The Effects of Speed of Lift on Static and Inertial Moments

IE 5332: Biomechanics II

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1.0 Introduction

Biomechanical models are used to predict the physical stresses imposed on the musculoskeletal system. In general, two types of models, static models and dynamic models, have been used to predict the stresses which occur while the body performs a lifting action. Static models predict the stresses due to gravity while ignoring the inertial effects due to the accelerations of the load and body, while dynamic models consider both types of effects. Since lifting is a dynamic activity, there is concern that static models underestimate the stresses on the body. The studies described in the following section have postulated and verified that static models, by ignoring inertial factors, substantially underestimate stresses. Most studies investigating lifting actions analyzed moments and forces on the spine, particularly at the L5/S1 disc, as the dependent variables of interest. According to NIOSH, the disc between the L5 and S1 vertebrae has the potential to incur the greatest moment in lifting and is one of the most vulnerable tissues to force-induced injuries (Waters, 1993). When examining the difference between static and dynamic predictions, the peak compressive force estimated by each model were typically compared. This peak stress usually occurs early in the lift, shortly after lift-off (De Looze et al., 1993), on average in the first 240 msec (Garg et al., 1982) or about one-fifth of the way though the lift (Hall, 1985)..

1.1 Static vs Dynamic Models

Leskinen et al., (1983a, b) compared the peak spinal compression predicted by static and dynamic models using identical lifts for both models, i.e., inertial forces and moments were ignored by setting accelerations to zero in the static case. The subjects lifted a 15 kg box to knuckle height using four lifting techniques: leg lift, back lift, trunk kinetic lift and load kinetic lift. Depending on the particular lifting style in use, the predicted peak forces on the lumbar spine were on average 33 to 60% higher when inertial forces were considered in dynamic models as compared to static models. Leskinen et al., also compared static to dynamic compression x time integrals during the accelerative phase of the lift, i.e., when the load was upwardly accelerating, as an indication of the total stress of the lift. Depending on the particular lifting technique in use, this integral was found to be 28 to 36 % larger in the dynamic case as compared to the static case. Leskinen et al., limited their study to lifts completed at normal speeds of less than 2.5 s duration.

McGill and Norman (1985) reported that peak moments at the L4/L5 level were 19 % higher on average when calculated using a dynamic model as compared to a static model. Maximum differences as large as 52 % were observed in an 18 kg lift performed at an extended reach. Average static moments were 232 Nm while average moments from a dynamic model were 276 Nm. The authors reported that spinal compression values predicted by the static model were below the NIOSH maximum permissible limit; whereas those predicted by the dynamic model were above this limit. Thus inertial factors may be appreciable in certain tasks.

Garg et al., (1982) investigated the joint moments and forces predicted from both static and dynamic biomechanical models. Subjects lifted psyschophysically determined maximum acceptable weights of lift (MAWL) using four different box size/handle conditions. The static model was found to grossly underestimate the stresses on the musculoskeletal joints. Ratios comparing peak moments predicted by the dynamic model to the static model were in the range 2.1 to 3.03 at the L5/S1, hip and knee joints, thus moments predicted by the dynamic model were 2 to 3 times larger than static moments depending on the box size/handle condition. Like McGill and Normal (1985), compression values predicted with the static model were below the NIOSH action limit while those predicted by the dynamic model exceeded the maximum permissible limit. The effects of acceleration and moment are not negligible.

1.2 Speed of Lift

In the research described above which compared static to dynamic model predictions, the lifting activities were typically performed at "normal" speeds, the speeds at which the subjects were most comfortable lifting. No attempts were made to relate the size of the inertial component to the speed of the lift. The following describes studies in which the effects of the speed of lift were examined.

Hafez and Ayoub (a) examined the effects of speed of lift on the stresses at the joints. Subjects lifted 18.15 and 27.22 kg loads on an isoinertial lifting apparatus from floor to overhead reach height . This sliding apparatus was used to decrease the variability of lifting motions due to different load motion paths. The dependent variable of interest was a cumulative measure of stress, i.e. the sum over the lifting time of the absolute values of the reactive moments across the five joints, both static and inertial (dynamic). Subjects were instructed to lift the load at various speeds from slow to fast based on their own perceptions of speed. Hafez and Ayoub reported that when lifting at slow speed, the resulting inertial moment component was practically negligible. However, at faster speeds the inertial component approached and at time exceeded the value of the static component. The speeds of lift in this study averaged 1.07 m/s and ranged between a minimum of 0.26 to a maximum of 2.62 m/s.

Using a dynamic model, Bush-Joseph et al., (1988) investigated the effects of speed of lift and lifting technique on the flexion-extension moments at the L5/S1 level of the spine. Three subject-selected speeds (slow, normal and fast) and three lifting techniques (back, leg and freestyle lifts) were performed with a constant load of 150 N to a lift height of 1 m. Bush-Joseph et al., found that the peak moments on the spine normalized for body height and weight increased linearly with the peak speed of lift. In both the back and leg lifts the effect of peak speed was statistically significant, and although a similar trend occurred in freestyle lifts the effect was non-significant. Interestingly, Bush-Joseph et al., reported that at slow speeds the back and leg lifts produced significantly smaller moments than the freestyle lifts, but at faster speeds there was little difference in the moments produced by the three techniques

Hall (1985) also investigated the effects of attempted speed of lift, as well as weight of lift, on several variables including the peak and average values of compressive force, shear force and moments at the L5/S1 region. Subjects performed "clean and jerk" lifts in which a weight bar was lifted from the floor to a full overhead reach position. The speed of lift was manipulated by having subjects attempt to time their lift to imitate the duration of a tone lasting 1.5, 3.5 and 7 s. The three times represented the time of a normal lift, and lifts that were clearly slower and faster than normal. The three weights were 40, 60 and 80 % of each subject's maximum lifting capacity in the clean and jerk task. This capacity was in the range of 503 to 774 N. Hall reported that both main effects, speed and weight of lift, were significant to mean compressive and shear forces, but only speed of lift affected the mean moment at the L5/S1 region. The interaction speed*weight was non-significant in all cases. Hall further found that the faster lifts (target 1.5 s) had significantly larger mean moments than the normal and slow lifts, while the normal and slow lifts did not differ. Hall concluded that when the lifting speed is relatively fast, dramatic increases occur in the compressive and shear forces and moments of the lumbar region.

1.3 Weight of Load

Schipplein, et al., (1990) investigated the influence of the weight of the load from 50 to 250 N in 50 N increments on the lifting techniques selected to perform a floor to knuckle height lift. Subjects used a freestyle technique, i.e., the technique which they considered most comfortable, and all lifts were completed at a normal speed. The average peak vertical velocity of the hand was 1.16 m/s. Unlike Hall (1985) who did not find a significant effect on the L5/S1 moment due to weight , Schipplein et al., found a significant linear increase in the peak L5/S1 moment as the weight of load increased. The peak moment increased from 225 to 344 Nm when the load increased from 50 to 250 N. Similarly, the peak hip moment significantly increased with an increased weight of load, whereas the peak knee moment significantly decreased. The angular impulse, the integrals of the moment curves, for the L5/S1 and the hip were found to increase linearly with increasing weight of lift. It was suggested that these findings were a result of a change in lifting technique: subjects used more of their back strength to lift heavier weights.

1.4 Objectives

The primary objective of this study was to determine the effect of lifting speed on static, inertial and total absolute moments. The secondary aim was to examine whether the effects were similar at different weights of load. As discussed above, the majority of biomechanical lifting studies focused on effects on the spine, particularly the L5/S1 level. However, lifting is a complex task requiring the use of the whole body, thus the variables under investigation in this study (static, inertial and total absolute moments) will be summed across all joints. These values may act as an indication of the cumulative stresses exerted on the entire body when performing a lifting action. As stated by Hafez and Ayoub (b), the reason for using the absolute values is that whether positive or negative, a joint reaction moment results in mechanical work which represents a form of loading on the musculoskeletal system.

2.0 Methods

2.1 Subjects

Five healthy male subjects were recruited from the student population of Texas Tech University. The subjects were told the purpose of the experiment and signed consent forms prior to experimentation. They received $5.00 per hour of participation. The height and weight characteristics of the subjects appear in Table 1.

2.2 Equipment

Each subject was asked to lift a container from the floor to a shelf set at a standard height of 32 in. (0.8128 m), a floor to knuckle height lift. Upon completing the lift, the shelf automatically lowered the load and the subjects slid the container off the shelf to its initial position on the floor. The container was a 12x12x12 in^3 box with handles. The box was loaded with lead weights. The lifts were performed using a freestyle lifting technique.

Reflective markers were placed on the wrist, elbow, shoulder, hip, knee and ankle joints of each subject. Joint trajectories were collected at a rate of 60 fps by the Motion Analysis System. The lifts were sagittally symmetric, thus a two-dimensional analysis was performed on the data.

2.3 Procedures

Each subject participated in five one-hour lifting sessions: two psychophysical sessions and three speed sessions. During the first two sessions, psychophysical experiments were performed to obtain a one-hour MAWL for each subject. Beginning with a randomly light (6.82 kg) or heavy (27.3 kg) load, subjects lifted at a rate of one lift per minute and adjusted the weight of the load to determine their MAWL. Table 1 shows the MAWLs selected in each session. The MAWLs differed by 15% or less within each subject; therefore the average of the two sessions was used to set the weights in the speed experiments.

Table 1. Subject Height, Weight and Psychophysical MAWL.

Subject	Height (m)	Weight (kg)	MAWL I (kg)	MAWL II (kg)
1	1.90	93.0	15.6	17.0
2	1.70	77.3	20.0	17.3
3	1.66	51.0	21.8	18.2
4	1.90	82.0	29.3	25.2
5	1.68	71.0	27.3	24.1

Motion data was collected during the three speed sessions. Fifteen combinations of weight and speed were performed: 3 weights (50%, 65% and 80% MAWL) and 5 speeds (very slow, slow, normal, fast and very fast). The speeds were subjectively selected by each subject according to the following directions. They were instructed to lift as slowly as possible while still being able to complete the lift for the very slow condition. For the very fast one, they were to lift as fast as possible without risking injury. In the slow (fast) conditions, they were told to lift somewhat slower (faster) than normal. A total of 150 sets of data were collected (5 subjects x 3 weights x 5 speeds x 2 replications).

2.4 Experimental Design

Each subject participated in three speed sessions. Within each session, a single weight (50%, 65% or 80% MAWL) was selected and used with each of the five speeds throughout the session. Five trials at each speed x weight condition were performed but only the third and fourth trials were collected and digitized. A split-plot design with repeated measures on subjects was used to analyze the data; the % MAWL was the whole plot and speed was the split-plot. A split-plot design was required for analysis due to the restriction on randomization required to run a single weight level in each session. Subjects were modeled as random effects, while both speed and weight were fixed effects.

3.0 Results and Discussion

The static and inertial moments at the joint centers were calculated at each frame of the lift, then normalized such that each lift was 50 frames in duration as shown in Figures 1 and 2. This study examined the effects of lifting speed and weight of lift on the cumulative stresses on the joints. Specifically, three variables were analyzed: (1) the sum across the five joints of the absolute values of the static moments, (2) similarly, the sum of the inertial moments, and (3) the total absolute moment, i.e., the sum of the absolute static and inertial moments. These three variables were then investigated in three ways: the average moments, the ratio of inertial to static moments, and the moments integrated over the time of the lift (angular impulse). The peak sum of the absolute moments across the five joints was considered as a potential variable of interest, particularly for purposes of comparison to studies described in the introduction. However, this variable was an inappropriate measure. For example, in Figure 1, the peak value of the sum of the static moments across the five joints is a maximum at the very last frame; whereas for the studies described previously, the moment at a specific joint (L5/S1) peaks early in the lift.

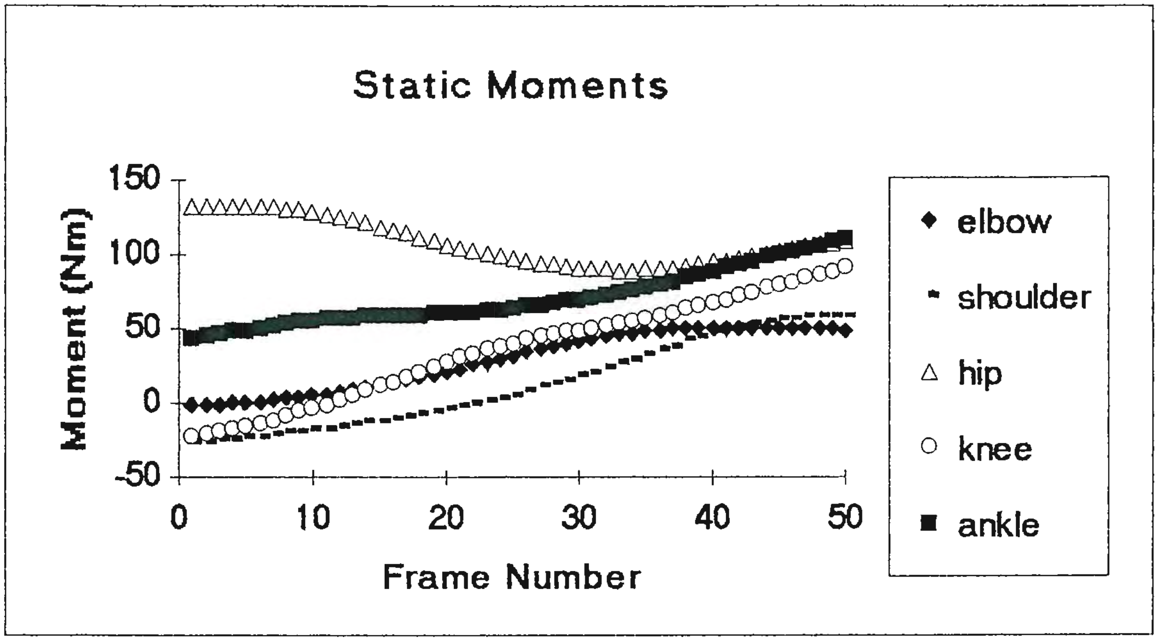

Figure 1. Static Moments Normalized over Time for a Normal Speed Lift.

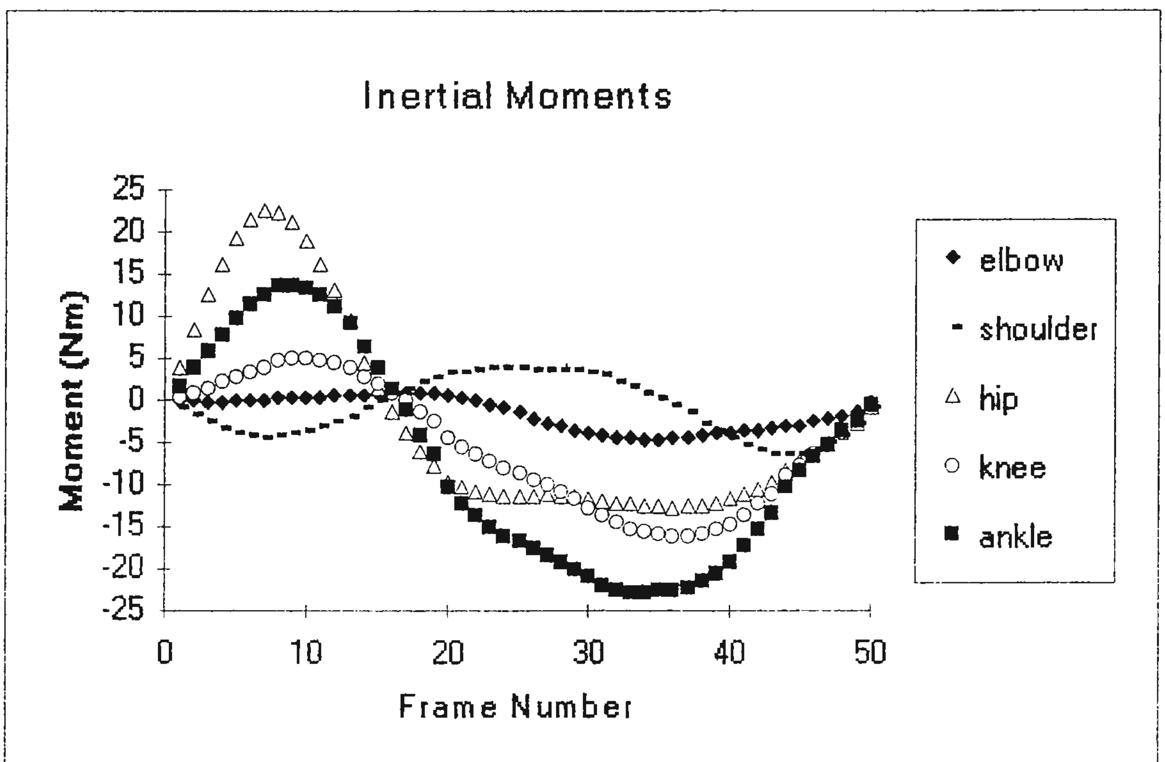

Figure 2. Inertial Moments Normalized over Time for a Normal Speed Lift.

3.1 Average Absolute Moments

The sums of the absolute values of the 50 frames of the normalized lifts were divided by 50 to obtain the average static, inertial and total moments for purposes of comparison. Figure 3 shows the average moment values for each of these three variables for all subjects obtained in the experiment. Analysis on the static moments, inertial moments and the total moments was performed using a split-plot experimental design. Table 2 summarizes these results. As shown, % MAWL significantly affected the static moments and the total moments, speed significantly affected all three moments, while the % MAWL*SPEED interaction was non-significant.

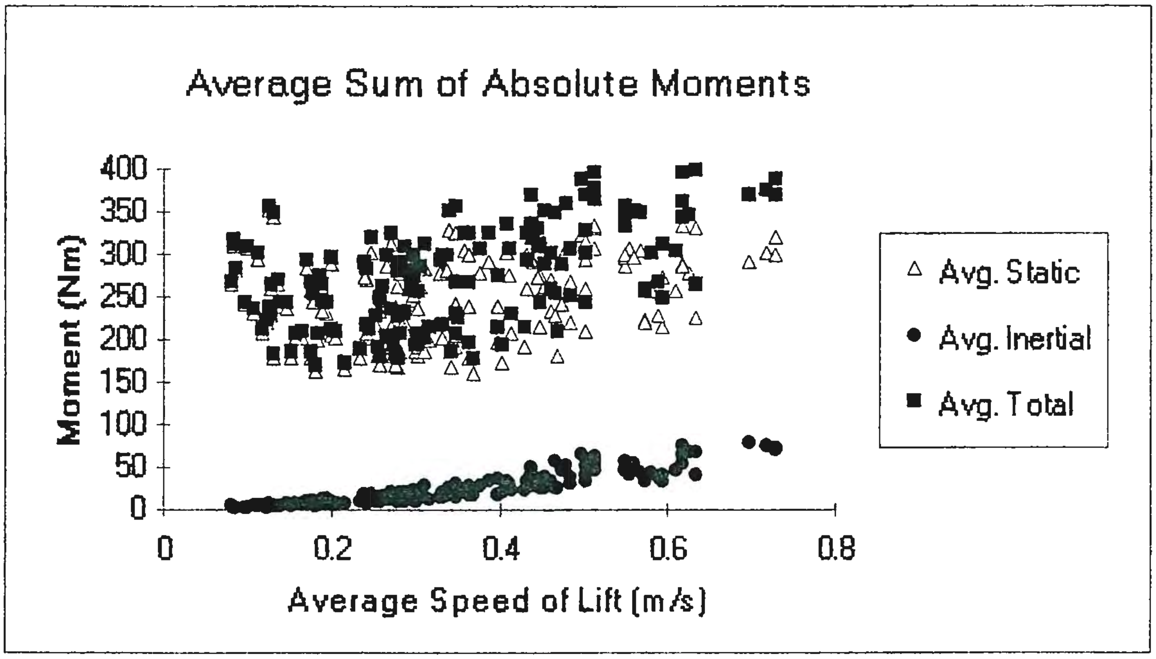

Figure 3. Average Absolute Moments (Static, Inertial and Total) across all subjects x percent MAWLs x speeds.

Table 2. ANOVA for split-plot design on average moments.

FACTOR	STATIC	INERTIAL	TOTAL
%MAWL	*	NS	*
SPEED	*	***	***
%MAWL*SPEED	NS	NS	NS

*** = p < 0.001 ** = p < 0.01 * = p < 0.05 NS = Non-significant

3.1.1 Average Absolute Static Moments

As indicated above, both speed of lift and % MAWL significantly affected the average static moment. Table 5 in the Appendix contains the means and standard deviations of each combination of speed x % MAWL. Figure 4 contains the mean values of the average static moments for each speed x % MAWL condition. The average static moment increased with both increasing weight of load and increasing speed of lift. The average absolute static moments of the five speeds were significantly different at alpha = 0.05 when testing for the difference of means using Duncan's multiple comparison test. The average static moment of both slow speeds was significantly smaller than the moments of the normal and fast speeds, and the normal speed was significantly lower than the very fast. On average, moments at the slowest speed were 4% smaller than those at normal speeds, while moments at the fastest speed were 3% larger than normal. Although these differences are statistically significant, the actual differences are fairly small. Hafez and Ayoub (a) reported that the average static moments obtained in their study were fairly constant regardless of speed, but did not perform a statistical analysis. In regard to the weight of lift when compared to 50% MAWL, the average static moments were 13% and 19% larger for the 65% and 80% MAWLs, respectively. Hafez and Ayoub (a) found that the average static moment increased by 27% when the load increased from 18.15 to 27.22 kg.

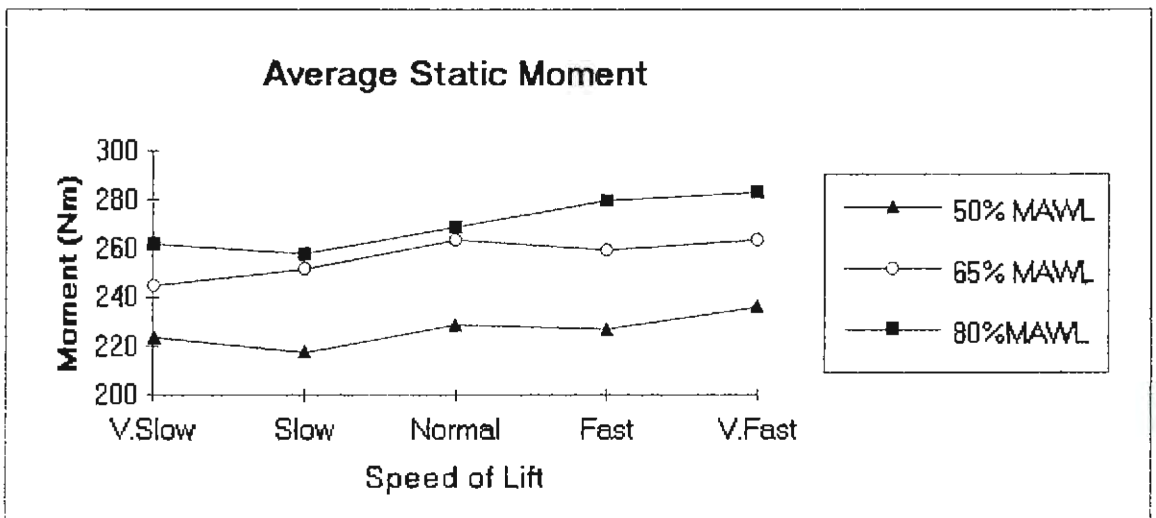

Figure 4. Average Static Moment Means.

3.1.2 Average Absolute Inertial Moments

The ANOVA listed above indicated that speed had a significant effect on the average inertial moment, while % MAWL and the speed* % MAWL interaction were non-significant. Table 3 contains the mean values of the average inertial moments. The average absolute inertial moments for the five speeds were significantly different at alpha

= 0.05 when testing for differences in means with Duncan's multiple comparison test. The inertial moments were all significantly different from one another. The smallest average inertial moment occurred at the slowest speed, and continued to increase with increasing speed. The inertial moments of the slowest lifts were 77% smaller on average than the moments of normal speed lifts, and in the fastest lifts they were 55% larger than in normal lifts.

Table 3. Average absolute inertial moment (per frame)

SPEED	MEAN (Nm)	S.D.
Very Slow (1)	6.37	2.69
Slow (2)	14.36	5.15
Normal (3)	28.22	14.65
Fast (4)	34.16	17.52
Very Fast (5)	43.87	16.86

A regression analysis was performed on the average inertial moments to model the data presented in Figure 5. The inertial moments were modeled as a function of the speed of lift. The continuous variable average speed of lift was used instead of the five categorical speed levels. For each lift, the average vertical lifting speed was calculated and used for the purposes of modeling. Average lifting speed ranged from a minimum of 0.08 m/s to a maximum 0.73 m/s, with a mean of 0.35 m/s. The model which was selected accounts for 89% of the variance (i.e., R^2=0.89):

$$\text{(Avg. Inertial Moment)}^{1/2} = 1.02 + 10.5 \text{ Avg. Speed} \qquad (I)$$

where: Average Inertial Moment is the average of the 50 frames of the sum of the absolute inertial moments (Nm), and
Average Speed is the average speed of a particular lift (m/s).

Note that it was necessary to transform the dependent variable, to the square root of the average inertial moment. The error variances were not constant in the untransformed model, thus violating the assumption of constant variance of regression modeling. The transformation corrected this problem, and the remaining assumptions were not violated.

Hafez and Ayoub (b) found that as the speed of the lift increased, the inertial moment increased and suggested the relationship between the two variables which reasonably predicted the data was a quadratic of the form:

$$\text{Avg. Inertial Moment} = 230\,(\text{Avg. Speed})^2 \qquad (II)$$

There is a large difference in the predictions of the two regression models. For example, at a speed of 0.73 m/s model *I* predicts an average inertial moment of 151 Nm while model *II* predicts 122 Nm. It is assumed that Hafez and Ayoub modeled the moments of both the left and right side of the body together, whereas the values reported in this study are for one side of the body only thus the value of model *I* was doubled.

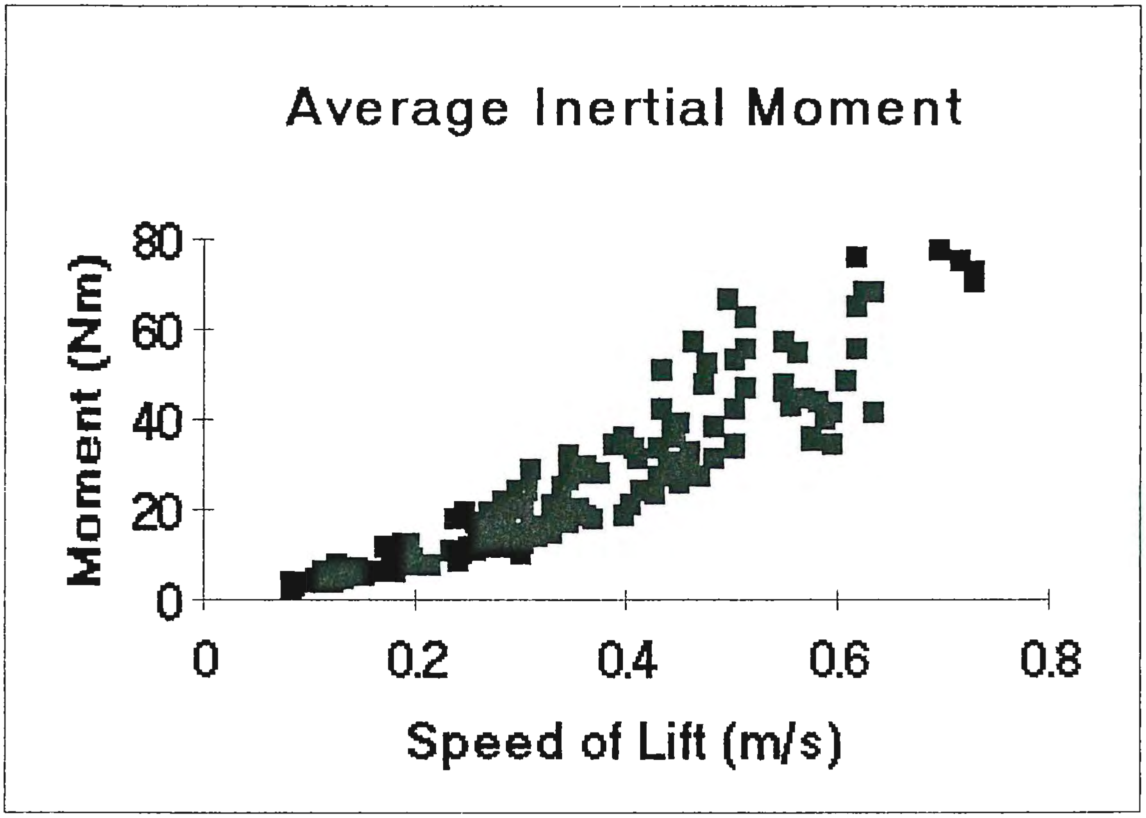

Figure 5. Average Sum of Absolute Inertial Moments

3.1.3 Average Sum of Static and Inertial Moments

As indicated above, both speed of lift and % MAWL significantly affected the average sum of the absolute static and inertial moments. Table 6 in the Appendix and Figure 6 below contain the mean for each combination of speed x % MAWL. The average sum of the absolute static and inertial moments for the five speeds were significantly different at alpha = 0.05 when testing for differences in means with Duncan's multiple comparison test. The sum of the moments were all significantly different from one another, with the smallest average moment occurring at the slowest speed and the largest at the fasted speed. The slowest and fastest speeds, respectively, had 11% smaller and 8% larger total moments on average than the normal speed. The moments were 11% and 17% larger for the 65% and 80% MAWL as compared to the 50% MAWL. Figure 6 indicates that to minimize the average stress on the entire body, one should lift as slowly as possible. Any increase in speed acts to increase this stress. From this data, it appears that the average moment experienced over the duration of the lift is not a good indicator of the biomechanical stress experienced during a lift due to lifting at different speeds although it does correctly depict increased stress with increased load weight.

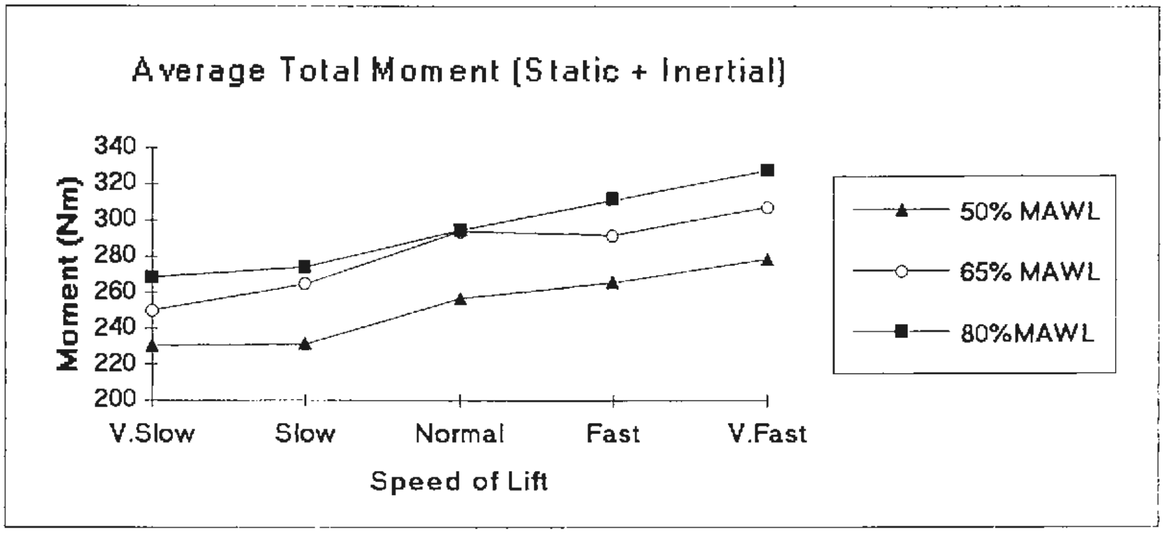

Figure 6. Average Total of Absolute Moments

3.1.4 Summary: Average Absolute Moments

Figure 7 shows the three measures, static, inertial and total average absolute moment. The inertial component is 2.5, 5.5, 10, 12 and 14% of the total moment during the very slow, slow, normal, fast and very fast speeds of lift, respectively.

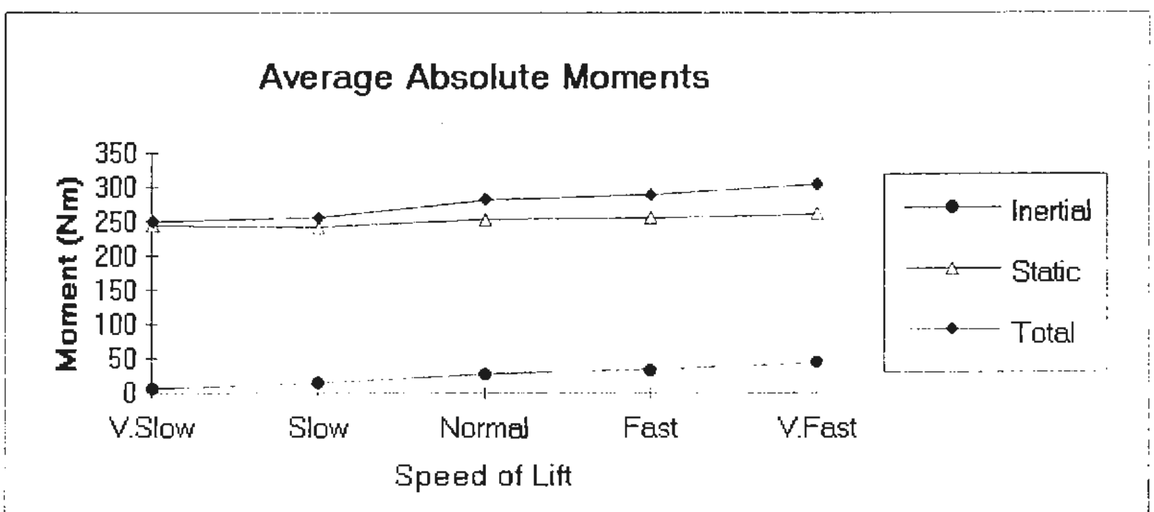

Figure 7 Average Absolute Static, Inertial and Total Moments.

3.2 Inertial/Static Ratio

A regression analysis was performed on the ratio of inertial to static moments. The ratio was modeled using the speed of lift, weight of lift and their interaction. The five speed levels were converted to a continuous variable, average speed of lift, while the weight of lift remained categorical variables. The final model, selected for parsity and goodness of fit, with R^2=0.91 was: **$(RATIO)^{1/2}$ = 0.089+0.592 AVGSPEED.**

Note that it was necessary to transform the dependent variable because the error variances were not constant in the untransformed model, thus violating the assumption of constant variance. The transformation corrected this problem, and the remaining assumptions were not violated.

Figure 8 contains the ratio data. As the average speed of lift increases, the ratio also increases. This is expected since the inertial component increases more rapidly with increasing speed than the static component. As shown in Figure 8, the maximum ratio approached a value of 0.20 when the speed of lift was very fast. Hafez and Ayoub (a) reported ratios that approached a value of 2.0 when the speed of lift neared 1.8 m/s, and in one case an extremely fast lift of 2.62 m/s which had an inertial to static value exceeding 5.

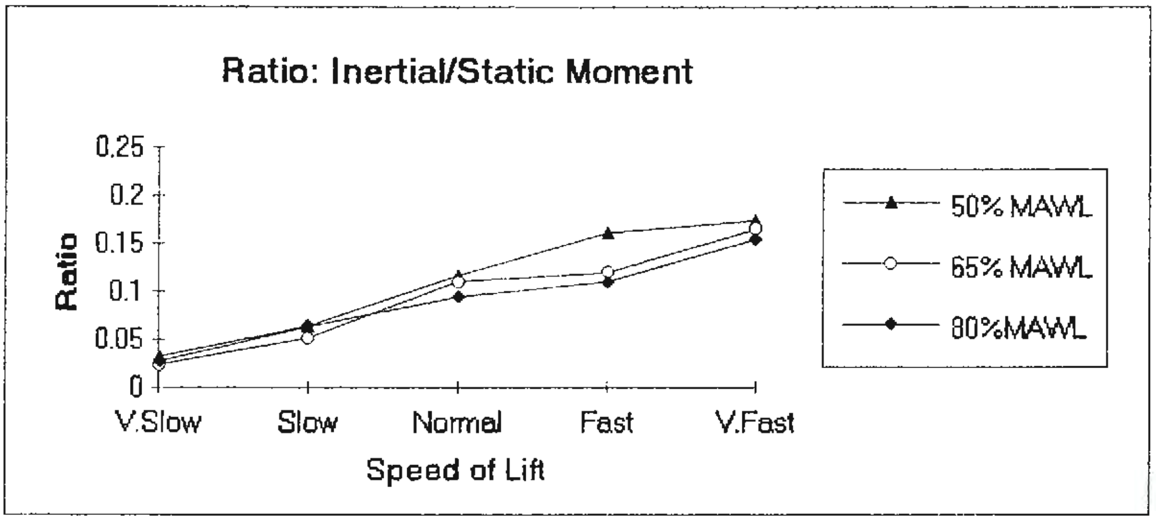

Figure 8. Inertial/Static Moment Ratio

3.3 Integrated Moments (Angular Impulse)

Angular impulse, the time integrals of the moments, can be defined as the net muscular effort needed to move the body through the lifting event (Strickland, et al., 1983 as cited by Schipplein et al., 1990). This study investigated the time integrals of the absolute moments as a measure of the angular impulse. As indicated in Table 4, the main effect of speed of lift was significant to each of the three type of integrals, but the main effect % MAWL was not significant.

Table 4. ANOVA for split-plot design on moments integrated over time.

FACTOR	STATIC	INERTIAL	SUM
%MAWL	NS	NS	NS
SPEED	***	***	***
%MAWL*SPEED	NS	*	NS

*** = $p < 0.001$ ** = $p < 0.01$ * = $p < 0.05$ NS = Non-significant

Figure 9 contains the angular impulse values for each of the speed x % MAWL combinations. It shows that both the static and total moment integrals decreased dramatically as the speed increased from slow to normal speed and continued to decrease with increasing speed, whereas the inertial integral increased somewhat with increasing speed. If the integrated absolute moments do represent the net muscular effort required to perform a lift, this graph indicates that slow lifts greatly increase the effort required, whereas faster lifts decrease the effort. This figure suggests that one should lift as quickly as possible to minimize the effort required to perform a lift. It appeared that the subjects intuitively used this information to some extent since their normal speeds approached the faster speeds. However, although the integrated absolute moment appears to be a somewhat better measure of cumulative stress than the average moment, it does not indicate an ideal speed. It only suggests that faster motions will decrease the stress.

Hafez and Ayoub (b) reported similar trends in the time integrals of the absolute moments when the speeds were less than 0.8 m/s, i.e., the static integrals decreased as speed increased, whereas the inertial moments increased as speed increased. While the trend is similar, the type of lift performed (an isoinertial lifting apparatus in which the load slides along a controlled path) permitted subjects to lift at unusually fast speeds up to 2.6 m/s as compared to the maximum 0.73 m/s found in this study. As lifting speeds became extremely fast, Hafez and Ayoub found that the decreasing static and increasing inertial integral values intersected at a speed slightly faster than normal. This intersection, which was very close to the subject's preferred speed, minimized the total integrated absolute moment. Thus they hypothesized that the optimal speed occurred at this intersection and was the speed which minimized the cumulative stress of the lift.

The subjects in this current study were lifting a box in a realistic situation. They were unable to lift quickly enough for the static and inertial moment integrals to intersect or even closely approach one other to reproduce the results on Hafez and Ayoub. The speeds in this study were realistic as compared to values reported in the literature; for example Gagnon and Smyth (1991) reported an average lifting speed of 0.45 m/s. It should be noted that even though the lifting apparatus used by Hafez and Ayoub permitted very fast lifting speeds, two subjects failed to produce a wide enough range of speeds to exhibit the characteristic intersection of static and inertial moment-time integrals, thus they were unable to lift quickly enough to perform at their "ideal" speed.

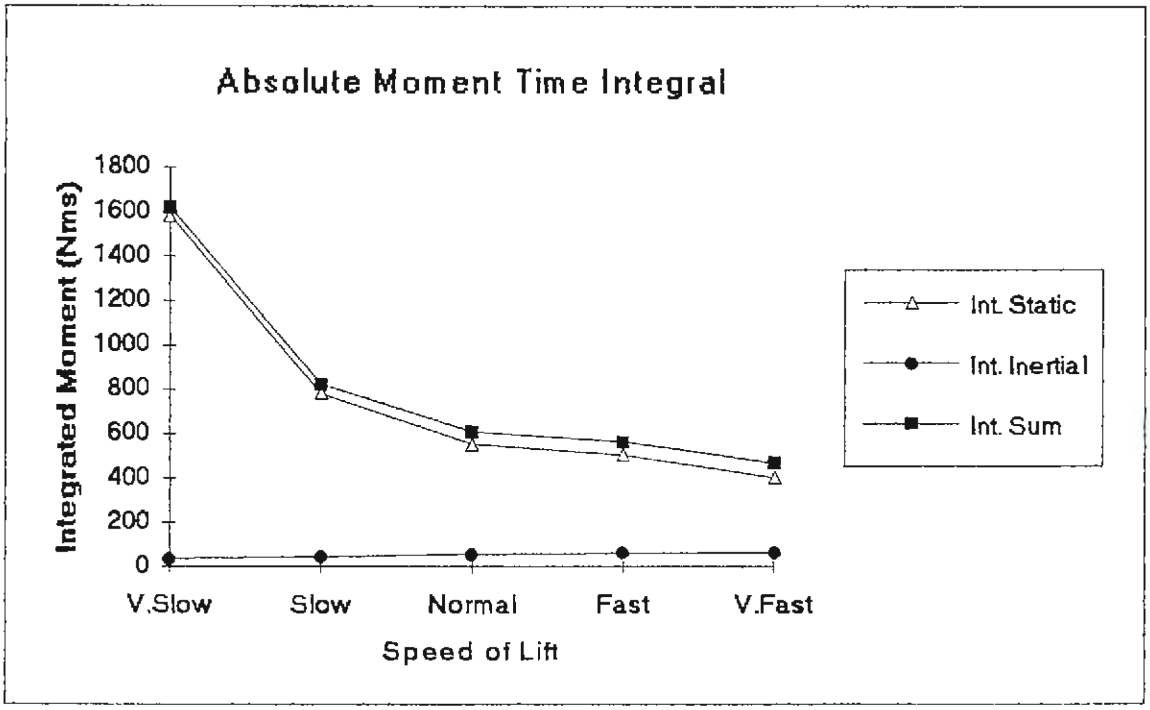

Figure 9. Integrated Absolute Moments.

4.0 Conclusions

(1) The average absolute static moment increased slightly with increased speed of lift and increased significantly with increased percent MAWL.

(2) The average absolute inertial moment increased with increasing speed. A simple regression model using average speed of lift to predict the average inertial moment was fit to the data.

(3) The average total sum of the static and inertial moments increased with increased percent MAWL and speed. Figure 7 indicates that to minimize the average moment, one should lift more slowly than normal. Similarly, Bush-Joseph et al., (1988) and Hall (1985) reported that peak and mean moments at the lower back, respectively, increased with increasing speed. Hall concluded that dramatic increases in stresses in the lumbar region occur when the lifting speed is relatively fast.

(4) The ratio of inertial to static moment increased with increasing speed and approached a maximum value of 0.20. Average speeds were in the range 0.08 to 0.73 m/s. The ratios observed in this study are much smaller than those observed by Hafez and Ayoub which reached values of 2.0 to 5.0 in extremely fast lifts.

(5) As lifting speed increased, the time integral of the absolute inertial moments increased while the static integral decreased.

(6) Within the range of speeds observed in this study, the moment time integral of the sum of the static and inertial components continued to decrease. This suggests that one should lift quickly to minimize the effort or stress.

(7) It appears that in realistic lifting situations subjects are unable to lift at speeds fast enough for the inertial and static moment-time integrals to intersect. This intersection was hypothesized by Hafez and Ayoub to identify the ideal speed of lift which minimizes the stress on the body. Thus the ideal speed of lift cannot be identified in this manner.

(8) The main effect percent MAWL was found to be insignificant to the moment-time integrals. The moment-time integrals should have reflected an increase in stress due to increased load weight.

In conclusion, a single measure such as the average summation across the joints of the absolute values of the moments or their moment-time integral as investigated in this report appears to be an inappropriate measure of the total effort or stress of a lift. Gagnon and Smyth (1991) agree that research efforts should aim to evaluate not only the lower back, but the loading of all the body joints. They evaluated the muscular work, the integral of power over time where power was the product of the joint moment and angular velocity, at each joint, then used a measure called mechanical work adjusted (MWA) to account for both positive and negative work. The MWA assumed that negative work was 1.5 times more efficient than positive work. They reported that the mechanical work-energy approach appeared to better represent the total effort and detect potential risks than the single peak moment value in current use. It may be more appropriate to investigate the effects of speed of lift through alternative measures such as the mechanical work-energy approach rather than the measures used in this report.

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5.0 Appendix

Table 5. Average Absolute Static Moment Means.

SPEED	%MAWL	N	MEAN (Nm)	S.D.
VERY SLOW (1)	50	10	223.67	52.47
	65	10	244.80	32.95
	80	10	261.84	59.03
SLOW (2)	50	10	217.27	47.71
	65	10	251.48	31.28
	80	10	257.86	48.69
NORMAL (3)	50	10	228.79	50.39
	65	10	263.54	40.25
	80	10	268.64	47.30
FAST (4)	50	10	226.96	45.14
	65	10	259.44	43.85
	80	10	279.73	47.04
VERY FAST (5)	50	10	235.94	46.34
	65	10	263.52	43.39
	80	10	283.07	47.51

Table 6. Average Absolute Total Moments

SPEED	%MAWL	N	MEAN (Nm)	S.D.
VERY SLOW (1)	50	10	230.37	51.51
	65	10	250.44	31.90
	80	10	268.63	58.85
SLOW (2)	50	10	231.03	49.73
	65	10	264.52	33.42
	80	10	274.14	52.25
NORMAL (3)	50	10	256.91	64.00
	65	10	294.11	56.49
	80	10	294.61	56.37
FAST (4)	50	10	265.45	65.02
	65	10	291.81	57.40
	80	10	311.37	59.28
VERY FAST (5)	50	10	278.55	63.88
	65	10	307.79	56.82
	80	10	327.82	61.67