

Differences in Closed-Loop Control of Cutting Movements Between Collegiate Athletes and Non-Athletes

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Background: The ability of athletes to make quick adaptations or adjustments in their movement is based on the closed-loop control system. One area of interest in athletic performance is the ability for athletes to perform cutting movements in unpredictable environments. **Objective:** To determine the interactions of two groups of participants and cutting angles in vertical ground reaction forces (GRFs) and time of foot contact in a closed-loop environment. The study also compared the two given time-frames to process feedback between athletes and non-athletes. **Design and Setting:** Measurements of the time of foot contact and the active vertical GRF were recorded to compare the movement efficiency. Collegiate athletes and healthy young adults were used for base samples. **Subjects:** Ten participants (5 collegiate soccer players and 5 healthy young adults) volunteered. **Measurements:** The time of foot contact and the active vertical GRF were measured in a total of 8 trials in 4 different angles and two different time-frame conditions. Data were analyzed using two 2*4 mixed-design ANOVA, $p < 0.05$. **Results:** The athletes performed higher active vertical GRF in the shorter time of foot contact, compared to the non-athletes. The results did not show significant interactions with the angles and the participants in the vertical force ($F_{3,24} = .789$, $p > .05$). Significant interaction was found with the angles and the participants in the time of foot contact ($F_{3,24} = 4.48$, $p < .05$). **Conclusion:** The athletes had overall movement efficiency as well as superior information processing system in the closed-loop condition as compared to the non-athletes. **Key Words:** motor-control, information-processing, force

In the realm of sports, athletes are often seen making quick decisions during the events of an athletic contest, while maintaining the appearance of fluidity. The decisions made are translated into quick adaptations of movement based on the changing environment. Information received by the brain based on the environment is rapidly assessed by the motor system and changes are made in movement based on the new information. The ability of athletes to make quick adaptations or adjustments in their movement is based on their closed-loop motor control system. The closed-loop motor control system is used to integrate constant changes in the environment to the adjustments made in movement used to adapt to those changes. The motor control system is the central processing unit that takes in new input from the environment and sends feedback to the brain, which in turn sends the new information to the nervous system to make the proper changes in movement.¹ This processing unit is essential when the environment in which we perform in is changing constantly. In the realm of sport and athletic performance, the closed-loop system is important for the ever-changing environment. In order for athletes to be successful, they must be able to make adjustments in their movement. During the course of a contest, the unpredictability of the opponent forces the athlete to rapidly make changes to their movement, as well as momentum.

Recent literature has examined the closed-loop control system in athletes' function when performing tasks. The closed-loop system in soccer players was examined during penalty kicks

Kryklywec S, Sato K, Cremades JG. Differences in closed-loop control of cutting movements between collegiate athletes and non-athletes. In Cleary MA, Eberman LE, Odai ML, eds. *Proceedings of the Fifth Annual College of Education Research Conference: Section on Allied Health Professions*. [online conference proceedings]. April 2006;1:26-31. Miami: Florida International University.
http://coeweb.fiu.edu/research_conference/.

in order to determine an optimum time for penalty kickers to change the direction of their desired kick based on the movement of the goalkeeper. It was concluded that the “point of no return” for changing direction of the kick was 240-245 ms before striking the ball. However, for the penalty kicker to show 100% reliability in performance, 450-500 ms before the kick was needed. This study suggests that the more time an athlete has to make a decision, the better chance the feedback loop has to make adjustments in movement. In addition, several studies have compared reaction time and simple reaction time of athletes and non-athletes.³⁻⁶ The bulk of these studies indicated that response time was faster and more effective in athletes than in non-athletes. Moreover, one research study also attempted to show how the closed-loop system is much more effective in athletes than that of untrained or unfit individuals.³ The effects of aerobic fitness and age were examined in an attempt to show how age and fitness levels impacted response time in closed-loop tasks. This study showed that as age increases and fitness decreases, the ability for the closed-loop control system to be affected also decreases.⁷

The purpose of this study was to determine the interactions of two groups of participants (athletes & non-athletes) and cutting angles in active vertical ground reaction force (GRF) and time of foot contact at the closed-loop environment. This study also compared two given time-frames to process feedback between athletes and non-athletes. The hypothesis of this study was that there would be a higher failing rate in 1 meter line (1M-line) sign change than in 3 meter-line (3M-line) sign change. Furthermore, athletes were predicted to have less chance of failing trials than non-athletes because of the decision making experience in closed-loop situations. In addition, it was hypothesized that the active vertical GRF was assumed to be a similar amount between 3M and 1M sign changes, as well as, a time of foot contact for the athletes at the time direction change as compared to the non-athletes.

Methods

A total of 10 participants volunteered for this study. Five collegiate soccer players (age, 18.6 ± 0.5 yr.; height, 170.4 ± 3.2 cm; weight, 68.4 ± 3.1 kg; all reportedly right foot dominant) and five healthy young adults, all reported right-foot dominance (age, 20.2 ± 1.3 yr; height, 176.0 ± 5.3 cm; weight, 74.2 ± 5.3 kg) volunteered for this study.

Procedure

All participants reported to the Barry University Biomechanics Laboratory at the date of the data collection. After an adequate amount of stretching and warm-up, the participants started at a distance of 4 m from the force plate, and then ran to step on the force plate with the foot opposite of the direction they were guided to go by the instructor. The active vertical GRF (push-off phase of the vertical GRF) was measured by an AMTI force plate (Advanced Medical Technologies, Inc., Watertown, MA) that sampled at 600 Hz. The Peak Motus software (version 8.2, ViconPeak, Centennial, CO) was used to reduce the data with Fast Fourier Analysis. The active vertical GRF was converted from Newton to body weight (BW) and averaged for the groups. To maximize the concepts of closed-loop control in cutting movement, the investigator provided a direction sign (e.g., left (L) 30°, L60°, right (R)30°, R60°) prior to the start, and then switched the sign to the different directions at the 3M-line as condition I, and then again at the 1M-line as condition II before reaching the force plate. Visual demonstration and verbal instruction were provided to place a foot on the force plate properly. Participants were instructed to run with a comfortable pace (2-2.5m/s), and were also allowed to practice until they felt comfortable with a proper foot placement and running speed. A total of 8 trials were given to each participant, as the signs were assigned randomly.

Statistical Analysis

Microsoft Excel (Microsoft, Inc. Seattle, WA) was used to generate graphs to simplify the comparison between the average active GRF and the average time of foot contact of both conditions in the athletes and the non-athletes. The results of this study were analyzed using two separate 2*4 (athletes/non-athletes x 4 cutting angles) mixed-design ANOVA performed in the Statistical Package for Social Sciences (SPSS). The test was performed for each dependent variable: the active vertical GRF and the time of foot contact.

Results

The results showed that the athletes had a higher active vertical GRF to push-off their body when changing the directions with shorter time of foot contact as compared to the group of non-athletes in Condition I (Figures 1 and 2). The average active vertical GRF of 60° directions (L & R) from the athletes was 2.14 ± 0.32 *body weight (BW), as compared to the non-athletes with 1.81 ± 0.11 *BW. The average time of foot contact of 60° directions (L & R) from the athletes was 0.21 ± 0.06 s, whereas the group of non-athletes was 0.30 ± 0.05 s. The average active vertical GRF of 30° directions (L & R) from the athletes was 2.11 ± 0.21 *BW, as compared to the non-athletes with 1.85 ± 0.15 x BW. The average time of foot contact of 30° directions (L & R) from the athletes was 0.27 ± 0.06 s, whereas the group of non-athletes was 0.29 ± 0.04 s. A 2*4 mixed-design ANOVA was calculated to examine the effects of the participants (athletes vs. non-athletes) and angles (L30°, L60°, R30°, R60°) on the active vertical GRF. No significant main effects or interactions were found. The angles and participants interaction ($F_{3,24} = .789$, $p > .05$), the main effect for angles ($F_{3,24} = .324$, $p > .05$), and main effect for participants ($F(1,8) = 6.47$, $p < .05$) were not significant. The active vertical GRF was influenced by neither participants nor angles. A 2*4 mixed-design ANOVA was calculated to examine the effects of the participants (athletes vs. non-athletes) and angles (L30°, L60°, R30°, R60°) on the time of foot contact. A significant angles and participants interaction was present ($F_{3,24} = 4.48$, $p < .05$). In addition, the main effect for angles was not significant ($F_{3,24} = 2.44$, $p > .05$). The main effect for participants was significant ($F_{1,8} = 4.97$, $p < .05$). Upon examination of the data, it appears that soccer players showed shorter time of foot contact (Figure 3). The results showed that the group of non-athletes failed all trials when the sign was changed at 1M-line from the force plate. This indicated that the participants recognized the sign change, but the motor process cannot activate quick enough to go in the guided directions. On the other hand, the group of athletes succeeded a total of 18 out of 20 trials (90% success rate) in the same condition. Due to all failing trials among the non-athletes, only the data from the group of the athletes was used to compare between condition I (3M-line) and condition II (1M-line). The active vertical GRF was higher when the sign was changed at 3M-line than when the sign was changed at 1M-line due to the faster running velocity prior to reaching the force plate. When the sign was changed at 1M-line, participants were forced to decrease running speed that caused to reduce the active vertical GRF during the cutting maneuver. In addition, among the group of athletes, the results also showed that the average time of the foot contact was shorter when the sign was changed at 3M-line (30°, 0.27 s; 60°, 0.20 s) as compared to the 1M-line (30°, 0.33 s; 60°, 0.29 s).

Discussion

When observing the results, there was significantly less failure in Condition I (3M sign change) as compared to Condition II (1M sign change), which supports the first hypothesis of this study. In addition, it was concluded that the athletes' performance is superior to non-athletes when having only 1M to change their decision, which ultimately supports our second hypothesis. However, because no data could be compiled in Condition II for the non-athletes due to the 100% failing rate of all trials; we could not compare groups and therefore were unable to support

our third hypothesis. The third hypothesis was not supported due to the fact that the active vertical GRF was higher and the time of foot contact was shorter when the sign was changed at the 3M-line as compared to the 1M-line. The results also indicated that athletes produced a longer time of foot contact when the sign was changed to R30° than any other angle or direction. The findings reported by Etnier and colleagues indicated that trained individuals might have faster response time than untrained individuals.³ The present study supported the findings and indicated that because of the traits a trained person may have, as well as their experiences, their closed-loop control system functions more effectively than that of non-athletes. Other studies have been done to find the “point of no return” in which individuals cannot send feedback of a desired movement fast enough to make a change in their movement pattern. The findings reported by Morya and associates stated that the point of no return was 240-245 ms before the movement was needed in order to effectively change directions of a penalty kick in soccer.² The 100% failing rate at the 1M-line by the group of non-athletes in the present study may indicate that somewhere between 1M and 3M lies the “point of no return” for non-athletes to effectively make fluid changes in an unpredictable environment. The point of no return may be closer than 1M in the athletes because of the high success rate.

When the athletes were guided to R30° in Condition I, the time of foot contact was longer than when they moved in all other directions. When the athletes used their non-dominant foot to move to the right, their time of foot contact was longer especially at the 30° acute angle as compared to all other angles and directions. This may have an indication as to how dominant as compared to non-dominant foot can affect force production during cutting movements in different directions. Overall, the athletes showed improved movement efficiency by performing the cutting maneuver with higher active vertical GRF in shorter time of foot contact as compared to the non-athletes.

Figure 1. Comparison of active ground reaction force between athletes and non-athletes at the 3M sign change

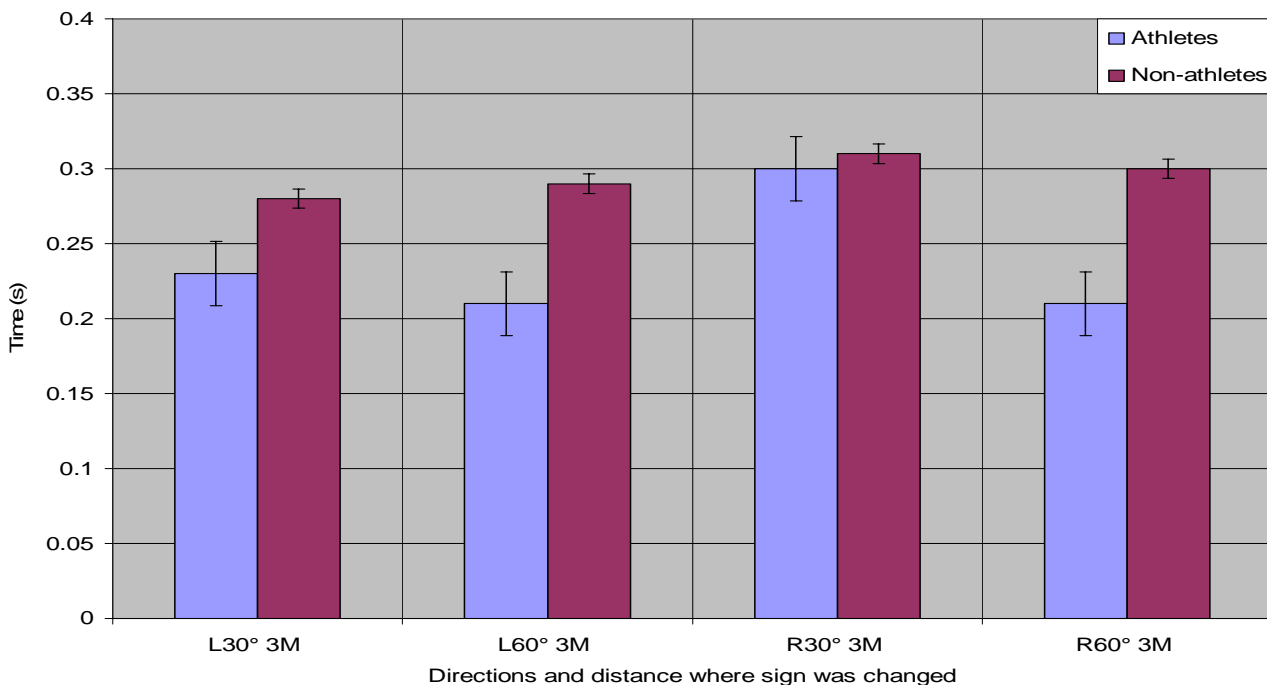


Figure 2. Comparison in time of foot contact between athletes and non-athletes at the 3M sign change

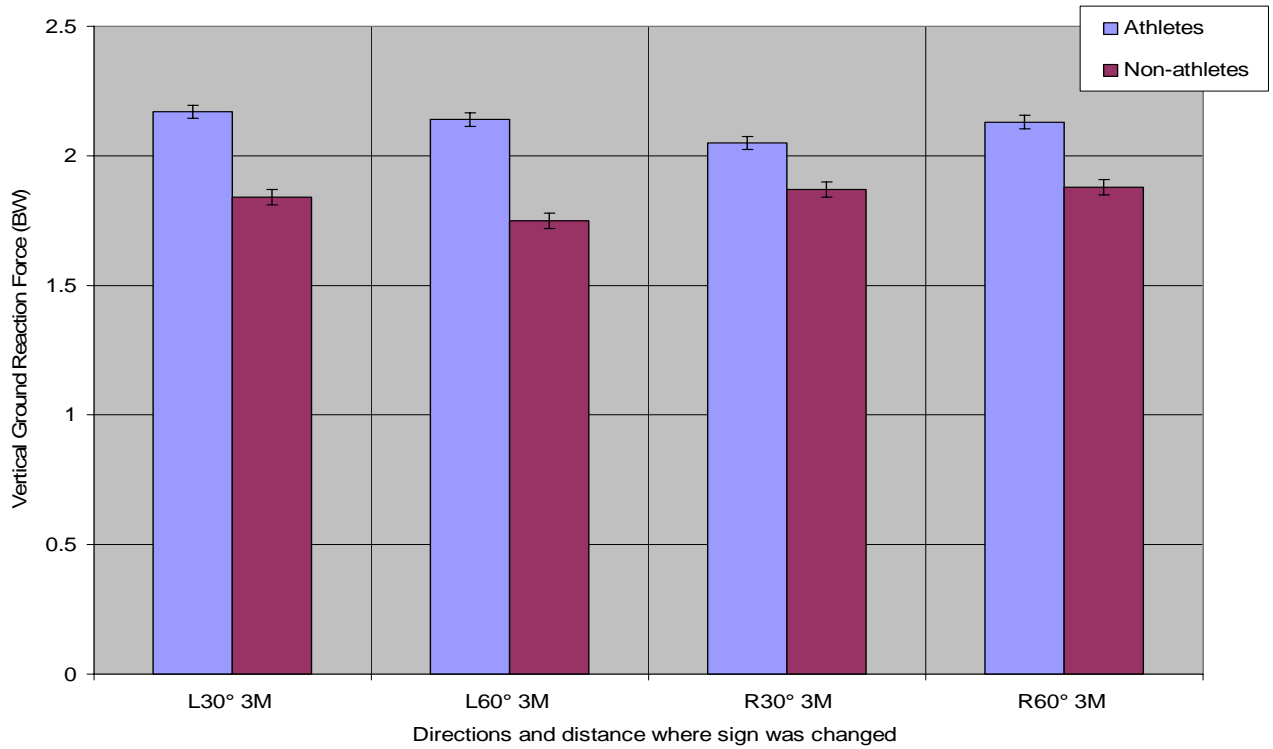
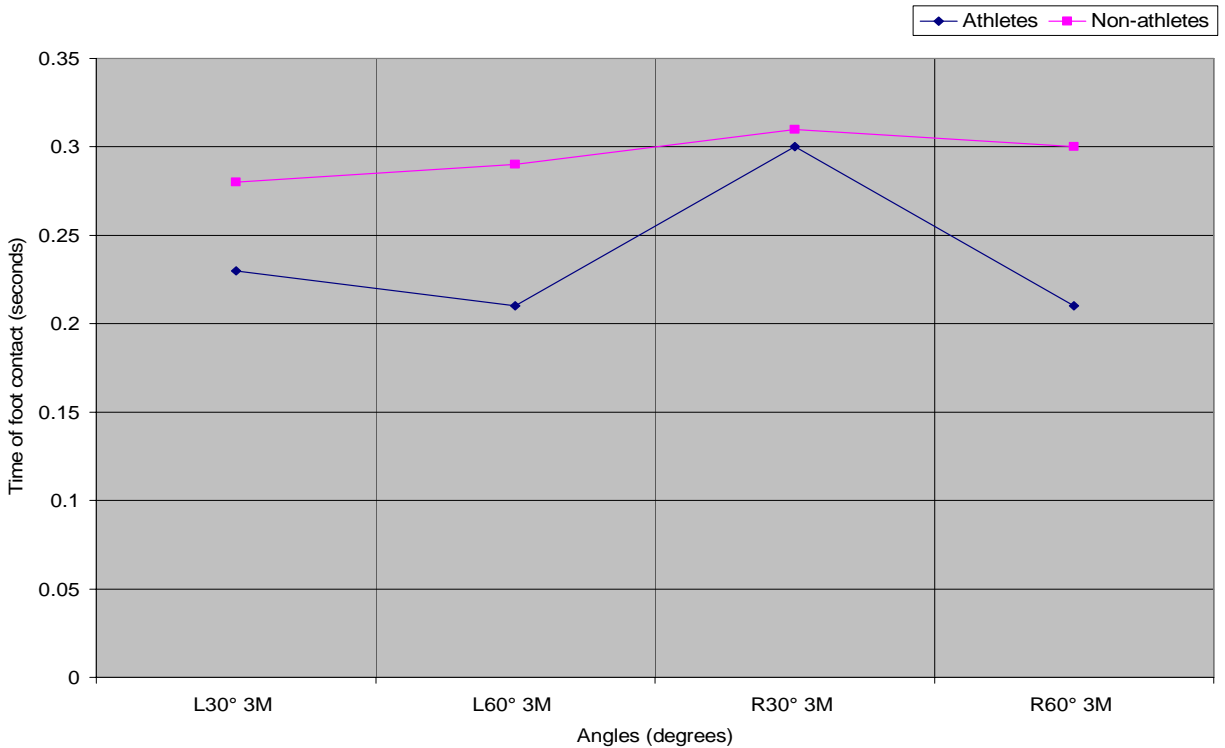


Figure 3. Comparison in the average time of foot contact in four angles between athletes and non-athletes



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