Gait & Posture 42 (2015) 240–245

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

# Whole body mechanics differ among running and cutting maneuvers in skilled athletes

Kathryn L. Havens [*], Susan M. Sigward

*Division of Biokinesiology & Physical Therapy, University of Southern California, United States*

ARTICLE INFO

*Article history:*
Received 12 January 2014
Received in revised form 3 June 2014
Accepted 23 July 2014

*Keywords:*
Cutting
Turning
Whole body mechanics
Dynamic stability
Anticipatory postural adjustments

ABSTRACT

Quick changes of direction during running (cutting) represent a whole body mechanical challenge, as they require deceleration and translation of the body during ongoing movement. While much is known with respect to whole body demands during walking turns, whole body mechanics and anticipatory adjustments necessary for cutting are unclear. As the ability to rapidly change direction is critical to athletes' success in many sports, a better understanding of whole body adjustments made during cuts is needed. Whole body center of mass velocity and position during the approach and execution steps of three tasks (straight running, 45° sidestep cut, and 90° sidestep cut) performed as fast as possible were compared in 25 healthy soccer athletes. Repeated measure ANOVA revealed that overall, braking and translation were greater during the cuts compared to the straight run. Interestingly, with systematically increased cut angle, disproportionately greater braking but proportionately greater translation was observed. Anticipatory adjustments made prior to the execution of the cuts suggested that individuals evenly distributed the deceleration and redirection demands across steps of the 45° cut but prioritized deceleration over translation during the approach step of the 90° cut.

## 1. Introduction

Changing directions involves braking in the original direction of forward progression, translation and reorientation into the new direction, all without stopping ongoing locomotion [1]. Athletes who participate in multi-directional sports are required to change direction frequently [2] and to varying angles throughout competition [3], which is mechanically, cognitively [4], and physiologically [5] challenging. They may change directions as an act of deception, in response to a player, or to pursue the ball. The ability to change directions quickly is a key metric of athletic skill, as performance is used to identify talent [6] and guide player selection in teams [7]. Despite its importance in athletics, little is known regarding the whole body demands of the task.

Previous studies evaluating walking turns indicate that adjustments to whole body position and velocity are necessary to accomplish changes in direction, and these adjustments vary based on the specific turning requirements. For example, in order to decelerate before turning, individuals generate posteriorly-directed ground reaction forces (GRF) and ground reaction force impulse (GRI) and position their body's center of mass (COM) posterior to their center of pressure (COP) [8–12]. Individuals make similar adjustments in the medial–lateral (ML) direction to accomplish translation away from the original direction [13]. When turning to larger angles, these alterations for both deceleration and translation subtasks are greater [12]. While whole body adjustments during walking turns are well defined, it is not clear whether the same strategies are used to change of direction at faster velocities (i.e., cutting).

Current cutting literature focuses on lower extremity biomechanics and provides little insight into whole body mechanics associated with successful cutting. Previous studies have found that when compared to cuts to smaller angles, those made to larger angles result in larger knee moments and GRFs [14,15], suggesting that greater forces are needed to change direction to larger angles. In addition, lower knee moments have been observed during cuts performed under pre-planned compared to randomly cued conditions [16,17], indicating that when adequate time is available, individuals make anticipatory adjustments prior to the cutting step to complete the task. These anticipatory adjustments have been quantified in walking turns [12] but may be even more important during athletic cutting. Based on the

---

[*] Corresponding author at: University of Southern California, 1540 Alcazar St, CHP 155, Los Angeles, CA 90089, United States. Tel.: +1 323 442 2940; fax: +1 323 442 1515.

*E-mail addresses:* khavens@usc.edu, kate.havens@gmail.com (K.L. Havens).

http://dx.doi.org/10.1016/j.gaitpost.2014.07.022

limitation of the current research, evaluation of whole body position and velocity during the approach and execution of cutting tasks will provide greater insight into how individuals change directions during running.

The purpose of this study was to evaluate the strategies necessary for cutting by comparing whole body COM velocity and position during the approach and execution steps of cutting. In order to assess how individuals alter their strategies to accomplish tasks with different change of direction demands, comparison were made between straight run, 45° sidestep cut, and 90° sidestep cut conditions. We hypothesize that more braking and translation will be observed with greater cut angle and will be accomplished with greater GRI, peak GRF and greater separation of the COM and COP. In addition, we hypothesize that whole body adjustments will be observed during the approach and execution of the cutting tasks.

## 2. Methods

### 2.1. Participants

Twenty-five healthy soccer players participated (12 females, mean age = 22.4 ± 3.9 years, height = 1.74 ± 0.1 m, mass = 70.9 ± 9.3 kg). An a priori power analysis based on pilot data determined that with 25 subjects, the study would be adequately powered to detect differences in GRI and COM position between tasks with an alpha of 0.05 and 95% power. Athletes were considered experienced, high-level soccer players (college, semi-professional, professional), with an average of 16.7 ± 4.3 years of soccer experience. Twenty-two participants reported that they were right-limb dominant, when asked which foot they would kick a ball with.

All subjects were healthy without complaints associated with lower extremity injuries. Subjects were excluded if they had a: (1) history of previous lower extremity surgery, (2) lower extremity injury preventing participation in sport (>3 weeks) in the last 6 months, or (3) any physical, cognitive or other condition that would impair their ability to perform this study's tasks. Prior to participation, subjects were explained testing procedures; informed consent was obtained as approved by the Investigational Review Board at the University of Southern California Health Sciences Campus.

### 2.2. Instrumentation

Three-dimensional motion analysis was performed using a marker-based, 11-camera digital motion capturing system (250 Hz; Qualisys, Gothenburg, Sweden). GRF data were obtained using two 1.20 m × 0.60 m force platforms (1500 Hz; AMTI, Newton, MA, USA) embedded into the floor surface. Kinematic and kinetic data were collected synchronously using motion capture software (Qualisys Track Manger, v2.6). Reflective markers (25 mm spheres) placed on specific bony landmarks were used to define body segments. Laser timing gates (Brower IRD-T175; Brower Timing Systems, Draper, UT, USA) were used to determine task completion time.

### 2.3. Procedures

All testing took place at the Division of Biokinesiology & Physical Therapy's Human Performance Laboratory, located within the Competitive Athlete Training Zone (CATZ), Pasadena. Participants wore their own running/athletic shoes. Tracking marker clusters mounted on semi-rigid plastic plates were secured to nylon/lycra bands on subjects' arms, forearms, thighs, shanks, and shoes. Using a full-body marker set, reflective markers were placed over 45 anatomical landmarks, similar to Song et al. [18]. Following a static calibration trial, tracking markers remained on the subject.

Prior to testing, subjects were led through a 15 min warm-up and were given time to stretch. Participants were then instructed to perform three tasks: straight running (RUN), and sidestep cutting maneuvers to 45° (CUT45) and 90° (CUT90) at their fastest speed. For RUN, subjects ran as fast as possible across a 15 m path. For both cutting tasks, subjects ran as fast as possible 7.5 m, planted their dominant foot and changed direction away from their plant foot at the designated angle (45° or 90°), and continued running as fast as possible for 7.5 m (Fig. 1). Cutting angles were marked on the floor with tape. Laser timing gates were placed at each end of the 15 m path. The 45° and 90° cut order was counterbalanced between subjects to prevent effects related to testing order. Trials were accepted if subject's completion time was within a ± 2.5% interval and if their non-dominant foot fully contacted the first force platform and dominant foot fully contacted the second force platform.

### 2.4. Data analysis

Marker coordinates were reconstructed in three-dimensions (Qualysis, Inc., Sweden) and raw coordinate and force data were used to compute segmental kinematics and kinetics (Visual 3D v4.8, C-Motion, Inc., Rockville, MD, USA). Force and coordinate data were low-pass filtered using a fourth-order zero-lag Butterworth filter with a 200 and 12 Hz cutoff frequency, respectively. Lower and upper extremity segments and thorax were modeled as frustra of cones, pelvis as a cylinder, and head as a sphere. Whole body COM position was calculated as the weighted average of COM positions of 15 modeled segments [19]. Data was exported and analyzed using customized Matlab programs (Version R2011b, The MathWorks, Natick, MA, USA). Foot contact events were defined using a 30 N vertical force threshold. Stance time was calculated by dividing the number of frames that the foot contacted the force plate by 1500.

Rotation into the new direction during cutting orients the body in the new travel path [9,14]. As a result, the body's local coordinate system is no longer aligned with GRF and COP variables,

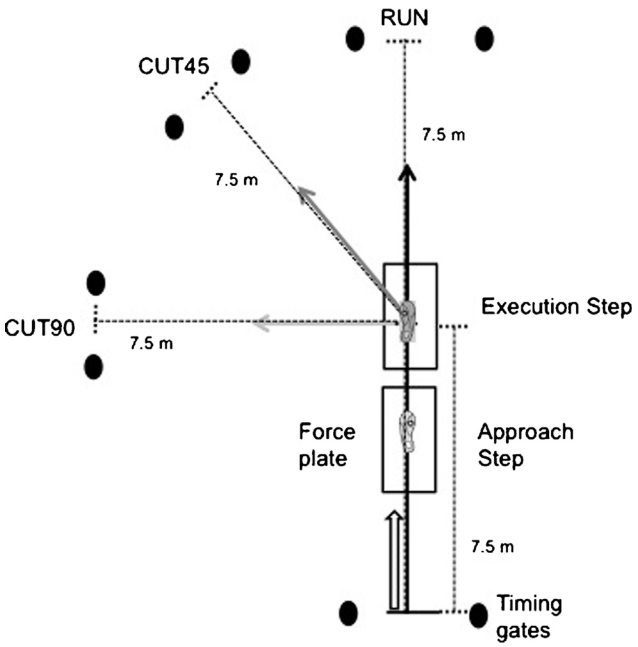

**Fig. 1.** Experimental set up for right-foot dominant subject. Open arrow indicates original direction of progression.