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Analysis of the lifted weight including height and frequency factors for workers in Colombia

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Abstract. Factors related to the height of the load and the frequency of handling have become a way to predict the acceptable standard weight lifted for workers whose main task is the manual lifting of materials and measuring the conditions is important to determine a maximum weight lifted. This study was conducted to twenty (20) workers between eighteen (18) and forty (40) years old with a minimum six months experience and belonging to the warehouse and packaging area of a dairy products company. Consideration was given to three different heights such as knuckle, shoulder and total height as well as frequencies of 2, 4 and 6 times per minute. Average values for lifted weight were 17.9306 ± 2.37 kg. The conclusions and recommendations included a review of legislation related to Colombian maximum acceptable weight of lifting due to the current law does not match the acceptable weight handled in this research.

Keywords: acceptable lifted weight, manual material handling, muscle skeletal disorders, ergonomics design

1. Introduction

Since the beginning of the twentieth century, the first Colombian trading companies were created to meet new market needs; however, manual material handling operations has always been developed by low cost labor by uneducated workers. It was never paid attention to the workplaces conditions of these were carried out and whether complaints or injury occurs, which can interfere with their work, usually occurring dismissal and replacement of the person. [5] [6] [15].

Although, there is a high degree of mechanization, in material handling and, an increasingly usage of technical elements; those, are in general unsuitable for the workers in Colombia due to their size and proportions with respect to the local anthropometrics [3] [4]. Even the imported equipment from USA, Germany or some European countries, need to be adjusted to correspond to the anthropometry of Colombian and Latin American workers.

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In the United States, a research study conducted by the National Safety Council found that the major cause of workplace injuries were overexertion in 31%. The back was the body part most often injured by 22% or 1.7 million injuries. This problem is also present in many European Union countries. According to the latest figures of the European Survey on Working Conditions (ESWC)(2005), 24.7% of the European workers complain of backache, 22.8% of muscular pains, 45.5% report working in painful or tiring positions while 35% are required to handle heavy loads in their work. Blue-collar and service workers tend to be more exposed to physical risks such as carrying or moving heavy loads, painful and tiring positions and vibrations, while repetitive work and working at high speed affect all occupations. Prolonged standing and walking is a notable risk factor in the "traditional" sectors such as agriculture, construction, and also greatly affects workers in service professions; above all in hospitality and retail. The fact that is, the statistics barely reflected the monitoring and recognition of lower-limb disorders. Self-employed workers are also very concerned, being overexposed to tiring and painful positions (54.8% vs. 43.5% of the employed), carrying or moving heavy loads (44.7% vs. 33.1% of the employed), repetitive movements (64.5% vs.61.7%), and prolonged standing and walking (77.3 vs. 72%). The available data from the Member States give a more detailed picture concerning the groups at risk in the different countries [2] [3][4].

Over the years, the companies aware of the occupational risks, has tried to reduce progressively the maximum lifting of loads, because it has detected the danger posed by the handling of excessive loads. Studies have estimated that individuals who perform manual handling of heavy materials are three times more likely to develop lower back pain for workers who perform tasks that do not include it. These injuries, although not fatal injuries can be long and difficult in healing, and in many cases require a long rehabilitation periods, causing great human and economic costs, since the worker is often unable to perform their usual work and their quality of life may be affected.

The International Labor Organization (ILO) says that 20% to 25% of accidents are caused by manual-material handling. In response, the ILO established the Convention # 127, which contains provisions on the maximum weight of load carried by one worker [7][8][11]. Until 1962 allowed the lifting the arm up to 80 kg, but in that year, the ILO found the load weight not suitable for occasional lifting technique as shown in Table 1.

Table 1
Load weight established by the ILO

AGE	WEIGHT PERMITTED MALES (Kg)	WEIGHT PERMITTED FEMALES (Kg)
14 to 16	15	10
16 to 18	19	12
18 to 20	23	14
20 to 35	25	15
35 to 50	21	13
Over 50	16	10

In Colombia, after the Law 100 of 1,993 has devoted invested new economical resources to research, new solutions related to occupational diseases and thus have better control and prevention of them [1]. A clear example of this initiative was the study by the Social Security Institute (ISS) in Colombia, where it was identified ergonomic risk factor with respect to physical loads and awkward postures in workers who were located in the Bogota and Cundinamarca ISS, in addition the study also determined the prevalence of musculoskeletal diseases in the population studied [9]. This research included a sample of 53 companies of different economic activities which analyzed 203 jobs in specific areas of warehousing, storage and production. The results are striking and show the need for further research in this field: the exposure to awkward postures was 100% to 90.5% repetitive tasks and handling charges of 86.8%. The level of physical load determined for 77.8% of jobs assessed a higher charge level. The total of the jobs studied some risk for material handling.

2. Objective

To determine the maximum acceptable weight of lifting a (30x40 cm) basket under pre determined height and frequency conditions

3. Method

3.1. Reference population

The necessary requirements of the employees to perform this study were: males between 18 and 40 years of age with at least six-month experience in manual material handling, being gainfully employed by the company during the study, and voluntarily accepting the commitment with the study through an informed consent.

The sample size was determined with the normal function using the following equation with a confidence level of 95%. Eq. (1):

$$n = \left((Z_{\alpha/2})^2 * \sigma^2 * N\right) \Big/ \left(e^2 * (N-1) + (Z_{\alpha/2})^2 * \sigma^2\right) \quad (1)$$

Where

Z= Value obtained from the Normal Distribution chart. For this, the Z value for a significance level of 0.05 is 1.96.

σ = is the value for sigma, taken from the study by Leonardo Quintana in 1999. σ = 1.96 [10]

N = total number of records per employee to perform the nine treatments. For this number of records has been applied the following calculation:

N= (3 Heights * 40 registers) + (3 Heights * 80 registers) + (3 Heights * 120 registers)

N= 720;

$\alpha/2$ = Significance level;
e = Error
e =0.05 * x, where, x = mean of the records. [14]

After applying the formula, it is obtained a sample size equal to 14.45 people and this result is obtained approaching a value of n = 15. However, providing any kind of difficulty on the part of employees or loss of records in some treatments, it was decided to take an additional of 30% of the sample as a safety measure, resulting in a sample of **n = 20 individuals**.

Importantly, the research was developed with all proposed records, working with 20 employees, without loss of data.

3.1.1. Independent or control variables

The variables which controlled the experiment were the frequency and heights are detailed below:

Frequency

It is the number of times an individual performs a task during a period of time (in this case during a minute) in equal fractions of time. The following table describes the three frequency categories.

Table 2
First variable. Frequency

First Variable	Category	Description
Frequecy (F)	**1**	2 times per minute, that is every 30 seconds
	2	4 times per minute, that is every 15 seconds
	3	6 times per minute, that is every 10 seconds

Recording was performed for each of the frequencies, ensuring accuracy in time for the execution of the task with the following methodology: the recording started and allowed three seconds for each lifting, instructing the participant with the following sentence: "three, two, one, lift".

Height

It refers to different heights to which employees are subjected to the task of lifting material. The following table describes the three height categories.

Table 3
Second variable. Height

Second Variable	Category	Description
Height (H)	**1**	From the floor to the knuckles. (0 to 52.5) cm.
	2	From the knuckles to the Shoulders. (50 to 125) cm.
	3	From the Shoulders to the Maximum Reach. (125 to 175) cm.

3.1.2. Dependent variables

Recommended Weight Lifted (RWL)

Participants had to test the weight of the plastic crate before each lift to remove or insert bags. They were to assess the weight they could lift without doing much physical effort and accommodation of the bags according to the capacity of the crate.

3.2. Description

Each of the 20 participants performed nine (9) treatments. The number of treatments needed was obtained through the possible combinations of the two independent variables with their respective categories. The treatments described below by the following table:

Table 4.
Assignment of treatment number according to its description

Frequency	Height	Treatment	Description of Treatment	
1	1	I	2 Times / minute	Floor - Knuckles
	2	II	2 Times / minute	Knuckles - Shoulders
	3	III	2 Times / minute	Shoulders – Maximum reach
2	1	IV	4 Times / minute	Floor - Knuckles
	2	V	4 Times / minute	Knuckles - Shoulders

Once the participant was informed of the conditions of the treatments, an explanation was done on the equipment to use. Then through the Polar software the pulse data was transmitted to a computer, data related to the name, date of birth, weight and height of the participant, were also recorded in the database. After the heartbeat monitor was placed and detected heart rate, then the data entry was performed from the electronic scale information.

The method was explained to the participant during the treatment, according to the combination of height and frequency variables. There was no established protocol to the positions adopted by participants while performing the lifting load. Immediately, the heartbeat monitor and voice recording were set, to variate the frequency of the lifting according to the protocol. This allowed the heart to take the frequencies at a given time and ensuring accuracy over time. After 20 minutes the heart rate monitor was stopped.

4. Results

4.1. Statistical elimination of recorded extreme values

A statistical procedure was done to depurate the data obtained, called "elimination of outliers," in this, we eliminated records for lifted weights, which were found in each of the ends of the distribution; they are not representative in the real values of the load, this allowed to eliminate values that did not correspond to patterns of decisions and actual perceptions of the participants using the psychophysical method, but is related to unilateral and personal decisions to add weight too low or too high that do not correspond to the generality of its lifting.

The percentage of data elimination through this method is usually 5%; said value is applied to eliminate registers corresponding to these weights; thus, discarding 2.5% of the extreme low values, as well as 2.5% of the 37 extreme high values. This also permits eliminating atypical or outlying values, i.e., extreme observations found beyond the interval (x ± 3σ).

Detection of values corresponding to the upper and lower 2.5% is done by determining the corresponding percentiles, that is, the 97.5 and 2.5 percentiles obtained via the SPSS program; the results obtained are presented in Table 5

Table 5
Percentiles of elimination of extremes

N	VALID	14,400
	Lost	0
Percentiles	2.5	11.4808
	97.5	24.02

From the above, of the 14,400 points of data obtained, only 13,403 registers were used for the recommended weight lifted analysis. These are the data comprised between the values of 11.48 and 24.02 Kg., i.e., the 997 data not used correspond to the values eliminated within the 5% of the extreme data.

4.2. RWL variables descriptive statistics

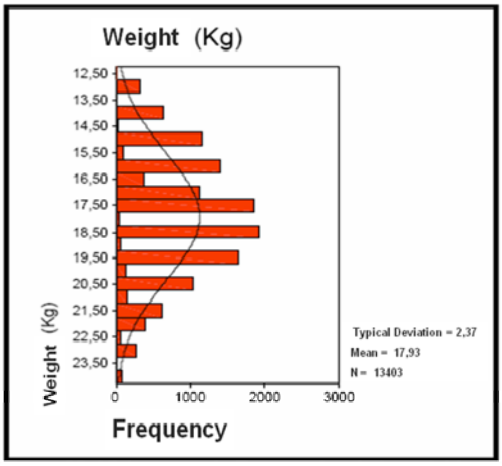
As can be observed (table 6), the general mean for all the registers obtained for weight lifted in all the sessions, for all the participants, corresponds to 17.93 Kg, which becomes our mean acceptable maximum weight for the lifting task. The maximum weight for the lifting task for males with prior experience in handling materials, corresponding to the 90 percentile, according to this study is 21.2 Kg, which is 15.2% below the maximum 25 Kg weight permitted by the Colombian legislation under the same characteristics

Table 6
Variable descriptive statistics

N	VALID	13,403
	Lost	0
Mean		17.9306
Typical Deviation		2.37099
Variance		5.62161
Minimum		12.69
Maximum		24.01
Percentiles	5	14.05
	10	14.9300
	25	15.8800
	50	17.7000
	75	19.5000
	90	21.2800
	95	22.1900

4.3. Normality analysis for the RWL variable

As a complement for the descriptive statistical analysis carried out, it was determined if the data corresponding to the weight lifted variable present a normal distribution, which will be considered for further analyses. To verify this, it was conducted a preliminary graphic analysis, from Figure 1, contrasting the frequency histogram against the normal curve; although, it apparently does not follow this distribution.



Figure•1. Frequency histogram for the WL variable

The final verification is done through the Kolmogorov Smirnov test. This test stems from the hypothesis that the data present a normal distribution, as long as the significance is above 0.05 when working with a 95% confidence level. In this case, the alternative hypothesis is accepted given that it obtained a value of 0.00, which proves the non-normality of the data.

It is observed in Figure 1, in the frequency histogram, comparing the normal distribution curve, although generally the data tend to form the Gaussian distribution, there are intermediate values whose frequency is very low with respect to values presenting high frequencies; this generated the non-normality of the data

4.4. Univariate analysis of variance (ANOVA) for the RWL

First, given that the variable of analysis does not have a normal distribution, prior to conducting an analysis of variance (ANOVA), we proceeded to confirm the assumptions of the origin variable, which permit conducting the parametric ANOVA test, as a statistically valid test. If these assumptions are not fulfilled, a nonparametric test must be done. The assumptions to be fulfilled are:

1. Equality Variance of the Groups
2. Normality of the Residuals

If these two assumptions were confirmed, we could state that the significance relationships found in the subsequent ANOVA test are valid for the study, although the distribution of the RWL origin variable is not normal.

The Levene test was done to prove the variance homogeneity of the groups (Table 8), i.e., it contrasts the null hypothesis that the error variance of the dependent variable is equal along all groups, obtaining the following results. The significance of 0.000 indicates that the null hypothesis is rejected and, thus, the variances of the groups are not homogeneous.

The Kolmogorov – Smirnov test was performed of the typified residuals of the origin variable to prove if such present a normal distribution. The significance result of 0.000 is lower than 0.05, for which the null hypothesis is rejected, indicating that the residuals are not normal. With these results, we cannot validate the results obtained by the ANOVA, leading us to conduct an alternative analysis of this test, which is the non-parametric KRUSKAL-WALLIS test.

As an alternative means to the ANOVA analysis, there is the possibility of conducting a nonparametric analysis through the Kruskall-Wallis test, which permits determining the differences among the groups analyzed (categories 1, 2, 3) of the height and frequency variables. The 0.0 significances obtained are not above 0.05, for which the null hypothesis is rejected, confirming differences among weight groups, caused by the influence of height and frequency control variables. It may be concluded that the groups (factor categories) are different amongst themselves and that each category and variable influences differently on the response of the dependent variable, in this case the weight variable.

The homogeneous subsets of the dependent variable, generated by the factors cannot be determined through this test, for which, from the determination of the significance of the factors with respect to the variable, through the nonparametric Kruskall Wallis test, we proceeded to an analysis from descriptive statistics and the nonparametric Mann-Whitney test to identify these groups

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4.5. Relationship among the control variables and the RWL variable

It can be seen the means for the weights lifted with respect to the possible combinations of the independent variables (height, frequency). It has purpose to compare them (Table 7).

Table 7
Relationship between control variables and the RWL variable

H	F	RWL(Kg)	TD	N
1	1	18.8875	2.21415	715
	2	18.3145	2.24366	1538
	3	18.0856	2.29287	2280
	Total	18.2897	2.28054	4533
2	1	18.5336	2.55348	780
	2	18.4179	2.43978	1460
	3	18.1589	2.37276	2266
	Total	18.3077	2.43101	4506
3	1	17.2024	2.18723	743
	2	17.2935	2.03969	1434
	3	17.0741	2.32626	2187
	Total	17.168	2.21386	4364

H: Height F: Frequency
RWL: Weight Lifted TD: Typical Desviation

It can be observed that the greatest average weight lifted was presented by Frequency 1 (2 times per minute) combined with Height 1 (Floor – Knuckles), and the average values tend to diminish as frequency and height increase, that is, when increasing the number of repetitions (Freq 2 = 4 times x min & Freq 3 = 6 times x min) and when increasing discomfort of load heights (Height 2 = Knuckles – Shoulder & Height 3 = Shoulder – Max Reach). Bearing in mind the previous tendency, it is clear that the lower average value registered for the weights lifted, corresponds to height 3 combined with frequency 3.

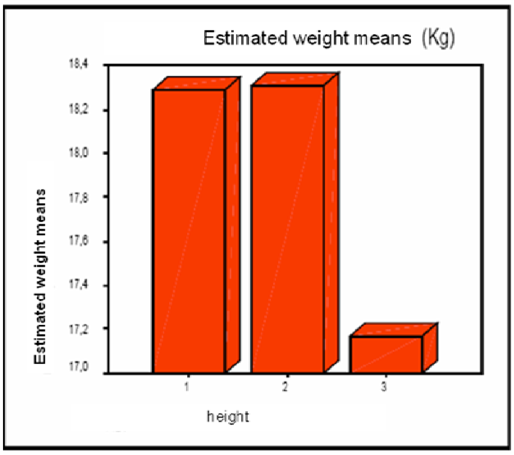
4.6. RWL variable and height

Note the descriptive statistics corresponding to each of the 3 categories of the height control variable (Table 8). It can be observed that the confidence intervals are very close to the mean values; hence, these values are quite representative for each height.

Table 8
Descriptive statistics of the RWL Variable and Height

H	Mean RWL	TD	Lower limit 95%	Upper limit 95%
1	18.28	2.28	18.222	18.357
2	18.30	2.43	18.24	18.375
3	17.16	2.21	17.099	17.237
Total	17.93	2.37		

It can be noted that, in spite of differences among the means of the groups corresponding to categories 1 and 2 (18.2 and 18.3 Kg), they are sufficiently close to consider them like one sole homogeneous group, differenced from the group made up of category 3 with a 17.16-Kg mean (Figure 2).



Figure•2. Weight means for each height category

It can be concluded that definitely height 3, corresponding to elevation of loads between shoulder height and the maximum reach, generates a reduction in weight lifted.

4.7. RWL variable and frequency

It can be seen (Table 9) the descriptive statistics corresponding to the frequency control variable; regarding the dependent weight lifted variable, it may be observed that the confidence intervals are very close to the mean values, thus, these are quite representative values for each frequency.

Table 9
Descriptive statistics of the RWL variable and Frequency

F	Mean RWL	TD	Lower limit 95%	Upper limit 95%
1	18.20	2.43	18.107	18.303
2	18.01	2.30	17.949	18.088
3	17.78	2.38	17.725	17.838
Total	17.93	2.37		

From the bar graph in Figure 3, it can be seen that each of the three frequency categories generates differences with the others, with respect to weight lifted, i.e., three groups are formed clearly differentiated in their means (17.7 – 18 and 18.2 Kg).

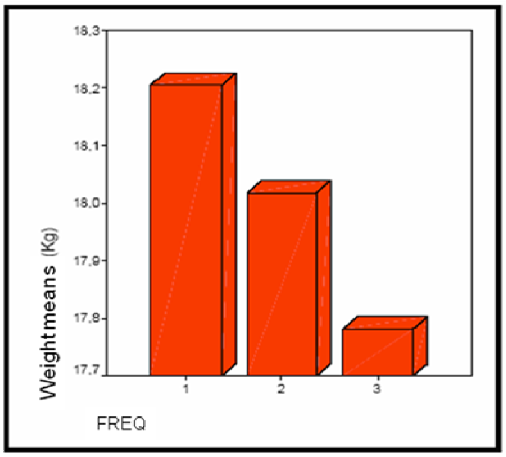


Figure 3. Weight means for each of the Frequency categories

5. Conclusions

For these types of studies, it is recommend the statistical elimination of the 5% from the extreme or outlying data because the behavior of the participants through psychophysical analysis does not always respond to the sense of comfort the participants may have, but to particular and unilateral decisions toward high weights (competition) or low (no collaboration).

The maximum acceptable weight for the lifting task with a 30x40-cm basket is 21.2 Kg, corresponding to the 90 percentile of the distribution; this value is 15.2% below the 25-Kg limit established by Colombian legislation [9]. This limit keeps and improves the guarantee of adequate ergonomic conditions by reducing the exposure to strain and reduces the individual's physiological response; thereby improving work comfort during the course of the activity [7] [8].

The height control variable directly influences upon the magnitude of the weight lifted directly proportional to increased load movement height [12] [13]. Heights 1 and 2 (18.28 and 18.30 Kg.), form a homogeneous data subset, different from the subset formed by height 3 (17.16 Kg.) in which the weights lifted are lower than those for the two other categories. It is concluded that between heights 1 and 2 the weight lifted is not significantly affected, and that height 3 diminishes the weight lifted by 6.6% with respect to weights lifted by the other two categories, this height poses the greatest difficulty for lifting loads with this type of tray.

The frequency control variable directly influences upon the magnitude of the weight lifted inversely proportional to increased frequency of load lifting, and the weights lifted, corresponding to each frequency category, present different values (17.7, 18 and 18.2 Kg.), forming three homogeneous data subsets. It can be concluded that each increase of repetitions per minute, significantly influences upon the load lifting capacity, diminishing the weight lifted as the number of repetitions per minute increases.

6. Recommendations

The protocol developed during this study, established by the University of Houston, should have an initial phase of prior assessment of the load conditions from the labor context in the country where it is being executed. So that, from this assessment, we can determine the best combination of heights and load frequencies that are actually representative of the real labor activity to obtain results according to such, which permit optimally concluding the acceptable conditions for handling loads.

Participant times of preparation prior to the activity and the times of recovery should be approximately 20 minutes. With lower times it is necessary to foresee that the activities developed by the individuals before treatment do not affect their physiological response and, likewise, affect the measurement of the treatment subsequently done. A 20-minute period of time guarantees rest conditions before performing the activity.

The maximum recommendable weight to handle in the 30x40-cm basket should be 18 Kg, which corresponds to the mean obtained for all the treatments, given that the 21.2-Kg weight corresponding to the 90 percentile does not permit adequate functionality of the basket, given that it takes to the limit the acceptable values of the physiological response. Additionally, this weight level fills the basket to a point that it hinders its functionality, when avoiding the assembly of one basket over another.

A study should be conducted on the maximum acceptable weight for pulling activity, buecause during daily activities in the company there are numerous tasks that are developed through this method when moving pallets while loading or unloading of trucks or moving products on the loading dock

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