ALTERATIONS IN GROUND REACTION FORCES DURING TETHERED WALKING

A. Finch, J. Santiago, and K. Sasaki

Indiana State University
Terre Haute, Indiana, USA

INTRODUCTION

This study compared the effects of tethering on ground reaction forces (GRF) while walking at 4 km/hr (2.5 mph) supported by the Conva-Lift prototype in a Kinney upper body vest at unweighting conditions of 0%, 25%, 50%, and 75% of their body weight (BWT) to normal walking.

METHODOLOGY

Six adult males walked 30 minutes at each randomly selected unweighting condition in a 3.7 m diameter circle. Ten right and left stride impacts were collected at 1000 Hz with an Ariel APAS system using a Kistler force plate during each condition at 4 km/hr (±7%). Normal walking consisted of walking straight while untethered and the walking velocities were verified by an infra-red timing system. Five right and left strides in which the velocity was closest to 4 km/hr were selected for analysis. The stride was delineated into the phases of heelstrike (HS), midfoot support (MFS), and toe-off (TO). The vertical GRF (Fz) at the 3 phases, the fore-aft GRF (Fy) at HS, TO, and contact time were calculated. A 3x5x2x5 ANOVA (PHASExWTxFTxSTRIDE) with repeated measures on all factors was used to analyze the vertical forces and a 2x5x2x5 ANOVA (PHASExWTxFTxSTRIDE) analyzed the fore-aft (Fy) forces at HS and TO and a 5x2x5 ANOVA (WTxFTxSTRIDE) was used to analyze the contact time.

RESULTS and DISCUSSION

The subject's mean height was 179.5 ± 57.4 cm., the mean body mass was 87.5 ± 11.8 kg., and the mean age was 21.3 ± 1.2 years. Table 1 provides a summary of the vertical GRF (Fz) and fore-aft GRF (Fy) at HS, MFS, and TO. A significant unweighting factor ($p \leq .05$) was found for the vertical and fore-aft forces at the HS, MFS, and TO phases. No significant differences in the Fz and Fy forces were found between the straight walking, and 0% traction Conva-Lift walking conditions.

Post-hoc analyses revealed significant reductions in the Fz forces observed at the 50% and 75% unweighting conditions for the HS and TO phases and 25%, 50% and 75% conditions for the MFS phase.

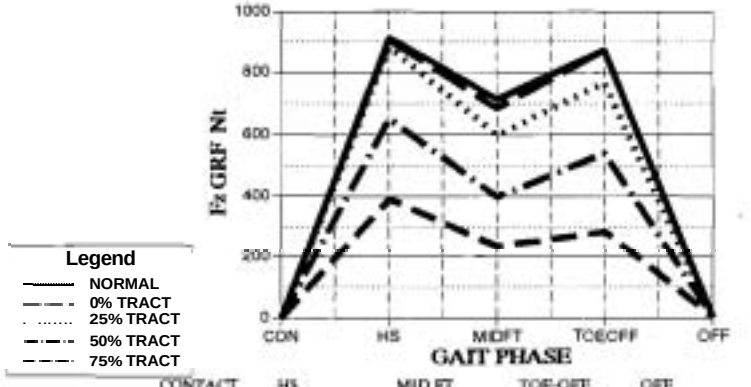
TABLE 1. GROUND REACTION FORCES WHILE WALKING UNDER TRACTION

Phases	Heel Strike Nt		Mid Ft Nt	Toe-off Nt		Contact Time Sec	
Norm Walk	Fz 911.7±142.6 117%BWT	Fy 124.7±38.4 16%BWT	Fz 712.9±84.9 92%BWT	Fz 869.8±129.4 112%BWT	Fy -165.8±42.9 -21%BWT	R .73±.04	L .72±.03
0% Tract	902.0±118.3 105%BWT NSIG	136.0±35.5 16%BWT NSIG	682.7±73.4 80%BWT NSIG	869.1±118.5 101%BWT NSIG	-119.8±68.1 14%BWT NSIG	.71±.03	.68±.03
25% Tract	881.4±128.1 103%BWT NSIG	135.5±31.7 16%BWT NSIG	595.7±73.3 69%BWT SIG	765.6±105.4 89%BWT NSIG	-146.1±55.8 -17%BWT NSIG	.71±.03	.69±.04
50% Tract	649.8±112.9 76%BWT SIG	87.3±39.0 10%BWT NSIG	395.9±49.8 46%BWT SIG	537.9±91.8 63%BWT SIG	-98.9±56.8 -12%BWT SIG	.70±.03	.67±.05
75% Tract	389.3± 76.8 45%BWT SIG	33.8+17.4 4%BWT SIG	234.3±28.7 27%BWT SIG	281.4±78.2 33%BWT SIG	-37.0±12.6 -4%BWT SIG	.70±.04	.69±.04

SIGNIFICANT DIFFERENCES ARE IN REFERENCE TO NORMAL WALK ($P \leq .05$)

The vertical GRF loadings at HS expressed as a percentage of BWT were 117% and 105% for the straight walking and Conva-Lift walking, respectively. These values were consistent with the magnitudes of 1.1 to 1.3 BWT reported by Cavanagh, Williams, and Clarke (1981). The consistent loading patterns observed would indicate that walking about a 3.66 m diameter circle was similar to straight walking.

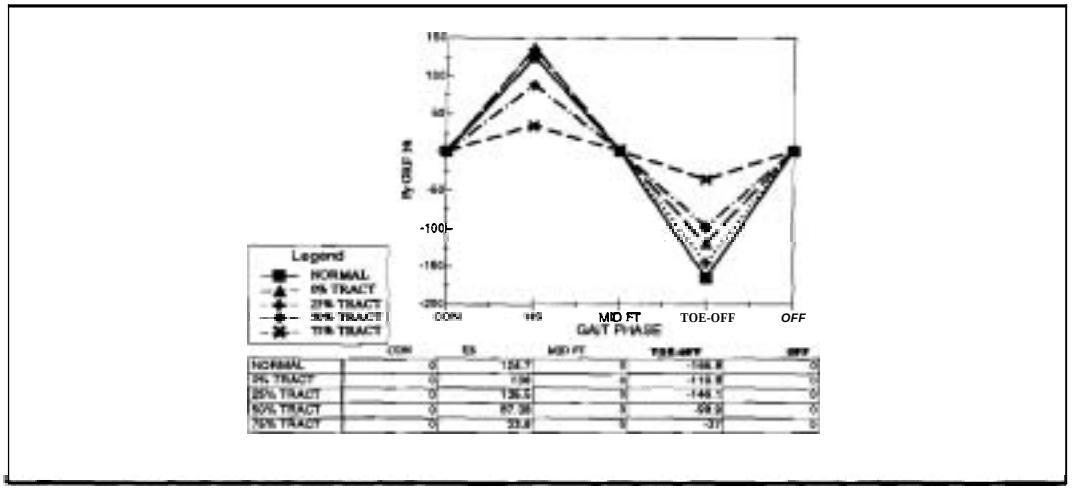
The midfoot Fz forces reflected a reduction or absorption of the initial HS impact GRF of 22% for walking, 24% for 0% unweighting, 32%, 39%, and 40% for the 25%, 50%, and 75% unweighting conditions. This alteration in the midfoot absorption would suggest that the "windlass" weight bearing mechanism of the arch of the foot functioned differently when unloaded.



	CONTACT	HS	MID FT	TOE-OFF	OFF	
NORMAL	0	911.7	712.9	869.8	0	
0% TRACT	0	902	682.7	863.1	0	
25% TRACT	0	691.4	595.7	765.6	0	
50% TRACT	0	649.8	395.9	537.9	0	
75% TRACT	0	389.3	234.3	281.4	0	

FIGURE I. VERTICAL GRF WHILE WALKING UNDER TRACTION

Significant differences in the fore-aft (Fy) forces were found for the 75% condition for the MFS phase and 50% and 75% unweighting at the toe-off. The fore-aft forces at HS representing the decelerative forces were 16%, 16%, 10% and 4% BWT for the respective unweighting conditions.



No significant differences in stride contact time were found to exist for the different unweighting conditions but the stride contact times significantly differed between .705 $\pm$ .03 sec. and .68 $\pm$ .04 sec. for the right and left strides, respectively. Significant time differences were attributable to the outside leg having to travel a greater distance in the same time as the inner leg, while walking in a circle. The Conva-Lift's travel direction is reversible to prevent any imbalances due to circular walking.

CONCLUSIONS

The percentage of reduction of the vertical GRF at HS, MFS, and TO were similar for the same degree of unweighting. The greatest percentage decreases in the fore-aft GRF occurred at toe-off. This reduction would suggest that this active traction/tethering prototype might be beneficial in the rehabilitation of posterior compartment injuries. The significant differences in the ground reaction forces in the vertical and fore-aft directions produced as the subjects walked while unweighted would indicate that the Conva-Lift is a viable means of providing regulated reductions in ground reaction forces while ambulating.

REFERENCES

Cavanagh, P.R., Williams, K.R. & Clarke, T.E. (1981). **A** comparison of ground reaction forces during walking barefoot and in shoes. IN: **A.** Morecki, K., Kedzior, & **A.** Wit (Eds.): Biomechanics VII (pp. 151-156). Baltimore: University Press.

Rodgers, M. (1985). Planter pressure distribution measurement during barefoot walking: Normal values and predictive equations. Unpublished doctoral dissertation, The Pennsylvania State University, University Park.