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# THE CORRELATIONS BETWEEN DYNAMIC WALKING STABILITY AND PERCEPTION-MOTOR ABILITIES OF HUMANS

**Junxia Zhang, Juan Ge, Wenwu Wang, Yan Zhang, Na Yin, Yefang Liu**

**College of Mechanical Engineering, Tianjin University of Science and Technology, Tianjin, P. R. China**

External perturbations can challenge a person's walking stability, and people will autonomously make a series of responses to regain the balance of walking, which includes two periods: perturbation-perception (reaction time, RT) and posture-adjustment (motion time, MT). The purpose of this paper was to investigate the correlations between the dynamic walking stability and perception-motor abilities. During the 30 level walking trials preformed by sixteen healthy participants, perturbations were applied at random. The fall probability (FP) during the walking with perturbations was calculated to evaluate the dynamic walking stability of each participant. Furthermore, the ground reaction force (GRF) of each participant during walking with perturbations was recorded and analyzed. The experimental results show that the RT had a significant positive-correlation with FP, while MT had no correlation with FP.

**KEY WORDS:** correlation analysis, reaction time, motion time, fall probability, perturbations, ground reaction force.

**INTRODUCTION:** Dynamic walking stability is the ability to respond to external or internal perturbations without falling (Dingwell & Kang, 2007). A person's walking stability can be challenged by external perturbations (Emily et al., 2012). When a walking person subjected to the external perturbation, a series of autonomous responses will occur to deal with the occasional instability, in which the posture is adjusted to regain the balance. This process includes two periods: perturbation-perception and posture-adjustment which can be respectively expressed by reaction time, RT and motion time, MT. RT and MT are two commonly used parameters in sports psychology. RT is defined as the elapsed time between stimulus presenting and motion starting, and it is a reflection of an individual's perception ability. MT is defined as the elapsed time between motion starting and motion completing which reflects one's motor ability (Fitts et al., 1964).

Dynamic walking stability is one of the basic requirements for human activities and that is of great importance to individuals, especially to some special populations such as athletes. For the athletes, they suffer with various disturbances during competitions and the excellent balance ability of the body is indispensable.

It has been suggested in the literature that RT is one of the many factors associated with dynamic stability (Pavol et al, 1999a, b, 2001; Tammy et al, 2001). However, the relevance between MT and dynamic stability has not been well-studied. The purpose of this study was to investigate the correlations between the dynamic walking stability and RT、MT.

**METHODS:**

**Research design:** Sixteen healthy individuals (No.1 to No.16) volunteered to participate (8 M/ 8 F; age 24.3±1.5 years; height 165.2±3.3 cm; body mass 55.4±5.6kg). All participants were free of any neurological, cardiovascular, musculoskeletal or visual disorders, which might interfere with the gait or perception and motor ability. All participants were provided written, informed consent prior to participation.

Each participant performed 30 level walking trials at their natural walking speeds. During the trials, vegetable oil was applied on the walking surface at random (20 times for each participant). GRF data were recorded by two force plates (AMTI-BP400600, Advanced Mechanical Technology, USA) located in the middle of a 10 m walkway. The participant was asked to step his/her two feet on different force plates.

Participants were protected from fall-down by a synchronous protection rig, which was attached to the upper torso and waist of the participant and its moving speed can be changed along with the participant's velocity. Before the trial, the ropes were adjusted to a suitable length so that the participant did not feel the pull.

The RT and MT of the participants were measured by a reaction-motion time tester (EP206-P, China). And because the RT and MT of the feet can be predicted through the RT and MT of the hands, participants' dominant hands were used in the tests.

**Data collection and analysis:** The FP value of each participant was calculated and listed in table 1. In this study, the results of the walking trials on slippery surfaces were graded as fall or recovery. Fall was identified visually, in which the situation of the participants' body being completely supported by the synchronous protection rig was used as the criterion, and all other outcomes were considered as recovering response. The correlation tests between FP and RT/MT were conducted using SPSS 19.0.

**RESULTS:** The mean values of RT and MT of each participant were listed in table 1.

**Table 1**
**Mean RT/MT (ms) and FP（%）**

| No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RT | 300 | 283 | 339 | 354 | 285 | 318 | 280 | 304 | 282 | 288 | 337 | 352 | 260 | 332 | 245 | 299 |
| MT | 297 | 300 | 326 | 317 | 319 | 290 | 307 | 302 | 333 | 329 | 306 | 297 | 339 | 305 | 310 | 308 |
| FP | 30 | 20 | 40 | 60 | 25 | 30 | 15 | 35 | 25 | 25 | 45 | 50 | 10 | 40 | 5 | 30 |

For RT and FP, the correlation coefficient between them was 0.964 (>0.8) and the correlation was significant at the 0.01 level, which meant there was an obviously positive linear-correlation between the two variables. For MT and FP, the correlation coefficient between them was -0.239 (0.239 <0.3), which can be identified that there was no correlation between the two variables (table 2).

**Table 2**
**Correlations**

| | | RT | MT | FP |
|---|---|---|---|---|
| RT | Pearson Correlation | 1 | -0.314 | .964** |
| | Sig. (2-tailed) | | 0.236 | 0.000 |
| | N | 16 | 16 | 16 |
| MT | Pearson Correlation | -0.314 | 1 | -0.239 |
| | Sig. (2-tailed) | 0.236 | | 0.374 |
| | N | 16 | 16 | 16 |
| FP | Pearson Correlation | .964** | -0.239 | 1 |
| | Sig. (2-tailed)） | 0.000 | 0.374 | |
| | N | 16 | 16 | 16 |

**. Correlation is significant at the 0.01 level.

The correlation analysis shows that the RT had a significant positive-correlation with FP. To make a further investigation in the correlation between RT and FP, the GRF of three chosen participants were recorded. The chosen participant's number was No.15, No.16 and No.4 and each of them was a representative of the one who's RT was the fastest, the middle and the slowest, respectively. GRF were calculated from the digitized output of each trial under perturbations. Each of the three GRF component curves were normalized to body weight (BW) and ensemble averaged to obtain composite GRF curves for all three activities (figure 1).

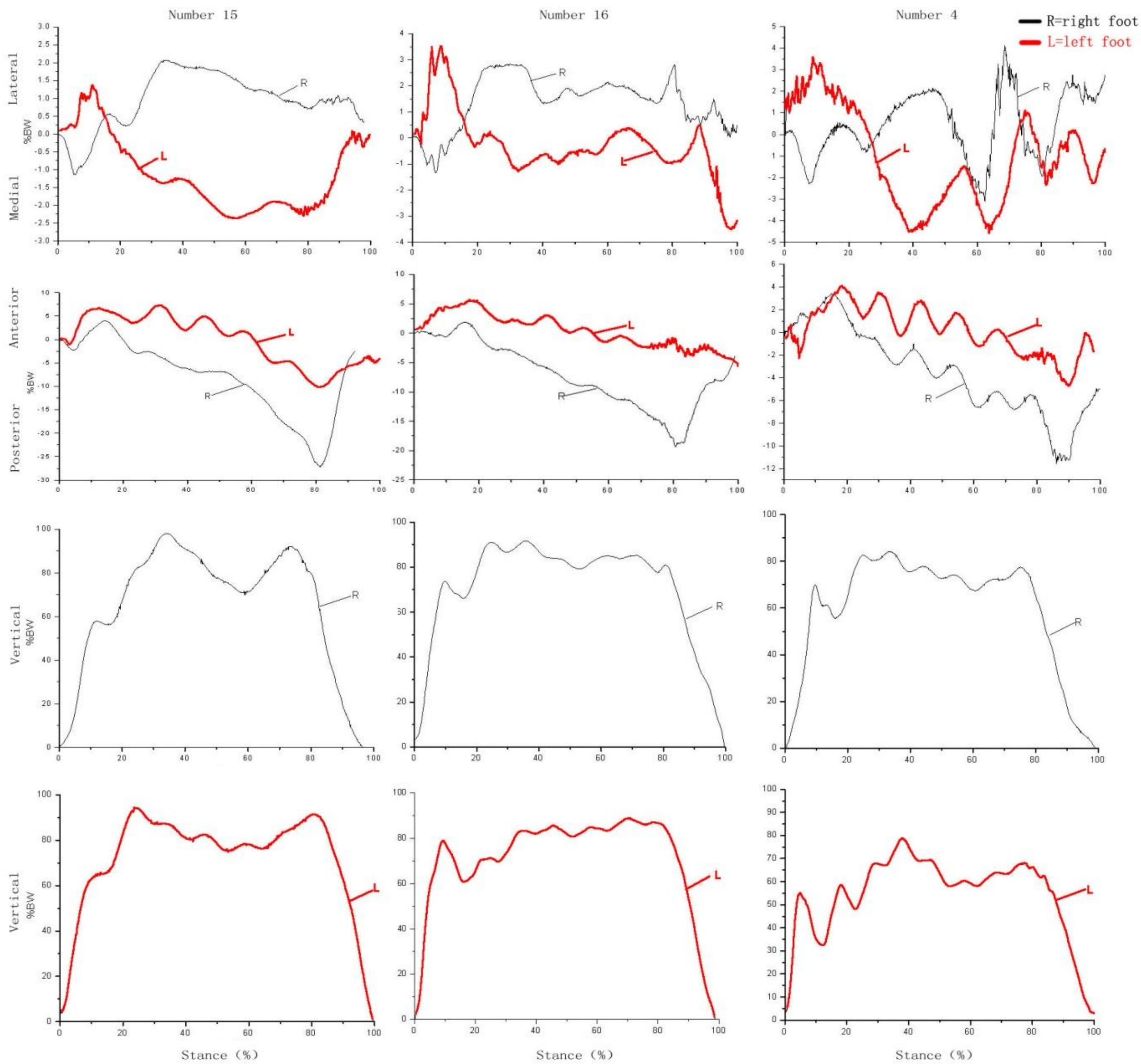


**Figure 1: GRF curves for all three activities. R=right foot, L=left foot, BW=body weight.**

Six GRF values were calculated and listed in table 3 which includes the maximums of the medial-lateral GRF ($F_X$) of the left and the right foot ($F_{X1}$ and $F_{X2}$,), the maximums of the anterior-posterior GRF ($F_Y$) of the right and the left foot ($F_{Y1}$ and $F_{Y2}$), and the maximums of the vertical GRF ($F_Z$) of the right and the left foot ($F_{Z1}$ and $F_{Z2}$).

**Table 3**
**The maximums of mean ground reaction forces（N/Kg %）**

| Number | Variable | | | | | |
|---|---|---|---|---|---|---|
| | $F_{X1}$ (%) | $F_{X2}$ (%) | $F_{Y1}$ (%) | $F_{Y2}$ (%) | $F_{Z1}$ (%) | $F_{Z2}$ (%) |
| 15 | -2.430 | 2.200 | -27.500 | 10.086 | 98.2 | 94.4 |
| 16 | -3.667 | 3.342 | -19.936 | 6.211 | 93.1 | 88.9 |
| 4 | -4.666 | 4.454 | -11.590 | 4.107 | 86.2 | 81.7 |

**DISCUSSION:** A comparison of the GRF curves for No.15, No. 16 and No.4 participants reveals several distinct differences. For the participants with a slow RT, the GRF curves under perturbations appeared to be more varied (figure 1). The maximums increased in the medial-lateral direction with the increasing of RT, which was opposite the anterior-posterior and the vertical directions (table 3). These differences suggest that the subject with faster RT had better control ability in the lateral direction and a better buffer capacity in the heading direction. And the participant with slower RT was more inclined to half dragging during walking.

Both internal and external factors can influence an individual's dynamic walking stability. External factor refers to the environmental conditions, such as falls resulting from reduced coefficient of friction (COF). Internal factor refers to one's body condition, such as anatomical features and physiology limits (e.g., muscular strength, rate of force et al.) of the body. In the present study, we had studied how internal factors (RT, MT) affected individuals' dynamic walking stability under external perturbations (decreased the COF between the shoe and floor). Through the correlation analysis, we know that a walker with a slower RT was more likely to fall when encountered external perturbations. What's more, the GRF data verified the result.

In this study, slippery surfaces were used to produce a postural perturbation to walking young adults. A similar perturbation might be experienced by a walker, a skier or a skater. When they encounter a sudden change of the environment, a series of autonomous responses will occur in their body: sensory organs detect the outside stimulation. And then the nervous system transfers the stimulating signals to the brain. After processing the signals, the brain transfers the processed signals to the effecter, and then acts on a certain object outside. Sensory organ needed time, the brain processing consumption time, nerve conduction time and muscle reacting time are included in this process. The total time is called RT. Because there are individual differences among people, RT can be different. When meeting the same external stimulation, the ability controlling the body to regain balance is not same.

**CONCLUSION:** In this study, we got the conclusion that the person who had faster RT had better dynamic walking stability. This information is very significant for evaluating an athlete's balance ability and for selecting athletes.

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