©Journal of Sports Science and Medicine (2025) **24**, 721-728
http://www.jssm.org DOI: https://doi.org/10.52082/jssm.2025.721

Research article

Biomechanical Differences Between Ipsilateral and Contralateral Change-Of-Direction Movements Using the Same Planting Foot in Recreational Team Sport Players

Chi-Hsien Chen [1], Mingchia Yeh [2], Chiang Liu [3,4]✉, Yan-Jer Tseng [3] and Sung-Ting Lu [4,5]
[1] Department of Kinesiology, Iowa State University, IA, USA; [2] Department of Exercise Science, Slippery Rock University, Slippery Rock, PA, USA; [3] Graduate Institute of Sports Equipment Technology, University of Taipei, Taipei, Taiwan (R.O.C); [4] Taiwan Institute of Sports Science, Taiwan (R.O.C.); [5] Graduate Institute of Athletics and Coaching Science, National Taiwan Sport University, Taoyuan, Taiwan (R.O.C)

Abstract

Change-of-direction (COD) movements are critical for predicting injury risk or identify sport performance. Multiple studies have examined contralateral COD (contra-COD) comprehensively, but few studies have examined ipsilateral COD (ipsi-COD). This study investigated the kinetic and kinematic parameters of the same planting foot during ipsi-COD and contra-COD movements. In total, 29 recreational team sport players performed 60° ipsi-COD and contra-COD movements. Biomechanical data were collected using a three-dimensional force plate and a motion capture system. The ipsi-COD task exhibited a 6% shorter contact time than the contra-COD task. In addition, ipsi-COD resulted in a significantly greater ankle pronation–supination range (+27%), smaller inversion–eversion range (-19%), and decreased plantarflexion-dorsiflexion range (-37%). Lower ground reaction forces (horizontal: -14%, vertical: -32%, resultant: -14% to -279%) and impulse values (horizontal: -24%, vertical: -23%, resultant: -24%) were observed for ipsi-CODs than for contra-CODs. The musculoskeletal structure of the lower limbs provides an anatomical advantage for excessive eversion during ipsi-COD, leading to a more rounded execution path compared with contra-COD. The differences in contact time, ankle range of motion, and ground reaction force in ipsi-COD may result from joint alignment, force application techniques, and movement execution strategies. The observed phenomenon of shorter contact time with lower ground reaction force and smaller ankle range in ipsi-COD offers new insights for future studies investigating COD mechanics across different movement contexts.

Key words: Symmetric movement, movement of relativity, cutting movement, ground reaction force, rang of motion.

Introduction

Change of direction (COD) ability is a crucial skill for team sport players (Dos' Santos et al., 2017), particularly in multidirectional COD movements (M-COD) and during competitions (Brughelli et al., 2008; Dos' Santos et al., 2018; Young et al., 2015). Effectively executing COD requires technical proficiency, sprinting speed, and lower-extremity strength (Spiteri et al., 2015; Young et al., 2002). Both the dominant and nondominant leg can serve as the planting foot (PF), which determines the direction and angle of movement (Dos' Santos et al., 2018; Taylor et al., 2017). Overall COD capability comprises COD across multiple directions and angles, it may help profile an athlete's COD performance.

COD movements can be categorized as ipsilateral (ipsi-COD) and contralateral (contra-COD). Contra-COD has been widely studied in athletes and team sport players (Nimphius et al., 2016; Taylor et al., 2019), particularly for directional changes ranging from 45° to 90°. Studies on contra-COD have examined shuffle movements (Dayakidis and Boudolos, 2006), injury risk (Fox, 2018), and the asymmetry of lower extremities (Rouissi et al., 2016). Ipsi-COD refers to a movement in which the COD matches the foot used as the PF. For example, if a player plants the left foot, an ipsi-COD involves changing direction to the left. By contrast, a contra-COD occurs when the movement direction is opposite to the PF. Contra-COD is used to determine movement difficulty and injury risk based on the angle of directional change (Dos' Santos et al., 2018). To date, ipsi-COD movements remain largely unexplored. A substantial gap exists in ipsi-COD research, particularly regarding ground reaction force (GRF) and ankle joint characteristics such as pronation–supination, inversion–eversion, and plantarflexion–dorsiflexion.

A study demonstrated the "angle-velocity trade-off," where athletes adjust their speed and technique on the basis of their physical capacities when performing COD movements at higher speeds or with greater directional changes (Dos' Santos et al., 2018). COD movements are classified into different difficulty levels: minor (0° - 45°, green), moderate (45° - 60°, amber), and sharp (60° - 180°, red). As the COD angle increases, both approach and exit velocities decrease due to the greater braking force required. Moderate directional changes are crucial because they provide biomechanical insights into braking force, propulsive force, and COD strategies (Dos' Santos et al., 2018). Several studies have investigated ipsi-COD and contra-COD movements at directional changes of 20° - 30° (Besier et al., 2001; Fuerst et al., 2017; Fuerst et al., 2021; Mornieux et al., 2014). No studies have investigated force-time data for ipsi-COD. However, van der Merwe et al. (2020) examined both ipsi-COD and contra-COD at a directional change of 45° but did not provide kinematic data for ipsi-COD. Ipsi-COD may have been treated as a control condition in their study.

On the basis of movement direction, M-COD can be classified as ipsi-COD, contra-COD, or shuffle movement. Although the mechanism of shuffle movement may be

Received: 05 December 2024 / Accepted: 24 February 2025 / Published (online): 01 December 2025

similar to that of ipsi-COD, the two are not identical. To the authors' knowledge, this is the first study to compare biomechanical differences in the PF between contra-COD and ipsi-COD tasks. This study examined the kinetic and kinematic parameters of the identical PF during ipsi-COD and contra-COD movements. This study hypothesized that ipsi-COD exhibits differences in contact time, ankle angles, GRF, and impulse when compared with contra-COD.

Methods

Subjects

A G*Power priori analysis indicated that the required sample size was 32 (two-tailed test, effect size = 0.6, α = 0.05, power = 0.8). In total, 32 participants were recruited. Three participants were excluded from analysis because they either failed six consecutive ipsi-COD trials or felt unwell during M-COD tasks. The final sample included 29 recreational team sport players (basketball, grass hockey, rugby, and soccer) who trained at least three times per week for at least 3 years (height: 175.10 ± 7.01 cm; weight: 77.55 ± 11.97 kg; age: 23.59 ± 2.75 years; Table 1). Exclusion criteria were any lower limb injury within 3 months prior to data collection or a history of surgery on the lower limb. Participants were instructed not to train or exercise for the 48 hours before the experiment.

The PF (nondominant leg or stance leg) was defined as the foot used to jump off during a right-handed basketball layup or the foot participants preferred to stand on when kicking a ball as far as possible (Chen et al., 2022). All participants provided written consent before the experiments. The experimental protocol was approved by the Institutional Review Board of the University of Taipei (IRB-2023 - 015) and conducted in accordance with the tenets of the Declaration of Helsinki.

Procedures

Biomechanical parameters were defined on the basis of time-force characteristics and joint angles collected through force platform and motion capture analysis. A familiarization trial was conducted at least 24 hours before the experimental protocol. Each participant performed all M-COD tasks on the same day while wearing a designated pair of indoor-court boots (VG111, Victor Sport, Taipei, Taiwan). M-COD tasks were conducted in a laboratory setting on a wooden floor. Kinetic and kinematic data were collected using a three-dimensional motion capture system (MotionAnalysis, Santa Rosa, CA, USA) set to record at 200 Hz and a force platform (BP-600900; AMTI, Massachusetts, USA) set to sample at 1400 Hz. A FootTrack model (MotionAnalysis) with reflective markers was used to capture joint angles of the PF. Reflective markers were placed on both legs in accordance with the manufacturer's instructions at the following anatomical locations: lateral and medial sides of the knee, lateral and medial sides of the ankle, first and fifth metatarsophalangeal joints, and lateral, superior, and inferior sides of the calcaneus. Kinematic and force data were smoothed using a low-pass filter with a cutoff frequency of 6 Hz.

Ipsi and contra-COD protocols

To examine COD ability in both the ipsilateral and contralateral directions, a conventional COD60° protocol (Chen et al., 2022; Condello et al., 2016) was modified into a multidirectional COD60° (M-COD60°) protocol, incorporating both 60° ipsilateral and contralateral movements. Participants performed M-COD tasks starting from a standing position with their chosen leg forward. To minimize reaction time bias, no external starting signal was provided. Each trial involved a 5-m sprint toward the force platform, followed by a COD60° movement by using the PF on the force platform and another 5-m sprint toward the contralateral direction. Participants completed four trials in the contralateral direction and four trials in the ipsilateral direction (Figure 1). A 1-minute rest period was provided between trials to ensure adequate recovery. Participants were instructed to perform each task with maximum effort. The 5-m approach time was measured using two pairs of photocells (Smartspeed; Fusion Sports, Queensland, Australia) placed at the starting line and across the force plate. A trial was considered unsuccessful if any of the following errors occurred while contacting the force platform: inaccurate foot placement, instability, slipping, and premature deceleration. A total of eight successful trials (four in each direction) were included for analysis.

Data process

The center, pronation–supination, inversion–eversion, and plantarflexion–dorsiflexion for the ankle joint were defined in accordance with the Cortex manufacturer's instructions (MotionAnalysis). The dependent variables included 5-m approach time, contact time, range of motion (ROM), GRF, impulse, and the vertical/horizontal (V/H) ratio during the stance phase. GRF data were classified into horizontal GRF (HGRF), vertical GRF (VGRF), and resultant GRF (RGRF). Impulse data were categorized as horizontal impulse (HImpulse), vertical impulse (VImpulse), and resultant impulse (RImpulse). The stance phase was defined as the period when VGRF exceeded 10 N and ended when VGRF dropped below 10 N (Chen et al., 2022; Spiteri et al., 2015). The ROM was measured as the difference between the peak and minimum joint angles. GRF data were defined as the peak GRF value for each axis. All force variables were normalized by body weight.

Table 1. Basic anthropometric measurements (N = 29).

Sport discipline	Sample size	Age (years)	Height (cm)	Weight (kg)
Basketball	7	25.7 ± 1.6	179.4 ± 7.4	74.1 ± 9.3
Grass hockey	3	23.7 ± 3.2	174.7 ± 3.1	77.0 ± 13.1
Rugby	10	22.9 ± 2.8	175.4 ± 7.5	84.1 ± 10.7
Soccer	9	22.7 ± 2.8	171.6 ± 5.8	73.1 ± 13.4
Total	29	23.6 ± 2.8	175.1 ± 7.0	77.6 ± 12.0

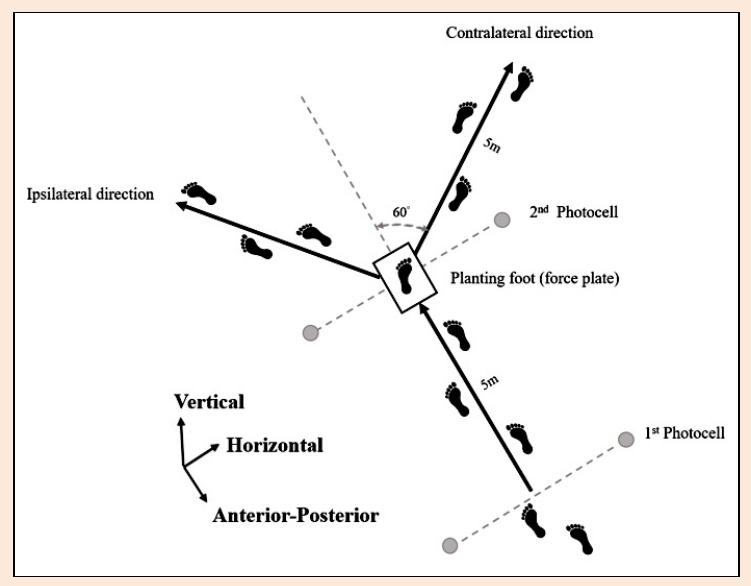


Figure 1. Experimental setting of M-COD60° and planting foot position.

Differences are expressed as percentages. Other studies have distinguished GRF data into braking and propulsive phases on the basis of the minimal VGRF during the mid-support phase. Nevertheless, although previous studies have distinguished GRF data as braking phase and propulsive phase based on the minimal VGRF during the mid-support phase, no such minimal VGRF was detected during ipsi-COD movements in the present study (Figure 2c).

Data process

The center, pronation–supination, inversion–eversion, and plantarflexion–dorsiflexion for the ankle joint were defined in accordance with the Cortex manufacturer's instructions (MotionAnalysis). The dependent variables included 5-m approach time, contact time, range of motion (ROM), GRF, impulse, and the vertical/horizontal (V/H) ratio during the stance phase. GRF data were classified into horizontal GRF (HGRF), vertical GRF (VGRF), and resultant GRF (RGRF). Impulse data were categorized as horizontal impulse (HImpulse), vertical impulse (VImpulse), and resultant impulse (RImpulse). The stance phase was defined as the period when VGRF exceeded 10 N and ended when VGRF dropped below 10 N (Chen et al., 2022; Spiteri et al., 2015). The ROM was measured as the difference between the peak and minimum joint angles. GRF data were defined as the peak GRF value for each axis. All force variables were normalized by body weight. Differences are expressed as percentages. Other studies have distinguished GRF data into braking and propulsive phases on the basis of the minimal VGRF during the mid-support phase. Nevertheless, although previous studies have distinguished GRF data as braking phase and propulsive phase based on the minimal VGRF during the mid-support phase, no such minimal VGRF was detected during ipsi-COD movements in the present study (Figure 2c).

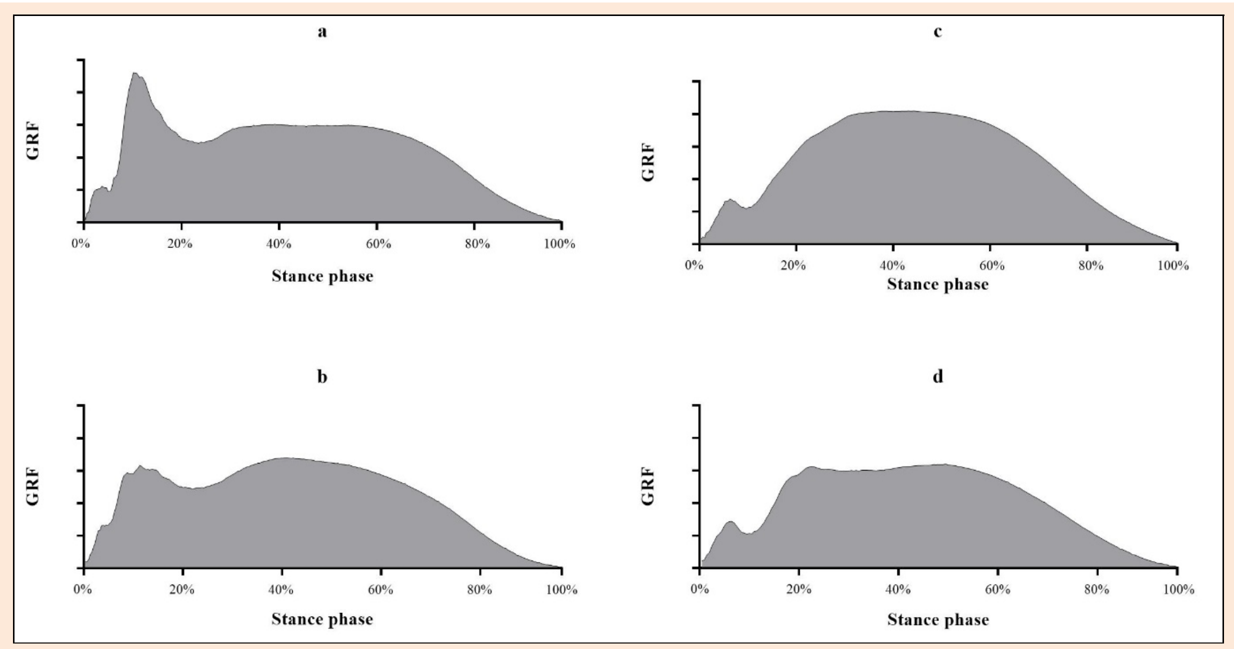


Figure 2. Typical ground reaction force pattern in contralateral COD (a and b) and ipsilateral COD (c and d) movements.

Statistical analysis

Mean and standard deviation values for all variables were calculated using Microsoft Excel 2016 (version 2308; Microsoft, Redmond, WA, USA). A paired t test was conducted to compare time-force and joint angle parameters between ipsi-COD and contra-COD tasks. To minimize the risk of Type I errors, the significance level was set at $p < 0.017$ (0.05/3) on the basis of a Bonferroni correction.

Results

The nonsignificant difference in 5-m approach time indicated a comparable sprint speed between ipsi-COD and contra-COD tasks during data collection (ipsi-COD: 1.259 ± 0.090 s; contra-COD: 1.283 ± 0.080 s; $p = 0.133$).

Ipsi-COD exhibited a significantly shorter contact time than did contra-COD (ipsi-COD: 0.205 ± 0.021 s; contra-COD: 0.218 ± 0.025 s; $p = 0.014$). A significantly greater ankle pronation–supination range was observed in ipsi-COD than in contra-COD (ipsi-COD: 21.70° ± 6.94°; contra-COD: 17.12° ± 6.60°; $p = 0.011$). By contrast, ipsi-COD exhibited a significantly smaller ankle inversion–eversion range (ipsi-COD: 28.10° ± 9.12°; contra-COD: 41.51° ± 8.99°; $p = 0.008$) and plantarflexion–dorsiflexion range (ipsi-COD: 5.91° ± 2.90°; contra-COD: 9.43° ± 2.75°; $p = 0.001$) than did contra-COD. In addition, ipsi-COD resulted in significantly lower HGRF (-14%), VGRF (-32%), RGRF (-279%), HImpulse (-24%), VImpulse (-23%), and RImpulse (-24%) than did contra-COD ($p < 0.001$). No significant difference was found in the V/H ratio between the two COD movements ($p = 0.599$; Table 2, Figure 3).

Table 2. Comparison of biomechanical parameters between ipsi-COD and contra-COD during M-COD60° task.

Variable	Variable	Ipsi-COD		Contra-COD		*p*
		Mean ± SD	CV%	Mean ± SD	CV%	
Time (s)	Contact time	0.205 ± 0.021	10 %	0.218 ± 0.025	11 %	.007*
Ankle range (°)	pron-sup	21.70 ± 6.94	32 %	17.12 ± 6.60	39 %	.011*
	inver-ever	8.68 ± 3.01	35 %	10.68 ± 3.90	36 %	.008*
	plantar-dorsi	5.91 ± 2.90	49 %	9.43 ± 2.75	29 %	.001*
GRF (BW)	HGRF	1.323 ± 0.248	19 %	1.541 ± 0.237	15 %	.001*
	VGRF	2.284 ± 0.309	14 %	3.360 ± 0.719	21 %	.001*
	RGRF	2.617 ± 0.335	13 %	3.673 ± 0.719	20 %	.001*
Impulse (BW*s)	HImpulse	0.141 ± 0.022	16 %	0.186 ± 0.022	12 %	.001*
	VImpulse	0.274 ± 0.030	11 %	0.358 ± 0.034	10 %	.001*
	RImpulse	0.315 ± 0.035	11 %	0.414 ± 0038.	9 %	.001*
Ratio	V/H	1.259 ± 0.090	45 %	1.283 ± 0.080	53 %	.599

**p* < 0.017; CV% = coefficient of variation %; pron-sup = pronation (−) / supination (+); inver-ever = inversion (−) / eversion (+); plantar-dorsi = plantarflexion (−) / dorsiflexion (+); BW, body weight; H, horizontal, V, vertical; R, resultant; V/H, vertical/horizontal.

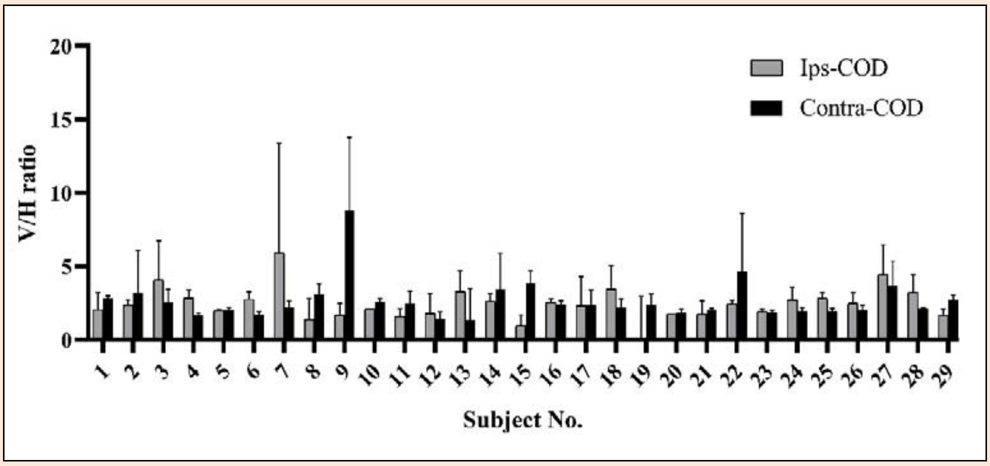


Figure 3. V/H ratio of each participant during ipsilateral COD and contralateral COD movements.

Discussion

To the authors' knowledge, this is the first study to investigate the biomechanical parameters of recreational team sport players performing both ipsi-COD and contra-COD movements by using the same PF. The findings demonstrated significant biomechanical differences between ipsi-COD and contra-COD movements, including contact time, ankle ROM, GRF, and impulse parameters, supporting the study's hypothesis. The results indicated that recreational team sport players exhibited a significantly shorter contact time (-6%) during ipsi-COD, a greater change in ankle ROM for pronation–supination (+27%), and smaller changes in inversion–eversion (-19%) and plantarflexion–dorsiflexion (-37%) compared with contra-COD. Other studies have reported that an increase in COD angle during contra-COD tasks is associated with higher HGRF and shorter contact time (Chen et al., 2022; Chen et al., 2023). By contrast, the present study found that ipsi-COD, despite having a significantly shorter contact time, exhibited lower GRF and impulse distribution compared with contra-COD. In addition, the approach time of the initial 5-m sprint did not significantly differ between ipsi-COD and contra-COD (p = 0.133), indicating similar sprinting speed when approaching the force platform during trials. This finding confirms that the observed biomechanical differences were not affected by variations in sprinting velocity. The differences observed between ipsi-COD and contra-COD in the M-COD tasks may be attributed to joint alignment, force application strategies and path of execution.

Variability in execution strategies (planting or movement path) across participants may have contributed to the larger coefficient of variation (CV%) observed in certain parameters, such as contact time, ankle range, GRF, and impulse. During COD execution, the ipsi-COD task was associated with more rounded movement paths compared with contra-COD task on the same PF, leading to shorter contact times and reduced GRF, potentially due to smoother transitions and lower impact forces. Another study on contra-COD also reported rounded movement paths by using motion capture in contra-COD task (Condello et al., 2016). By contrast, the present study found that rounded paths were more pronounced and occurred more frequently in ipsi-COD. These findings suggest that ipsi-COD is more challenging to execute than contra-COD, as indicated by the larger CV% in the V/H ratio for ipsi-COD (Figure 3). In addition, the mean ± SD differences in the V/H ratio suggest that participants employed distinct strategies for receiving and applying GRF in ipsi-COD and contra-COD movements (Figure 3). Furthermore, the higher CV% of the V/H ratio in ipsi-COD implies greater variability in force application, making it more difficult to isolate PF-related data from continuous movements during ipsi-COD execution (Figure 4).

The present study found that ipsi-COD had a shorter contact time than contra-COD along with lower GRF in the horizontal, vertical, and resultant axes. Several studies have identified contact time as a key performance indicator for COD performance (Dos' Santos et al., 2018; Dos' Santos et al., 2017; Spiteri et al., 2013; Spiteri et al., 2015). In contra-COD tasks, a negative correlation (r = -0.65) was observed between COD contact time and total completion time (Sasaki et al., 2011), indicating that shorter contact times are typically associated with greater horizontal GRF and impulse (Fox, 2018; Spiteri et al., 2013; Young et al., 2002). This relationship arises because athletes must efficiently generate HGRF in the intended direction, leading to a faster directional change and decreased contact time (Chen et al., 2022; Chen et al., 2023; Dayakidis & Boudolos, 2006; Dos' Santos et al., 2017). On the basis of the findings of studies on contra-COD, ipsi-COD would be expected to follow a similar braking and propulsion strategy due to its shorter contact time. Nevertheless, the present study found that ipsi-COD exhibited a shorter contact time while producing lower GRF. This discrepancy suggests that ankle ROM differences may affect force application and movement efficiency in ipsi-COD.

The present study revealed that ankle ROM was smaller in ipsi-COD than in contra-COD. The M-COD protocol was designed with both ipsi-COD and contra-COD at a 60° angle. Other studies have indicated that participants with greater braking GRF and larger ankle ROM tend to follow a sharper sprinting path (Dos' Santos et al., 2018; Schot et al., 1995). In addition, a larger COD angle has been associated with increased ankle dorsiflexion and longer contact times (Falch et al., 2020). The differences in ankle ROM between ipsi-COD and contra-COD suggest that movements require different execution techniques, even when performed at the same directional angle. The shorter contact time and smaller inversion–eversion range in ipsi-COD suggest that ipsi-COD is related to the ankle skeletal structure and follows a more rounded movement path than does contra-COD. Participants in this study demonstrated a greater inclination to sprint with a rounded path during ipsi-COD, which may correspond with a smaller ankle ROM.

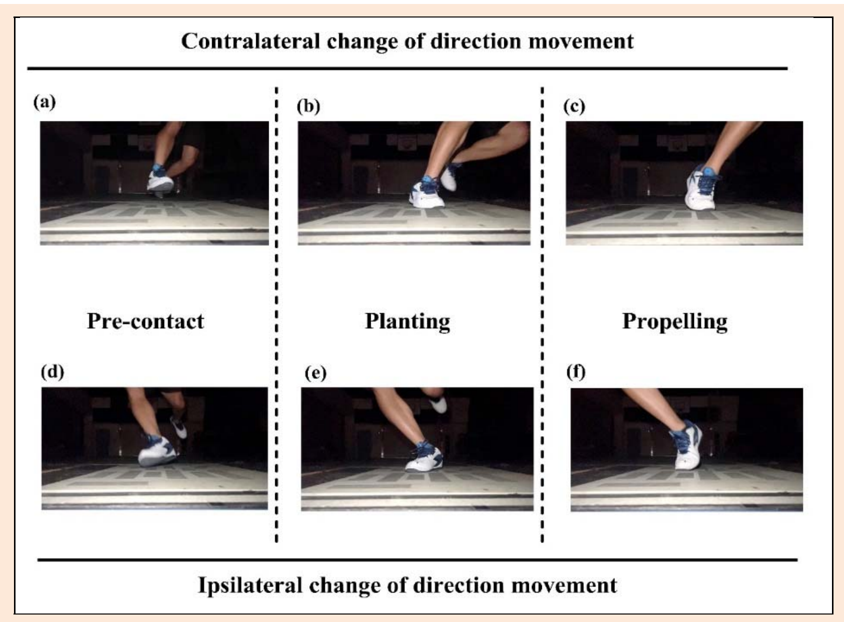


Figure 4. Foot motions of time frame of pre-contact phase (a, d), planting phase (b, e) and propelling phase (c, f) in contra-COD and ipsi-COD.

The significantly smallest inversion–eversion range observed in ipsi-COD compared with contra-COD (Table 2) can be explained by joint alignment. Anatomically, the fibula extends further to the lateral malleolus than the tibia extends to the medial malleolus, providing a structural advantage for excessive eversion (Fong et al., 2009). As a result, a smaller ankle ROM may help maintain velocity and redirect motion rather than absorbing braking (Dos' Santos et al., 2018). According to Dos' Sontos et. al. (2018), reducing braking and propulsive contact time during contra-COD while simultaneously increasing braking and propulsive forces, regardless of the length of contact time, is recommended. Producing impulse with a shorter contact time and higher peak GRF might be a better strategy when applying force to the ground. Because of the limitations in force production on the PF during ipsi-COD, the present study found smaller GRF and impulse despite the unexpectedly shorter contact time.

In real competition, M-COD tasks are typically executed along either an orbital or a sharper route, requiring moderate to sharper braking before push-off. Because this study selected directional changes classified as moderate (45° - 60°) and sharp (60° - 180°), braking and propulsive phases were expected to be identifiable. However, the results indicated that GRF and impulse differed between ipsi-COD and contra-COD on the same PF, suggesting that braking strategies and technical demands vary on the basis of the degree of directional change and ankle ROM. Dos' Santos et al. (2018) classified COD difficulty levels on the basis of the magnitude of directional change. By contrast, the present findings suggest that ipsi-COD and contra-COD movements may not be symmetrical in terms of execution difficulty. Instead, ipsi-COD may present unique biomechanical challenges distinct from those observed in contra-COD.

Other studies have suggested that GRF data enable the distinction between the braking and propulsive phases (Chen et al., 2022) or between braking and propulsive peak force (Dayakidis & Boudolos, 2006; Spiteri et al., 2015). By contrast, in the present study, the smaller ankle ROM observed during ipsi-COD along with the effect of the skeletal structure may have contributed to the inability to identify two distinct VGRF phases (braking and propulsive), as seen in contra-COD tasks (Figure 2c and Figure 2d). This limitation may also be dependent on braking strategy and the ankle technique in COD for each participant (Cortes et al., 2012; Uno et al., 2022). Further research is needed to develop a methodology for distinguishing the braking and propulsive phases in ipsi-COD.

This study has several limitations. First, the results are applicable only to recreational team sport players. The study recruited recreational team sport players, which is one of the most common populations in COD research (Chen et al., 2022; Domaradzki et al., 2021; Dos' Santos et al., 2017; Dos' Santos et al., 2018); however, execution techniques differ from one sport to another, even though participants performed the M-COD protocol in a controlled laboratory environment. Second, the ipsi-contra COD protocol may not fully replicate the conditions in which COD movements occur in real-world competition. Lastly, the factor (i.e., ankle ROM, GRF, impulse, or V/H ratio) that has the greatest influence on ipsi-COD performance remains unknown.

Conclusion

This study serves as a foundation for ipsi-COD research, aiming to enhance performance across various sports disciplines and providing a new M-COD research methodology for further exploration of COD mechanics. The findings demonstrate that ipsi-COD and contra-COD involve distinct execution strategies and exhibit different biomechanical characteristics on the same PF due to variations in ankle ROM among recreational team sport players. Compared with contra-COD, ipsi-COD was associated with a shorter contact time and lower GRF parameters. In addition, ipsi-COD exhibited a smaller ROM in pronation–supination, inversion–eversion, and plantarflexion–dorsiflexion. The observed phenomenon of shorter contact time with lower GRF in ipsi-COD offers new insights for future studies investigating COD mechanisms in different movement contexts.

Acknowledgements

The authors would like to thank Shih-Ping Lin, Liang-Chi Chen and Yu-Chen Lin for their support in data collection. This study was funded by National Science and Technology Council in Taiwan: NSTC 112-2410-H-845-023-MY2 and NSTC 114-2918-I-845-001. The authors have no conflicting interests to declare. While the datasets generated and analyzed in this study are not publicly available, they can be obtained from the corresponding author upon reasonable request. All experimental procedures were conducted in compliance with the relevant legal and ethical standards of the country where the study was carried out.

References

Besier, T. F., Lloyd, D. G., Cochrane, J. L., & Ackland, T. R. (2001). Besier, T.F., Lloyd, D.G., Cochrane, J.L. and Ackland, T.R. (2001) External loading of the knee joint during running and cutting maneuvers. *Medicine & Science in Sports & Exercise* **33,** 1168-1175. https://doi.org/10.1097/00005768-200107000-00014

Brughelli, M., Cronin, J., Levin, G. and Chaouachi, A. (2008) Understanding change of direction ability in sport: a review of resistance training studies. *Sports Medicine* **38,** 1045-1063. https://doi.org/10.2165/00007256-200838120-00007

Chen, C.H., Condello, G., Chen, W.H., Liu, T.H., Tessitore, A., Shiang, T.Y. and Liu, C. (2022) Effects of a novel inclined-adaptive footwear on change-of-direction performance in male athletes. *Gait & Posture* **94,** 189-194. https://doi.org/10.1016/j.gaitpost.2022.03.010

Chen, W.H., Chen, C.H., Yang, W.W., Lin, G.Y., Hsu, W.C., Shiang, T.Y. and Liu, C. (2023) Comparison of ground reaction force and contact time during variousdirection lunges between badminton shoes without and with a lateral forefoot wedge sole. *Journal of Sports Engineering and Technology.* https://doi.org/10.1177/17543371231213772

Condello, G., Kernozek, T.W., Tessitore, A. and Foster, C. (2016) Biomechanical analysis of a change-of-direction task in college soccer players. *International Journal of Sports Physiology and Performance* **11,** 96-101. https://doi.org/10.1123/ijspp.2014-0458

Cortes, N., Morrison, S., Van Lunen, B.L. and Onate, J.A. (2012) Landing technique affects knee loading and position during athletic tasks. *Journal of Science and Medicine in Sport* **15,** 175-181. https://doi.org/10.1016/j.jsams.2011.09.005

Dayakidis, M.K. and Boudolos, K. (2006) Ground reaction force data in functional ankle instability during two cutting movements. *Clinical Biomechanics* **21,** 405-411. https://doi.org/10.1016/j.clinbiomech.2005.11.010

Domaradzki, J., Popowczak, M. and Zwierko, T. (2021) The mediating effect of change of direction speed in the relationship between the type of sport and reactive agility in elite female team-sport athletes. *Journal of Sports Science & Medicine* **20,** 699-705. https://doi.org/10.52082/jssm.2021.699

Dos' Santos, T., Thomas, C., Comfort, P. and Jones, P.A. (2018) The effect of angle and velocity on change of direction biomechanics: An angle-velocity trade-off. *Sports Medicine* **48,** 2235-2253. https://doi.org/10.1007/s40279-018-0968-3

Dos' Santos, T., Thomas, C., Jones, P. and Comfort, P. (2017) Mechanical determinants of faster change of direction speed performance in male athletes. *Journal of Strength Conditioning Research* **31,** 696-705. https://doi.org/10.1519/JSC.0000000000001535

Dos' Santos, T., Thomas, C., Comfort, P. and Jones, P.A. (2018) Comparison of change of direction speed performance and asymmetries between team-sport athletes: Application of change of direction deficit. *Sports* **6,** 174. https://doi.org/10.3390/sports6040174

Falch, H.N., Rædergård, H.G. and van den Tillaar, R. (2020) Effect of approach distance and change of direction angles upon step and joint kinematics, peak muscle activation, and change of direction performance. *Frontiers in Sports and Active Living* **2,** 594567. https://doi.org/10.3389/fspor.2020.594567

Fong, D.T., Chan, Y.Y., Mok, K.M., Yung, P.S.H. and Chan, K.M. (2009) Understanding acute ankle ligamentous sprain injury in sports. *BMC Sports Science, Medicine and Rehabilitation* **1,** 1-14. https://doi.org/10.1186/1758-2555-1-14

Fox, A.S. (2018) Change-of-direction biomechanics: Is what's best for anterior cruciate ligament injury prevention also best for performance? *Sports Medicine* **48,** 1799-1807. https://doi.org/10.1007/s40279-018-0931-3

Fuerst, P., Gollhofer, A. and Gehring, D. (2017) Preparation time influences ankle and knee joint control during dynamic change of direction movements. *Journal of Sports Sciences* **35,** 762-768. https://doi.org/10.1080/02640414.2016.1189084

Fuerst, P., Gollhofer, A., Wenning, M. and Gehring, D. (2021) People with chronic ankle instability benefit from brace application in highly dynamic change of direction movements. *Journal of Foot and Ankle Research* **14,** 1-11. https://doi.org/10.1186/s13047-021-00452-0

Mornieux, G., Gehring, D., Fürst, P. and Gollhofer, A. (2014) Anticipatory postural adjustments during cutting manoeuvres in football and their consequences for knee injury risk. *Journal of Sports Sciences* **32,** 1255-1262. https://doi.org/10.1080/02640414.2013.876508

Nimphius, S., Callaghan, S.J., Spiteri, T. and Lockie, R.G. (2016) Change of direction deficit: A more isolated measure of change of direction performance than total 505 time. *Journal of Strength and Conditioning Research* **30,** 3024-3032. https://doi.org/10.1519/JSC.0000000000001421

Rouissi, M., Chtara, M., Berriri, A., Owen, A., & Chamari, K. (2016). Asymmetry of the modified Illinois change of direction test impacts young elite soccer players' performance. *Asian Journal of Sports Medicine* **7(2)**. https://doi.org/10.5812/asjsm.33598

Sasaki, S., Nagano, Y., Kaneko, S., Sakurai, T. and Fukubayashi, T. (2011) The relationship between performance and trunk movement during change of direction. *Journal of Sports Science & Medicine* **10,** 112-118. https://pubmed.ncbi.nlm.nih.gov/24149303/

Schot, P., Dart, J. and Schuh, M. (1995) Biomechanical analysis of two change-of-direction maneuvers while running. *Journal of Orthopaedic & Sports Physical Therapy* **22,** 254-258. https://doi.org/10.2519/jospt.1995.22.6.254

Spiteri, T., Cochrane, J.L., Hart, N.H., Haff, G.G. and Nimphius, S. (2013) Effect of strength on plant foot kinetics and kinematics during a change of direction task. *European Journal of Sport Science* **13,** 646-652. https://doi.org/10.1080/17461391.2013.774053

Spiteri, T., Newton, R., Binetti, M., Hart, N., Sheppard, J. and Nimphius, S. (2015) Mechanical determinants of faster change of direction and agility performance in female basketball athletes. *The Journal of Strength Conditioning Research* **29,** 2205-2214. https://doi.org/10.1519/JSC.0000000000000876

Taylor, J.B., Wright, A.A., Dischiavi, S.L., Townsend, M.A. and Marmon, A.R. (2017) Activity demands during multi-directional team sports: a systematic review. *Sports Medicine* **47,** 2533-2551. https://doi.org/10.1007/s40279-017-0772-5

Taylor, J.M., Cunningham, L., Hood, P., Thorne, B., Irvin, G. and Weston, M. (2019) The reliability of a modified 505 test and change-of-direction deficit time in elite youth football players. *Science and Medicine in Football* **3,** 157-162. https://doi.org/10.1080/24733938.2018.1526402

Uno, Y., Ogasawara, I., Konda, S., Wakabayashi, K., Miyakawa, M., Nambo, M., Umegaki, K., Cheng, H., Hashizume, K. and Nakata, K. (2022) Effect of the foot-strike pattern on the sagittal plane knee kinetics and kinematics during the early phase of cutting movements. *Journal of Biomechanics* **136,** 111056. https://doi.org/10.1016/j.jbiomech.2022.111056

van der Merwe, C., Shultz, S.P., Colborne, G.R., Hébert Losier, K. and Fink, P.W. (2020) The coordination patterns of the foot segments in relation to lateral ankle sprain injury mechanism during unanticipated changes of direction. *The Foot* **45,** 101745. https://doi.org/10.1016/j.foot.2020.101745

Young, W., Dawson, B. and Henry, G. (2015) Agility and change-of-direction speed are independent skills: Implications for training for agility in invasion sports. *International Journal of Sports Science Coaching* **10,** 159-169. https://doi.org/10.1260/1747-9541.10.1.159

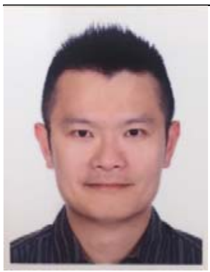
Young, W., James, R. and Montgomery, I. (2002) Is muscle power related to running speed with changes of direction? *Journal of Sports Medicine and Physical Fitness* **42,** 282-288.

Key points

- The shorter contact time and lower ground reaction force observed in ipsilateral change-of-direction movements (COD) provide new insights for future studies investigating COD mechanisms in different COD tasks.
- This study establishes a foundational framework for ipsilateral COD research and introduces a multidirectional COD protocol as a feasible methodology for further investigation.
- Contact time, ankle joint range of motion, and ground reaction force were analyzed using a 60° multidirectional COD protocol to compare ipsilateral and contralateral movements.
- Ipsi-COD and contra-COD movements may not be symmetrical in terms of execution difficulty.

AUTHOR BIOGRAPHY

Chi-Hsien CHEN
Employment
Department of Kinesiology, Iowa State University, IA, USA
Degree
MSc, PhD student
Research interests
Biomechanics, gait analysis, footwear science
E-mail: og1653gama@gmail.com



Mingchia YEH
Employment
Department of Exercise Science, Slippery Rock University, Slippery Rock, PA, USA
Degree
PhD, assistant professor
Research interests
Sport performance, exercise science, wearable technology
E-mail: yehmingchia@gmail.com

	**Chiang LIU** **Employment** Graduate Institute of Sports Equipment Technology, University of Taipei, Taipei, Taiwan (R.O.C) **Degree** PhD, professor **Research interests** Biomechanics, sport equipment, sport science **E-mail:** chiangliu1974@gmail.com
	**Yan-Jer TSENG** **Employment** Graduate Institute of Sports Equipment Technology, University of Taipei, Taipei, Taiwan (R.O.C) **Degree** MSc **Research interests** Biomechanics, gait analysis, footwear science **E-mail:** yanjer0123@gmail.com
	**Sung-Ting LU** **Employment** Graduate Institute of Athletics and Coaching Science, National Taiwan Sport University, Taipei, Taiwan (R.O.C) **Degree** MSc, PhD student **Research interests** Sport performance, sport science **E-mail:** zx0237700@gmail.com

✉ **Chiang Liu, PhD**
Graduate Institute of Sports Equipment Technology, University of Taipei, Taipei, Taiwan (R.O.C)