DOES LOAD MAGNITUDE ALTER CUMULATIVE LOAD TOLERANCE? "WEIGHTING" FOR AN ANSWER

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INTRODUCTION

Previous research examining cumulative compression exposure in the low back has employed a linear summation of force-time magnitudes to obtain estimates of total exposure. More recently, force magnitudes have been weighted (square or tetra power) based on the idea that higher load magnitudes have a greater impact on the development of injury than do lower magnitudes [1,2]. Although researchers have indicated a need to adjust higher loading magnitudes for their role in cumulative injury development, the relationship between load magnitude and cumulative load tolerance has not been quantified. This study was performed to quantify this relationship and provide useable weighting factors to be employed when quantifying cumulative load exposure.

METHODS

40 porcine cervical spinal units were each randomly assigned to one of four loading groups, corresponding to 40, 50, 70, or 90% of the estimated compressive strength of the unit. The compressive tolerance of each spinal unit was estimated using a previously developed equation based on average endplate area [3]. Each spinal unit was mounted inside aluminum cups using non-exothermic dental plaster, mounted in a materials testing machine (8872, Instron Canada, Toronto, ON, Canada) and preloaded with 300N for 15 minutes. The inferior vertebral mounting of the spinal unit was placed on a bearing table to allow unconstrained translations in two directions and rotation about one axis. After preloading, specimens were cyclically compressed with a physiological loading profile at 0.5 Hz until failure occurred or a maximum of 21,600 cycles was reached. Failure was characterized by a distinct drop in stiffness and increase in displacement (figure 1). The relationship between load magnitude and cumulative load tolerance was mathematically characterized and used to generate weighting factors to adjust all loading magnitudes (1-100%) for their contribution to injury development.

RESULTS AND DISCUSSION

The average cumulative load tolerated in each group is provided in table 1. It was found that load magnitudes below 70% did not always induce failure prior to the cycle limit, as indicated in table 1. The measured relationship indicated that load magnitudes below 37.5% resulted in a minimal risk of injury and were therefore assigned a weighting factor of 1. Above this threshold value, equation 1 can be used to determine the necessary weighting factor. The square and tetra power approaches previously employed [1,2] are not supported by the current findings.

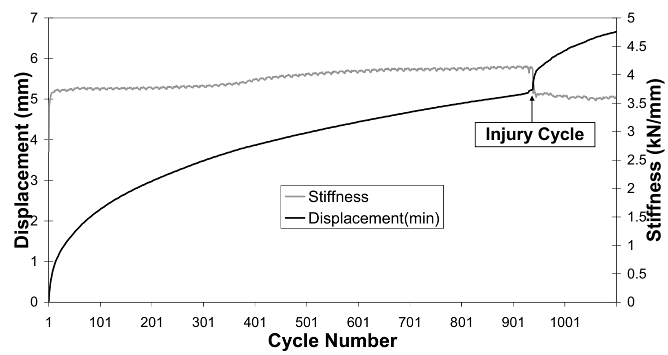

Figure 1: Displacement (mm) and stiffness (kN/mm) versus cycle number obtained from a specimen cycled to a peak load of 50% of the estimated compressive tolerance. Only the peak cycle displacement is plotted for clarity. Plots are overlaid to highlight the simultaneous decrease in stiffness and increase in displacement occurring at failure. The failure cycle is indicated.

REFERENCES

1. Seidler A, et al. *Occup Environ Med* **58**, 735-746, 2001.
2. Jager, M, et al. *Int J Ind Ergon* **25**, 553-571, 2000.
3. Parkinson, RJ et al. *Spine*, Submitted.

Table 1: Average cumulative load tolerance (standard deviation) and number of surviving specimens for each loading group.

Loading Group	Number of Surviving Specimens	Cumulative Load (MN*s)
40%	8	83.2(1.3)
50%	4	3.5(2.1)
70%	0	0.9(1.9)
90%	0	0.1(0.2)

Equation 1:

$$\begin{aligned} \textit{Weighting Factor} &= 5.4617470 \times 10^{-8} \times (\textit{loading magnitude})^5 - 1.3802063803 \times 10^{-5} \times (\textit{loading magnitude})^4 \\ &+ 1.4601005081\ 73 \times 10^{-3} \times (\textit{loading magnitude})^3 - 7.8813626392\ 557 \times 10^{-2} \times (\textit{loading magnitude})^2 \\ &+ 2.1412519178\ 06310 \times (\textit{loading magnitude}) - 22.2341862486\ 371 \end{aligned}$$