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The Effect of Limb Dominance on Reaction Time and Anticipatory Postural Adjustments During Gait Initiation in Healthy Subjects

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Abstract

Objectives: The stability and mobility function of dominant and non-dominant limbs are different. Considering the lack of any previous investigation in this regard, this study aimed to investigate the effect of limb dominancy on anticipatory postural adjustments and reaction time (RT) during gait initiation in healthy people.

Materials and Methods: Twenty healthy people with the right limb dominant participated in the study. The two stimuli of warning and response were used within a 2-second interstimulus interval. In addition, the participants were instructed to get ready to initiate walking as soon as they hear the warning stimulus and initiate gait immediately after hearing the response stimulus, followed by measuring the RT and duration of the anticipatory postural adjustment phase.

Results: The RT was slower when a person initiated gait with the dominant limb as compared with the non-dominant limb and no significant differences were observed in anticipatory postural adjustment phase duration between the two limbs.

Conclusions: In general, our findings demonstrated that information processing capacity for perception, motor planning, and selection of proper motor responses for movement initiation is affected by limb dominance.

Keywords: Limb, Dominance, Reaction time, Postural balance, Gait initiation

Introduction

There is high evidence that the function of the two limbs is different, namely, one limb is used for mobility whereas the other contributes to control (1). According to Gabbard and Hart (2), the mobilizing limb is the preferred foot (dominant) while the limb used for postural support is the non-preferred foot (non-dominant). In addition, limb dominancy is related to the differentiation of the function and motor organization of the two hemispheres of the human brain (3). Differences in the stability and mobility function of dominant and non-dominant limbs have been the focus of multiple studies. In this regard, research findings are contradictory. Although some studies found no significant difference in postural stability measure between dominant and non-dominant limbs (4), others reported the asymmetrical behavior of the two limbs (1,5,6). For instance, Huurnink et al (4) found no significant difference in postural stability measures between preferred and non-preferred limbs during the five-leg preference tasks of the step up, hop, ball kick, balance, and pick up. Contrarily, Sung (5) reported significant differences in the temporal and spatial parameters of gait between the dominant and non-dominant limbs of healthy older adults. Aizawa et al also confirmed asymmetry in medial ground reaction force during a single-leg jump landing (6). Previous works are basically concentrated on asymmetrical kinematic, as well as the kinetic and neuromuscular behavior of the lower limbs (7), and no knowledge exists on the effects of limb dominancy on central control mechanisms for postural control. Accordingly, the evaluation of central control mechanisms for postural control during gait initiation, which is inherently unstable, could be valuable because of the integrity of biomechanical, neurophysiological, and motor control factors in gait (7). Gait initiation is a transient phase between standing and walking and consists of a preparatory and an execution phase. The preparatory phase, so-called anticipatory postural adjustments (APAs), occurs before stepping forward and is associated with a backward and lateral shift of the center of pressure toward the swing limb (8). During this high demanding phase, the central nervous system selects an appropriate motor program to maintain postural balance while propelling the body forward. Many researchers studied APA in

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the elderly population (8-10), people with neurological (11), and musculoskeletal disorders (12). For example, Khanmohammadi et al (8) showed that elderly people have slower APA compared to healthy subjects, indicating a higher risk of falling in the elderly population. Another research reported alterations in the APA in people with low back pain (12).

Reaction time (RT) is another factor regarding evaluating central control mechanisms that relate to the body preparation for movement in the preparatory phase of gait initiation. RT is the elapsed time between the presentation of a sensory stimulus and the following motor response (13). The selection of an appropriate motor goal and motor planning occurs during the RT (14). RT was investigated in neurological disease (15) and among the elderly population, and another previous study showed the relationship between increased RT and the risk of falls in elderly people (16).

Objectives

Considering the above-mentioned findings, identifying the effect of limb dominancy on the central control mechanism seems to be valuable not only in preventing falls but also as a basic concept in designing exercises for the treatment of people with postural control deficiencies. Therefore, the purpose of this study was to clarify the relationship between central control mechanisms used in gait initiation (RT and APA) and limb dominancy.

Materials and Methods

Participants

Twenty healthy people (1 male and 19 females within the age range of 60.25 ± 8.2 years) with the right (Rt) leg dominant and the Berg Balance Scale score of >40 participated in this cross-sectional study. The participants had no lower extremity, postural control, and hearing problems. They also had no history of seizure, dizziness, and other diseases that might cause disturbances in balance.

Procedure

The criterion of the kicking limb (17) was used to determine limb dominance, and all participants reported right leg-preference for kicking a ball. To assess RT and APA, the participants stood barefoot and relaxed on a force platform (Bertec Corporation, Columbus, Ohio, USA) and were instructed to load their weight equally on both right and left legs. In addition, both arms were hanged at the sides, feet were abducted at 10˚, and heels were separated mediolaterally by 6 cm (8). For gait initiation, participants were presented with two auditory stimuli including the warning stimulus (S1) and the response stimulus (S2) with an inter-stimulus interval of 2 seconds (8). Further, participants were asked to begin forward stepping with the self-selected limb as soon as possible in response to S2 and continue walking along a pathway. Furthermore, the intensity, duration, and frequency of auditory stimulus were 60 dB, 100 ms, and 2 kHz, respectively (8). To familiarize the subjects with the test, five practice trials were performed before the main test, followed by overall 10 trials with a 3-minute rest interval between the familiarization and test trials and a minimum of 1-minute rest interval between the trials for each limb. All recording systems were synchronized in time. Moreover, an experienced physiotherapist observed the participants and ensured that they do not shift to one side prior to starting the test.

Data Analysis and Statistics

The center of pressure (COP) data were recorded by a force platform (Bertec Columbus, Ohio, USA, height: 15.2 cm and size: 90 × 90 cm) at a sampling frequency of 500 Hz. The analysis of gait initiation (GI) data extracted specific temporal events using a program written in Excel. The GI period was defined from the response stimulus (S2) to the toe-off of the stance limb. Additionally, the first shift of the COP toward the swing limb in the mediolateral direction was defined as the step initiation (COP displacement greater than 3SD from the mean amplitude in the 1500 ms before S2). In addition, the end of the mediolateral deviation of the COP toward the stance limb was defined as the foot-off, namely, the absolute COP slop lesser than 100 mm/s (10). The RT was calculated as the time from S2 to step initiation and the APA phase was defined as the time from step initiation to toe-off (9), related data are shown in Figure 1. The averages of 10 trials were used for statistical analysis. A paired *t* test was used to test the mean differences in RT and APA duration between the two limbs. Further, Cohen's d values were measured for investigating the effect size. All statistical analysis was conducted using SPSS, version 20 and statistical significance threshold was set at 0.05.

Results

The normality of data distribution was confirmed by the Kolmogorov-Smirnov test (RT: $P = 0.329$, APA: $P = 0.403$). The RT while initiating gait with the non-dominant leg was significantly longer compared to the dominant leg ($P = 0.04$, Cohen's d=0.63). No significant difference was observed in the APA phase duration between the two limbs ($P = 0.71$, Cohen's d=0.09), the details of which are presented in Table 1.

Discussion

This study, to the best of our knowledge, provided the first evidence asymmetry in RT between non-dominant and dominant limbs. Our result indicated a shorter RT while initiating gait with the dominant limb. The results revealed no significant differences in the anticipatory postural adjustments (APA) phase duration between dominant

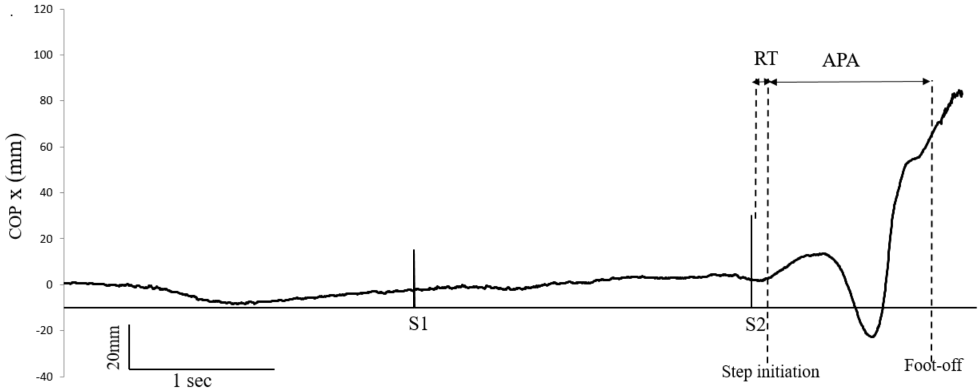

Figure 1. A Representative Sample for COP Trajectory in Mediolateral Direction

Note. COP: Center of pressure; Reaction time (RT): The time from S2 to step initiation (the first shift of the COP toward the swing limb); Anticipatory postural adjustment (APA): The time from step initiation to foot-off (the end of the mediolateral deviation of the COP toward the stance limb); mm: Millimeters; Sec: Second.

Table 1. Measurement Parameters of COP Analysis Between the 2 Limbs

	Rt limb (Mean ± SD)	Lt limb (Mean ± SD)	*P* Value	Cohen's d
$RT_{(ms)}$	184 ± 25	199 ± 22	0.04	0.63
$APA_{(ms)}$	368 ± 64	374 ± 65	0.71	0.09

Note. COP: Center of pressure; SD: Standard deviation; Rt: Right; Lt: Left; RT: Reaction time; APA: Anticipatory postural adjustment; The level of significance was set at $P < 0.05$ in paired *t* test analysis.

and non-dominant limbs during gait initiation (GI).

There is a controversy over how limb dominance affects the behaviors of the lower extremities. A common definition of limb dominancy is that the preferred limb used for mobilizing activity is the dominant limb while the non-dominant limb relates to postural support (2). A review by Sadeghi et al (7) showed that asymmetries in limb function do exist and contribute to the role of each limb to propulsion and control tasks. Several studies assessed asymmetrical kinetic and kinematic behavior of lower extremities (7). For instance, Sung (5) reported a relationship between temporal and spatial gait parameters and dominancy. Accordingly, the stride length and single limb loading pattern on the dominant limb were longer compared to the non-dominant limb. In addition, in the stance phase, the initial double support was longer on the non-dominant limb. A larger medial ground reaction force during single-leg jump-landing on the non-dominant leg was reported as well (6).

To the best of our knowledge, this was the first study to describe the effect of limb dominance on RT and anticipatory postural adjustment during GI. RT is the time interval from the presentation of a stimulus to the consequent motor response (14) which involves perceptual decision-making and motor planning that are related to the preparation of the movement. Our findings demonstrated that when the participant with the right (Rt) limb dominant initiates gait with the Rt limb, RT is smaller than the left (Lt) limb. Generally, in people with Rt limb dominant, Rt limb is used for mobilizing activity whereas Lt limb provides postural support (2). Thus, a person with Rt-limb dominance is accustomed to using Rt and Lt limbs for propulsion activity and support provision in the whole life, respectively. Therefore it seems logical that when one wants to initiate gait, it takes less time for perceptual processing and motor planning to move the dominant limb compared to the non-dominant limb. Conversely, since the non-dominant limb is used to maintaining stability, more time is needed to initiate the gait. Overall, our findings indicated that information processing capacity for perception, motor planning, and selection of proper motor responses for movement initiation is affected by the limb dominancy.

The APA phase difference was not statistically significant between dominant and non-dominant limbs during the GI. In agreement with this finding, some studies showed that limb dominance had no statistical effect on postural stability in healthy hockey athletes (18) on unilateral postural stability by measuring the sway area and sway path length (17) and for some functional tests like isokinetic quadriceps and hamstring tests, hamstring: quadriceps ratios, single-leg hop for distance, single-leg vertical jump, and vertical ground reaction force during a single-leg vertical jump (19). To our knowledge, this was the first study that focused on the relationship between the limb dominancy and APA; thus the direct comparison with the findings of previous studies may not be well done. APAs stabilize posture and balance before the initiation of the voluntary movement (20) and, during the APA phase, the COP moves backward and laterally toward the swing limb to propel the body for walking (8). According to our results, this motor control phenomenon for postural control prior to the execution of movement was not affected by limb dominancy.

Conclusions

In general, this study evaluated the effect of limb dominance on central control mechanisms (i.e., reaction time and anticipatory postural adjustments) during gait initiation in healthy subjects. Therefore, when the participants initiated gait with the dominant limb, the reaction time was slower compared with the non-dominant limb, and anticipatory postural adjustments demonstrated no significant differences between dominant and non-dominant limbs. Generally, our results demonstrated that information processing capacity for perception, motor planning, and selection of proper motor responses for movement initiation is affected by the limb dominancy.

Limitations of the Study

Our study has some limitations. This study did not investigate the relationship between genders, the limb dominancy, and central control variables. Some researchers indicated that the male brain might be more lateralized or asymmetrical than the female brain (18), thus further investigation is suggested in this regard. Because of the lack of knowledge about the effects of the limb dominancy on the central control strategies, further research on the other parameters of the motor control, and in people with biomechanical and neuromuscular dysfunctions is warranted.

Conflict of Interests

The authors declare no conflict of interests.

Ethical Issues

All subjects signed an informed consent form that was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences [No. IR.AJUMS.REC.1396.947].

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