Advances in Industrial Ergonomics and Safety III
Edited by W. Karwowski and J.W. Yates
Taylor & Francis, 1991

INVESTIGATION OF FORCES AT THE LOW BACK MODELED WITH INPUT OF MEASURED HAND FORCES DURING THE PULL PHASE OF A LIFTING TASK

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Peak measured hand forces were compared to peak modeled hand forces calculated with a dynamic biomechanical model for normal and fast floor to knuckle lifting. Peak measured hand forces were found to be statistically greater than the modeled hand forces. Calculation of L5/S1 compression and shear forces with measured hand forces as input significantly increased the peak values of the L5/S1 forces for fast speeds of lift.

INTRODUCTION

This paper summarizes a portion of recent research regarding calculated compressive forces at the low back for floor to knuckle height lifting. For this research, hand forces applied to the load were measured and used as additional input to the dynamic biomechanical model called Dynalift, developed by Ayoub, Chen and Coss (1986). The Dynalift model is based on the dynamic model developed by Ayoub and El-Bassoussi (1976).

NIOSH (1981, p. 40) states that "dynamic forces imparted by rapid or jerking motions can multiply a load's effect greatly," and recommends that loads be handled in a smooth and deliberate manner to avoid increasing dynamic forces. NIOSH (1981, p. 36) also states that "jobs which place more than 650 kg (6.4 kN) compressive force on the low-back are hazardous to all but the healthiest of workers," based on studies by Evans and Lissner (1959) and Sonoda (1962). And a lower limit, suggested to be 350 kg (3.4 kN), should be used for design purposes.

A recent study by Danz (1991) measured hand forces for a floor to knuckle lift and used these forces as input to the Dynalift dynamic biomechanical model to calculate compression and shear forces at the low back (L5/S1 joint). Analysis of the data indicated that measured peak hand forces were significantly greater than the modeled values. In addition, the plotted measured hand forces over time consistently exhibited peaks in magnitude which were not predicted by the biomechanical model. These peaks in hand force magnitude occurred within .067 sec of load liftoff. This paper reports the effects of these findings regarding measured hand forces on the calculated compression and shear forces at L5/S1.

METHOD

Two experiments were designed to investigate the effects of speed of lift (normal and fast), frequency of lift (1, 4 and 8 lpm), load in terms of percent maximum acceptable weight of lift (35, 60 and 85%MAWL) and weight (6.25, 10.91, 15.45, 20.00 and 24.77 kg) on the measured peak

applied hand forces to the load. Five male college students participated in the two experiments.

The horizontal and vertical forces applied to the load by the hands were measured with a strain gage apparatus mounted to the load. The strain gages mounted to the handle of the load are shown in Figure 1. The apparatus, which simulated a box-type container with dimensions 45.72 x 30.48 x 30.48 cm, was an aluminum frame which could be loaded from 5.68 kg (empty) to 49.0 kg (maximum load).

The strain gage A/D data was synchronized with the two-dimensional joint coordinate data obtained with a video camera system. With the kinematic, anthropometric and load data, hand forces and forces at L5/S1 were calculated using the Dynalift dynamic biomechanical model. The modeled peak applied hand forces were statistically compared to the measured peak hand forces for each lifting condition. The measured hand forces over time were then used as input into the Dynalift model and new estimates of the compression and shear forces at L5/S1 were calculated to account for the hand forces that were measured in the experiments. The method for comparison of measured and modeled forces at L5/S1 is summarized in Figure 2.

SUBJECTS

Mean age of the five male subjects was 23.2±2.77 years. Mean height and weight were 179.24±1.73 cm and 89.86±11.40 kg. Mean MAWLs at 1, 4 and 8 lpm were 35.69±8.88, 27.52±5.48, and 17.80±2.10 kg.

RESULTS

The peak applied hand forces did not carry through to significantly affect L5/S1 compression and shear for each of the lifting conditions investigated in this study, but for many trials the introduction of the measured hand forces into the model caused a corresponding peak in L5/S1 compression and shear forces. Examples of peaks in compression force at L5/S1 plotted in comparison to modeled values are shown in Figure 3, for normal speed of lift, and in Figure 4, for fast speed.

Peak force values at L5/S1 comparing modeled with measured hand forces with modeled without hand forces are shown in Table 1 for compression, and in Table 2 for shear. As shown in Table 2, shear forces are below the maximum tolerance limit of 1.735 kN as defined by Farfan (1970).

However, several lifting conditions resulted in peak magnitudes of L5/S1 compression as shown in Table 2. The values which exceed the 637 kg (6.24 kN) maximum tolerance limit of the spine as reported by Jager and Luttman (1989) are shown by asterisks. (Note that most of these also exceed the 650 kg maximum limit specified by NIOSH (1981)). As shown in Table 2, lifting only 35%MAWL at fast speed resulted in dangerous compression forces with respect to the tolerance limit of the spine.

Table 1. Comparison of Average Peak L5/S1 Shear Forces (N) During the Pull Stage of the Lift for Condition 1: Modeled, and Condition 2: Measured Input into Model, by Speed (Normal and Fast), Frequency (1, 4, and 8 lpm) and %MAWL (35, 60 and 85%).

		Normal Speed		Fast Speed	
		Modeled	With Measured	Modeled	With Measured
F	%				
1	35	534±152	567±154	639±215	731±271
	60	694±99	808±200	816±129	964±144
	85	697±198	734±181	775±261	968±384
4	35	509±145	526±141	631±211	708±234
	60	641±113	662±117	791±128	939±158
	85	645±199	687±227	832±168	1003±217
8	35	493±118	532±126	577±186	648±226
	60	616±113	678±156	668±165	766±175
	85	652±119	722±138	713±196	823±251

Table 2. Comparison of Average Peak L5/S1 Compression Forces (N) During the Pull Stage of the Lift for Condition 1: Modeled, and Condition 2: Measured Input into Model, by Speed (Normal and Fast), Frequency (1, 4, and 8 lpm) and %MAWL (35, 60 and 85%).

		Normal Speed		Fast Speed	
		Modeled	With Measured	Modeled	With Measured
F	%				
	35	5611±768	5648±785	6538±1340	7117±1566
1	60	6836±1017	7136±1628	7876±629	8463±703
	85	6831±1254	6642±1127	7668±1645	8543±2054
	35	5210±821	5184±725	6674±1058	6986±1222
4	60	6421±997	6401±1097	7651±807	8366±1007
	85	6499±1063	6434±962	7813±940	8295±1081
	35	5328±711	5428±737	6093±1119	6334±1217
8	60	6238±1198	6421±1412	6988±843	7470±986
	85	6625±874	6801±1057	7243±913	7647±990

SUMMARY

1. Peaks in hand forces were measured for floor to knuckle lifting which were not indicated by the biomechanical model, and were significantly greater in magnitude than the modeled values.
2. The peaks in hand forces resulted in corresponding increases in shear and compression forces at L5/S1.
3. The increase in peak magnitude of compression and shear due to modeling with input of measured hand forces was significant for fast speeds of lift.

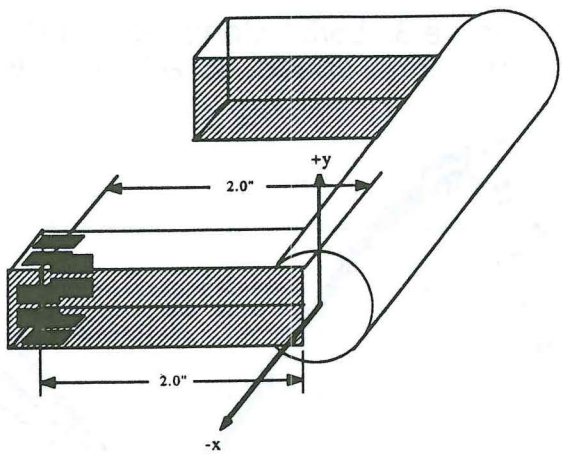


Figure 1. Location of strain gages on handle, and orientation of gages for each of the two channels.

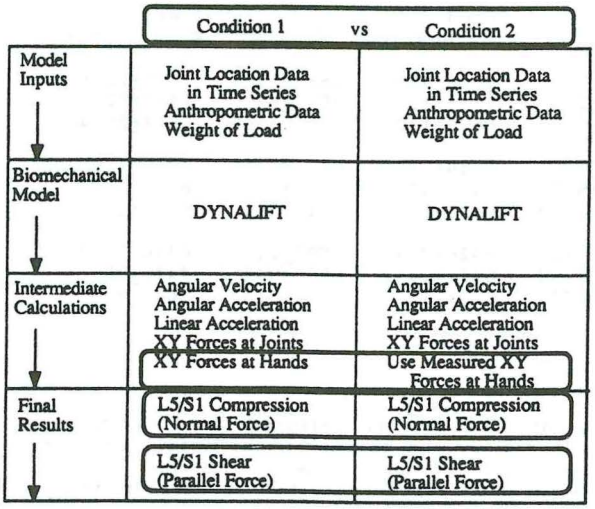
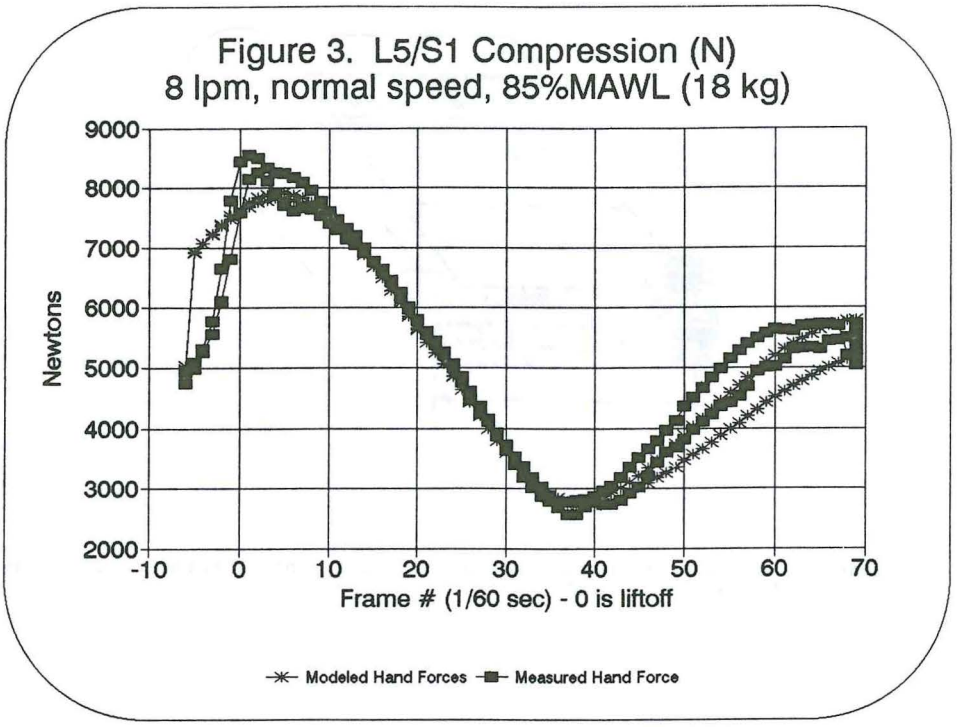
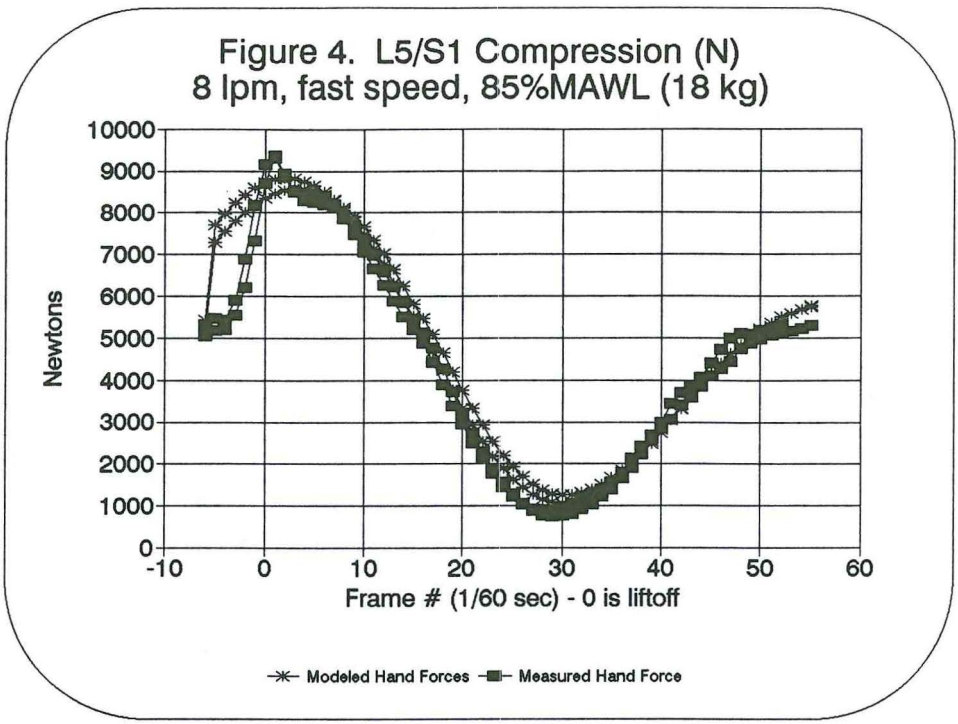


Figure 2. Illustration of approach using the Dynalift model under two conditions: Calculated forces at the hands and measured forces at the hands.





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ADVANCES IN INDUSTRIAL ERGONOMICS AND SAFETY III

Proceedings of the Annual International
Industrial Ergonomics and Safety Conference
held in Lake Tahoe, Nevada, 10-14 June 1991

The Official Conference of the International Foundation
for Industrial Ergonomics and Safety Research

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Taylor & Francis
London · New York · Philadelphia

UK **Taylor & Francis Ltd, 4 John St., London WC1N 2ET**

USA **Taylor & Francis Inc., 1900 Frost Road, Suite 101, Bristol, PA 19007**

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library.

ISBN 074840 006 0

Library of Congress Cataloging-in-Publication Data is available

Printed in Great Britain by Burgess Science Press, Basingstoke.