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GROUND REACTION FORCES AND FRICTION DURING STROKE GAIT: THE FLOORING SURFACE EFFECT

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SUMMARY

The aim of this study is to investigate the effect of flooring surfaces in the ground reaction forces and foot/floor friction during stroke gait. The participant was oriented to walk, in its own preferred speed, over two force plates on the following surfaces: HOV, carpet and HTV. The results of this study showed no differences between the hemiparetic and the control group when de GRF and COF where compared. It was observed GRF and COF differences when the flooring types were compared, the flooring rigidity and the hemiparetic gait characteristics may be related to these results.

INTRODUCTION

Falls are common adverse event among stroke survivors [1]. Floor surfaces have an important influence on gait and affect walking stability [2]. Studies focusing specifically on coefficient of friction (COF) and the ground reaction forces (GRF) during the stroke gait over different flooring surfaces were not found, but, when the spatio-temporal variables were analyzed, Stephens and Goldie [3] noted that twenty four stroke patients walked slower on carpet than vinyl flooring.

So, the current study attempted to quantify the potential effects of surfaces on indoor walking in stroke patients. The aim of this study is to investigate the effect of flooring surfaces in the GRF and foot/floor friction during stroke gait. It was hypothesized that the GRF and the peak COF would show differences when the surfaces type are compared. And also, when this variables where compared between groups the stroke patients would differ those of healthy controls.

METHODS

The present study was approved by the Ethics Research Committee of the University of Campinas (UNICAMP; protocol No. 319/2011) and the volunteers gave written informed consent to participate.

The hemiparetic group (HG) consisted of 12 individuals affected by stroke (5 females and 7 males). The HG average characteristics were: age = 62.83 ± 6.86 years; body mass = 69.50 ± 13.96 kg; height = 1.68 ± 0.06 m; Fugl-Meyer = 89.6 ± 6.86; Berg Balance Scale = 50.3 ± 6.94. The control group (CG) consisted of 12 healthy adult (5 females and 7 males) and the average characteristics were: age = 63.58 ± 6.95 years; body mass = 73.08 ± 14.31 kg; height = 1.69 ± 0.05 m.

Data collection was performed in Laboratory of Instrumentation for Biomechanics in UNICAMP. The original laboratory flooring is a homogeneous vinyl (HOV - Type: Homogeneous single layered vinyl flooring; Description: Pavifloor prisma tile, 2mm thickness,2X23m, (ref 909, Charcoal); Manufacturer: Tarkett Fademac/Brazil; μe = 0,44), and even covers the upper side of the force platforms. To position the HOV on the platforms we used a high fixation double-sided tape (3M VHB flow pack white 12mmX5m 4950). It were developed two runways (2mx8m) of heterogeneous vinyl (HTV - Type: Compact flexible vinyl floorcovering; Description: Floor chinese teak/ natural, 2,50mm thickness, 2X25m (imagine Wood); Manufacturer: Tarkett Fademac/Brazil; μe = 0,52) and carpet (Type: Needlepunch carpet; Description: Needel punch carpet plain quality - 100% pet fiber, 2mm thickness, 2X70m (Flortex eco); Manufacturer: Inylbra/Brazil.; μe = 0,53), in which in its central part were cut to in the exact locations of each force platforms. To fix these surfaces (HTV and carpet) on the floor of the original lab was used 5 cm masking tape (3M - 48mm x 50m - General Purpose) and on the force platforms a double-sided tape (3M Dual-Face 19mm TNT 4880 x 30m - Junction/Fixation). The original laboratory flooring and the runways are shown in Figure 1.

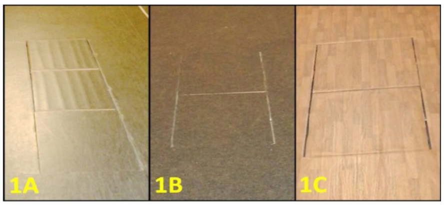

Figure 1. The lab surfaces: 1A: homogeneos vinyl (HOV); 1B: heterogeneos vinyl (HTV); 1C: carpet.

The participant was oriented to walk, in its own preferred speed, over two force plates on the following surfaces: HOV, carpet and HTV. There were performed three trials for each experimental condition. Two force plates (Kistler 9286BA) measured the ground reaction forces and the friction. The force plates were sampled at 62 Hz. Force plate data were normalized by body weight and percent of the support phase. The data acquisition was performed by the software BioWare. Matlab algorithms filtered the raw data and calculated the dependent variables. The kinetic raw data was filtered using a low-pass, 2nd order digital Butterworth filter, with a cut-off frequency of 10Hz.

The independent variables were: type of surface (HOV, HTV and carpet) and lower limb (control group and most and less affected limp for the hemiparetic group). The dependent variables were: (a) the vertical component of the GRF: first peak impact (Fz1), valley (Fz2), and the propulsion peak (Fz3); (b) the anteroposterior component of the GRF: negative phase (deceleration or braking - Fy1) and positive phase (acceleration - Fy2); (c) the component mediolateral of the GRF: maximum lateral force (Fx1), medial first force maximum (Fx2) and second medial maximum force (Fx3); (d) the dynamic friction (μd): friction maximum at initial contact (COF1) and toe off (COF2). The μd was is defined as the ratio between the mediolateral (horizontal) and vertical components of the GRF.

The data which showed normality (test Lillifors) was treated through two-way ANOVA for repeated measures, with type of surface (HOV, carpet and HTV) and lower limb (GC member most affected and least affected member) as factors, the post hoc test used was LSD. For non-normal distribution variables the differences among surfaces (HOV, carpet and HTV) were treated by Friedman test and differences between lower limbs separately for each type of surface were compared by Kruskal-Wallis H. For both tests, the Dunn-Sidak test was applied as post hoc test. The SPSS ® software (SPSS for Windows, version 10.0) performed the statistical analysis with a significant level of $p < 0.05$ for all tests.

RESULTS AND DISCUSSION

The CG right side versus CG left side (T-test) showed no significant differences between CG left- and right-limb movements in any variable ($P \leq 0.05$). Taking this into account we only used the CG's right gait cycle results for all comparisons between CG and HG.

The results showed no differences between the hemiparetic and the control groups when the GRF and COF were compared. Durá et al. [4] and Burnfield et al. [5] had found the same results. The lack of significant differences in COF between HG and CG found in both studies suggests that individuals with stroke are not at greater risk of slipping when walking at a self-selected pace on the selected surfaces than were healthy individuals.

On the other hand, the results of this study concerning the floor effect are consistent with the hypothesis that the GRF and the peak COF would show differences when the surfaces types were compared (see Table 1). The HOV showed higher impact peak (Fz1) during the heel contact when it was compared to the HTV and carpet. These results can be explained by the HOV features where it is more rigid compared to other surfaces. The HOV is made of reinforced polyurethane, while the HTV, even being made of the same material is more flexible because it is vinyl floored, and, the carpet is also more flexible by being made of pet fiber. Robbins et.al. [6] have tested the efficiency of rigid and compressible materials used for making soles and found that the higher the stiffness of the sole major is the impact peak of the heel with the ground. The forward motion foot after heel strike, on most dry surfaces, is quickly decelerated to almost a complete stop [7], which was observed in this study. However, during the transfer weight time (FZ2) the gait on the HOV took greater impact absorption force than the others surfaces. Unleashing a more cautious strategy of the hemiparetic patient which showed lower peak deceleration (FY1) during the initial contact, smaller mediolateral GRF during the load response phase (FX2 and FX3), and during the toe off greater strength acceleration (Fy2) on HOV compared to HTV and carpet. These results can perhaps be explained by gait speed, because according to Stephens and Goldie [3] stroke patients walked slower on carpeted floor surfaces than on vinyl flooring surfaces. These results may have influenced the COF2, where the HOV dynamic friction was observed higher than in other floorings. It is believed that the increased acceleration force may be involved with these results. Furthermore, the characteristics of hemiparetic gait, as smaller range of motion in the ankle joint [8] may be related to this result. Future studies involving kinematic and dynamic analysis of these patients walking on different flooring surfaces can bring knowledge about the results found in this study.

CONCLUSIONS

It was observed GRF and COF differences when the flooring types are compared. The flooring rigidity and the hemiparetic gait characteristics may be related to these results. As expected, when this variables where compared between groups the stroke patients require the same levels of GRF and COF than do normal walkers.

ACKNOWLEDGEMENTS

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Table 1. Means and standard deviations of the GRF and dynamic friction variables for each surface (HOV, carpet and HTV), ANOVA and Friedmann tests' value (test value) and significant level (p), and post hoc test results (post hoc).

VARIABLES	SURFACES			Test Value	P	Post hoc
	HOV	CARPET	HTV			
Fx1	-0.022±0.013	-0.024±0.013	-0.024±0.0312	$F_{2,66} = 0.889$	0.416	-
Fx2	0.041±0.002•°	0.066±0.003•	0.064±0.004°	$F_{2,66} = 21.719$	0.001	carpet, HTV>HOV
Fx3	0.043±0.002•°	0.067±0.004•	0.065±0.005°	$F_{2,66} = 17.436$	0.001	carpet, HTV>HOV
Fy1	-0.15±0.006•°	-0.11±0.008•	-0.106±0.008°	$F_{2,66} = 17.436$	0.001	HOV>carpet, HTV
Fy2	0.186±0.031•°	0.1258±0.061•	0.1144±0.062°	$xr^2=22.722$	0.001	HOV>carpet, HTV
Fz1	1.034±0.157°	1.03±0.07	1.004±0.073°	$xr^2=9.722$	0.008	HOV>HTV
Fz2	0.76±0.019•°	0.88±0.01•	0.872±0.01°	$F_{2,66}=28.329$	0.001	carpet, HTV>HOV
Fz3	1.034±0.064	1.015±0.064	1.002±0.051	$F_{2,66}=0.969$	0.385	-
COF1	-0.256±0.198	-0.281±0.214	-0.248±0.136	$xr^2=1.778$	0.411	-
COF2	0.330±0.043•°	0.2265±0.095•	0.2108±0.1085°	$xr^2=32.190$	0.001	HOV>carpet, HTV