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Ergonomics
Case Study: Revised NIOSH Lifting Equation Instruction Issues for Students

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This case study investigated the effectiveness of formal instruction of the Revised NIOSH Lifting Equation for university students who may use the equation in their future work. Their successes and challenges were examined through a class exercise and two exams, all of which followed the classroom instruction in applying the Lifting Equation. Results showed students (1) had difficulty determining relevant values for task variables from reading a job description, and (2) generally were able to calculate the Recommended Weight Limit (RWL) and Lifting Index (LI) when task variables were such that the associated multipliers were less than or equal to 1. However, when the multiplier was calculated to be greater than 1, students had difficulty interpreting the result. The task variable and multiplier (consistently the greatest challenge) were the asymmetry task variable, A, and the asymmetric multiplier, AM. Results indicate that the layout of the Job Analysis Worksheet for Step 1 may make it easy to make arithmetic errors when calculating multipliers. It is recommended that the worksheet be redesigned to help individuals decrease the probability of making an arithmetic error when calculating the task variables, multipliers, RWL, and LI. It is also recommended that the redesigned worksheet be tested to determine whether fewer arithmetic errors are made and if the worksheet is less confusing for an inexperienced user to use.

Keywords lifting index (LI), recommended weight limit (RWL), Revised NIOSH Lifting Equation, university students

INTRODUCTION

Evaluation of the risk for back injury while performing manual material handling is very important, as back injuries account for almost 20% of all workplace injuries and illness and 25% of the yearly workers' compensation expenses in the United States.[1,2] To reduce the risk of back injuries while lifting or lowering materials, several methods that evaluate and calculate the risk under various conditions have been developed. These methods are grouped in the Ergonomics Toolkit. One method used by ergonomists for manual materials handling is the Revised NIOSH Lifting Equation.[3]

The objective of this case study was to evaluate the effectiveness of training students in the use of the Lifting Equation for the evaluation of relative risk of back injury. A series of class exercises and exams were conducted with a class of students enrolled in an occupational ergonomics course. These students, who generally had not been exposed to ergonomic issues, were from a major midwestern university that requires students to take this course if they are in certain plans of study in occupational health science or general health science majors. For this reason, there is an opportunity to (1) evaluate training in the Lifting Equation for new students with little prior ergonomics experience, and (2) evaluate their readiness to apply the equation in the workplace.

The case study identified successes and difficulties of students in understanding and following specific instructions in the Lifting Equation after first being introduced to it, which could provide insights that may improve instruction methods and determine the best way to complete the Job Analysis Worksheet, thereby increasing the understanding of concepts in the equation and reducing errors in calculating injury risks.

The evaluation provides four main advantages: (1) students' math background should be adequate to understand the equation and its restrictions, as all students have completed calculus; (2) students can receive feedback and help in understanding Lifting Equation concepts from a teaching assistant and the class professor, unlike the possible situation of a professional trying to apply the equation in the workplace without prior training in its use; (3) students are accustomed to classroom instruction, which is probably not the case for industrial hygienists focused on safety who have been in the workplace for some time, and (4) students can be evaluated immediately following instruction and then at a later time.

METHODS

The purpose of this case study was to evaluate the effectiveness of instruction in the use of the Revised NIOSH Lifting Equation with students in a lecture course at a university. This was accomplished through a class exercise and two exams after students had received instruction in the equation:

- *Class exercise*. Assigned on same day instruction was completed
- *Exam 1*. Administered 1 week following class exercise and instruction in the Lifting Equation
- *Exam 2*. Administered 9 weeks after initial instruction in the Lifting Equation.

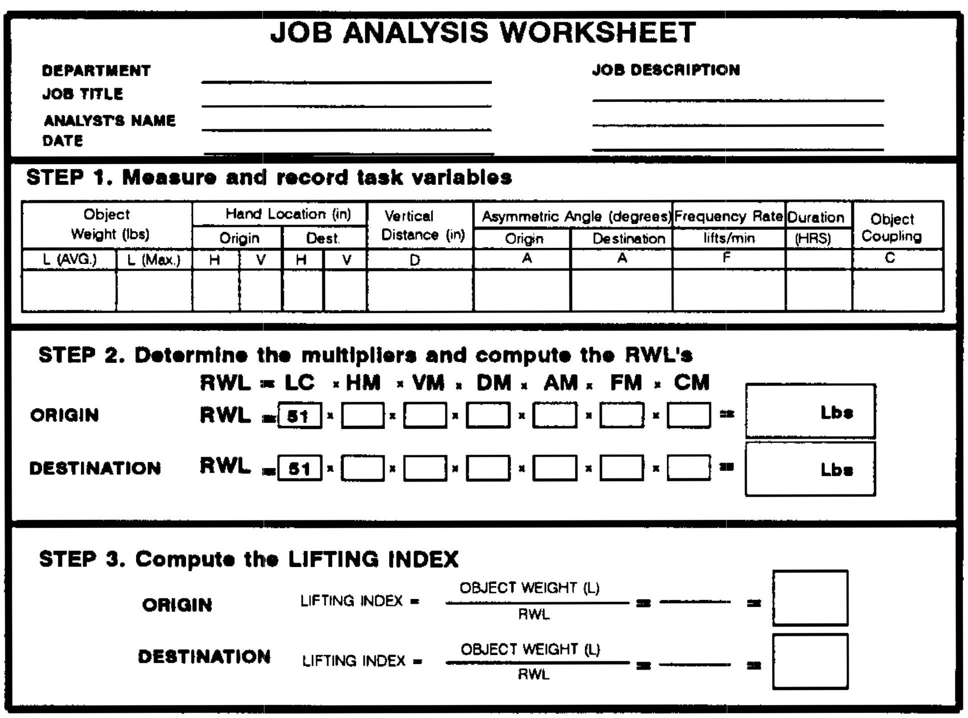
The sampling group was composed of 78 students who were enrolled in an occupational ergonomics course at a university; there were 77 undergraduate students with majors in the School of Health Sciences and 1 graduate engineering student. All students had completed at least a calculus sequence of two semesters by the end of the sophomore year.

Instruction

The following instruction methods for applying the Lifting Equation for a single task were employed: reading material concerning the equation, lecture on the equation, example calculation from a job description, individual instruction, and review sessions concerning the equation.

The first method of instruction required students to access online NIOSH Publication 94-110, *Applications Manual for the Revised NIOSH Lifting Equation*,(3) which was on the course reading list. Students were expected to use the website and read the material during the semester.

The second method of instruction was through lectures over 2 days (75 min each) during which the background task variables associated with multipliers, formulas, and tables (Tables I–III) used for calculating the multipliers from the task variables used in the recommended weight limit (RWL) and lifting index (LI) equations were presented. As part of the instruction, the Job Analysis Worksheet (Figure 1) was introduced as a way of collecting information needed for



JOB ANALYSIS WORKSHEET

DEPARTMENT
JOB TITLE
ANALYST'S NAME
DATE

JOB DESCRIPTION

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate lifts/min	Duration (HRS)	Object Coupling
		Origin		Dest.			Origin	Destination			
L (AVG.)	L (Max.)	H	V	H	V	D	A	A	F		C

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × ☐ × ☐ × ☐ × ☐ × ☐ × ☐ = ☐ Lbs

DESTINATION RWL = 51 × ☐ × ☐ × ☐ × ☐ × ☐ × ☐ = ☐ Lbs

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = OBJECT WEIGHT (L) / RWL = ——— = ☐

DESTINATION LIFTING INDEX = OBJECT WEIGHT (L) / RWL = ——— = ☐

FIGURE 1. Job Analysis Worksheet

TABLE I. Formulas for Calculation of Multipliers from Task Variables

		Metric	U.S. Customary
Load constant	LC	23 kg	51 lb
Horizontal multiplier	HM	(25/H)	(10/H)
Vertical multiplier	VM	1 – (0.003*|V – 75|)	1 – (0.075*|V – 30|)
Distance multiplier	DM	0.82 + (4.5/D)	0.82 + (1.8/D)
Asymmetric multiplier	AM	1 – (0.0032A)	1 – (0.0032A)
Frequency multiplier	FM	From Table 5	From Table 5
Coupling multiplier	CM	From Table 7	From Table 7

calculating RWL and LI. The RWL equation presented to the students was:

$$RWL = LC * HM * VM * DM * AM * FM * CM$$

where

LC = Load Constant = 51 lb (23 kg)
HM = Horizontal Multiplier
VM = Vertical Multiplier
DM = Distance Multiplier
AM = Asymmetric Multiplier
FM = Frequency Multiplier
CM = Coupling Multiplier.

Not only was the RWL equation presented, all of the multipliers and task variables associated with the multipliers were explained, including the restrictions and limitations on the task variables. The LI equation that was introduced was

$$LI = \frac{\text{Object Weight}}{RWL}$$

where

LI = Lifting Index
Object Weight = Actual weight of object to be lifted.

The third method was an example (Example 1 from Pub. 94-110) (Figure 2) in which a step-by-step calculation of all the multipliers in the RWL and LI was performed involving

TABLE II. Frequency Multiplier Table from Pub 94-110 (Table 5)

	Work Duration					
	≤ 1 Hour		>1 But ≤ 2 Hours		>2 But ≤ 8 Hours	
Frequency Lifts/min (F)[A]	V < 30[B]	V ≥ 30	V < 30[B]	V ≥ 30	V < 30[B]	V ≥ 30
≤ 0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

[A]For lifting less frequently than once per 5 min, set F = 0.2 lifts/min.
[B]Values of V are in inches.

TABLE III. Coupling Multiplier Table from Pub 94-110 (Table 7)

	Coupling Multiplier	
Coupling Type	V < 30 inches (75 cm)	V ≥ 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

class participation. During the calculation, a Job Analysis Worksheet was filled out first with relevant information about the task variables from the job description, then the multipliers were calculated from which the RWL, and finally, the LI were computed. Following the example calculation, a class discussion of job redesign suggestions was held that looked at the influence of the magnitude of each multiplier on the overall RWL and how increasing the RWL by increasing one or more of the multipliers up to a maximum of 1 decreases the LI, which indicates a lower risk of injury to workers.

Individual instruction and review sessions concerning the Lifting Equation occurred mainly after the first exam and immediately prior to the second exam. Fifty percent of the students went to the teaching assistant for a review of the first midterm exam. The instruction generally consisted of reviewing the questions on the first exam, which were related to the calculations of the RWL and LI. In particular,

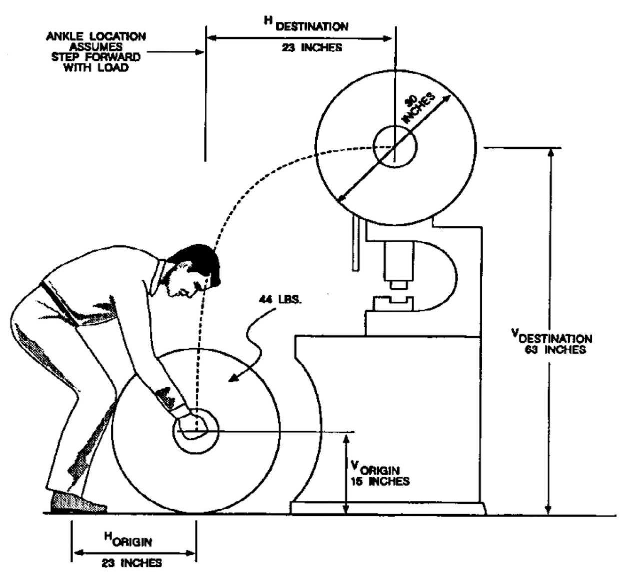


FIGURE 2. Example presented in class. Source: Waters, T., Putz-Anderson, V., and Garg, A. (eds.). *Applications Manual for the Revised Lifting Equation,* DHHS/NIOSH Publication No. 94-110. Cincinnati, Ohio: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (DHHS/NIOSH Publication No. 94-110), 1994.

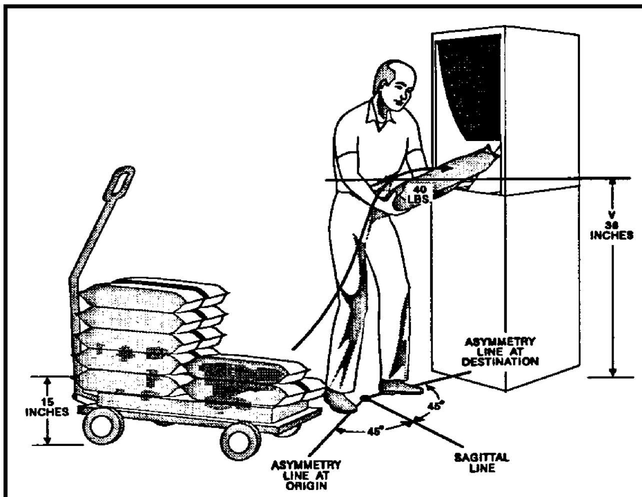


FIGURE 3. Job description and figure used for class exercise. Source: Waters, T., Putz-Anderson, V., and Garg, A. (eds.). *Applications Manual for the Revised Lifting Equation,* DHHS/NIOSH Publication No. 94-110. Cincinnati, Ohio: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (DHHS/NIOSH Publication No. 94-110), 1994.

instruction focused mainly on concepts not understood on the first midterm, such as neutral angle for the AM, HM, and restrictions on each multiplier, particularly the fact that none of the multipliers could be greater than 1. In addition, emphasis was placed on explaining errors in using the frequency multiplier and coupling multiplier tables, as well as errors in using the formulas to calculate the other multipliers.

Class Exercise – Assigned Immediately Following Formal Classroom Instruction

The goal was to give students an opportunity to: (1) use the Worksheet (Figure 1) for determining the RWL and LI, and (2) use the formulas and tables (Tables I–III) for calculating the multipliers at both the origin and destination under conditions of significant control at the destination.

Evaluation of the students' understanding of the calculations in the Lifting Equation occurred through a class exercise performed in 19 groups of 3–4 students, where 73 of 78 enrolled students were present. The class exercise was drawn from NIOSH Pub. 94-110, Example 3 (Figure 3). However, the exercise was modified so that significant control at the destination was required, therefore requiring calculations of RWL and LI at both the origin and destination. The class exercise was graded immediately by either the class professor or teaching assistant. Student groups were allowed to resubmit the class exercise until they had the correct answer and seemed to understand their errors on earlier submissions.

Exam 1 – Administered 1 Week Following Class Exercise and Instruction

The exam questions evaluated the evaluate students' ability to: (1) calculate the RWL and LI from reading a job description,

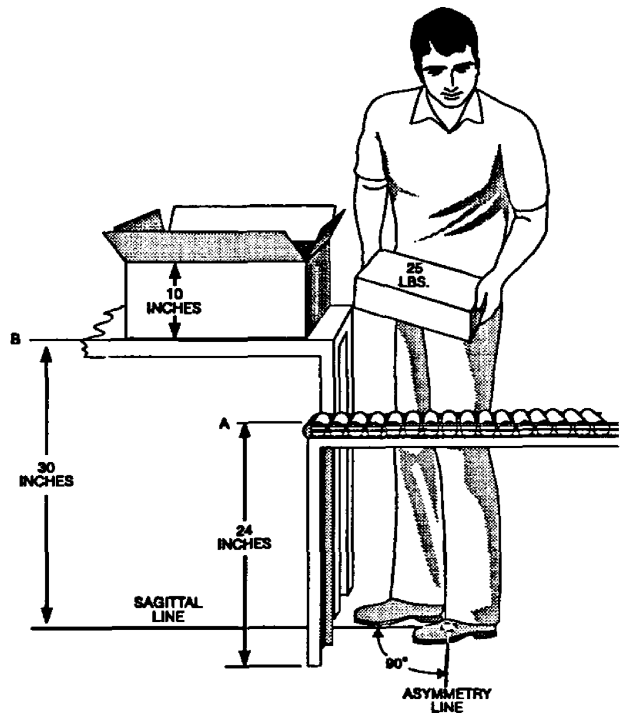


FIGURE 4. Job description for questions on Exam 1. Waters, T., Putz-Anderson, V., and Garg, A. (eds.). *Applications Manual for the Revised Lifting Equation,* DHHS/NIOSH Publication No. 94-110. Cincinnati, Ohio: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational safety and Health, 1994.

and (2) fill out the Worksheet while using the appropriate formulas and tables.

All students enrolled in the class were present for the exam. The format of the two exam questions was free response where students were required to: (1) complete the Worksheet by showing their work on any needed calculations, and (2) provide reasonable recommendations for a job redesign. Questions were taken from Example 6 in Pub. 94-110 (Figure 4), with the students having access to the formulas and tables (Tables I–III) for determining the multipliers following determination of the task variables.

The first question concerned the calculation of RWL and LI for an initial job description. The second question concerned a redesign of the job by modifying at least one of the multipliers in the first question, requiring a recalculation of RWL and LI and written recommendations. This required students to realize that the smallest multiplier(s) affected the value of RWL the most. Therefore, if possible, the associated task variable(s) should be changed so that the multiplier(s) is increased. The teaching assistant, who gave partial credit for the answers, evaluated the students' responses.

Exam 2 – Administered 9 Weeks after Initial Instruction

The purpose of the five questions (Questions 61–65) (Figure 5) that covered the Lifting Equation on the second exam was to evaluate students' understanding of the calculation of the multipliers and the restrictions on the multipliers and task variables, as well as understanding the calculation of LI. Specific emphasis was on understanding that a multiplier cannot be larger than 1.

Seventy-seven of the 78 enrolled students were present for the exam. The format of the questions was weighted multiple choice, with the five questions having different point values. Students were required to show the work calculations on the exam, in particular, for the last question in which LI was calculated for the correct answer of *e*) where LI = 2.04. The exams were machine graded.

RESULTS

Class Exercise

The average score on the class exercise was 9.85 out of 10 points. Further examination of the written exercise, which showed students' work calculations and Job Analysis Worksheet, revealed the aspects of the RWL and LI equations that students seemed to understand, and parts that were a greater challenge for them.

Inspection of the students' exercises showed that the calculations for the horizontal multiplier (HM), vertical multiplier (VM), and distance multiplier (DM) were generally easily performed, as only one group was unable initially to calculate all these correctly. This group had difficulty only with the HM calculation, and it appeared to be due to: (1) misreading the job description, or (2) the layout of the Job Analysis Worksheet for Step 1. Therefore, from this, it appears that students understood the HM, VM, and DM calculations when the values for the task variables H, V, and D, respectively, were not less than the restricted values.

However, students had several challenges in completing the exercise. The first challenge was the ability to read a job description, look at any relevant figures for the job description, and determine the relevant information to fill out Step 1 on the Worksheet correctly. A specific difficulty of the exercise was determining the quality of the object coupling from the figure and job description, which then influenced the choice for the coupling multiplier from the coupling multiplier table. Another major difficulty was understanding the steps to use the frequency multiplier table. A final difficulty was the layout of the Worksheet in Step 1, which appeared to make it easy to make arithmetic errors, especially when calculating the task variable, vertical travel distance D.

Exam 1

The overall outcome on the two questions concerning the Lifting Equation was 15.63 out of 20 points (78.14%), with 9 students receiving full credit on the first question; 20.81 out of 25 points (83.23%), with 12 students receiving full credit on the second question. This resulted in an overall performance of 36.44 out of 45 points (80.97%) with 6 students receiving full credit on both questions.

(1). **(5 points)**
You are using the 1991 NIOSH Lifting Equation to calculate the Recommended Weight Limit (RWL) for a box. The vertical location at origin, V_{origin}, is 30 inches with an Asymmetry of 0° and the vertical location at destination, $V_{destination}$, is 35 inches with an Asymmetry of 45°.
Given that the formula in U.S. Customary units is [0.82 + (1.8/D)], what is the Distance Multiplier? Show your work calculations on this page.

(A) 0.88
(B) 0.82
(C) 0.96
(D) 1.18
(E) None of the above are correct.

(2). **(5 points)**
A change in the job of the previous question requires the worker lift the box from a position 70° left of the mid-sagittal plane to a position 70° to the right of the mid-sagittal plane. Given that the formula in U.S. Customary units is [1 – (0.0032*A)], what is the Asymmetric Multiplier? Show your work calculations on this page.

(A) 0
(B) 0.552
(C) 0.776
(D) 1.0
(E) 1.12

(3). **(4 points)**
The horizontal position of the box in the previous two questions is 6 inches from the midpoint of a line between the ankles at the origin of the lift. Given that the formula in U.S. Customary units is (10/H), what is the Horizontal Multiplier? Show your work calculations on this page.

(A) 0
(B) 0.66
(C) 0.85
(D) 1.0
(E) 1.67

(4). **(3 points)**
At the origin of a particular lift, a box is picked up from the floor in a way that V is 0 inches. Given that the formula for U.S. Customary is [1 – (0.0075 * |V – 30|)], what is the Vertical Multiplier? Show your work calculations on this page.

(A) 0
(B) 0.78
(C) 0.92
(D) 1.0
(E) 1.23

(5). **(3 points)**
You were able to calculate the Recommended Weight Limit as 25 lbs for a particular lift. The load that you were doing the initial calculation for was 51 lbs. What was the Lifting Index? Show your work calculations on this page.

(A) 0.49
(B) 1.0
(C) 1.85
(D) 2.00
(E) None of the above are true, the answer is:

FIGURE 5. Exam 2, Revised NIOSH Lifting Equation calculation questions

Students' responses on the first question indicated that the major difficulty was determining the task variables from the written job description and figure corresponding to the description. This resulted in difficulty in the calculation of at least one of the multipliers or in determining the coupling or frequency multiplier from their respective tables. The specific multipliers that seemed to cause the greatest difficulty for students were the distance multiplier (DM), asymmetry multiplier (AM), frequency multiplier (FM), and the coupling multiplier (CM).

The apparent specific details for each multiplier were as follows. For the distance multiplier (DM) and distance task variable (D), the layout of task variable part of the Worksheet seemed to cause some students to make arithmetic errors. That is, a typical error was $D = |V_{destination}\text{-}H_{destination}|$ because these values are next to each other in Step 1 of the Worksheet, which then led to errors in DM. Another multiplier that most of the class had difficulties with was the asymmetric multiplier (AM), as 20% of the students performed the calculation correctly. Indications from responses and talking to students at review sessions were due to: (1) not completely understanding the concept of neutral body position, and (2) the figure showing the position and direction of the feet (along with job description) was thought to be unclear. Therefore, the typical errors for the task variable A at the origin and destination were (A_{origin}, $A_{destination}$): (90,90), (0,90), (45,45), leading to errors in the Worksheet and AM calculations.

As in the class exercise, the use of the frequency multiplier table was difficult for many students. The aspect in the frequency multiplier table creating the most difficulty was knowing to use V_{origin} for V after determining the duration of the job and frequency of the task. The final multiplier and task variable that students had the greatest difficulty with was the coupling multiplier. Most students decided incorrectly (Table III) that the coupling was Good instead of Fair, based on the job description and corresponding figure.

Students also had arithmetic errors, particularly in calculating D, resulting in an incorrect DM because of the layout of the Worksheet, as information was misread or entered in the wrong location in the table. Other concepts that students had difficulty with were understanding that LI could be less than 1 and that no significant control at the destination means that the calculations for RWL and LI have to be made only at the origin.

The second exam question concerned redesigning the job to lower the risk of injury. Students were more successful on this question, as they provided reasonable recommendations for the redesigned job. Most students could see readily that decreasing either H or A would increase the corresponding multiplier HM or AM, respectively. Some students also saw that FM has a significant effect on RWL and recommended reducing the lifting frequency rate and/or providing longer recovery periods to increase FM, thereby increasing RWL, which would decrease LI. However, even with these successes, some students still had difficulty understanding that decreasing LI (so that the risk of injury is lower) requires RWL to increase, thereby modifying at least one of the task variables (so that the corresponding multiplier increases will increase RWL). Some students did not realize that the multiplier that has the most impact on the RWL equation is the smallest multiplier, and by increasing this multiplier, RWL is increased. The reasoning behind this is difficult to determine; it may be due to an overall understanding of concepts concerning arithmetic and fractions or simply a lack of a sense of magnitude of the multipliers. Students also had difficulty connecting their written recommendations with the modifications of the mathematical values of the multipliers and task variables.

Exam 2

The overall result of the five questions on Exam 2, which involved concepts and calculations for the Lifting Equation, was 10.26 out of 20 points. Eight out of 77 students received full credit. Question 1: 24 out 77 students (31.2%) answered correctly, Question 2: 41 out 77 students (53.3%) answered correctly, Question 3: 39 out 77 students (50.6%) answered correctly, Question 4: 65 out 77 students (84.4%) answered correctly, and Question 5: 38 out 77 students (49.4%) answered correctly.

Questions 1 and 3 showed that students did not fully understand the restrictions placed on the task variables so that the corresponding multipliers would be less than or equal to 1. More specifically, on Question 1, fewer than half the students answered correctly, with 42 out of 77 students giving the answer *d*) 1.18. Answers indicated that students did not understand that $DM \leq 1$, so that in the equation $[0.82 + (1.8/D)]$, the smallest D is 10 inches. Many students appeared to blindly plug in the vertical distance of the hands at the origin and destination into $D = |V_{origin} - V_{destination}|$ or else forgot that D is always greater than or equal 10. Therefore, if the calculated D is less than 10, the D for the DM calculation is set to be equal to 10.

Question 3, as in Question 1, showed a lack of understanding of the restriction on task variables that affect whether the horizontal multiplier, HM, is less than or equal to 1 as required. Only half the students answered correctly, and by their work calculations, they showed that they understood the concept because even though the calculation for $HM = 1.67$, often, a student wrote a comment such as "HM must be less than 1 so $HM = 1$."

For those students who missed the question, two possible reasons could be observed or assumed, such as: (1) students do not actually understand the formula together with the restriction, or (2) students blindly plug in values without thinking about the equation and the meaning of results or any restrictions on variables in the equations. Question 2 was an opportunity for students to show their understanding of the asymmetric task variable and asymmetric multiplier. Results for Question 2 showed that even after review of the concept of neutral body position and the formula for calculating AM, many students apparently still did not understand the asymmetric task variable or asymmetric multiplier.

Results also showed that more than half the students appeared to understand the concept of neutral body position and the calculation for the asymmetric multiplier; however, 31 of 77 students answered *b*) 0.552, indicating that they took A to be 140° rather than 70°. Therefore, these students did not appear to understand the concepts of neutral body position and that asymmetry angle is based on the neutral position of the body relative to the midsagittal plane at both the origin and destination.

Students had the best results on Question 4; however, 12 students still missed this question by answering *d*) 1.0 and generally did not show their work; therefore, it was difficult to determine their misunderstanding of the calculation. For students who showed their work, the issue seemed to be in understanding the absolute value symbols in the equation. Few errors on Question 5 were due to not understanding the formula for the lifting equation. Some students (∼10%) apparently did not understand the equation, as they used LI = RWL/object weight. The majority of students answered incorrectly because of rounding errors and their understanding of significant figures, as the most answered response was *d*) 2.00, which was wrong.

DISCUSSION

The results of the evaluation indicate the successes and difficulties that students have when applying the Revised NIOSH Lifting Equation in the structured situation of formal instruction in a class with given job descriptions. Results indicate that more practice through homework and, possibly, practical experience on a job site would be required for many of the students to apply the equation consistently in a real workplace with fewer errors.

Overall performance of students indicated the unexpected difficulty of a consistent inability to: (1) read the job description, (2) examine the associated figure, and (3) determine the relevant information in order to fill out Step 1 on the Job Analysis Worksheet. This was unexpected because these senior students had taken many courses (such as physics, chemistry, and math) that required them to determine information needed to solve a problem. In addition, the lack of a sense of magnitude and a general lack of number sense was evident, as many students had difficulty understanding that the smallest multiplier is the most logical one to try to modify, by modifying the associated task variable, if possible. Many students did not seem to realize that increasing a multiplier value would increase RWL, thus decreasing LI, which would be a desired result.

Results of the class exercise and Exam 1 indicate that if students manage to fill out the Worksheet correctly, then they generally can apply the formulas but still may have problems with the frequency multiplier table or still may be blindly substituting task variable numerical values without thinking about what is meant by each multiplier. That is, these two evaluation methods did not require students to understand that each multiplier must not be greater than 1. However, Exam 2 tested students' understanding of the restrictions on the task variables and how these restrictions are used when calculating the associated multiplier, RWL, and LI. Exam 2 results indicate that many students substituted the values of the task variables into the multiplier equations and then took the answer even if the multiplier was greater than 1. This was due either to: (1) a lack of understanding of the restrictions on the multiplier and task variables, or (2) possibly the stress of time in an exam situation.

Object Weight (lbs)		Hand Location (inches)				Vertical Distance (inches)	Asymmetric Angle (degrees)		Frequency Rate	Duration	Object Coupling
		Origin		Destination			Origin	Destina-tion	Lifts/Min	(hours)	
L (Avg.)	L (Max.)	H	V	H	V	D	A	A	F		C

(a)

Object Weight (lbs)		Hand Location (inches)				Vertical Distance (inches)	Asymmetric Angle (degrees)		Frequency Rate	Duration	Object Coupling
		H = Horizontal		V = Vertical			Origin	Destina-tion	Lifts/Min	(hours)	
L (Avg.)	L (Max.)	Origin	Destina-tion	Origin	Destina-tion	D	A	A	F		C
										≤ 1 hour > 1 but ≤ 2 hours > 2 but ≤ 8 hours	Poor Fair Good

(b)

FIGURE 6. (a) Original Step 1 of Job Analysis Worksheet; (b) Suggested redesign of Step 1

A difficulty for students arose in the use of the Worksheet for Step 1. Several students had difficulty recording the task variables in the right place. In particular, the vertical distance, D, was often calculated as $D = |V_{destination}\text{-}H_{destination}|$, rather than the actual value of $D = |V_{origin} - V_{destination}|$ because these values are next to each other in Step 1, which then leads to errors in DM. Other problems for students on the Worksheet were the mixing of values for task variables and multipliers in Step 1, which may be addressed by redesigning the worksheet for Step 1 (Figure 6). The first modification would be to place the horizontal (H) component at the origin and destination adjacent to each other. Next, place the vertical location of the hands (V) at the origin and destination in adjacent columns, and then, in the next column, place D so that the calculation seems more natural. To avoid mixing task variables and multipliers, the redesign has the individual who is evaluating the task *circle* the task variables for duration of job and coupling type.

RECOMMENDATIONS

This study of the difficulties students had in understanding the concepts, formulas, and tables involved in the Revised NIOSH Lifting Equation has led to two recommendations: (1) students may need more supervised practice in using the Job Analysis Worksheet before they try to analyze a complete task on their own (giving them well-designed homework in which they have to use the tables and formulas, as well as homework that takes into account the restrictions on the task variables); (2) redesign the layout of Step 1 (Figure 6) in the Worksheet, since the current layout (Figure 1) of Step 1 seems to make it easy to make arithmetic errors.

In addition, students mixed values for task variables and multiplier calculation values in Step 1. The redesign will reduce arithmetic errors in both determining task variables, multiplier values, RWL, and LI. In particular, by placing the columns for H at the origin and destination next to each other, and placing V at the origin and destination next to each other with D in the next column following the two columns for V, D will be more easily calculated.

The redesign will force the individual who is analyzing a job to fill out the Worksheet with all the task variables before making any calculations for multipliers or looking at the tables for multiplier values. The individual performing the job analysis will be more likely to use both the coupling and frequency multiplier tables correctly because he/she has entered in lifts/min, circled the duration and coupling type, and then looked at V for the origin and/or destination depending on whether significant control is required. It is recommended that the redesigned Worksheet be tested to determine whether fewer arithmetic errors are made and if it is less confusing for an inexperienced user to complete.

CONCLUSION

This case study shows that formal instruction in applying the Revised NIOSH Lifting Equation still raises issues of understanding the calculations of RWL and LI. The study identified difficulties that students have with the restrictions on the task variables and multipliers and recognized that students have a difficult time obtaining relevant information from a written job description. The limitation of the study is that there is no comparison of the students with a group of individuals who have studied the Lifting Equation through self- or independent study of the material in Publication 94-110. It is recommended that the Job Analysis Worksheet be redesigned and then evaluated for the effectiveness in reducing arithmetic errors in the calculation of RWL and LI.

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