

# **An Evaluation of Manual Lifting and Carrying Works in Forest Nurseries by Means of the Revised NIOSH Lifting Equation Method**

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**Abstract:** This study aimed at an evaluation of the working postures in loading the sapling pots on to tractors and loading the saplings to be transported on to trucks in the forest nurseries by means of the Revised Lifting Equation (NIOSH) ergonomic risk assessment method. Under this study, we camera-recorded the works we examined in the Trabzon-Of forest nursery thoroughly and determined the working posture types of workers in the footage. We weighed the load (L) that workers carried manually, and scaled the values such as horizontal position (H), vertical position (V), vertical carrying distance (D) and asymmetry angle (A) on workers. We put the data obtained into the interface of NIOSH ergonomic risk assessment method in the ErgoFellow software and calculated the values of lifting index (LI) for both works. These evaluations provided us with the LI values of the works of loading the pots on to the tractors and loading the saplings on to the trucks as 0,54 and 0,35 respectively. In both loading works, lifting index values were found different despite the fact that workers made similar movements. This may be because workers lifted the pots from different height and put them up to different heights in loading sapling pots on to tractors whereas they carried them from the same height to the same height in loading the saplings on to trucks. Lifting index values lower than 1 may be due to the fact that the load lifted was light and the loading work was conducted by several workers at a time.

**KEYWORDS:** Hand carrying works, Work position, Ergonomic risk assessment, Revised lifting equal, Forest nursery.

## I. INTRODUCTION

As a result of the physical effort exerted by workers, one of the most common health problems worldwide is musculoskeletal system diseases (WMSD) [1, 2, 3, 4]. In a study conducted by the Occupational Safety and Health Administration (OSHA) with a view to reflecting the occupational health profile in member countries, it was found that 34% of workers complain from exposure to heavy lifting [5]. Examination, analysis and improvement of working postures by means of scientific methods contribute significantly in mitigating WMSDs. It is therefore critically important to determine the ergonomic risk levels by means of scientific methods in manual load lifting and carrying works.

Manual load lifting and carrying works are among the main works conducted in daily life in working environments. These works have been defined as any activity requiring the use of force exerted by a person to lift, lower, push, pull, carry, move, hold or restrain a person, animal or object [6, 7]. MLSS (2013) [8] enjoins the employers to make a work organization in such a way that there would not be any need to carry the loads manually in the working place and to ensure carrying of loads by appropriate methods. In cases where manual load carrying is indispensable, employers shall be responsible to apply the methods and to make the required adjustments in order to mitigate the risks that may arise from manual carrying considering the characteristics of the load, physical force requirement, and characteristics of the working environment as well as requirements of the work.

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Main factors that turn working postures dangerous include awkward positions, extreme frequencies and speed of movement, manual load lifting and carrying, excessive forces and insufficient time for regeneration between two movements [9, 10]. The most compelling elements for those who work in the lifting works are that the load is on the ground level or higher than the level of shoulders, sloping up excessively, and leaning down instantly directly from the back without crouching down through the knees [11].

## II. RELATED WORK

There are some studies on ergonomic risk assessment of lifting and carrying works in activities of wood raw material production in forestry industry [12, 13] while those on forest nurseries are only limited [14]. It was evaluated in [13], the lifting, holding and carrying works in wood raw material harvesting activities by means of the Leitmerkmalmethode zur Beurteilung von Heben, Halten, Tragen (LMM-HHT) method. Risk score of this work was calculated as 63,6 and the work was found to be in the risk class 5, which revealed that it was highly probable for chopping workers to suffer from musculoskeletal system problems due to overloading.

[15] has listed the work branches where musculoskeletal diseases are most often seen particularly as forestry, farming, gardening, loading and unloading, fishing, mining, manufacturing, and machinery operation. Many studies emphasized the need to conduct further research on work-related diseases in labour-intensive industries [16, 17, 18, 19]. Manual load lifting and carrying works are conducted at different scales and under different ergonomic conditions in each work place. As standard criteria can hardly be defined for these works, it is necessary to evaluate every individual manual lifting and carrying work by taking into consideration the individual parameters of that individual work. This study, therefore, looked at an ergonomic risk assessment of manual lifting and carrying works that are intensively carried out in forest nurseries.

There are various ergonomic risk assessment methods available to evaluate manual lifting works. Nevertheless, many of these methods do not take into account the distance of carrying the loads although they take into account the working posture and the weight of the load lifted. Among these methods, the revised NIOSH method has been improved for repetitive static works, while the other methods such as OWAS (Ovako Working posture Assessment System) and PATH (Posture, Activity, Tools and Handling) may be used in dynamic conditions [20]. This method requires detailed information about specific parameters of the posture, to give high sensitivity with respect to the defined indices [21]. [22] determined that 59% of the certified ergonomists for JHSC members recommended the revised NIOSH equation method. Similarly, [23] stated that ergonomists found the revised NIOSH lifting equation method suitable to evaluate the lifting works in various professions.

Therefore, this study evaluated the risks inherent in the works of loading the sapling pots on to tractors and loading the saplings to be transported on to trucks in the forest nurseries by means of the Revised Lifting Equation (NIOSH) [24].

## III. PROPOSED METHODOLOGY AND DISCUSSION

This study was conducted in the forest nursery of Trabzon-Of (40°58'39"-40°59'03" N, 40°19'34"-40°20'19" E). General outlook of study area was presented in Figure 1. The Trabzon-Of forest nursery is 5 meters high from sea level, facing to the South, with a surface area of 242,04 ha. This forest nursery has a production capacity of 2.468.0420 piece/year.



Figure 1. General Outlook of Study Area

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This study examined the works of loading the empty polyethylene pots on to tractors and loading the saplings ready to sell on to trucks in the Trabzon-Of forest nursery. First, we recorded both works from beginning to end, then analyzed the records to determine the work processes and working posture types of workers. We observed that during these works workers displayed working postures such as bending down and stretching, lifting, carrying, lifting up and stretching. As shown in Figure 2, when loading polyethylene pots on to tractors, pots piled on the ground on top of another were taken from different heights at every time and put on to the shelves of the cabinet on the tractor-trailer at different heights. Research and observations have shown that workers displayed 18 different working postures until the work is concluded as pots were taken from different heights and placed on to different heights.



Figure 2. Loading pots on to tractors

The work of loading saplings on to trucks was conducted by workers taking the saplings placed side by side and carrying them to trucks and putting them on to the truck haulage. It was found that workers displayed only one single working posture because all saplings were taken from the same height and put on to the same height as well.

Risk levels of manual lifting and carrying works examined in forest nurseries were assessed by means of the NIOSH ergonomic risk assessment method. As shown in Figure 3, the values of load (L: kg), horizontal lifting distance (H: cm), vertical lifting height (V: cm), vertical travel distance (D: cm) and asymmetry (A: (o)) were measured on workers in these works (Figure 3).

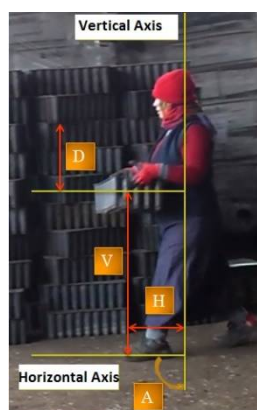


Figure 3. Manual carrying parameters of workers

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We have examined the footage of the works thoroughly and determined the duration of lifting period (F) which shows the number of lifting per minute (number of lifting/min). Furthermore, the gripping (C) variable, which is the object-gripping quality of hands, was categorized as good, sufficient or bad. These data obtained were put into the NIOSH ergonomic risk assessment method interface in the ErgoFellow software to calculate the lifting index values for both works.

The NIOSH lifting equation method is based on a calculation of the Recommended Weight Limit (RWL) equation by determining the factors given in standard tables prepared for seven different mission variables measured and observed [25].

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

Here, LC (load constant) stands for the weight that can be lifted at the acceptable limits under optimal conditions while HM (horizontal multiplier) indicates the variable depending on the distance between the middle point of hand and the spinal axis (if  $H \leq 25$  cm,  $HM=1$ , for  $25 < H \leq 63$  cm,  $HM=25/H$  and for  $H > 63$  cm,  $HM=0$ ). VM (vertical multiplier) depends of the distance of the load-holding point to the base and is taken as 0 for  $V \geq 175$  cm while for  $V < 175$  cm,

$$VM = \{1 - [0.003 * (V - 75)]\}$$

is calculated from the equation [26]. DM (distance multiplier) is a factor depending on the distance and taken as 1 for  $D \leq 25$  cm, 0 for  $D > 175$  cm and for  $25 < D \leq 175$ ,

$$DM = \left[0.82 + \left(\frac{4.5}{D}\right)\right]$$

is calculated from the equation. AM (asymmetric multiplier) is the angle of asymmetry that determines the body position according to the plane that divides the body into two pieces as right and left at the beginning or end of the lifting movement, and is taken as 0 for  $A > 135^\circ$  while for  $A \leq 135^\circ$ ,

$$AM = (1 - 0.0032 * A)$$

is calculated from the equation [27]. The FM (frequency multiplier) value is calculated depending on the number of lifting work per minute (F), the vertical lifting distance (V) and working time (t) from Table 1.

Table 1. Frequency of weight lifting

Number of Lift (F) (n/sec)	Working time					
	t < 1 hour		1 hour < t < 2 hours		2 hours < t < 8 hours	
	V < 75	V ≥ 75	V < 75	V ≥ 75	V < 75	V ≥ 75
≤0,2	1	1	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
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

CM (coupling multiplier) is a factor that depends on how easy and well a hand can grip the load to be carried and determined by a classification according to the vertical distance (Table 2).

Table 2. Classification of gripping status [28].

Gripping Status	V < 75 cm	V ≥ 75 cm
Good	1	1
Mean	0,95	1
Poor	0,90	0,90

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Lifting index (LI) value is calculated [29] as the proportion of the value of weight lifted (L) to the RWL value calculated from Equation as

$$LI = \frac{L}{RWL}$$

According to the lifting index (LI) value, danger classes and measures to be taken for the work assessed are determined from Table 3.

Table 3. Danger classes of lifting index and measures [28].

Lifting Index	Class	Measure
> 1	Safe	Not necessarily
1,0 - 3,0	Dangerous	Make a ergonomical adjustment
>3,0	Very Dangerous	Very urgent make a ergonomical adjustment

The H, V, D, A, F, C and L values that are determined by measurements for the lifting works are put into the relevant parts in the NIOSH method interface of the ErgoFellow software and the RWL and LI values were calculated thereby (Figure 4).

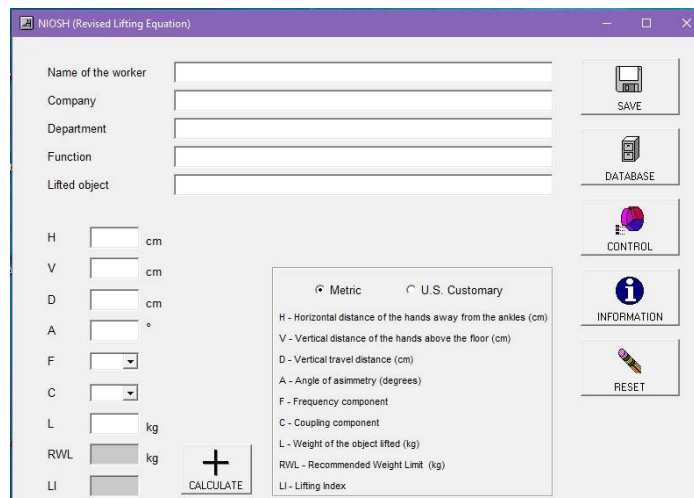


Figure 4. The NIOSH method interface in the ErgoFellow software

## IV. EXPERIMENTAL RESULTS

Ergonomic analysis of the works of loading the sapling pots on to tractors and loading the saplings to be transported on to trucks in the forest nurseries were conducted by means of the NIOSH method.

RWL and LI were calculated by using the V, D, H and I data in the NIOSH lifting equation determined for 18 different movements specified for loading on to tractors, and the LI values were averaged (Table 4).

Table 4. RWL and LI values for loading pots on to tractors

Moves	V (cm)	D (cm)	H (cm)	A (o)	RWL	LI
1	150	15	28	45	5,58	0,45
2	130	10	20	60	6,34	0,39
3	110	20	10	45	7,20	0,35
4	50	55	40	45	3,88	0,64

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5	30	70	42	180	3,93	0,64
6	10	115	38	160	3,93	0,64
7	150	0	20	60	5,90	0,42
8	130	20	15	105	5,17	0,48
9	110	40	16	90	5,53	0,45
10	90	55	20	180	8,02	0,31
11	70	85	30	180	6,11	0,41
12	160	70	32	60	3,90	0,64
13	150	70	30	180	5,32	0,47
14	130	90	28	135	3,45	0,72
15	10	115	38	120	2,44	1,02
16	50	85	30	105	3,79	0,66
17	30	70	20	150	6,55	0,38
18	10	145	20	105	3,89	0,64
Average						0,54

RWL and LI values were calculated by using the V, D, H and A values measured on 5 workers for the work of loading on to trucks, and the LI values were averaged (Table 5).

Table 5. RWL and LI values for loading saplings on to trucks

Workers	V (cm)	D (cm)	H (cm)	A (o)	RWL	LI
1	0	45	10	45	8,01	0,31
2	0	40	15	45	8,11	0,31
3	0	50	10	90	6,58	0,38
4	0	48	0	90	6,61	0,38
5	0	55	20	90	6,52	0,38
Average						0,35

As a result of the evaluations, the averages of lifting index values of the works of loading sapling pots on to tractors and loading saplings on trucks were found to be 0,54 and 0,35 respectively. The fact that the lifting index values in both loading works is smaller than 1 indicates that the risk of pack pain is not high for these works in forest nurseries. The LI value was found to be more than 1 in different sectors where lifting and carrying works were evaluated by means of NIOSH method [30, 31]. [32] displayed in a study conducted by changing the parameters in NIOSH lifting equation that the most effective parameter that leads to a higher LI value was the weight of the load carried. It may be due to the fact that the pots lifted in forest nurseries and the load carried when loading the saplings on to trucks are lighter than those lifted in other sectors.

### V. CONCLUSION

The LI values were found lower than 1 in both of the works of manual lifting and carrying which originally seemed to be tiresome. It might stem from the fact that the loads lifted such as pots and saplings are not very heavy, that the carrying distance is not long and that the work is conducted simultaneously by many workers. The increased number of workers in the lifting and carrying works decreases the work load per person.



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In both of these forest nursery works, despite the fact that workers displayed similar working postures, their LI values were found different from each other. LI values were found different because, in the work of loading on to tractors, workers take pots on top of another from different heights and put them on the shelves on the tractor at a different height whereas, in the work of loading on to trucks, workers take the saplings standing side by side on the ground from the same height and load them on to the truck at the same height.

Lifting arms specifically designed for lifting and carrying pots, allowing workers to lift loads up to 10 kg without bending down, can be used to facilitate the work of workers. Moreover, workers should be given training about proper working methods and safe behaviour techniques relevant to manual carrying works at the recruitment.

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