Relationship between central control mechanisms used in gait initiation (rt and a...

INTRODUCTION

There is high evidence that the function of the two limbs is different, one limb is used for mobility whereas the other one contributes to control [1, 2] . Many researchers believe that the mobilizing limb is the preferred foot (dominant) while the limb that is used for postural support is the non-preferred foot (non-dominant) [3] . Limb dominancy is related to the differentiation of the function and motor organization of the two hemispheres of human brain [4] . Differences in the stability and mobility function of the dominant and non-dominant limb have been the focus of multiple studies. In this regard, research findings are contradictory, while some studies found no significant difference in postural stability measure between the dominant and non-dominant limbs [5, 6] , other reported asymmetrical behavior of the two limbs [1] . For instance, Huurnink et al. did not find any significant difference in postural stability measures between preferred and none-preferred limbs during five leg preference tasks of step up, hop, ball kick, balance, pick up [6] . Sung reported significant differences in the temporal and spatial parameter of gait between the dominant and non-dominant limbs of healthy older adults [8] . Asymmetry in medial ground reaction force during a single leg jump landing, and muscular activity of the limbs was also reported by Aizawa et al [9] andLiang et al [10] .

Previous works are basically concentrated asymmetrical kinematic, kinetic and neuromuscular behavior of lower limbs 7), to our knowledge, no knowledge exists on central control mechanisms of postural control in the dominant and non-dominant limbs. Evaluation of central control mechanisms of postural control during gait initiation which is inherently unstable. Gait initiation is a transient phase between standing and walking, and it contains of a preparatory and an execution phase. The preparatory phase, so called anticipatory postural adjustments (APAs), occurs before forward stepping, and it is associated backward and lateral shift of the center of pressure (COP) the swing limb [11)] . During this high demanding phase, the central nervous system (CNS) selects an appropriate motor program to propel the body forward while maintaining postural balance. Many researchers have studied APA in elderly population [12, 13)] , people with obesity [14)] and subjects with neurological [15)] and musculoskeletal disorders [16)] . For example, Khanmohammadi et al. [12)] , showed that elderly people had slower APA than healthy subjects, indicating higher risk of falling in elderly population. Alteration in the APA in people with low back pain have been reported in several studies [16, 17)] . Since the relationship between APA and balance control is well recognized, understanding the effect of limb dominancy on the function and motor organization of CNS in healthy people could be valuable for fall prevention.

Reaction time (RT) is another factor to evaluate central control mechanisms that relate to the body preparation for movement in the preparatory phase of gait initiation [19)] . RT is the elapsed time between the presentation of a sensory stimulus and the following motor response [20)] . Selection of an appropriate motor goal and motor planning occur during the RT [21)] . Several studies showed the relationship between increased RT and risk of falls in elderly people [23, 24] . According to these findings, identifying the effect of limb dominancy on the central control mechanism seem 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.

Most studies that have been conducted in this field were concentrated on the evaluation of RT in people with neurological diseases [22] and elderly population [23] , so RT has not been investigated on limb dominancy in healthy people as a basic principle in balance control.

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.

PARTICIPANTSAND METHODS

APA could be assessed by electromyography (EMG) and COP data. Studies using COP data have evaluated the timing of APA phase in mediolateral direction [18] and velocity-displacement variables in antroposterior and mediolateral directions [12, 13] .

Twenty healthy people (1 male, 19 females; age 60. 25±8. 2 years, weight 73. 95±8. 8 Kg and height 163±7 cm) (Table 1) with right (Rt) limb dominant and with no lower extremity, postural control and hearing problems participated in this study. The inclusion criteria for the participants was the Berg Balance Scale (BBS) score of > 40 for balance ability. Also, the participants had no history of seizure, dizziness and other diseases that might cause disturbances in balance. All subjects signed an informed consent approved by the Ethics Committee of the Ahvaz Jundishapur University of Medical Sciences [NO IR. AJUMS. REC. 1396. 947].

To determine limb dominance, we used the criterion of the kicking limb [25)] and all participants reported preferring to kick a ball with their right limb. To do experiment, the participants stood barefoot and relaxed on a force platform (Bertec Corporation, Columbus, OH, USA) and were instructed to load their weight equally on both right and left legs. Both arms were hanged at the sides, feet were abducted at 10˚ and heels were separated medio laterally by 6cm [12)] . For gait initiation, participants were presented with two auditory stimuli: the warning stimulus (S1), and the response stimulus (S2) with an inter-stimulus interval of 2 s [12)] . Participants were asked to begin forward stepping with the self-selected limb as soon as possible in response to S2 and continued walking along a pathway. Intensity, duration and frequency of auditory stimulus were 60dB, 100 ms and 2 kHz, respectively [17)] . To familiarize the subjects with the test, five practice trials were performed before the main test followed by overall 10 trials with 3 minutes' rest between the familiarization and test trials and with minimum of 1-minute rest interval between the trials for each limb. All recordings systems were synchronized in time. Moreover, an experienced physiotherapist observed the participants to ensure that they do not shift to one side prior to starting the test.

COP data were recorded by a force platform (Bertec Columbus, ohio, USA, height: 15. 2 cm, size: 90×90 cm) at a sampling frequency of 500 Hz. The analysis of GI data extracted specific temporal events, using a program written in Excel. GI period was defined from the appearance of the response stimulus (S2) to the toe-off the stance limb. As mentioned in the introduction, Uemura et al. [18)] used COP data to measure RT and APA phase duration and stated that 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) and the end of the mediolateral deviation of the COP toward the stance limb was explained as the foot-off (absolute COP slop lesser than 100mm/s). The Reaction Time was calculated as the time from S2 to step initiation and the APA phase was calculated as the time from step initiation to toe-off [13)] (Fig. 1). Averages of 10 trials were used for statistical analysis. We used paired t-test to reveal the presence of significant differences in RT and APA amounts between two limbs. Also, Cohen’s d values were measured for investigating 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 (KS) test (RT sig= 0. 329, APA sig= 0. 403). The reaction time differs significantly between the two limbs (sig <0. 04, Cohen’s d= 0. 63); that way it was longer in left limb (non-dominant) in comparison with the right limb (dominant). No significant differences were observed in APA phase duration between the two limbs (sig= 0. 71, Cohen’s d= 0. 09) (Table 2).

DISCUSSION

This study provides the first evidence that the reaction time is longer when a person initiates gait with the non-dominant limb as compared with dominant limb. We also found no significant differences in APA phase duration between dominant and non-dominant limb during gait initiation.

There is a controversy over how limb dominance affects the various behaviors of the lower extremities. A common definition of limb dominancy is the preferred limb used for mobilizing activity is dominant limb while the non-dominant limb relates to postural support [3)] . Review by Sadeghi et al. [7)] , showed that asymmetries in limb function do exist and it contributes to the role of each limb to propulsion and control tasks. Several studies have assessed asymmetrical behavior of lower extremities by using kinematic parameters like velocity, step and stride length, kinetic factors such as ground reaction force and EMG data [7)] . For instance, Sung [8)] has reported that there was a relationship between the limb support times and dominancy by assessing temporal-spatial gait parameters (cadence, speed, stride length, and limb support times), that way; the stride length and single limb loading pattern on the dominant limb were longer than non-dominant limb and also, in stance phase, the initial double support was longer on the non-dominant limb; however, the terminal double support was significantly longer on the dominant limb. Evaluation of limbs asymmetry by kinetic data has been demonstrated that when single-leg lateral jump-landing was done with the non-dominant leg, the medial peak ground reaction force was larger than that for the dominant leg [9)] . Also, Seeley et al. [26)] used ground reaction force impulses to evaluate functional limb asymmetry, their results showed little support for the functional limb asymmetry only in the fast speed.

Moreover, the results of using sEMG for the investigation of the asymmetrical behavior of lower extremities have shown that muscle activities between the two limbs were significant differences during static and dynamic steady state tests [10)]. Despite all these researchers, there are no reports related to the limb dominancy and central control mechanisms such as RT and APA.

RT is the time between the presentation of a stimulus to consequent motor response [21)] which involves perceptual decision making and motor planning related to the preparation of the movement. RT was investigated in neurological disease [22)] and in elderly population. It has been documented the associations between increased reaction time [23)] with the rate of falling in elderly people. Our findings demonstrated that when the participant with the right limb dominant initiated gait with Rt limb, RT was smaller than Lt limb. As we said earlier, generally, in people with Rt limb dominant Rt limb is used for mobilizing activity whereas Lt limb provides postural support [3)] . Thus, in the whole life, a person with Rt limb dominant is accustomated to using the Rt limb for propulsion activity and using the Lt limb to provide support, therefore it seems logical that when one wants to initiate gait, it takes less time to perceptual processing and motor planning for move the dominant limb than the non-dominant limb. On the opposite side, since the Lt limb is used to maintaining stability, so more time is needed to initiate the gait. Overall, our findings indicate that information processing capacity for perception, motor planning and selection proper motor responses for movement initiation are affected by the limb dominancy.

The APA phase difference was not statistically significant between the dominant and the non-dominant limb during GI. In agreement with this finding, several studies showed that there was no statistical effect of limb dominance on postural stability in healthy hockey athletes [27)] on unilateral postural stability with measuring sway area and sway path length [25)] and for the 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 [28)] . To our knowledge, this is the first study focusing on the relationship between the limb dominancy and APA, so direct comparison with previous studies may not be well done. APAs stabilize posture and balance before the initiation of the voluntary movement [29)] , actually these APAs move the COP beneath the feet backward and laterally toward the swing limb to propel body for walking [11)] . According to our results, this motor control phenomenon for postural control prior to execution of movement was not affected by the limb dominancy.

Our study has some limitations; the relationship between gender, the limb dominancy and central control variables was not investigated. Some researchers have indicated that the male brain might be more lateralized or asymmetrical than the female brain [27)] , thus further investigation are suggested in this regard. Because of the lack of knowledge about the effects of the limb dominancy on the central control strategies, future researches on the other parameters of the motor control in different situations like biomechanical and neuromuscular dysfunctions will be necessary. Moreover, we only recruited healthy people and did not investigate particular populations.

In conclusion, we evaluated the effect of limb dominance on central control mechanisms (reaction time and anticipatory postural adjustments) during gait initiation in healthy subjects. Thereby when people initiated gait with the dominant limb RT was slower than that with the non-dominant limb and APAs was not significant differences between the dominant and the non-dominant limbs. Generally, our research demonstrates that information processing capacity for perception, motor planning and selection proper motor responses for movement initiation are affected by the limb dominancy.

REFERENCES

1) Peters M: Footedness: Asymmetries in foot preference and skill and neuropsychological assessment of foot movement. Psychological Bulletin, 1988, 103: 179-192.

2) Singh I: Functional asymmetry in the lower limbs. Acta Anat, 1970, 77: 131–138.

3) Gabbard C, Hart S: A Question of Foot Dominance. The Journal of General Psychology, 1996, 123: 289-296.

4) Nachshon I, Denno D, Aurand S: Lateral preference of hand, eye and foot: relation to cerebral dominance. Int J Neurosci, 1983, 18(1–2): 1–9.

5) Alonso AC, Brech GC, Bourquin AM, et al.: The influence of lower-limb dominance on postural balance. Sao Paulo Med J., 2011, 129(6): 410-413.

6) Huurninka A, Fransz DP, Kingma I, et al.: The effect of leg preference on postural stability in healthy athletes. Journal of Biomechanics, 2014, 47: 308-312.

7) Sadeghi H, Allard P, Prince F, et al.: Symmetry and limb dominance in able-bodied gait: a review. Gait and Posture, 2000, 12: 34-45.

8) Sung PS: Increased double limb support times during walking in right limb dominant healthy older adults with low bone density. Gait & Posture, 2018, 63: 145-149.

9) Aizawa J, Hirohata K, Ohji S, et al.: Limb-dominance and gender differences in the ground reaction force during single-leg lateral jump-landings. J. Phys. Ther. Sci., 2018, 30: 387–392.

10) Liang S, Xu J, Wang L, et al.: An investigation into the bilateral functional differences of the lower limb muscles in standing and walking, Peer J, 2016, Aug 9; 4: e2315.

11) MacKinnon CD, Bissig D, Chiusano J, et al.: Preparation of anticipatory postural adjustments prior to stepping. J Neurophysiol, 2007, 97: 4368–4379.

12) Khanmohammadi R, Talebian S, Hadian MR, et al.: Preparatory postural adjustmets during gait initiation in healthy younger and older adults: neurophysiological and biomechanical aspects. Brain Research, 2015, 1629: 240-249.

13) Hayati M, Talebian S, Sherrington C, et al.: Impact of age and obstacle negotiation on timing measures of gait initiation. Journal of Bodywork & Movement Therapies, 2018, 22: 361-365.

14) Cau N, Cimolin V, Galli M, et al.: Center of pressure displacements during gait initiation in individuals with obesity. Journal of NeuroEngineering and Rehabilitation, 2014, 11: 82.

15) Plate A, Klein K, Pelykh O, et al.: Anticipatory postural adjustments are unaffected by age and are not absent in patients with the freezing of gait phenomenon. Exp Brain Res, 2016, 234: 2609-2618.

16) Jacobs JV, Lyman CA, Hitt JR, et al.: Task-related and person-related variables influence the effect of low back pain on anticipatory postural adjustments. Human Movement Science, 2017, 54: 210-219.

17) Sadeghi M, Talebian S, Olyaei GR, et al.: Preparatory brain activity and anticipatory postural adjustments accompanied by externally cued weighted-rapid arm rise task in non-specific chronic low back pain patients and healthy subjects. SpringerPlus, 2016, 5: 674.

18) Umeura KYM, Nagai K, Ichihashi N: Older adults at high risk of falling need more time for anticipatory postural adjustment in the processing phase of obstacle negotiation. Journal of Gerontology, 2011, 66A: 904-909.

19) Wong AL, Haith AM, Krakauer JW: Motor planning. The Neuroscientist: A Review. Journal Bringing Neurobiology, Neurology and Psychiatry, 2015, 21: 385–398.

20) Jensen AR: Clocking the mind: Mental chronometry and individual differences. (1st ed.). Amsterdam, Elsevier, 2006.

21) Delmas S, Moran AC, Park SH, et al.: Motor planning perturbation: muscle activation and reaction time. Neurophysiol J, 2018, 120: 2059-2065.

22) Bloxham CA, Dick DJ, Moore JM: Reaction times and attention in Parkinson’s disease. Journal of Neurology, Neurosurgery, and Psychiatry, 1987, 50: 1178-1183.

23) Pijnapples M, Delbaere K, Sturnieks DL, et al.: The association between choice stepping reaction time and falls in older adults—a path analysis model. Age and Ageing, 2010, 39: 99–104.

24) Lord SR, Fitzpatrick RC: Choice Stepping Reaction Time: A Composite Measure of Falls Risk in Older People. J Gerontol A Biol Sci Med Sci, 2001, 56(10): 627-632.

25) Hoffman M, Schrader J, Applegate T, et al.: Unilateral postural control of the functionally dominant and nondominant extremities of healthy subjects. J Athl Train, 1998, 33(4): 319-22.

26) Seeley MK, Umberger BR, Shapiro R: A test of the functional asymmetry hypothesis in walking. Gait & Posture, 2008, 28: 24-28.

27) McGrath TM, Waddington G, Scarvell JM, et al.: The effect of limb dominance on lower limb functional performance – a systematic review. J Sports Sci. 2016, 34(4): 289-302.

28) Massion J: Movement, posture and equilibrium: interaction and coordination. Prog Neurobiol, 1992, 38: 35–56.

29) Kapreli E, Athanasopoulos S, Papathanasiou M, et al.: Lateralization of brain activity during lower limb joints movement. An fMRI study. Neuroimage., 2006, 32: 1709-1721.