

INDEPENDENT ANALYSIS OF LOAD MAGNITUDE AND LOADING RATE: VARIABLES IN OSTEOGENESIS

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INTRODUCTION

Quantifying the force magnitude and rate of force application is central to defining a dose response of bone to mechanical loading via exercise. We have shown that drop landings from 24" increase hip bone mass in young children and concluded that both high magnitude loads and fast loading rates contributed to this outcome (Fuchs et. al, 2001). However, we do not know the independent effect of each variable on the bone response, and thus cannot determine their relative importance. In animal models, researchers have studied the independent effects of strain magnitude and strain rate on bone. However, no attempt has been made to evaluate the independent contributions of the analogous variables, load magnitude and loading rate, to a bone response in humans. Load magnitude and loading rate measured at the ground can be considered the noninvasive analogous variables for strain magnitude and strain rate used in animal models. In a recent study we have shown that up to 81% of the ground reaction force from drop landing is transmitted to the hip (Bauer et. al, 2001 in press).

Load magnitude and loading rate can be easily quantified by analyzing ground reaction force (GRF) traces. To study the independent effects of load magnitude and loading rate on osteogenesis in humans, each variable would have to be held constant while manipulating the other. We expect that varying drop height should result in different maximum load magnitude while

holding loading rate constant. In addition, changing landing style should result in different loading rates between heights while providing similar maximum load magnitude. In this pilot study our aim was to determine whether we could separate load magnitude and loading rate in drop landings by varying drop height and landing kinematics.

METHODS

Seven prepubescent children (males=4, females=3, age 6.4 ± 1.0 years) dropped off 12" and 24" boxes onto a force plate (1000 Hz, filtered at 125 Hz using 2nd order two pass Butterworth filter). Each subject dropped 5 times from each box height for each of three landing styles: normal/no instruction (norm), internal knee angle > 90 degrees (hard), internal knee angle < 90 degrees (soft). To insure that each subject would achieve a knee angle < 90 degrees upon landing he/she was asked to squat down with an internal knee angle < 90 degrees. While in the squat position a small light placed on a tripod was positioned at the level of the head of the subject. Each subject was asked to land so that the light was at eye level. Similarly, for the hard condition the light was positioned at eye level when standing upright. Each subject was asked to keep his/her eyes above the light. The order of landing styles and height was chosen randomly for each subject before testing.

Load magnitude was defined as the maximum GRF in each trial. Loading rate

was calculated by differentiating the filtered force data. The maximum value of the time derivative of the force trace was treated as the maximum loading rate for each trial. Maximum loading rate always occurred in the positive slope of one of the two impact peaks (Figure 1).

ANOVA was used to compare means for each subject across all conditions. LSD was used post-hoc to determine where the differences in the data occurred. SPSS 9.0 was used to calculate all statistics.

RESULTS AND DISCUSSION

There were several conditions where load magnitude was different while loading rate was the same (Table 1). Load magnitude for 24norm and 24hard was greater than all 12” conditions ($p < 0.05$). In addition, 24soft was greater than 12soft ($p < 0.05$), while magnitude for all 12” heights was similar. By contrast, we observed few differences in loading rate between landing conditions. For loading rate, the only significant difference was that 24norm and 24hard were greater than 12soft ($p < 0.05$). We expected differences in loading rate between the hard and soft landing conditions. However, the small number of subjects limited our statistical power and high standard deviations reduced our ability to observe

Table 1. Average. maximum force and loading rate for drop landings from a 12” box landing hard, normal and soft and from a 24” box landing hard normal and soft. (mean \pm standard deviation, $n=7$ subjects for each condition).

Variables	12norm	12hard	12soft	24norm	24hard	24soft
Force (BW)	6.3 \pm 2.3	6.1 \pm 1.5	5.4 \pm 1.7	9.0 \pm 2.5	9.3 \pm 2.5	7.5 \pm 2.3
Rate (BW/s)	324 \pm 204	263 \pm 123	192 \pm 86	410 \pm 208	429 \pm 224	342 \pm 155

significant differences between landing conditions.

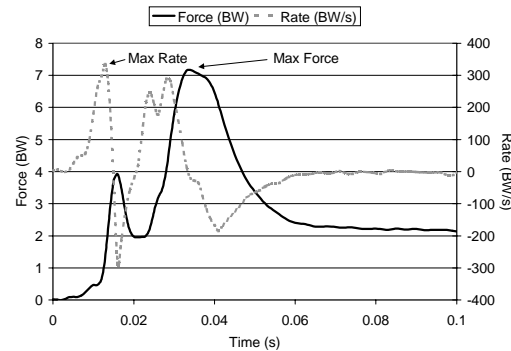


Figure 1. Plot of force and rate (24norm).

SUMMARY

In this small sample of children, we have shown that we can independently study load magnitude but not loading rate. If we can learn to separate loading rate in future studies, then it would be possible to study the independent osteogenic effect of these variables in humans.

REFERENCES

- Bauer, J.J., Fuchs, R.K., Smith, G.A., Snow, C.M. (2001 in press). *J. Appl. Biomech.*
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