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Psychophysical study of manual loads transportation - a comparative study between students and seasoned workers

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ABSTRACT

The psychophysical criteria are important to develop manual material handling guidelines. It is essential that the studies that use a psychophysical approach be carried out as accurately as possible. However, the sample used in these studies can influence the results, if not appropriate. This work intends to analyze the influence of the sample in determining the maximum acceptable weight (MAW) in tasks of manual transport of loads transportation. The study involved 10 students and 10 workers. The participants' task was to carry a box for 13 minutes and travel six meters. The box had the dimensions of 60 cm length × 40 cm width × 40 cm deep and the handles had 2.7 cm width and 9.0 cm in length. Moreover, subjects were required to carry out the movement of the box with the trunk erect and the forearms perpendicular to the body. In the end, the MAW and the rate of perceived exertion (RPE) were determined. A strength test was applied to each individual. The MAW was higher for students (11.6kg) than for workers (10.8kg), however, it was not verified significant differences between groups. For students, the MAW depended on the selected IW. Students also assigned RPE values higher than workers. These results suggest that the workers' experience may be a determining factor in the MAW. Although the study has not provided conclusive results, it can be argued that samples comprised by students may affect the results, being that these groups of samples should be used with caution. So, whenever possible it should be used experienced workers in real work context for psychophysical studies.

Keywords: Index of Perceived Exertion; Maximum Acceptable Weight; Psychophysical; Transportation Manual of Loads.

1. INTRODUCTION

Musculoskeletal disorders (MSDs) have become a priority in recent years at the occupational level, since that their number are considerable (Pheasant, 2003). These occur as a direct or indirect consequence of the nature and demands of task, surrounding environment and of the ability of the individual worker (Scheer & Mital, 1997). Therefore, Manual Material Handling (MMH), awkward postures, repetitive movements, mechanical shock, grip strength, mechanical stress, vibration and extreme temperatures have been identified as factors associated to the MSDs development (Pheasant, 2003). Among these, the MMH, including the transport of loads, are recognized as the largest source of the work-related injuries and illnesses, especially in the lumbar region (Wai *et al.*, 2010; DGS, 2008). The elimination or reduction of these problems can be seen through ergonomics interventions, since the ergonomic is seen as "the application of natural laws that rule the job in order to maximize safety and efficiency at work" (Scheer & Mital, 1997).

In order to reduce the risk of injury due to MMH tasks, many researches as been carried out. Researchers used different approaches to develop MMH guidelines. The biomechanical, physiological and psychophysical are the three most common approaches applied (Nussbaum & Lang, 2005). As far as the level of difficulty is concerned, these approaches are distinct of its application to the workplace, as well as the expected results. The biomechanical approach aims at "designing tasks that do not exceed the capacity of the musculoskeletal system" (Dempsey, 1998), being the lumbosacral compression the most commonly used in biomechanical criterion (Dempsey, 1999). The physiological approach, aims to design tasks where energy expenditure is limited to levels that do not result in excessive whole-body or localized fatigue (Dempsey, 1999), being the heart rate, rate of oxygen consumption, and percentage of maximum oxygen uptake used as criteria. On the other hand, the psychophysical approach aims to design tasks "acceptable" for most workers who perform them (Dempsey, 1998), being based on workers' perceptions. The psychophysical approach usually consists on tests where individuals determine forces or maximum weight that can be moved during an 8-hour shift per day, without feeling unusually tired, weakened or fatigued (Ciriello *et al.*, 2010).

Between these three approaches, the psychophysical is highlighted by the active participation of individuals in determining the psychophysical criteria, for simplicity and ease of application (Ciriello *et al.*, 2010), and also because it is a common approach to study the MMH tasks (see e.g. Wu & Chang, 2010, Li *et al.*, 2007, Choi & Fredericks, 2007, Wu & Cheng, 2001, Yoon & Smith, 1998, Mital *et al.* 1997; Ciriello, 1990). This approach includes criteria such as rate of perceived exertion (RPE), maximum acceptable forces, maximum acceptable frequency and maximum acceptable weights (MAW) (Nussbaum & Lang, 2005; Wu & Chen 2001; Yoon & Smith, 1998 Mital *et al.* 1997; Ciriello, 1990). The criteria have, implicitly or explicitly, the assumption that individuals detect the physiological and biomechanical incentives in order to provide a subjective evaluation of physical exertion (Nussbaum & Lang, 2005). In this direction, the ratings are based on the perception that the worker has the physical effort and its results are considered subjective (Asfour *et al.*, 1980).

The psychophysical approach has been the source of so-called psychophysical criteria which have, sometimes in conjunction with criteria biomechanical, physiological and epidemiological, served as a basis for risk reduction measures, as well as for some methods of risk assessment tasks MMH, as the NIOSH'91 the equation (Waters *et al.*, 1994) and the Mital *et al.* (1997) method. Given the importance of these criteria is essential that these studies be carried out as accurately as possible. However, associated with these studies, are some limitations. According to Gamberale (1985), quoted by Nussbaum and Lang (2005), there is no relationship between RPE and MAW. Furthermore, the determination to short periods (20 ± 25 minutes) is acceptable to represent 8 hours of work on tasks of low frequency, a fact not found in moderate and high frequencies (Dempsey, 1998). Already, Ciriello *et al.* (1990) states that the psychophysical methodology is suitable for the determination of maximum acceptable weights for tasks with frequencies of 3-4 minutes or slower. In short, the working frequency influences the determination of psychophysical criteria (Jung & Jung, 2010). In this sense, one should be careful and take prudence in the design of tasks with moderate to high frequency (Dempsey, 1998). Also, Wu & Chen (2001) report that these methodologies are considered to be reliable for short distances (up to 10 meters). Another situation, the determination of MAW through psychophysical approach requires an adjustment period, i.e., the period in which individuals are able to determine the MAW that can carry 8 hours of work (Wu & Chen, 2001). In most studies of this period is short, with 15, 20, 25 or 30 minutes, and rarely use periods 45, 50 or 60 minutes (Wu & Chen, 2002). In addition to these situations we highlight the sample to be used. The analysis of the work of Asfour *et al.* (1980) revealed that several studies in the 70's decade conducted by MMH, were based on the perception of students, that the individuals were not familiar/experienced with the tasks. However, other authors conducted the study in individuals experienced in MMH tasks (see e.g. Ciriello, 2005; Ciriello, 2001; Wu & Chen 2001; Snook & Ciriello, 1991). Therefore, begins to exist a tendency to change the samples under study, opting for the use of experienced workers, however, currently there are still authors who continue to use students as a basis for study (Nussbaum & Lang, 2005).

Given this situation, it is important to consider whether the use of students as a sample may skew the results. In this sense, this paper aims to analyze the implications of the sample in determining the MAW in tasks of manual transport of loads transportation.

2. METHODOLOGY

2.1. Sample

For the development of this study, it was considered a sample selected for convenience of 10 workers and 10 male students. For the sample used selection, were considered the following criteria: aged between 20 and 35 years, since this is a key determinant of physical capacity (Mital *et al.*, 1997) and could influence the results of the study. Individuals who present problems of hypertension, herniated disc, or surgery or suffered severe illness in the last 6 months were excluded.

2.2. Variables in study

2.2.1. Independent Variables

- The study considered the type of sample as the independent variable since it is intended to compare results between experienced workers and students.

2.2.2. Dependent Variables

- The maximum acceptable weight (MAW): each individual could determine the weight that could comfortably carry on the task for 1 hour of work because, according to Yoon & Smith (1998) is the period that is closer to intermittent work in 8 hours labor.
- Rates of perceived exertion (RPE): at the end of each task the subjects were asked to evaluate the degree of perceived exertion for the pulses (P), arms (A), shoulder (S), spine (S), legs (L) and whole body (WB).

2.2.3. Control variables

- Box dimensions: was used a cardboard box, with length 60 cm x 40 cm width x 40 cm deep. The box had handles with: 2.7 cm width and 9.0 cm in length. It was strengthened the bottom of the box and the handles with card and tape, to prevent or even get the box break and made it impossible to perform the task.
- Handle height: height of 76 cm, was corrected from the surface with a height of 34.5 cm. The box had the handle at a height of 28.5 cm.
- Transport distance: how distance used to transport the same as Wu & Chen (2001) and Cheng & Lee (2005), 6 m.
- Travel speed: standard speed about 1 m/s.
- Duration of task: according to Wu and Chen (2002), many authors use short periods of adjustment, in this sense we opted for a short adjustment period of 13 minutes.
- Environmental conditions: temperature between 20-25 °C and relative humidity of 45-60%, controlled by indoor air quality monitor, IAQ Calc (model 8760, TSI, USA).

2.3. Strength test

In order to analyze the implications of the resisting force in determining MAW, it was measured through the application of strength tests. This consisted in the repetition of crunches and abdominal exercises for each study participant. Push-ups allowed to analyze the resisting force of the upper abdominal and abdominal region and the sit-ups of the upper limbs resisting force. The exercises consisted of counting the number of sit-ups for 2 minutes and maximum push-ups made. The results were recorded on the field.

2.4. Determination of the Index of Perceived Exertion (RPE)

To determine the RPE was developed and applied an "Individual Questionnaire", in order to realize the intensity of the effort that is perceived by individuals. This was divided into two parts: "Evaluation of pain or discomfort during manual transport of loads" and "Effort made". The first aimed to analyze the feelings of pain or discomfort, through the diagram presented, adapted from Coluci *et al.* (2009), and using an increasing range of 5 degrees (0 = absent and 4 = unbearable) adapted from Silva *et al.* (2011). The second was designed to analyze the perceived exertion for the wrists, arms, shoulders, back, legs and whole body through the Borg scale, using a scale of increased 15 degrees (6 = no effort and 20 = maximum effort) (Borg, 1990).

2.5. Procedure

The task carried out by the participants consisted on carrying a box for 13 minutes, walk 6 meters in an aposture designed to isolate three major joints: shoulder, elbow and lower trunk (Nussbaum & Lang, 2005). The worker carried the box closely to the body, i.e., elbows remained in line with the trunk and the trunk erect. Moreover the box had a false bottom, in which were hidden weights that accounted for a total of 5 kg.

Initially they were asked to select the weight that they could carry for 1 hour of work. Therefore, to each individual, it was requested to adjust the weight displayed, 17.25 kg, to the weight that they found suitable for the conditions proposed. This weight was considered the Initial Weight (IW). Every 6 meters the individuals placed the box on the support surface and during this time they could add or remove weights. During the entire journey, individuals were encouraged to make adjustments to the IW (adding or removing weights) in order to get to the MAW for the period of 1 hour without pain, fatigue or tiredness (Ciriello, 2005). During this journey individuals adjusted the weight whenever necessary. The weight obtained at the end of 13 minutes was considered the MAW for 1 hour of work, which is considered representative of 8 hours of intermittent work (Yoon & Smith, 1998).

Once the task completed, MAW values were recorded in the respective field form. Later, an individual questionnaire was applied to assess the RPE and pain/discomfort.

In the end, a strength test was applied to each individual based on the performance of crunches and push-ups in order to evaluate the strength in the abdominal region and upper limbs, respectively. The former were performed during a period of 2 minutes, while the latter were performed for the maximum number the individuals could withstand.

3. RESULTS AND DISCUSSION

3.1. Anthropometric characteristics of the sample

This study aims to highlight the importance of sampling in determining the MAW, which seeks to compare the results with students and workers. In this sense, we used individuals with similar anthropometric characteristics between the two groups. The students showed on average 23.3 years, a height of 176.4cm and weights of 69.3kg. The workers showed on average 28.1 years, a height of 178.3cm and weights of 73.7kg.

Table 1- Anthropometric dimensions for students and workers

	Age (years)	Height (cm)	Weight (kg)
Students	23.3	176.4	69.3
Workers	28.1	178.3	73.7

3.2. Strength test

The students made, on average, more crunches and push-ups, 46.7 and 24.7, respectively, than workers. Workers made an average of 33.7 crunches and 21.1 push-ups. Thus, students showed a higher strength than workers and statistically significant differences were observed in relation to abdominal strength ($p < 0.05$, Mann-Whitney test). The results can be explained by the fact that some students practice physical exercise and are more suitable for these activities, performing them with greater skill, as individuals engaged in exercises like crunches and push-ups gain more strength and resistance in the upper abdominal region in comparison to individuals who do not practice this type of exercise (Jacinto, 2001).

3.3. Maximum Acceptable Weight (MAW) for manual load carrying

The MAW is one of the criteria used in most psychophysical approach defined as: maximum acceptable weight that an individual can comfortably carry for 8 hours of intermittent work (Wu, 2006; Cheng & Lee, 2006; Wu & Chen, 2001).

The results obtained for the conditions of the experiment, in which individuals have walked 6m during 13minutes, are presented in Table 2. The MAW obtained for students was 11.6kg and 10.8kg for the workers. Thus, it was observed that the students carried, in average, a weight of 0.8kg more than the workers. However, no significant statistically differences were observed between groups ($p>0.05$, Mann-Whitney test). This difference between the samples was seen in the analysis of previous studies. For example, Wu and Chen (2001) and Cheng & Lee (2006), using the same methodology for the determination of MAW, reflected the sample implication on the MAW determination. In both studies was determined MAW to transport loads along 6 meters. The first used a sample of students and a second sample of workers. It is verified that the results obtained by Wu & Chen (2001) with students (39.9kg) are very different from the results obtained by Cheng & Lee (2006) with workers (14.8kg), so the MAW is higher in students, as in this work. Thus, it seems to exist the influence of the type of sample to determine the maximum acceptable weight.

Table 2- Average MAW obtained for students and workers

	MAW (kg)	Standard Deviation
Students	11.6	2.33
Workers	10.8	1.80

The influence between the strength and the IW on the MAW was analyzed. There was no relationship between the MAW and the strength ($R^2<0.252$). For students, there is a relationship between IW and MAW ($R^2=0.859$). Thus, for students, the higher the initial weight selected by the students, the greater the MAW obtained. For workers this relationship was not observed ($R^2=0.019$).

These results may be related with a greater experience in the transport of loads by workers, and therefore with a greater perception of risk by these individuals (Bye & Lamvik, 2007), regarding the need for continuity of effort and, consequently, increasing the perception of pain or discomfort. Therefore, a different behavior can be expected of these professionals in the psychophysical tests in particular in the MAW selection.

3.4. Rate of Perceived Exertion (RPE) for manual load carrying

The perceived exertion for the wrists, arms, shoulders, back, legs and whole body was obtained based on the "Individual Questionnaire" application, being the results presented in Table 3. Through the results obtained, it appears that, in average, students assign RPE values higher than workers. From the results presented, three areas may be highlighted for obtaining the highest values: arms (14.5 for students and 12.3 for workers), back (13.1 for students and 10.1 for workers) and whole body (12.3 for students and 10.2 for workers). However, among these, the region of the arms is the one with higher marks for both students (14.5), and workers (12.3). These results are in line with those obtained by Wu & Chen (2001) for students and Cheng & Lee (2006) for workers and may be associated with the need to maintain the required posture and thus require further efforts in this region. The results also showed that there were no significant differences between groups in relation to the RPE ($p>0.05$, Mann-Whitney test).

Table 3- Values of RPE obtained for students and workers

RPE	Students		Workers	
	Mean	Standard Deviation	Mean	Standard Deviation
Wrist	12.0	2.00	9.7	2.26
Arm	14.5	2.59	12.3	3.20
Shoulder	12.1	2.60	9.7	1.95
Back	13.1	2.60	10.1	2.10
Legs	10.8	1.62	8.8	2.20
Whole Body	12.3	2.06	10.2	2.25

Considering that MMH potentiates the development of MSDs in the lumbar region (DGS, 2008 and Colim, 2009), it was expected that the back would be the region with greater relationship between perceived exertion and weight that people carry, situation verified in this study only for workers (Table 4). This may be associated with their daily work that requires the handling and load transport, power factor of this perception (DGS, 2008). However, there is no significant relationship between the MAW and the RPE ($R^2 < 0.448$). These results are in accordance with the Gamberale (1985) results, quoted by Nussbaum and Lang (2005).

Table 4- Relationship between MWA and RPE obtained for students and workers

Body part	R ²	
	Students	Workers
Wrist	0.003	0.067
Arm	0.146	0.024
Shoulder	0.067	0.025
Back	0.107	0.448
Legs	0.242	0.080
Whole Body	0.180	0.202

3.5. Classification of pain/discomfort

The European Agency for Safety and Health at Work describes the back pain as one of the major health problems related to work (23.8%) in the European Union (EU-OSHA, 2007). Thus, and considering the nature of the task, it was expected that the individuals, specially the workers, would perceive greater pain/discomfort in the lumbar region. In this study, the results highlighted three areas of the body: elbows, wrists and lower back. Students attributed, respectively, 1.90, 1.10 and 1.60, and workers 1.60, 0.80 and 0.80 (Table 5).

Among the three, the region of the elbow was the one with a higher rate of pain/discomfort in both groups during the transportation of the load. This may be associated with the obligation to maintain the position of the forearm perpendicular to the body, as requested.

Although students assigned higher values of perceived pain/discomfort than workers for all areas under analysis, there was no significant difference between groups for all outcomes of the sensations of pain/discomfort ($p > 0.05$, Mann-Whitney test). These results may be related with the higher loads carried by students and the fact that they are not accustomed to MMH tasks.

Table 5- Values of pain/discomfort experienced by students / workers

Pain/Discomfort	Students		Workers	
	Mean	Standard Deviation	Mean	Standard Deviation
Neck	0.70	1.06	0.20	0.42
Shoulders	1.00	0.82	0.40	0.52
Column	0.60	0.97	0.30	0.48
Elbows	1.90	0.88	1.60	1.17
Pulses	1.10	1.20	0.80	0.79
Lumbar	1.60	0.84	0.80	0.92
Buttocks	0.80	1.03	0.40	0.70
Knees	0.50	0.71	0.10	0.32
Feet	0.30	0.68	0.10	0.32

4. CONCLUSIONS

The psychophysical approach applied in this work allows the development of measures in order to create acceptable working conditions for most individuals, in order to reduce/eliminate the appearance of MSDs. The psychophysical approach is easier to apply to the workplace than the biomechanical and physiological approaches, moreover, the results are simple to interpret. This approach can also be seen as a complement to methods of risk assessment. However, and considering the subjectivity associated with this approach, is essential that it is carried out in a proper way.

The sample used for the psychophysical studies may be a conditioning factor of the MAW determination. Therefore, in this paper, the implications of the sample in determining the MAW, in tasks of manual transport of loads, was analyzed.

This study demonstrated that the MAW was depending on the sample groups (students and workers). Despite there was no significant differences between groups, the MAW obtained was higher for students (11.6kg) than for workers (10.8Kg). In addition, it was found that, for students, the MAW depends on the selected IW and the resisting force does not interfere in the determination of MAW in both groups.

It is expected that the workers' experience in the transport of loads and their perception of the work reality and their physical limitations may be a determining factor in the MAW. They are those who know better the task demands and its resulting fatigue. So, samples comprised by students may affect the results, being that these groups of samples should be used with caution. Therefore, whenever possible, sample groups should comprise workers, the studies must be adapted to the work conditions and include other factors as years of experience and training.

5. STUDY LIMITATIONS

Sample size may be a limitation in the present study. A larger sample might prove statistically the influence of the sample in determining the MAW. As the study was developed in a company, the sample was limited to the available workers. Therefore, subjects were exposed to the same working conditions (daily weight carried, working patterns, temperature, humidity, age, among others), and there was only 10 workers that satisfied with the stipulated conditions. So it was not possible to use a larger sample in this work. The introduction of workers of another company could lead to bias in the results.

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