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FORCE AND MUSCULAR ACTIVITY DURING PULLING ACTIVITY WITH AND WITHOUT USING A CART

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Abstract

Recyclable material collectors perform manual material handling activities using nylon bags. In cooperatives, these bags are dragged on the floor; however, this activity has been replaced by carts to facilitate activity, improve logistics, increase the useful life of bags and reduce musculoskeletal complaints. However, there is no evidence that the use of carts can bring benefits to this activity. Thus, we compared the traction force and the muscular activity of the upper limb during manual handling with and without the aid of a cart. Fifteen workers pulled bags with plastic (20 kg), cardboard (30 kg) and aluminum (40 kg), with and without the use of a cart. The traction force was greater when the bag was handled manually and increased according to the bag's mass; no differences were found between the masses with the use of the cart. Muscle activity was greater for the cart and with a tendency to increase activation as the mass increases. Thus, we noticed that the use of the cart reduced the traction force and increased the activation of the muscles of the upper limbs.

Keywords: Collectors of Recyclable Materials; Electromyography; Strength; Manual Materials Handling.

1. INTRODUÇÃO

The increase in waste production highlights the importance of recycling materials worldwide. In developing countries, recycling is also an important source of income for non-skilled workers (Medina, 2000; Miglioransa et al., 2003; Asim et al., 2012). Concerns about the waste production has prompted the governments of many countries in Latin America and Asia to create public policies that encourage waste pickers to organize themselves in cooperative work (Medina, 2000; Carmo & Oliveira, 2010; Cockell et al., 2004).

Some studies have identified risks and inadequate working conditions among waste pickers (Carmo & Oliveira, 2010; Cockell et al., 2004; Porto et al., 2004; Alencar et al., 2009; Castilhos Júnior et al., 2013; Gutberlet et al., 2013; Auler et al., 2014; Souza et al., 2014; Engkvist, 2010; Engkvist et al., 2011). These workers are exposed to physical, chemical,

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biological, and ergonomic risk factors and have been highly affected by work-related musculoskeletal disorders. In Brazil, the cooperated waste picker workers are responsible for collecting, sorting and selling the recyclable materials (Guardebassio et al., 2014). Many of these activities involve manual materials handling, such as pulling nylon bags filled with recyclable materials.

The pulling and pushing activity has been extensively studied and it is still inconclusive which activity presents greater exertion (Garg et al., 2014). However, a strong relationship between pushing and pulling forces and shoulder complaints has been verified (Hoozemans et al., 2002). The pulling is characterized by exertion of hand force in a horizontal direction toward the body with different vertical components, depending upon the vertical height of the hands during the pulling (Garg et al., 2014). The activity can be performed in forward walking with the item behind of the body (Laursen & Schibye, 2002; Harris-Adamson et al., 2016) or in backward walking with the item in front of the body (Tiwari et al., 2010; Lin et al., 2013; McDonald et al., 2012; Yu et al., 2018), using one (Laursen & Schibye, 2002; Harris-Adamson et al., 2016; Lin et al., 2013; Yu et al., 2018) or two hands (Bennett et al., 2008, Tiwari et al., 2010). Each pull technique has an individualistic muscle activation profile, suggesting that workers may vary the method of pulling throughout the work shift in order to avoid cumulative musculoskeletal injuries (Bennett et al., 2011).

A frequent form adopted by the waste picker workers to pull the bags in forward walking is with the bag behind of their body. In general, the workers pull the bag with one hand, with the elbow and shoulder fully extended, the forearm pronated, and the trunk twisted. Similar position of pulling has been studied in other work environments (Laursen & Schibye, 2002; Harris-Adamson et al., 2016; Bennett et al., 2011); and it was considered favorable regarding upper extremity muscle activity, lumbar compressive force and anterior-posterior shear forces compared to pushing with two hands (Harris-Adamson et al., 2016). Variations in surface, speed, and load cause differences in shoulder torques, which are proportional to the speed and the magnitude of the pulled load (Laursen & Schibye, 2002).

In some Brazilian cooperatives these bags are dragged on the ground; however, this task has been progressively replaced by carts in order to become the activity easier, improve logistics operations, increase the lifetime of the bags and reduce musculoskeletal complaints. Some studies point out that the muscular activity and the forces required to push/pull depend on floor leveling, handling mode, friction, tire diameter, type of cart, cart weight, proper tire and floor maintenance, and trunk posture (Garg et al., 2014; Glitsch et al., 2007; Argubi-Wollesen et al, 2017). We could not find studies that evaluated the biomechanical requirements of handling recyclable materials under two conditions, with and without the aid of the cart, using objective measurements of pulling force and surface electromyography. Moreover, studying how new tools and techniques affect the worker's exertion is important to ensure a safer working environment.

Therefore, the objective of this study was to compare the pulling force and upper limb muscular activity during a manual materials handling activity with and without the aid of a cart. The hypothesis of the study is that the use of the cart will decrease the pulling forces and the upper limb muscular activity. In addition, it is expected that increasing the mass of the bags will increase the pulling force and muscular activity on both materials handling conditions.

2. Methods

2.1. Study design and participants

This study was conducted in a recycling cooperative located in a medium-sized city in the countryside of São Paulo State, Brazil. In this cooperative, the sorting and materials handling within the workplace was carried out exclusively by women. Therefore, the population of this study was composed only by the female collectors. At the time of data collection there were 29 collectors in this cooperative, being 19 women in the sorting sector, seven men collecting the materials in the streets and three women in the administration office.

The inclusion criteria were: 1. to be a woman working in the sorting sector; 2. job seniority higher than three months; 3. do not present physical symptoms or illness on the evaluation day; 4. and do not present any chronic disease or mobility restriction. Individuals who met the criteria were invited to participate and those who agreed and signed an informed-consent form were included. The research project was approved by the Research Ethics Committee the University (Opinion N. 459.482).

Thus, fifteen workers who fulfilled all the inclusion criteria participated in the study. All participants had right hand dominance. The mean age was 37 years (SD=10.8); the mean body mass index (BMI) was 29.9 kg/m2 (SD=4.9) and the mean job seniority was 27.7 months (SD=21.4).

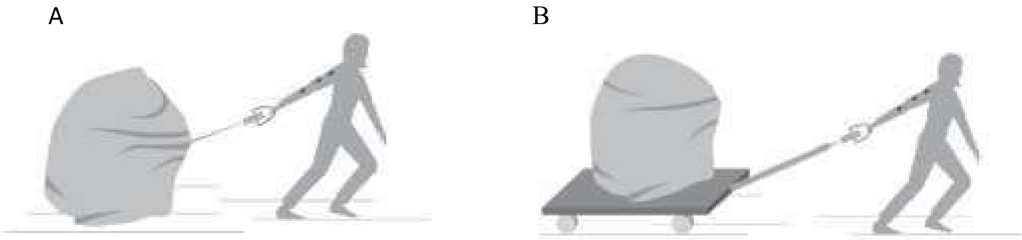
2.2. Equipments

Pulling peak force was recorded by a traction electronic dynamometer (Kratos, model DDK, São Paulo, Brazil) with accuracy of 0.5% and maximum capacity of 100 kgf. Muscle activity was assessed using an 8-channel electromyographic system (Trigno Wireless System, Delsys Inc., Boston, USA), consisting of electrodes with 4 parallel bars, two active bars and two stabilizers, which waived the use of reference electrode, contact size 5x1mm, material contact 99.9% (Trigno™ Standard Sensor), with RRMC> 80dB. The signal conditioning module features 16-bit resolution with 168 nV/bit signal, general channel noise <0.75 uV and 2000 Hz sampling frequency.

2.3. Activities

The activity was to pull recycled materials accommodated within the bags. Two forms of handling were evaluated: drag the bag on the floor (manual) and pulling the bags using a cart (cart). The bag dimensions were 130x90x90 cm. The bags were filled with plastic (20 kg), cardboard (30 kg) and aluminum (40kg). The cart was made of metal with a wood platform, measuring 120x60 cm, with pneumatic wheels of 14", mass of 29.4 kg and capacity for 500 kg (Figure 1). The order of the activity types was randomized for each subject.

Figure 1. Pulling activities: A. Dragging the bag on the floor (manual) and B. Pulling the bag using a cart (cart).



2.4. Procedures

Data collection was done at the workplace. The volunteers were informed and instructed about the procedures. They were asked to pull the bags for 10 m in a natural velocity. Each activity was carried out one time for each material, summing up six handlings for each worker. The dynamometer was engaged in the bag strap for the manual activity and in the cart handle. Peak force was normalized by body mass and expressed as the percentage of body mass.

The electrical activity of the trapezius (upper, middle and lower), deltoid (middle and posterior), triceps brachii (long and lateral head), and wrist extensor muscles was evaluated. Before attaching the electrodes, theBskin was shaved and cleaned with alcohol (Luca, 2003). The sensor locations and the maximum voluntary contraction tests (MVC) were performed according to the SENIAM protocol (Surface Electromyography for the Non-Invasive

Assessment of Muscles) (SENIAM, 2016) for all muscles, excepted for the wrist extensor, which was not available at SENIAM webpage.

For wrist extensor muscles, the sensor was placed over the muscle belly located by palpation during MVC with the forearm pronated (Akesson et al., 1997). The MVC test was done with the subject seated, with the elbow flexed at 90° and pronated forearm resting on an adjustable height surface. The maximum wrist extension was done with an inelastic band attached to a metal plate on the ground (Akesson et al., 1997).

The electromyography signal was digitally filtered through a bandpass filter from 20 to 450 Hz, rectified and the maximum RMS (Root Mean Square) value was calculated by means of a 150 ms moving window algorithm with 50 ms interposition using the Matlab software (Math Works, Inc., version 2013a, Massachusetts, USA). Normalization was performed by the average of the three peak values MVC (Mathiassen et al., 1995) and the muscle activity during the handling activities was transformed as a percentage of the MVC.

2.5. Data analysis

Pulling force data (percentage of body mass) and normalized maximal RMS value of each muscle (% MVC) were analyzed using SPSS software (version 17.0). Statistical analysis was conducted using two way ANOVA for repeated measurements. The fixed effects were: activity (manual x cart) and mass (20, 30 and 40 kg). The dependent variables were pulling force and muscular electrical activity for each muscle. The values of F, P and the effect size (partial eta squared) are shown for both the main effects of each factor (activity and mass) and for the interaction between factors (activity*mass). When the interaction between the factors was significant, the simple effects were interpreted instead of the main effects of each factor. When the interaction was statistically significant the differences between the means (MD), the confidence interval of these differences (95% CI) and the effect size (Cohen's d) were calculated. The effect size > 0.8 was considered large, 0.5-0.8 moderate, 0.2-0.5, small and <0.2 poor31. For all comparisons the level of significance was set at 5%.

3. Results

The pulling force was higher when the bag was dragged on the floor compared with the aid of the cart, being statistically significant for the cardboard (MD=1.02 N/kgf; IC 95%=0.41-1.62; d=5.49) and aluminum (MD=2.25 N/kgf; IC 95%=1.39-3.11; d=10.07). For the manual handling, the peak force increased according to mass of the bag; and the force was significantly higher for the aluminum when compared to plastic (MD=1.72 N/kgf; IC 95%=1.07-2.38; d=0.65) and cardboard (MD=1.25 N/kgf; IC 95%=0.96-1.55; d=0.43). When the activity was performed with the cart no differences between plastic, cardboard and aluminum bags were found.

Table 1. Mean and standard deviation [mean (SD)] for the peak pulling force (N/kgf) during the manual and cart handling for plastic (20 kg), cardboard (30 kg) and aluminium (40 kg).

Mass	Activities		Factors	*F*	*P*	Effect size
	manual	cart				
plastic	15.19 (4.86)[a]	11.31 (6.28)	activity	18.48	0.001	0.57
cardboard	22.90 (7.37)[b*]	12.53 (7.24)*	mass	58.81	<0.001	0.80
aluminium	35.71 (9.45)[a.b.*]	12.69 (8.26)*	activity*mass	42.05	<0.001	0.75

Equal letters represent differences between masses and * represent differences between activities.

The muscle activation results are shown in Table 2 (in appendix). The muscle activation was higher when the material handling was performed with the aid of the cart, except for the upper portion of the trapezius. For this muscle, the post hoc analysis indicated a difference between the activities only for aluminum (P=0.04; MD=7.82; 95% CI=0.29-15.35; d=0.27) with greater activation in manual handling. For the other muscles, the differences between activities occurred for all masses, except for aluminum handling in trapezius (middle and lower) and posterior deltoid.

The difference among the masses was only significant for the manual material handling, with a significant trend of increasing the activation as the mass increases for the three portions of trapezius and posterior deltoid. No differences among the masses were identified for the other muscles.

4. Discussion

The purpose of this study was to compare the pulling force and upper limb muscular activity during the activity of pulling recyclable materials manually and using a cart. The hypotheses of the study were that the use of the cart would decrease the pulling force and upper limb muscular activity, and increasing the mass of the bags would increase the pulling force and muscular activity on both material handling conditions.

Our results partially confirmed the hypotheses, since the use of the cart diminished the pulling force for cardboard and aluminum handling. However, when using the cart, the muscle activity increased for all muscles, except for upper trapezius. Besides this, increasing the mass caused an increase in the pulling force and the activity of the three portions of the trapezius and posterior deltoid, only for manual handling.

The pulling force was expected to decrease when using the cart, and this result was also found by Schibye et al. (2001), evaluating the pulling forces when waste pickers handle bags from 25 to 50 kg. However, we did not expect that the muscle activation to be greater when using the cart. Some factors may have contributed to the increase in muscle activity in handling the cart. The rod used to pull the cart makes the worker to be far from it, shifting the center of gravity of the cart-operator system, possibly requiring further joint stabilization to prevent unwanted movements and to keep the path straight.

Further, depending on the direction of force application, the cart could move laterally. Then, we can suppose that the shoulder muscles, especially the middle and lower portions of the trapezius, increased its activation to stabilize the scapula (Mottram, 1997) and prevent lateral displacement of the cart. An additional explanation for this finding may be related to higher attrition force in manual handling, which requires less muscle activity to stabilize the load.

Another hypothesis of this study was that the increase of the mass would increase the pulling force and muscle activity. This hypothesis was also partially confirmed, since for the pulling force and the muscle activity of the three portions of the trapezius and posterior deltoid significantly increased when the mass increased only for the manual handling. These findings can be explained by the main function of these muscles to pull the load. The middle deltoid and triceps brachii were not much active during the activity, and its activation did not depend on the mass pulled. The wrist extensor muscles act as wrist stabilizers and their activation during pulling activity was also independent of the mass.

Future studies should consider the evaluation of the usability of the cart and perception of the workers about the use of the cart to understand the reason for the increased upper arm muscular activity. Also, it is possible that the workers used different motor strategies according to the stability of the load. We also recommend that future studies evaluate other muscular groups potentially involved in the task, such as the trunk and lower limbs muscles.

4.1. Limitations of the study

This study had as main limitation the reduced sample size, however all eligible subjects were evaluated. Another aspect to be considered is that the sample is consisted exclusively of women, which does not allow generalizations for male workers. The technique used by the workers to perform the activities might also influence our results, requiring a more comprehensive biomechanical approach.

5. Conclusion

The use of the cart to handle the recycled materials reduced the pulling force, but increased upper limb muscle activation. These results indicate that the use of this device may not be advantageous to reduce upper arm muscular overload. The implementation of carts to pull the bags requires a more in-depth study of the motor strategies and the effects of the increased upper arm muscle activity.

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APPENDIX - Table 2. Mean and standard deviation [mean (SD)] for the muscular activity (RMS) during the manual and cart handling for plastic (20 kg), cardboard (30 kg) and aluminium (40 kg).

Muscles	Mass	Activities		Factors	*F*	*P*	Effect size
		manual	cart				
Upper Trapezius	plastic	21.34 (16.46)[a.c]	23.51 (18.40)	activity	0.42	0.53	0.03
	cardboard	24.53 (18.65)[b.c]	24.86 (17.52)	mass	6.98	<0.01	0.35
	aluminium	32.71 (23.54)[a.b.*]	24.89 (17.52)[*]	activity*mass	7.31	<0.01	0.36
Middle Trapezius	plastic	20.05 (16.53)[d.*]	37.85 (19.99)[*]	activity	14.91	<0.01	0.53
	cardboard	25.03 (21.16)[e.*]	38.32 (24.60)[*]	mass	4.08	0.03	0.24
	aluminium	36.39 (31.02)[d.e]	36.39 (20.68)	activity * mass	4.99	0.02	0.28
Lower Trapezius	plastic	6.99 (5.18)[f.h.*]	15.97 (8.66)[*]	activity	12.16	<0.01	0.50
	cardboard	10.01 (7.19)[g.h.*]	14.61 (8.87)[*]	mass	5.08	0.01	0.30
	aluminium	14.05 (10.41)[f.g]	16.75 (10.76)	activity * mass	3.81	0.04	0.24
Middle Deltoid	plastic	6.6 (3.49)[*]	18.77 (9.20)[*]	activity	30.58	<0.01	0.69
	cardboard	7.38 (4.65)[*]	20.64 (14.53)[*]	mass	1.28	0.29	0.08
	aluminium	9.76 (6.24)[*]	19.75 (10.21)[*]	activity * mass	0.62	0.48	0.04
Posterior Deltoid	plastic	9.99 (5.15)[i.k.*]	19.74 (10.2)[*]	activity	4.67	0.05	0.26
	cardboard	12.32 (6.15)[j.k.*]	20.01 (11.54)[*]	mass	6.53	0.02	0.33
	aluminium	21.81 (14.04)[i.j]	21.42 (14.04)	activity * mass	9.13	<0.01	0.41
Triceps brachii - long head	plastic[i]	4.48 (2.01)[*]	10.38 (5.75)[*]	activity	5.21	0.04	0.32
	cardboard	6.50 (6.44)[*]	9.57 (5.70)[*]	mass	4.79	0.02	0.30
	aluminium[i]	9.43 (4.88)[*]	9.78 (5.25)[*]	activity * mass	3.42	0.08	0.24
Triceps brachii - lateral head	plastic	9.31 (6.18)[*]	18.91 (13.69)[*]	activity	11.59	<0.01	0.45
	cardboard	11.76 (11.44)[*]	17.72 (12.69)[*]	mass	1.60	0.22	0.10
	aluminium	14.76 (12.75)[*]	18.00 (11.75)[*]	activity * mass	1.52	0.24	0.10
Wrist extensors	plastic	14.92 (11.02)[*]	29.85 (16.65)[*]	activity	25.55	<0.01	0.65
	cardboard	16.11 (13.95)[*]	30.02 (13.94)[*]	mass	1.14	0.33	0.08
	aluminium	16.83 (12.09)[*]	31.74 (20.73)[*]	activity * mass	0.03	0.89	0.01

Equal letters represent differences between masses and * represent differences between activities.