Understanding Change of Direction Performance via the 90° Turn and Sprint Test

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SUMMARY

RAPID CHANGE OF DIRECTION (COD) MOVEMENTS ARE COMMONLY PERFORMED IN MANY TEAM SPORTS SUCH AS SOCCER, ICE HOCKEY, BASKETBALL, AND NETBALL. COD MOVEMENTS MAY OCCUR IN RESPONSE TO AN OBJECT (E.G. BALL, PUCK, BOUNDARY LINE, ETC), IN RESPONSE TO PLAYER MOVEMENTS (E.G. TEAMMATES), OR IN AN ATTEMPT TO EVADE AN OPPONENT. THERE ARE A WIDE VARIETY OF STRATEGIES USED TO COMPLETE COD MOVEMENTS; HOWEVER, LITTLE RESEARCH HAS INVESTIGATED THE STRATEGIES OR TECHNICAL CUES THAT RESULT IN SUPERIOR PERFORMANCE. THIS ARTICLE PROVIDES A DESCRIPTION OF 3 MOVEMENT STRATEGIES (FALSE-START PIVOT, FORWARD-MOVING SIDESTEP, AND PIVOTING CROSSOVER).

INTRODUCTION

Movement agility has been defined in many different ways (e.g., a rapid whole body movement with a change of velocity or direction in response to a stimulus (15), the ability to change direction or start and stop quickly (11), and any movement involving a rapid change of direction [COD] in response to a sport-specific stimulus (7)). What is clear from these definitions is that agility is multifactorial in nature and comprised of 3 main components: technical, physical, and perceptual (12,14,16). Based on a deterministic model of agility (Figure 1), it can be deduced that if one of these primary components is missing or lacking, the overall agility performance may be compromised. As indicated in the model, important aspects of agility are the COD factors, which include both leg strength qualities and technique factors. Although there is an abundance of literature on leg strength and power, relatively little is known about optimal techniques for changing direction tasks. Hence, the aim of this article was to explore some of the technical considerations for superior (i.e., faster) COD performance.

STRATEGY 1: FALSE-START PIVOT

In the false-start pivot (FSP) strategy, the movement is first initiated by taking a small step with the trail leg (right leg) in the opposite direction of the straight sprint (Figure 2a and 2b). As the player sinks into a wide squat, the left leg (lead leg) externally rotates in the direction of the intended travel (Figure 2c). The right arm is driven forward and upward across the body, whereas the left arm is driven backward, causing the torso to rotate into the new direction (Figure 2d). Body weight is then transferred from a relatively equal distribution between the legs to the lead leg. As the trail leg pushes off (Figure 2e), the body is completely rotated into the new direction, and a straight sprint takes place.

STRATEGY 2: FORWARD-MOVING SIDESTEP

The forward-moving sidestep (FMS) strategy begins with the player first lowering into a small squat (Figure 3a and 3b). The player then begins transferring their weight from an equal distribution between the legs onto the lead leg (left leg) (Figure 3c). The arms remain extended at the sides as the athlete begins to lower into a slightly deeper squat. As the player sinks, increasing the forward lean of the torso, they simultaneously abduct their right arm away from their body while both flexing and externally rotating their lead leg (left leg) (Figure 3d). The player then increases the external rotation at the hip of the lead leg, as

KEY WORDS:
change of direction; technique; 90° turn; agility; kinematics; critical features

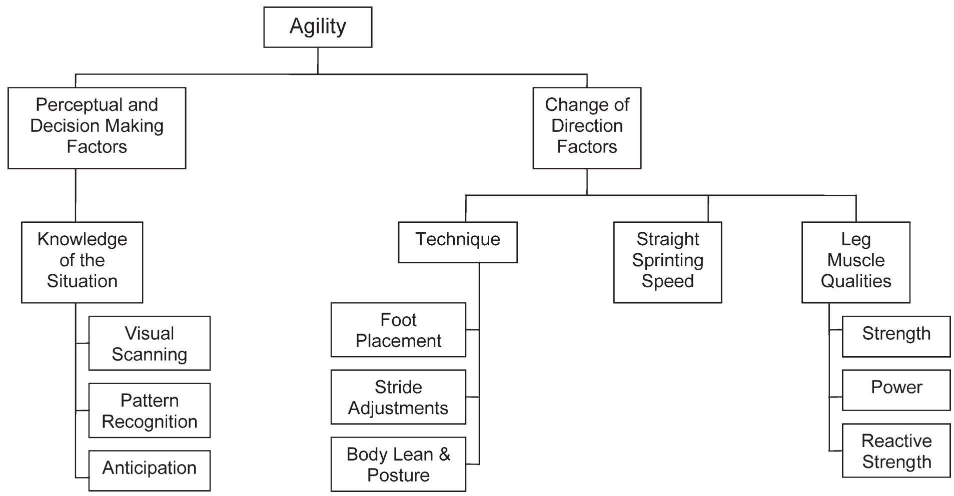


Figure 1. Deterministic model of agility (adapted from Young et. al. (16)).

the right arm swings low across the body causing the torso to rotate to the left. The trail leg (right leg) fully extends at the ankle, knee, and hip, driving the body forward into the straight sprint (Figure 3e). As the trail leg pushes off, the lead leg touches down while the right arm is driven upward and forward in line with the body.

STRATEGY 3: PIVOTING CROSSOVER

The pivoting crossover (PC) movement is initiated by an almost immediate abduction of both arms away from the body. Similar to the FMS, the weight is transferred from both legs to the lead leg (left leg) (Figures 4a and 4b). However, in this strategy, the torso remains relatively vertical throughout, as opposed to leaning forward into a deep squat. As the right arm crosses in front of the body, the left arm is pulled behind, rotating the torso (Figure 4c). As shown through Figures 4c and 4d, the whole body rotates, whereas strategies 1 and 2 indicate rotation only in the lower body initially. As the body turns, the lead leg pivots into external rotation, increasing knee flexion as the weight is further transferred (Figure 4d). In contrast to the 2 previous strategies, the trail leg (right leg) is also pivoted slightly (internally) before takeoff. While the lead leg remains in contact with the ground, the right leg crosses in front of the left as the right arm drives backward and the left drives forward (Figure 4e). The left leg now becomes the trail leg, pushing off in the same plane as the sprint.

MOVEMENT ANALYSIS

Based on principles of biomechanics, there appears to be various features of the 90° COD that produce superior performances. These critical features, along with the rationale as to why this feature would improve the performance, are listed in Table 1.

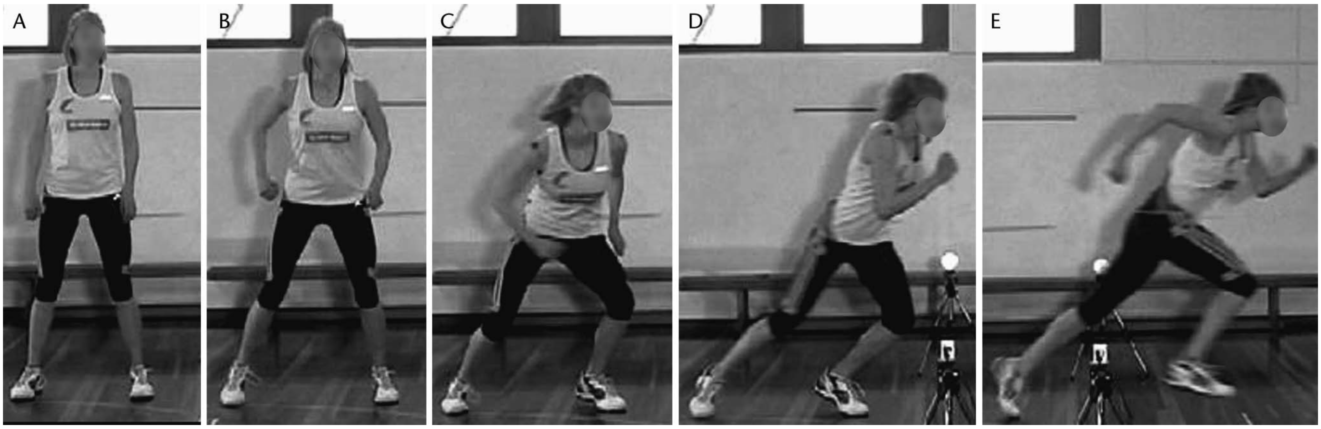


Figure 2. (a–e) False-start pivot.

Figure 3. (a–e) Forward-moving sidestep.

CRITICAL FEATURE 1 (LOWERING THE CENTER OF MASS BEFORE THE TURN)

The relatively erect torso and minimal squat of the participant employing the FMS in particular do not allow for much force generation against the ground compared with a deeper squat. By lowering down into a deep squat, the leg muscles are preloaded and as a result are able to produce greater vertical and horizontal force into the ground, creating a larger ground reaction force in the intended direction of travel at takeoff.

Although the initial step backward of the FSP may appear to be ineffective, it does allow for effective use of the stretch-shortening cycle. By preloading the muscles of the trail leg with potential elastic energy, a greater amount of force may potentially be produced over a greater amount of time (greater impulse). Given the relationship between impulse (force [f] × time [t]) and momentum (mass [m] × velocity [v]), this strategy could result in greater movement velocity, which could arguably make up for the increased time taken by the initial step backward (6).

CRITICAL FEATURE 2 (MOVING THE CENTER OF MASS INTO THE SPRINTING DIRECTION)

As soon as the downward motion is initiated, the body begins to transfer weight into the new direction (to the left). Force is applied horizontally, and body parts are aligned in the desired movement direction.

CRITICAL FEATURE 3 (ARMS AND LEGS CLOSE TO THE BODY WHEN TURNING)

The body's rotational inertia (*I*) (resistance to turn) is primarily dependent

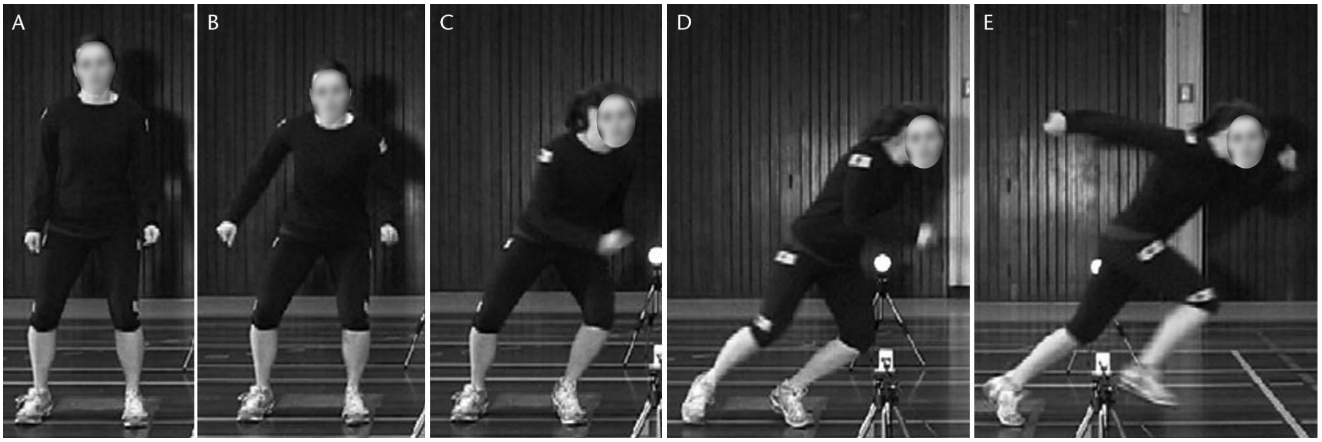
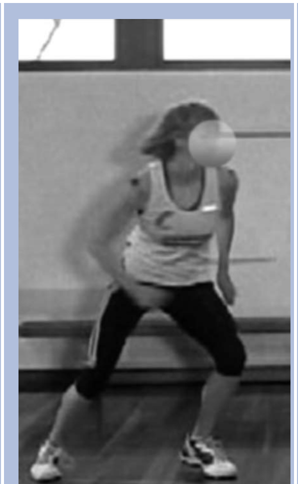
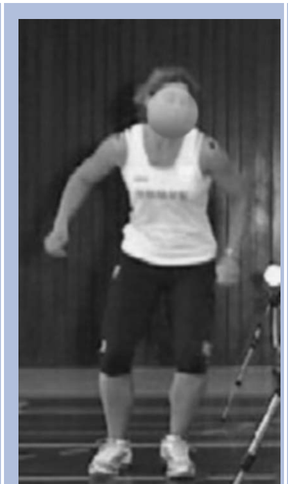


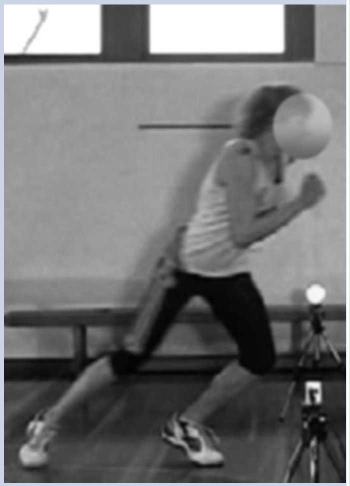
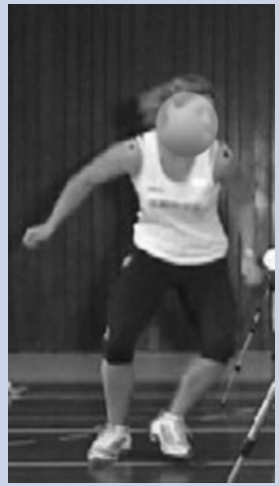
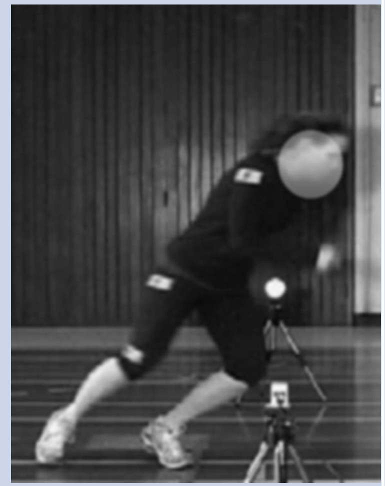
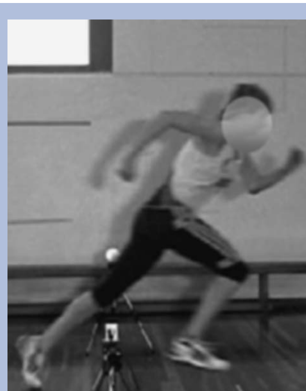
Figure 4. (a–e) Pivoting crossover.

Table 1
Critical features of the 90° COD

Phase	COD strategy			Critical features	Biomechanical rationale
	False-start pivot	Forward-moving sidestep	Pivoting crossover		
2–3 frames after rest (B)				Lowering the COM before the turn	Rapid squatting motion increases stability and enables explosive force and power application through the stretch-shortening cycle when used immediately
				Moving the COM into the sprinting direction	Helps contribute to increased momentum in the direction of travel
Turn (C)				Arms and legs close to the body when turning	Decreased rotational inertia (resistance to turn) when the body's mass is distributed close to the axis of rotation (i.e., the takeoff foot) ($I = mr^2$)

(continued)

Table 1
(Continued)

Phase	COD strategy			Critical features	Biomechanical rationale
	False-start pivot	**Forward-moving sidestep**	**Pivoting crossover**		
First foot takeoff (D)				COM ahead of the takeoff foot (takeoff distance)	Large takeoff distance equals a large step length (SL), which results in increased velocity ($v = SL \times SF$). Decreased stability in the direction of travel helps promote momentum of the COM in that direction
Second foot takeoff (E)				Full lateral extension of the takeoff leg	Applying force over a longer time (impulse) will result in increased velocity as long as the force is at least maintained ($f \times t = m \times v$)
				Intense driving action of the arms	Extension of the arms (increased rotational inertia) stops trunk and pelvic rotation both through the turn and counteracting the turning effect of the lower extremities when sprinting, allowing the body to continue in a straight line in the new direction

COD = change of direction; COM = center of mass; SF = step frequency.

upon the distribution of the body's mass around the axis of rotation ($I = mr^2$). Increased rotational inertia (arms wide) increases the stability of the rotating body but results in a decreased turning effect. By bringing the arms (mass, m) closer to the body (axis of rotation, r) during the turn, a faster rotation will occur while still maintaining stability through the squat and postural adjustments already being employed (2,9).

CRITICAL FEATURE 4 (CENTER OF MASS AHEAD OF THE TAKEOFF FOOT)

The distance of the center of mass in relation to the takeoff foot when it leaves the ground is known as the takeoff distance. The larger this distance is, the greater the step length will be, resulting in increased takeoff velocity and a faster sprint (assuming that the frequency of each step is maintained) (10). The takeoff distance of the first foot take off is clearly larger for the participants using the FSP and PC strategies than the FMS. In both the pivoting strategies, the participants begin with a wider stance, which allows for a greater takeoff distance once the pivot has been completed. In contrast, the FMS participant begins with a narrower stance and the takeoff is completed before any foot adjustments (pivot, false start, etc). If a wider base of support was employed by this participant, then the takeoff distance would not be increased as the takeoff foot will always be the foot closest to the new direction, as opposed to the rear foot in the pivoting strategies. Additionally, by creating a simultaneous or near simultaneous takeoff and touchdown of contralateral legs, the flight phase is minimized or possibly eliminated, thereby increasing the ground contact time (GCT). Because propulsive force can only be produced when in contact with the ground, the increased GCT may allow for greater impulse to be generated than might occur if the flight phase was increased. An increase in generated impulse would likely result in a faster sprint time ($f \times t = m \times v$) (5,9).

Once the player has rotated into the new direction (second foot takeoff), the takeoff distance is similar across all the 3 strategies. However, at this point, the participant employing a FMS strategy uses a lateral takeoff, whereas the pivoting participants are able to potentially generate more force in the direction of travel at takeoff through a foot placement parallel to the direction of travel (9).

CRITICAL FEATURE 5 (FULL LATERAL EXTENSION OF THE TAKEOFF LEG)

There are conflicting reports as to whether superior sprinting performances use a full triple joint extension (ankle, knee, and hip). By applying force into the ground over a longer time as the leg extends fully, a greater velocity can be attained ($f \times t = m \times v$) (5,9). However, it may be an abbreviated range of motion at these joints that is more beneficial for tasks that require quick adjustments to their direction and speed (3,10,13). Because minimizing the amount of time taken to complete a directional change is the goal of this movement, a full extension at the ankle, knee, and hip may not be essential.

The perpendicular position of the trail leg at takeoff in relation to the rest of the body, as well as the movement direction, may not be as effective at producing the large propulsive forces as a foot positioned in the intended direction of motion. When placed parallel to the intended direction, the foot is able to produce potentially greater amounts of force into the ground through plantarflexion as opposed to eversion with a perpendicular (lateral) foot placement (4).

CRITICAL FEATURE 6 (INTENSE DRIVING ACTION OF THE ARMS)

As the athlete reaches the final portion of the turn, a rapid elbow extension occurs. This movement increases the rotational inertia, causing the body to slow (or stop) the turning effect (9). This movement may be more noticeable in the PC strategy but is present to some extent in all 3 strategies. The more rapid this movement is performed, the faster the rotation will cease and the sooner the player can continue on in the sprinting direction. The intense driving action of the arms once the body has completed the turn can assist in the takeoff velocity when accelerating (1,8,10), although it is important to note that this driving action must be performed in line with the body, as opposed to lifting the arms away from the sides, which would create a tendency to rotate.

SUMMARY AND CONCLUSIONS

The COD movement strategies that athletes commonly employ and the technical cues to improve activity and/or sport-specific COD have received little attention and provide an exciting area for research. Of the 3 COD movement strategies discussed, the fastest COD time through both the first and the second steps in the new direction likely occurs with the PC. The slowest of the 3 strategies is likely the FMS (Table 2). It appears that 2 technical characteristics may be critical features to a superior 90° COD movement performance when using the PC: aggressive driving arm action through the turn and a limited forward lean (both of which are critical features of effective sprinting). Differences using a static start compared with a dynamic situation need further investigation.

Several factors (i.e., individual anthropometric measures, physical coordination, situation-dependent requirements, etc) may contribute to the ability to execute these strategies with a superior performance. A greater distribution of body mass from the axis of rotation will increase the rotational inertia that the player must overcome when turning. Therefore, certain adaptations or adjustments to the COD movement strategy may be needed to overcome this factor. Likewise, an athlete who is less proficient at completing rapid movements, those involving proprioceptive awareness or gross/fine motor skills, may not be as successful at the same COD movement strategy as a more proficient athlete. However, this aspect has the potential to be improved with practice.

Table 2
Extent of critical feature employment for the 90° COD

Strategy	Lowering COM before the turn	Moving COM into new direction	Small rotational inertia	Large TO distance at 1st TO	Full lateral extension at 2nd TO	Intense driving arms
False-start pivot	OK	-	OK	OK	+	+
Forward-moving sidestep	OK	-	-	-	+	OK
Pivoting crossover	+	+	+	+	OK	+

COD = change of direction; COM = center of mass; OK = observed but not to the extent described; TO = takeoff; + = fully present; − = not present.

Finally, the sporting task or situation that the player is responding to may have specific postural characteristics. For example, a netball player must remain relatively erect to read player movements and catch or intercept a pass. In contrast, an ice hockey player adopts a lower center of mass as a result of where the puck is played (on the ice as opposed to in the air) as well as to increase the length of reach and protect the puck when in possession. Although both players may have similar body types and coordination, the demands of the sport may determine which COD movement strategy is most likely to result in a superior COD movement performance.

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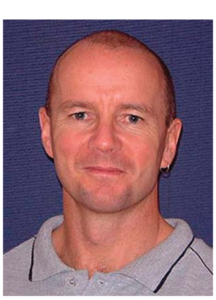

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