

# INFLUENCE OF WHEELCHAIR SUSPENSION ON SEAT FORCES AND HEAD ACCELERATIONS DURING CURB DESCENT LANDINGS

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## INTRODUCTION

For many persons with a spinal cord injury (SCI), a common method of mobility is a wheelchair. Shocks experienced during manual wheelchair use can decrease an individual's comfort, increase the rate of fatigue, result in injury, and consequently limit mobility and community participation<sup>1</sup>. The objective of this study was to determine the forces transmitted from the seat and accelerations experienced by wheelchair riders during independent curb descents on a rigid and 3 rear suspension type wheelchair frames. We hypothesized that rear suspension wheelchairs will significantly reduce the seat forces and head accelerations compared to non-suspension wheelchairs.

## METHODS AND PROCEDURES

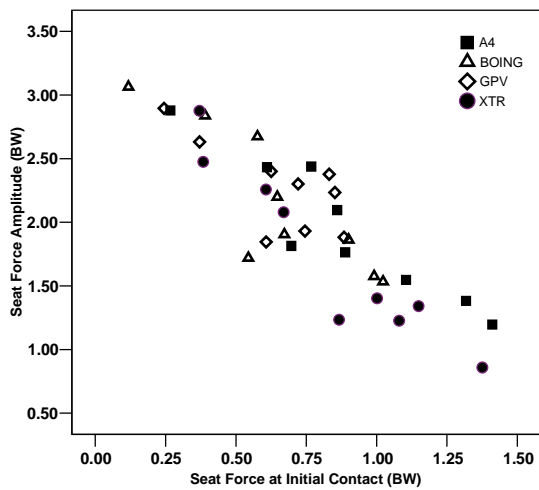
Eight men with paraplegia (T12; ASIA-A) performed an independently-controlled curb descent manoeuvres in four different wheelchairs: a rigid frame wheelchair (Quickie GPV) and three rear-wheel suspension wheelchairs (Invacare A4, Colours Boing, Quickie XTR). Subjects performed the curb descents from a 4 inch height, 5 times in each wheelchair. Load cells mounted on each seat frame measured the 3D seat

reaction forces and accelerometers attached to a helmet measured the subjects head accelerations<sup>2</sup>. Resultant seat forces at initial contact normalized to body weight (BW), change in resultant seat force from initial contact to peak force, rise time (initial contact to peak force); and peak vertical, forward (positive) and backward (negative) head accelerations were compared between wheelchairs.

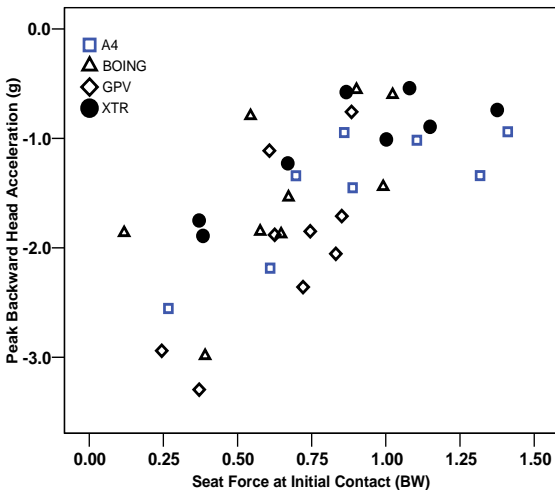
## RESULTS

Change in seat resultant force was lower in the suspension frames (XTR=1.51 ± 0.64 BW, A4=1.69 ± 0.48 BW, Boing= 1.87 ± 0.52 BW) compared to the rigid frame wheelchair (GPV=2.03 ± 0.35 BW). Rise time was shorter in the rigid frame (GPV = 59 ± 14 ms) compared to suspension frame wheelchairs (A4=68 ± 14ms, Boing = 90 ± 7 ms, XTR=103 ± 11 ms). Peak vertical head acceleration was lower in the suspension frames (XTR=1.33 ± 0.29 g, A4=1.51 ± 0.41g, Boing = 1.57 ± 0.37g) compared to the rigid frame wheelchair (GPV=1.69 ± 0.44g). Peak forward head acceleration was lower in the suspension frames (XTR=1.08 ± 0.51 g, Boing=1.46 ± 0.82g, A4= 1.47 ± 0.60g) compared to the rigid frame wheelchair (GPV=1.95 ± 0.80 g). Peak backward head

acceleration was reduced in the suspension frames (XTR=-0.23 ± 0.43g, Boing = -0.65 ± 0.51g, A4 = -0.96 ± 0.53g) compared to the rigid frame wheelchair (GPV=-1.10 ± 0.41g). Resultant seat force at initial contact was inversely related to change in seat force (Figure 1), peak vertical head acceleration, and peak backward head acceleration (Figure 2); indicating that wheelchair riders can reduce the reaction forces and head accelerations by increasing the seat reaction force prior to initial ground contact.



**Figure 1.** Change in seat force amplitude as a function of seat force at initial contact.



**Figure 2.** Peak backward head acceleration as a function of seat force at initial contact.

## DISCUSSION

Rear wheel suspension systems can reduce the forces transmitted from the wheelchair to the user by extending the peak force rise time. This resulted in decreased head acceleration for the wheelchair riders. Among the suspension frame wheelchairs, the Quickie XTR demonstrated the greatest attenuation of forces and reduction in head accelerations. However, wheelchair riders can also control the magnitude of the seat reaction forces and head accelerations during curb descent landings by controlling the velocity at contact as indicated by the magnitude of seat force.

## SUMMARY

Rear suspension is effective in absorbing shocks and vibration during wheelchair use. However, the suppression performance varies as a function of rear suspension configuration and landing strategies at contact.

## REFERENCES

1. Cooper RA, Boninger ML, Spaeth DM, et al. *IEEE Trans Neural Syst Rehabil Eng.* Dec 2006;14(4):438-455.
2. Kerdanyan G, Minkel J, et al. Measurement of Force and Acceleration Experienced in a Manual Wheelchair. Paper presented at: RESNA 28th Annual Conference, 2005; Atlanta, GA.

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