significantly different anthropometrics highlights the homogeneity of the groups and allows the cut to be understood as a mechanism of learned skill. The lack of kinematic
differences between the athletes and non-athletes is interesting and may stem from the controlled aspects of the cutting maneuver seen in this study. For example, the controlled speed of the cut which may have limited the athlete’s ability to perform the cut at maximum effort, thus increasing the GRF’s created as well as the time of their cutting trials. One previous study found differences in the cutting kinematics between professional rugby players of varying skill level, more specifically in their time spent in the breaking and propulsion phases (9). This research allowed the players to run at their preferred speed, which could have led to the noted differences by the players. We controlled the cut time so as to highlight kinematic or kinetic differences between the two populations, as we assumed the athletes would perform cuts faster, thus introduce a potential effect of speed. Additionally, by having a pre-determined path for the participants to follow, the cut is even more controlled and the predictability of the trials may have led the lower limb angles and GRF’s to be made similar.

Interestingly, each athlete exhibited a more consistent footfall in their cutting maneuvers than the non-athletes; however, there was not a singular footfall pattern that was defined as athletic. The athletes used primarily forefoot and heel strike loading whereas the non-athletes most frequently used the whole foot cut. We believe that the consistency of the footfall patterns being used by the athletes is representative of learning and proficiency, whereas the non-athlete inconsistency represents a lack of experience with the task. Foot fall patterns are discussed thoroughly in distance running literature (6, 12, 16); however, to our knowledge, there is limited discussion in the cutting literature characterizing footfall patterns. The main difference between the forefoot and heel striking seen in running literature is the difference in loading rates, force production and stability. In many analyses of forefoot running, the knee and ankle joints of the runner are less stiff (6, 12) which may play a role in cutting performance. We believe this should be investigated further to enhance not only the notion of a successful cut but also provide potential insights into the effect of footfall on injury rates while cutting. When learning and practicing the cutting maneuver during sports, we believe that athletes will develop a preference for a foot striking option depending on the purpose of the cut and potentially the shoe surface interface. Therefore, the consistency of the footfall types for the athletes may be a product of the type of sport background. Again, investigating this further may provide more insight into the specifics of cutting performance within a given sport.

With knowledge of the increased demands on the body exhibited during a multidirectional cut, the implications of this study can be used by coaches to improve the cutting mechanics of their players by emphasizing the importance of the propulsive phase of the cut in drills and practice. The propulsion phase of the cut is the phase in which a player accelerates into a new direction and is therefore important for performance. Generating more force in a shorter amount of time during the propulsive phase would be more advantageous since the defender would have less time to react to change in direction. In order to become accustomed to the skills needed to effectively make a moderate angle cut, specialized training and continual practice are vital for not only learning but perfecting the cutting maneuver (30). Therefore, we suggest greater emphasis while training and practicing be placed on the propulsion phase to improve cutting performance.
In conclusion, this study was conducted to identify the characteristics of a moderate angle cut that make the cut more effective in multidirectional sports. Anthropometric, kinematic, kinetic, and temporal variables were measured. Temporal variables and instantaneous ground reaction forces were significantly different between the group of athletes and non-athletes, suggesting that a faster, more powerful propulsion would be a more successful cut, because this would allow for better defender evasion. Additionally, footfall patterns do not seem to dictate performance, but athletes were more consistent with their footfall patterns, supporting the notion that they had a preferred cutting style, and were, therefore, more practiced. We suggest more emphasis be placed on the propulsion phase of cutting through training for a more successful cut performance.

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