Temporal Parameters of Foot Roll-over during Walking Straight Ahead and Stepping over Obstacles in Postmenopausal Women

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1 OBJECTIVES

One-third of postmenopausal women experience a fall annually (Randell et al., 2001). Stepping over obstacles have been associated with a greater risk of falls and injury then straight ahead tasks (Zhang et al., 2011).

The path of locomotion usually is not perfectly level and clear, therefore the human locomotor system needs to be able to adapt to avoid obstacles safely and negotiate uneven terrain (Austin et al., 1999, Sparrow et al., 1996).

There is a lack of plantar pressure studies that evaluate the effect of stepping over obstacles during walking despite its frequent occurrence during daily activities, which also induce important modifications in foot behaviour. Therefore, the purpose of this study was to compare, the temporal characteristics of foot roll-over of the trailing limb between the following tasks: straight ahead task (SAT); and obstacle task (OT).

2 METHODS

2.1 Subjects

Thirty-one postmenopausal women (age, 58.2 ± 6.5 years; height, 156.3 ± 4.2 cm; weight, 70.8 ± 15.3 kg, and BMI, 28.9± 5.8 kg/m^2) participated in the study. A physician performed an evaluation of the medical history before the subjects were included in the study and informative written consent was obtained after fully disclosure of the nature of the study. The evaluation used the Bone Estrogen Strength Training (BEST) Study (Center for Physical Activity and Nutrition, 2004) and the Greene scale (Greene, 2008). Subjects with (1) diabetes and/or signs associated with neuropathy were excluded, as well as subjects with (2) acute foot pain and deformities, (3) severe lower extremity trauma, and (4) coordination problems that resulted of eye disorders.

2.2 Instrumentation/Procedures

Plantar pressure parameters were evaluated by the Footscan platform (1m×0.4 m, 8192 sensors, RSscan International, Olen, Belgium) at 250 Hz using the 2-step protocol (Bus and Lange, 2005). Each subject was instructed to perform barefoot two tasks: SAT and OT (30% height of leg length) as illustrated in Figure 1.

In the present study the right foot (trailing limb) was the dominant foot for all of the subjects, and was used as the supporting foot during the stepping over the obstacle.

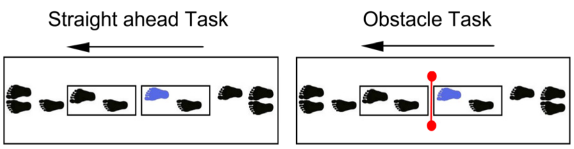

Figure 1: Performed Tasks. Straight ahead task (SAT) and obstacle task (OT).

Before measurements, the individuals practiced walking at a self-selected speed over the pressure platform for a period of ten minutes. Five valid trials (Bus and Lange, 2005), were collected. A trial was discarded if foot contact with the pressure platform was incomplete, if the participant targeted the platform, or if the coefficient of variation of the

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duration of contact was greater than 4%. This final criterion was employed to minimize the effect of walking speed on the data (Burnfiel et al., 2004, Warren et al., 2004).

The initial contact time (IC), final contact time (FC) and duration of contact (DC) was obtained for 10 anatomical pressure areas during foot roll-over. The areas considered were: medial and lateral heel (HM, HL), metatarsal areas (M1–M5), midfoot (MF), hallux (T1) and toes (T2–5).

Five instants of foot roll-over (Figure 2) were determined: (FFC-first foot contact, instant the foot made first contact with the pressure platform; FMC-first metatarsal contact, instant when one of the metatarsal heads contacted the pressure platform; FFF-forefoot flat, first instant when all the heads of the metatarsals made contact with the pressure platform; HO-heel off, instant the heel region lost contact with the pressure platform and; LFC-last foot contact, last contact of the foot on the platform). Based on these instants four phases were established (De Cock et al., 2005): initial contact phase (ICP; between FFC and FMC), forefoot contact phase (FFCP; between FMC and FFF), foot flat phase (FFP; between FFF and HO) and forefoot push off phase (FFPOP; between HO and LFC).

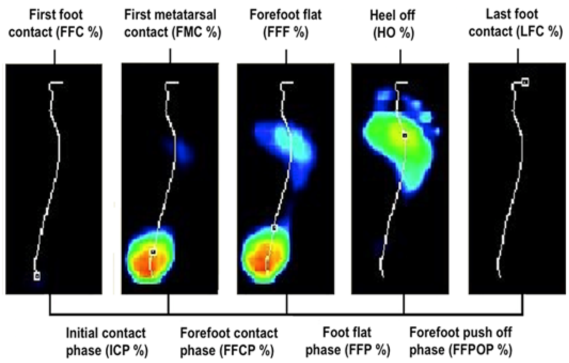

Figure 2: Instants and phases of foot roll-over.

3 RESULTS

The results were obtained and analysed between tasks (table 1).

Table 1: Relative initial, final and duration contact, and values of FMC, FFF, ICP and LFC between tasks.

Variables	SAT	OT
IC MF (%)^{U*}	7,8 ± 3,3	4,1 ± 2,1
IC M5 (%)^{U*}	20,2 ± 9,1	11,7 ± 9,4
IC M4 (%)^{U*}	15,4 ± 5,9	7,8 ± 4,1
IC M3 (%)^{T*}	15,5 ± 5,8	8,3 ± 3,5
IC M2 (%)^{T*}	20,2 ± 7,6	11,8 ± 5,8

Table 1: Relative initial, final and duration contact, and values of FMC, FFF, ICP and LFC between tasks. (cont.).

Variables	SAT	OT
IC M1 (%)^{T*}	32,2 ± 10,5	21,7 ± 10,5
IC T2-5 (%)^{U*}	60,3 ± 12,5	44,5 ± 14,7
IC T1 (%)^{T*}	50,3 ± 15,6	32,2 ± 15,4
FC M5 (%)^{U*}	86 ± 4,9	92,2 ± 6,4
FC M4 (%)^{U*}	93,2 ± 2,1	98,4 ± 1,6
FC M3 (%)^{U*}	95,5 ± 1,6	98,9 ± 1,1
FC M2 (%)^{U*}	95,7 ± 1,5	98,4 ± 1
FC M1 (%)^{U*}	94,1 ± 1,5	96,1 ± 1,7
FC T1 (%)^{T*}	99,9 ± 0,4	98,4 ± 1,7
DC M5 (%)^{U*}	65,9 ± 12,1	80,5 ± 10,2
DC M4 (%)^{T*}	77,8 ± 6,5	90,6 ± 3,9
DC M3 (%)^{U*}	79,9 ± 5,9	90,6 ± 3,6
DC M2 (%)^{U*}	75,5 ± 7,5	86,7 ± 6
DC M1 (%)^{U*}	61,8 ± 10,5	74,4 ± 10,9
DC T2-5 (%)^{U*}	37,8 ± 12,9	49,4 ± 15,6
DC T1 (%)^{T*}	49,4 ± 15,6	66,2 ± 15,2
FMC (%)^{T*}	13,7 ± 4,6	6,9 ± 2,9
FFF (%)^{U*}	33,7 ± 9,9	23,5 ± 11,1
ICP (%)^{T*}	13,7 ± 4,6	6,9 ± 2,9
LFC (ms)^{T*}	643 ± 60	853 ± 87

Data are mean ±SD. Independent T-Test $^{(T)}$, Man-Whitney U test $^{(U)}$. $^{*}P < 0.05$.

4 DISCUSSION

The purpose of this study was to compare, the temporal characteristics of foot roll-over of the trailing limb between the straight ahead task SAT and obstacle task OT.

Regarding the last foot contact, the results showed that the foot presented a longer duration during the OT. Such results are explained by the decreased speed (Austin et al., 1999, Begg et al., 1998, Sparrow et al., 1996) during stepping over obstacles and increased duration of the step (Begg et al., 1998, Sparrow et al., 1996).

A longer foot contact duration might be related to the need to generate and absorb greater forces associated with stepping over obstacles (Begg et al., 1998).

When comparing both tasks, the results indicated that the initial contact of the foot areas, with the exception of the heel areas, was made earlier during stepping over obstacles.

Begg et al. (1998), stated that during stepping over obstacles one of the roles of trailing limb is to arrest the body’s forward momentum. To undertake such task, there is an increase of the anterior–posterior maximum braking forces, that take place earlier during the stance phase (Begg et al., 1998).

The authors (Begg et al., 1998) also indicated that when stepping over obstacles, during the weight acceptance phase, the trailing limb presented an increased first vertical peak force which also take place earlier during the stance phase. Therefore, the earlier initial contact of several areas of the foot could be related to the deceleration of the body's forward momentum and the need to control the increased braking forces produced when stepping over obstacles.

The final contact of the foot areas M1-M5 was made later during the OT. Begg et al. (1998), found that during crossing obstacles, the trailing limb increased the second peak vertical forces and the timing in which it takes place was more lately on the stance phase. The authors consider that those results could be explained by one of the trailing limb roles, which is to generate sufficient vertical forces to ensure adequate vertical elevation of the center of mass, during the obstacle clearance by the leading limb. The results obtained in the present study may therefore indicate that the later final contact of the M1-M5 areas may occur due to its role during the stance phase on the OT.

A greater contact duration of the areas M1-M5, T2-5 and T1 were also found during OT. According to Chen and Lu (2006), Begg et al. (1998), a successful and safe obstacle crossing requires not only sufficient foot clearance of the swing leading limb but also the stability of the body provided mainly by the stance of trailing limb. The results of the present study seem to be in accordance with the previous statement, since several areas of the foot presented a longer contact duration during the stance phase, which could be a solution to the increased balance demands during obstacle crossing.

Concerning the instants and phases of plantar pressure of the trailing limb, the statistical outcomes indicate that on the OT, the FMC and FFF occurred significantly earlier and the duration of the ICP was significantly shorter. The reason for the earlier FMC and FFF and shorter ICP during the OT is related with the earlier initial contact time of the metatarsal areas previously explained.

The main findings were: the trailing limb presented a longer foot contact duration on the OT; during the OT the metatarsals areas showed an earlier initial contact, a later final contact and an increased duration contact, suggesting that these areas play a greater role in the initial break, the control of stability and on propulsion when compared with the straight-ahead walking.

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