

MAXIMUM ALLOWABLE FORCE ON A SAFETY HARNESS CABLE TO DISCRIMINATE A SUCCESSFUL FROM A FAILED BALANCE RECOVERY

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INTRODUCTION

A safety harness system is essential in experiments at the threshold of balance recovery where avoiding a fall is not always possible. An unsuccessful balance recovery then occurs when the maximum allowable force on the safety harness cable is exceeded. This maximum allowable force cannot be too small, as a minimum load is always generated just by the displacement of the safety harness system when the participant takes one or more steps (Wojcik *et al.*, 1999). Similarly, it cannot be too large, as the safety harness system then assists the participant in balance recovery and may be the only reason a fall is avoided. Unfortunately, the maximum force used varies a great deal. Moreover, to our knowledge, no one has explained how this maximum force is determined. The purpose of this study was thus to propose a method to determine the maximum allowable force on a safety harness cable to discriminate a successful from a failed balance recovery.

METHODS AND PROCEDURES

Data from 12 healthy younger adults, who participated in experiments to determine the maximum forward lean angles that participants could be suddenly released from and still recover balance using three different limits on the number of steps, were used (Cyr and Smeesters, 2007; submitted 2008).

Starting at 15 deg, the initial lean angle was increased in 2.5 deg increments at each trial, until the participant failed to recover balance twice at a given initial lean angle and was thus no longer able to avoid a fall. For this study, balance recovery was considered definitely unsuccessful if the vertical force on the safety harness cable was more than 50 % of the participant's body weight (%BW).

For each participant, the coefficients of the following asymptotic regression, between the maximum vertical force on the safety harness cable and the initial lean angle at each trial below 50 %BW, were evaluated by a least squares method:

$$\theta_i = a(1 - e^{-F_{max}/b}) + c$$

F_{max} = max vertical force (%BW)

θ_i = initial lean angle (deg)

$a = \theta_i(F_{max} = \infty)$ with respect to c (deg)

b = force constant (%BW)

$c = \theta_i(F_{max} = 0)$ (deg)

RESULTS

The proposed asymptotic regression represented well the behaviour of the initial lean angle as a function of the maximum vertical force on the safety harness cable with $a = 15.7 \pm 7.8$ deg, $b = 4.6 \pm 4.9$ %BW, $c = 17.0 \pm 7.8$ deg and $0.5742 \leq r^2 \leq 0.8807$ (Figure 1).

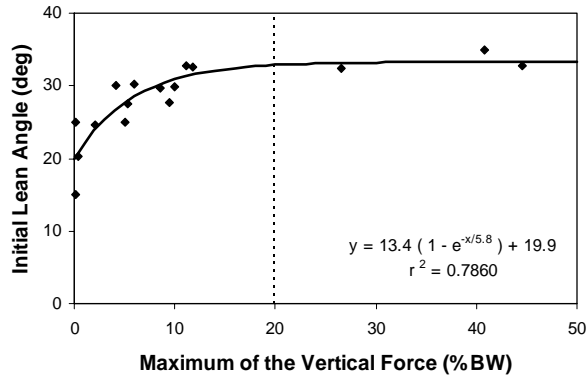


Figure 1. Asymptotic regression for a typical participant (full line) and the proposed 20 %BW threshold (dotted line).

It established that the initial lean angle reached 99 % of its steady state value a with respect to its initial value c when the maximum vertical force was five times the force constant b or 23.0 %BW. Rounding towards zero to avoid false positives, we thus proposed a 20 %BW threshold for the maximum allowable vertical force to discriminate a successful from a failed balance recovery for our experiments.

As the participants stepped forward, the anterior-posterior forces on the safety harness cable did increase (Figure 2). However, for trials at the maximum forward lean angle, the contributions of the medial-lateral (0 %) and anterior-posterior (2 %) forces were negligible relative to the vertical forces (98 %) at the maximum vertical forces.

DISCUSSION AND SUMMARY

The proposed asymptotic regression and threshold for the maximum allowable vertical force on a safety harness cable of five force constants discriminates well a successful (below the threshold) from a failed (above the threshold) balance recovery for experiments at the threshold of balance recovery.

Furthermore, although the amplitude of the horizontal forces should not be neglected in

safety harness system designs, their contribution can be neglected in experiments at the threshold of balance recovery.

Finally, although our five force constants method could be used on other safety harness systems, the actual value obtained for the maximum allowable vertical force probably varies between systems.

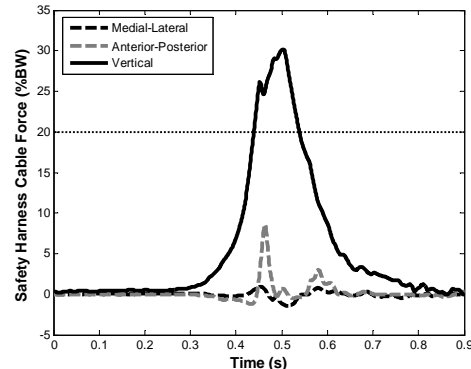


Figure 2. Horizontal (dashed lines) and vertical (full line) forces on the safety harness cable for a typical participant during the first trial to exceed the proposed 20 %BW threshold (dotted line).

REFERENCES

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