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Original Research

Biomechanical Evaluation of Time as a Golden Measure in the Assessment of Change of Direction Speed Performance

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ABSTRACT

Change of direction speed is globally assessed through temporal measurements. The underlying biomechanical mechanisms affecting Change of direction speed performance, however, could not be fully understood using performance duration. A more precise biomechanical analysis of change of direction speed performance in different phases of movement, including the deceleration, turning maneuver and reacceleration could cast a light on the importance of each phase during movement. This study investigated a new approach to Change of direction speed drill analyses using three factors of the radius of curvature, accuracy and speed. Twenty-four collegiate athletes (Age: 21.67±2.29years, Height: 1.79±0.07m, body mass: 71.38±3.12Kg) performed 6 trials of 5-0-5 Change of direction speed test with both dominant (n=3) and non-dominant (n=3) legs at the turning point. Paired sample T-test was run to determine the differences between biomechanical characteristics of the center of mass, such as radius of curvature (Rc), deviation, length and speed, as well as the performance time in both dominant and non-dominant legs. Data acquisition took place using 6 optoelectronic cameras (Vicon motion capture system – 240Hz). Outcomes indicated that the time difference between dominant and non-dominant leg performances was negligible; however, measurements of distances travelled and the associated speeds were significantly higher with non-dominant legs ($p \leq 0.01$). Rc and deviation were also higher in non-dominant legs ($p \leq 0.03$). It was shown that when the Change of direction speed was approached using the non-dominant leg, athletes performed the test with higher velocities and utilized more muscular engagements to compensate deficits in their performance. Measurements of time for drill duration however, failed to reveal such performance characteristics.

Keywords: Radius of curvature, Accuracy, Deviation, Execution time, 5-0-5 test

Introduction

The ability to quickly change the direction is vital for success in various sports such as soccer and handball. That is the main reason for emphasizing on agility training by coaches and athletes [1]. Agility has been divided into two main components of change of direction speed (CODs) and perceptual or decision-making factors [2-5]. Discrepancies on the precise definition of CODs are however encountered in sport science literature [5]. Traditional definitions described CODs as an ability to quickly change direction in running, while more recent studies defined it as the capability of accurate change in direction [6-8].

It has also been argued that a CODs drill which consists of three phases of deceleration, quick change in direction and acceleration are all performed in the shortest possible time while maintaining postural control [9-11]. CODs drill is also defined as the ability to change in direction using quick and harmonized movement of individual movements of individual segments [7], which highlights the importance of accuracy and coordination in CODs performances. Limitations of time as the lone measurement criterion has also been addressed [5, 9]. It has been argued that duration, could not necessarily explain all biomechanical factors influencing CODs performance and hence does not provide any assistance towards talent development programs [9]. Other studies have also tried to investigate CODs performance using metrics approach employing more advanced equipment [12, 13]; however, complicated calculation methodologies could pose a challenging effort for professional coaches. To this effect, a study on different aspects of CODs drill parameters such as accuracy of movement, change in direction and execution speed using motion capture systems could further develop an understanding of underlying biomechanical parameters affecting this critical skill.

CODs drills have been investigated using different approaches. Speed and acceleration of participants have been studied using motion capture systems [9, 14, 15]. Arshi et al. raised the significance of speed magnitude changes during all three phases of deceleration, change of direction and re-acceleration [9]. They also reported that although the test path was straight, the movement pattern was not. It is also pointed out that the radius of curvature and speed could portray significant information on biomechanical mechanisms affecting CODs drill [9]. Establishment of alternative approaches in studying CODs drill was the main objective of previous studies, in which parameters affecting movement patterns, such as control strategies, movement curvature and tangential velocity were investigated in detail [9, 10, 16]. Individual player preferences on a turning point and its impacts on CODs performance are still to be addressed. Bilateral motor control and mechanisms involved in the transfer of data from the brain to limbs and segments are considered influential in cognition [17]. It has been shown that non-dominant leg training could enhance motor performance in athletic training [17]. However, the effect of the dominant and non-dominant leg at the vicinity of the point of change of direction has not been fully explored. Although the leg choice might seem involuntary, it could have direct implications on performance parameters.

The majority of investigations on CODs performance have adopted execution time as a global criterion for CODs performance assessment [2, 15], while other biomechanical factors which seem to have a more fundamental impact on CODs profiles are disregarded [9]. Hence, further investigations are required to discover the biomechanical virtues of agility performance among athletes. It is therefore assumed that (a) CODs execution time might not reveal the biomechanical deficits of the movement and individual functional differences that could adversely affect CODs performance and (b) biomechanical factors such as radius of curvature, speed and path length covered by athletes could be considered as the key parameters influencing athletic CODs drill performance. No other study, to the best of the authors' knowledge, has addressed the concept of agility and CODs through biomechanical investigation of movement patterns to identify the deficits of CODs performance and compare it with execution time as a global measure.

Material and Methods

Participants

Twenty-four male collegiate athletes participated in this study (Age: 21.67±2.29years, Height: 1.79±0.07m, body mass: 71.38±3.12Kg). Participants were familiarized with the purpose of the study and methods in detail. The inclusion criteria were being healthy, physically active with no bone fracture or muscle, tendon, and ligament surgery background within the past twelve months of tests. Participants signed an informed consent form to participate in the study and had no prior history of acute musculoskeletal injuries.

Instruments and Procedure

This study was a part of an extensive research program. Sixteen 14mm-diameter passive reflective markers were attached to the skin at the bony landmarks of lower body extremities using Plug-In-Gait standard. However, for this study, the mid-distance between two markers attached to Anterior Superior Iliac Spines (ASIS) was considered as the trajectory of the center of mass (COM) [18, 19]. The standard 5-0-5 test was performed in sports biomechanics laboratory [4, 20], and the participants were familiarized with the test procedure and were shown how to turn at the marking cones once with dominant leg and once with the non-dominant leg. The participant performed the test three times with the dominant leg and three times with non-dominant leg after a 10-minute supervised warmup.

During the 5-0-5 test, participants ran a 15-meter distance to the cone, made 180 degrees turns and reaccelerated for the 5 meters to the final point (Figure 1). The last 5-meters of the first 15-meter sprint was used in 5-0-5 CODs performance calculations. This means that the kinematic parameters associated with the last 5-meter to the cone were used to determine the decelerations and the first 5-meters after CODs were adopted to determine re-acceleration characteristics. Dominant and non-dominant legs were determined prior to the tests. Participants were asked to make the turns and commence CODs six times; three times with dominant legs and three times with non-dominant legs. This meant that they had to use their dominant or non-dominant leg as a pillar to make the turn.

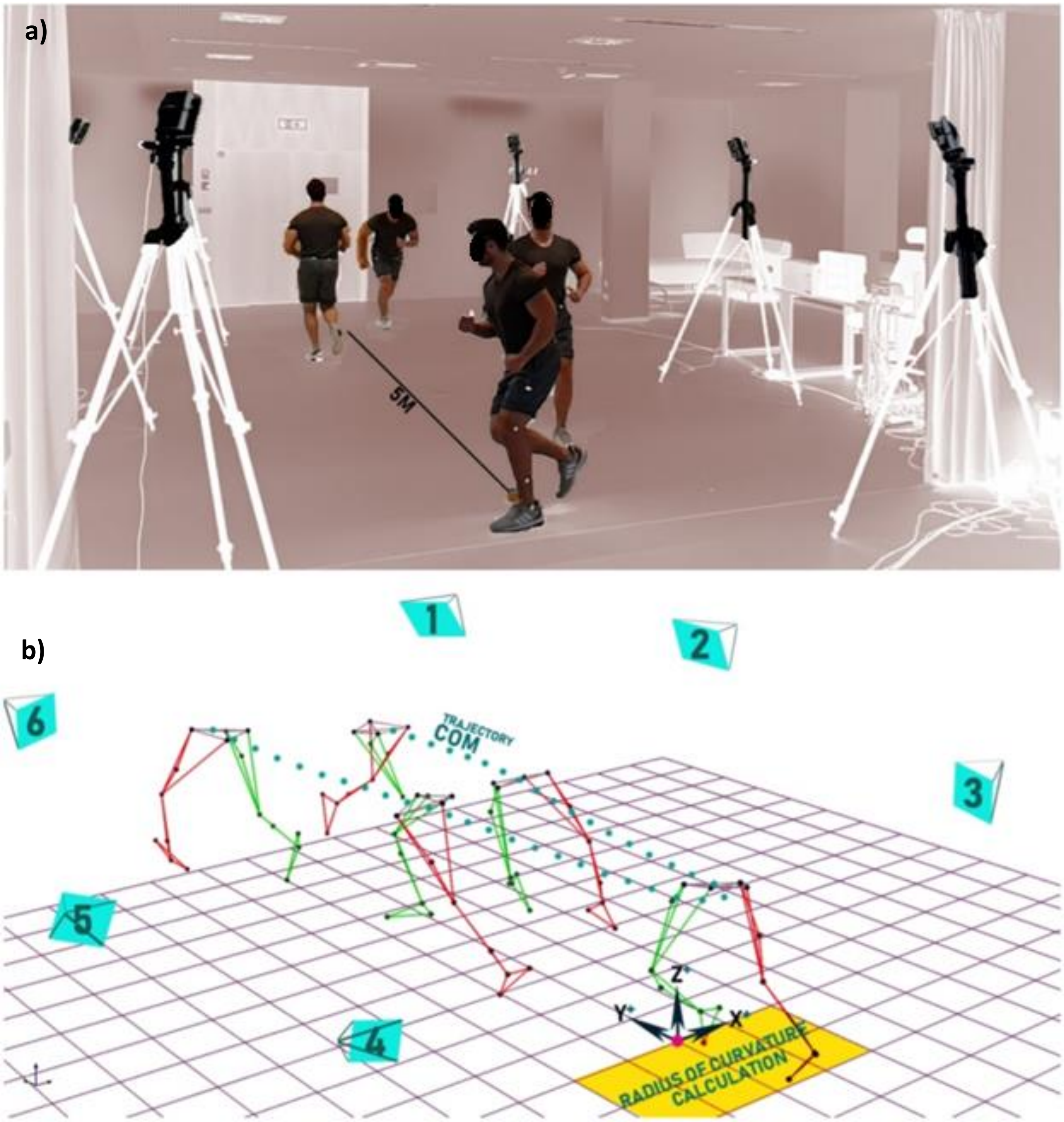

Figure 1. a) Manner of performing the 5-0-5 test (top), and b) Schematic view segments and COM trajectory (bottom)

Three-Dimensional kinematic data were recorded using six infrared Vicon motion capture system (Oxford Metrics, Oxford, UK) at a sampling rate of 240 Hz. A dynamic wand was used by a laboratory technician for static frame calibration and volume description. Reconstruction and labelling procedure was performed using Nexus (Windows Version 2.6.1).

Data Processing

Residual analysis method [21], was adopted to determine cutoff frequencies (10 Hz) for a Butterworth low-pass digital filter to smooth the acquired coordinate data. Missed markers were filled using gap-filling interpolation.

Although 3 Dimensional kinematic data of 16 markers were recorded, this study concentrated on the COM movement trajectory in the horizontal plane to simplify mathematical calculations.

Awareness about deficits at the turning points of CODs performance could considerably aid in more sufficient turns. The shorter the radius of motion, the less time is wasted in CODs drill, and vice versa. To this end, based on mathematical definitions, the radius of curvature (Rc) could be adopted as the criterion for measuring curvatures in movement trajectories. Rc is calculated as following [9]:

$$R_c = \frac{(\dot{x}^2+\dot{y}^2)^{\frac{2}{3}}}{(\dot{x}.\ddot{y}-\dot{y}.\ddot{x})}$$
(1)

where ẋ, ẏ, ẍ, and ÿ were the first and second derivatives of x and y. This equation could demonstrate the magnitudes of COM movement radius at the marking cone and provide athletes and their coaches with a tangible measure. In this study, the starting point for Rc calculation was set when the athlete's leg reached the marking cone and the finishing point was set when the athlete's leg toed-off at the cone (Figure 2).

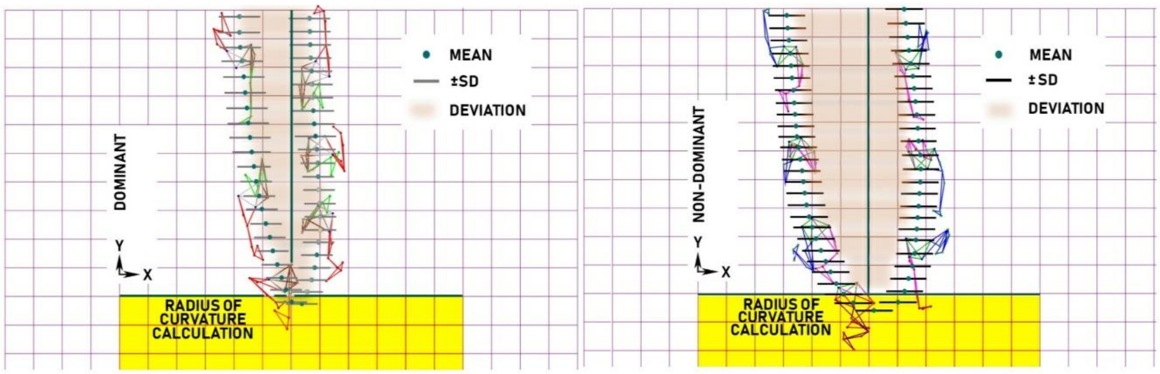

Figure 2. Representation of mean and standard deviation of COM trajectory and deviation measures in dominant (Left) and non-dominant (Right) condition.

Accuracy, on the other hand, is considered as the second crucial aspect of CODs performance. The importance of accuracy is highlighted when athletes deviate from the straight path, resulting in an increase in both time and covered distances. In this study, accuracy is divided into deviation and the length covered by an athlete. The deviation is calculated as the perpendicular to the distance between the COM and optimum test path. In this study, the deviation was calculated from the starting point to the final point (Figure 2).

Furthermore, it is hypothesized that adoption of a curved path will take COM away from the straight path and hence increase the length covered. Increased length of the exhibited path is calculated by summation of COM x and y trajectories recorded in individual frames, as shown below:

$$Length = Sum\sqrt{(y_2 - x_1)^2 + (y_2 - y_1)^2}$$
(2)

The average speed is calculated by dividing the distance covered during the turn, by execution time.

$$Speed = \frac{length}{time}$$
(3)

In this study, the speed measures were calculated from the start point to the turning point. Other parameters were provided by the Vicon software.

Statistical Analyses

Kolmogorov-Smirnov statistical test was performed to estimate the normality of mean data distribution. Paired sample T statistical test was run in order to determine the differences between parameters in both dominant and non-dominant leg conditions. The level of significance was set as $p<0.05$. This analysis was performed using SPSS software (version 22.0, IBM Corp., Armonk, NY).

Results

Kolmogorov-Smirnov test confirmed the normality of data distribution ($p=0.46$). Descriptive measures of CODs duration in both dominant and non-dominant legs, the radius of curvature, accuracy and speed are shown in table 1. The execution times of the 5-0-5 test were approximately the same for both dominant (318ms) and non-dominant (319ms) legs and no significant difference were observed. The radius of curvature assessments with non-dominant leg revealed that participants performed the test with an increased curvature at the vicinity of the turning point compared with that of the dominant leg (3%). More pronounced deviations were also observed on the non-dominant leg (8%). However, no significant difference was observed in time, the radius of curvature and deviation in both dominant and non-dominant leg conditions. On the other hand, the length or distance covered by the dominant leg was significantly less than that of the non-dominant leg (6 % - 0.79 m). The results indicate that athletes performed 5-0-5 test significantly faster (7 % - 0.26 m/s) with the non-dominant leg.

Table 1. Representation of mean and standard deviations of COM trajectory and deviation measures in dominant and non-dominant condition.

Parameter	Mean±SD		Differences		
	Dominant	Non-Dominant	t	df	Sig. (2tailed)
Time (ms)	318 ± 26	319 ± 21	0.06	23	0.99
Radius of Curvature	1.89 ± 0.36	1.95 ± 0.61	0.48	23	0.83
Deviation (m)	4.26 ± 0.81	4.63 ± 0.73	1.34	23	0.58
Length (m)	12.68 ± 1.01	13.47 ± 1.46	6.29	23	0.03†
Speed (m.s-1)	3.98 ± 0.35	4.22 ± 0.48	7.14	23	0.01‡

† Significantly different ($p\leq0.05$)
‡ Significantly different ($p\leq0.01$)

Discussion

The significance of CODs is widely recognized among coaches and athletes. CODs consists of three stages of fast deceleration, quick change in direction and reacceleration while maintaining postural control [7, 9]. Yet, the execution time is the current sole global criterion used for CODs skill assessment. It has also been reported that CODs execution time could not reveal effective biomechanical characteristics influencing CODs skill [9]. The main aim of this study was to address a new approach in the analysis of CODs performance and critically review time criteria as the golden measure in the assessment of CODs profile. Results of this study demonstrated that athletes performed 5-0-5 CODs test with less accuracy when the change of direction was performed using non-dominant leg; a point accompanied by coverage of significantly larger distances. This is in accordance with normalized deviation measures shown to be larger in tests with the non-dominant leg. The results also illustrated that radius of curvature was more prominent when athletes performed 5-0-5 test with the non-dominant leg. The CODs test speed, which plays a vital role in performance, also portrayed significantly higher values with the non-dominant leg.

The approach adopted in the current study illustrates that CODs is a biomechanically complex skill and current CODs drill duration measurements, although very practical, do not provide any valuable insight into the complexities involved in the performance of the neuromuscular system. Besides, the choice between dominant or non-dominant leg in approaching CODs has energetic implications. The result, in non-dominant leg tests, illustrates that athletes had to utilize more muscle contractions and consume more energy to reach a high speed in order to diminish biomechanical deficits. Considering that individual athletes perform the CODs several times during a training session or competition, the total amount of wasted energy could be very high which could be corrected once the athlete is made aware and has been trained on using a biomechanical approach to optimize the performance. The biomechanical deficits in CODs performance could not be revealed through measurements of execution time. This is further demonstrated in trial duration results which could only be explained by an increase in muscular involvements and consequential increase in energy consumption.

This will adversely affect the performance where multiple CODs maneuvers might be required during competition. Other studies have also reported similar CODs execution time when the two legs are compared [22]. However, the importance of biomechanical capacities is routinely ignored. Further studies on the subject might reveal that effective CODs training exercises should concentrate on skill development. The concept of accuracy becomes gradually more prominent in field performances where multiple CODs are present in consecutive maneuvers. The trade-off between accuracy and speed in a CODs performance could only be addressed through skill enhancement routines with reliance on how to manipulate the turning zone. Here the importance of radius of curvature is once again raised, as it has been by other studies where the influence of skill on CODs performance and relationship between the radius of curvature and skill have been investigated [9]. This study revealed that specifically designed CODs skill development routines could aim at reducing any deviations from the test path and hence reduce distances covered by the athlete as well as encouraging entrance into the change in direction zone using the dominant leg. The current study used a 5-0-5 test, which contains two linear sprinting and one 180 degrees turn. Studies on other CODs tests containing cutting maneuvers or different types of CODs accompanied by appropriate test protocols could be hence devised.

Limitations

Some limitations must be considered with the current research study. First, given the possibilities of markers separation during the tests, we were able to perform 6 agility tests (3 with each leg) to increase the recorded marker trajectories. Nevertheless, adopting only 3 trials per participants might not be sufficient to firmly claim that CODs performance was impacted if the participants entered with dominant or non-dominant legs. On the other hand, since the biomechanics laboratory floor was different from the surfaces that athletes usually dealing with, the CODs performances might have impacted by different surface structure. However, given that the laboratory floor was the same for both dominant and non-dominant legs during the test, the outcomes for both sides are assumed to be analogously impacted.

Conclusion

The study illustrates that radius of curvature, deviations from test path, and distances covered by athlete were significantly more in 5-0-5 CODs drill when the approach to change in direction zone was made using non-dominant leg; hence indicating that the athlete could benefit when encouraged to enter the change in direction zone using the dominant leg. The conclusion was to encourage further studies to establish an alternative trend in the assessment of CODs drills. The new approach should be capable of illustrating the biomechanical capacities of an individual athlete. The key finding of this research was that execution time, as a globally accepted measurement method, could not provide a comprehensive description of individual athletes' potentials and limitations. Further investigation of this biomechanical approach is suggested.

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چکیده فارسی

ارزیابی بیومکانیکی زمان به عنوان یک معیار ارزیابی طلایی در بررسی عملکرد سرعت تغییر جهت

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سرعت تغییر جهت به طور کلی به وسیله ی معیارهای زمانی ارزیابی می شود. با این وجود، مدت زمان اجرا نمی تواند به طور مناسبی مکانیزم های بیومکانیکی موثر در سرعت تغییر جهت را آشکار سازد. از این رو، یک تجزیه و تحلیل بیومکانیکی دقیق از فازهای مختلف عملکرد سرعت تغییر جهت، از قبیل فازهای کاهش شتاب، تغییر مسیر و افزایش شتاب مجدد، می تواند تاثیر هر یک از این فازها بر عملکرد کلی سرعت تغییرمسیر را نشان دهد. این مطالعه به بررسی یک روش جدید برای مطالعه ی سرعت تغییر مسیر پرداخت، که در آن سه متغیر شعاع انحنا، دقت و سرعت تجزیه و تحلیل شدند. بیست و چهار ورزشکار دانشگاهی (سن:۲/۲۹±۲۱/٦۷سال، قد:۰/۰۷±۱/۷۹متر، جرم:۳/۱۲±۷۱/۳۸ کیلوگرم) آزمون ۵-۰-۵ را شش بار و با دو پای غالب (سه بار) و غیرغالب (سه بار) در لحظه ی تغییر مسیر اجرا کردند. کینماتیک حرکت مارکرها به وسیله ی ۶ دوربین (وایکن – نرخ نمونه برداری ۲۴۰ هرتز) ثبت شد. با استفاده از آزمون آماری تی وابسته، تفاوت های بین متغیرهای بیومکانیکی مرکز جرم، شامل شعاع انحنا، انحراف از مسیر، طول مسیر طی شده، سرعت و همچنین مدت زمان اجرا بین دو پای غالب و غیرغالب بررسی شد. بررسی نتایج مشابه بودن مدت زمان اجرای تست با هر دوپای غالب و غیرغالب را نشان داد. با این حال، مقادیر مسیر طی شده و سرعت در اجرای با پای غیرغالب به طور چشمگیری بیشتر از پای غالب بود (P=۰/۰۱). علاوه بر آن، شعاع انحنا و انحراف از مسیر طی شده در پای غیرغالب به مراتب بیشتر از پای غالب بود (P=۰/۰۳). بررسی نتایج نشان داد که وارد شدن به محل تغییرمسیر با پای غیرغالب با سرعت های بیشتری انجام شد، که نشانگر استفاده از نیروی عضلانی بیشتر برای دستیابی به سرعت بیشتر بوده است تا نقصان های موجود در عملکرد سرعت تغییر مسیر پوشش داده شوند. با این حال اما مدت زمان اجرای آزمون سرعت تغییر مسیر نتوانست این ویژگی ها را به تصویر بکشد.

واژه های کلیدی: شعاع انحنا، دقت، انحراف، زمان اجرا، آزمون ۵-۰-۵