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ORIGINAL ERGONOMIC RESEARCH

The forearm positioning changes electromyographic activity of upper limb muscles and handgrip strength in the task of pushing a load cart

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Summary The aim of the present study was to analyse the electromyographic activity of the upper limb muscles as well as the handgrip strength during the activity of pushing a load cart. Eighteen healthy male right-handed volunteers (21.50 ± 2.77 years old) took part in the study. Electrodes were placed on upper trapezius fibres, brachial biceps, brachial triceps, and extensors and flexors of wrist and fingers. The original handle of the load cart was replaced by two handgrip systems mounted on load cells, thus allowing the handgrip strength to be measured according to the wrist position variation, that is, wrists in neutral position with pronated forearm (WN-PF) or in ulnar deviation with forearm in neutral position (WUD-NF). The signals generated by the load cells during manoeuvre of the load cart and the electromyographic signals were simultaneously captured. Signal processing was performed by using a specific routine developed for analysis of root mean square (RMS) and median frequency (MF). Greater

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handgrip strength occurred in WN-PF position. In maximal isometric contraction, the RMS of the flexors and extensors showed greater electromyographic activity in WN-PF (intra-muscles) and extensors position (inter-muscles). Decreased handgrip strength in the latter stages of the circuit, with variation of the RMS and MF of all muscles tested. One can conclude that electromyographic activity and handgrip strength are both affected during the phases of an elliptical displacement of the load cart.

Introduction

In the spite of the industrial modernisation and emergence of new technologies requiring workers with abilities such as comprehension, decision-making, participation, and technical and intellectual skills, even today many load-moving tasks are manually performed, which are related to the increased incidence of musculoskeletal dysfunctions (Straker, 1999; Ciriello et al., 1999). It has been reported that approximately 60% of the muscle problems are caused by load-lifting activities, whereas 20% result from the task of pulling or pushing loads (Bridger, 2003).

According to Dull and Weerdmeester (2004), the movements of pulling or pushing loads cause stress in arms, shoulders and spine. The labour task of handling loads is responsible for most of the muscle traumas among workers, causing cumulative harm due to the gradual overload of the musculoskeletal system resulting from these repetitive activities (Osha, 2007). Despite the harm to occupational health, load-handling activities have not been the main purpose of studies and little is known about the biomechanical effect on joint structures resulting from these tasks (Ciriello et al., 1999). Padula et al. (2006) also point out that although there are several studies assessing the musculoskeletal overload present in load-handling activities and its effect on vertebral column, little has been studied about the effects of this task on upper limbs, mainly the wrist joints.

Within this context, Lehmkuhl and Smith (1989) cited that the hand represents the effector extremity of the upper limb, constituting its support that is stabilised by the shoulder, elbow, and wrist. Therefore, several studies have been carried out to address the relationship between handgrip strength and different positions of the upper limbs, all reporting direct association between these variables (McGorry, 2001; Mircea et al., 2004; Jeremy and Peter, 2003).

Considering that the displacement of load carts requires the use of handgrip force (Herring and Hallbeck, 2007) and that the position of the hands influences the pulling and pushing forces, it becomes important to compare the handgrip strength variations in relation to different positions of the upper limbs during execution of these tasks. Moreover, the importance of studying the biomechanical aspects of certain labor tasks is highlighted in order to endorse the best body strategy that should be adopted in order to obtain the best performance with lower risk of injury, given that work-related upper limb injuries are common, especially with involvement of the musculoskeletal system, in addition to being considered a frequent cause of absenteeism (d'Errico et al., 2010; Dick et al., 2011).

Therefore, the purpose of the present study is to analyse the electrical activity of agonist and synergist muscles in the handgrip activity during the task of pushing a load cart in order to support the knowledge on the practice of ergonomics in the industrial environment. For such, a system of load—displacement employing a grocery shopping cart was developed to mimic the work activity.

Methods

Eighteen healthy male right-handed volunteers with mean age of 21.50 ± 2.77 years old, mean weight of 72.40 ± 6.00 kg, mean height of 1.76 ± 0.05 m, and mean body mass index (BMI) of 23.40 ± 1.70 kg/m^2 participated in the study. With regard to the ethical aspects, the study project was approved by the local research ethics committee and all the participants signed an informed consent form.

The following inclusion criteria were considered: age between 18 and 28 years old, BMI between 19 and 25 kg/m^2, and right-hand dominance. The exclusion criteria were presence of neuromuscular or orthopaedic disease interfering with the execution of activities and tasks of pushing loads regularly.

Only male subjects were included in the present study due to two aspects: men traditionally develop labor tasks related to strength activities, such as the task of pushing a cart load; furthermore, women's menstrual cycle reflects on the use of strength, and in this case it would be necessary to control the influence of this variable (Bambaeichi et al., 2004).

The muscle activity potential was captured by using five active surface electrodes (Lynx, São Paulo, SP, Brazil) consisting of two pure silver bars of 10 mm length × 1 mm width positioned in parallel and separated by 10 mm from each other, pre-amplifier circuit with gain of 20 times (±1%), common-mode rejection ratio >100 dB, and signal noise rate <3 μV RMS. The electrodes were connected to the signal conditioning module (EMG-1000, Lynx) by means of a coaxial cable of 1.40 m, with impedance of 10^9 Ohms, 16-bit resolution, and input range of ±1 V. A notebook (ECS 557S) was used as the interface. In order to allow autonomy of the load cart and eliminate possible electrical interferences, the signal acquisition module was connected to a 10 amp-hour battery of 12 V (Guirro et al., 2006).

For acquisition and storage of the digitised signals, the Aqdados software 7.2 (Lynx) was used. The sampling frequency of EMG signal was 2000 Hz and the cut off frequency ranged from 20 Hz to 1000 Hz by means of a Butterworth

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analog filter. Channels were adjusted to total gain of 1000 times for electromyographic signal. A reference electrode consisting of a metallic plate (30 × 40 mm) was attached to the lateral epicondyle of the homolateral ulna.

The load cart consisted of tubular frames supported on four wheels. A system was built and mounted on the cart to allow the height of the handles to be adaptable, including the horizontal distance between them, in order to provide adequate positioning of the participant during the manoeuvre (Fig. 1). The original handle of the cart was replaced by two handgrip systems mounted to load cells (MM-50, Kratos, Cotia, SP, Brazil), thus enabling the ability to measure the handgrip strength according to the wrist position variation, that is, wrists in neutral position with pronated forearm (WN-PF) or in ulnar deviation with forearm in neutral position (WUD-NF), as shown in Fig. 2. The signals generated by the load cells during the manoeuvre of the load cart and the electromyographic signals were simultaneously captured. Prior to the beginning of the evaluation, both electrodes and load cells were calibrated in microvolts and kilogram-force (kgf), respectively, according to the manufacturer's instructions.

The maximum handgrip strength of the right limb was initially determined in the WN-PF or WUD-NF positions during 3 maximum isometric voluntary contractions (MIVC) for 3 s with 2-minute rest intervals between the activities. During the MIVC, the volunteer had visual feedback by observing the force increment on the microcomputer monitor while being instructed to make maximum effort. After three evaluations, the mean force was calculated considering 100% MIVC.

Electrodes were positioned on the upper trapezius fibres, biceps, and brachial triceps muscles according to recommendations from the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM project) (Hermes et al., 1999; Hintermeinster et al., 1998), whereas the electrodes positioned on the flexor and extensor muscles of hands and fingers followed recommendations by Basmajian and Blumenstein (1989). The skin was shaved and cleaned with 70% alcohol (Hermens et al., 2000) prior to the placement of the electrodes, which were attached by means of hypo-allergic double-face adhesive tape.

In order to seek a correlation between simulated and actual activities within the industrial environment, a plain and rectilinear path (4 m) with cones positioned at its ends was projected for displacement of the load cart, thus allowing acceleration (initial displacement, 0–4 s), curve (curvilinear displacement, 5–11 s) and deceleration (final displacement, 12–17 s) phases to be performed. Therefore, signals were collected while the participant was walking

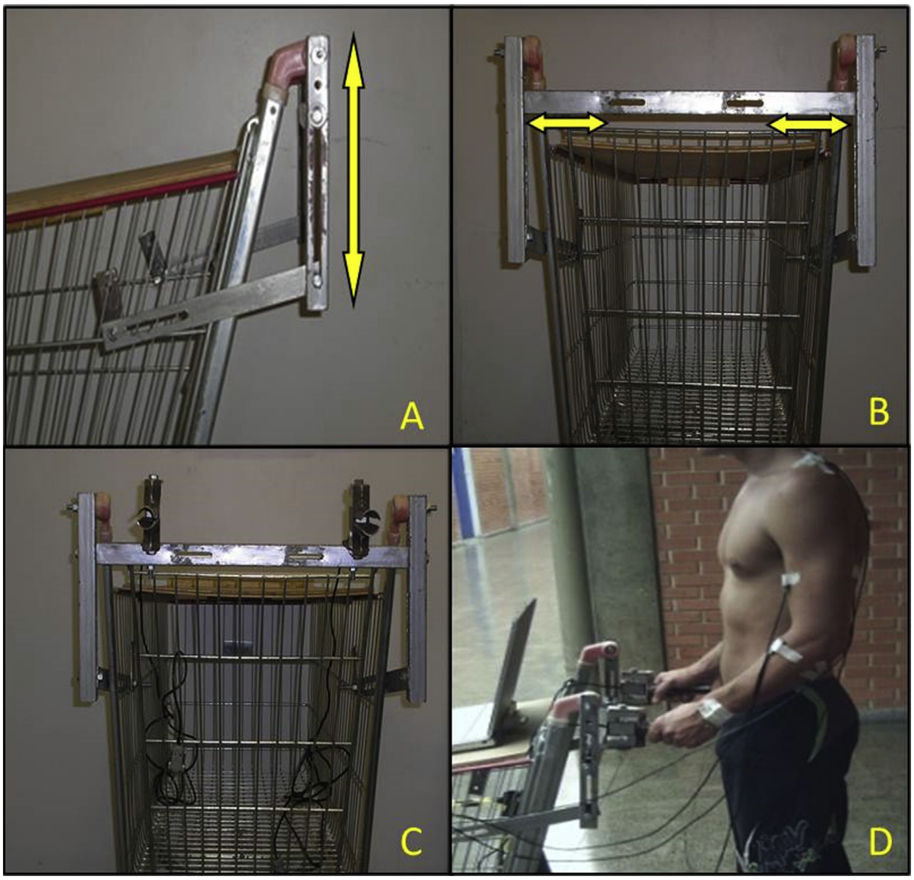

Figure 1 System attached to the load cart for the positioning of the grips. A) vertical adjustment of the grips (arrow), B) horizontal adjustment of the grips (arrow), C) system attached to the cart for fixing of load cells and positioning of the grips, and D) side view of the participant, showing the electromyographic signals and strength being captured during the task of pushing a load cart.

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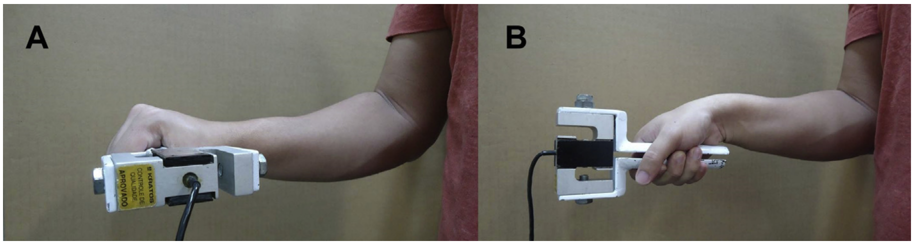

Figure 2 Position adopted by the volunteers during the collections: A) wrists in neutral position with pronated forearm and B) wrists in ulnar deviation with forearm in neutral position.

and pushing the load cart so that the handgrip strength could be exerted on the load cells at a speed compatible to normal walking, which was paced by sonorous signals from an electronic metronome (MA-30, KORG, Melville, NY, USA) operating at a frequency of 80 times per minute. Each participant performed the task of manoeuvring the load cart three times for each upper limb position, with a total load limited to 100% of the participant's body mass.

The signals collected were processed by using a specific routine developed with the Matlab 6.5 software (Natick, MA, USA) for electromyographic signal analysis of root mean square (RMS) in microvolts (μV) and median frequency (MF) in Hertz (Hz).

For statistical analysis, data were assessed by using the Shapiro–Wilk's test. Mann–Whitney or Wilcoxon test were applied to isometric data presenting non-normality, and *t*-test paired or independent samples were used when normality was observed. For analysis of handgrip strength, RMS, and MF obtained during displacement of the load cart, the Friedman's test was used. The analyses were performed by using the BioEstat 5.3 (Belém, PA, Brazil) software at $p < 0.05$.

Results

By comparing the maximum handgrip strength exerted by the dominant upper limb on the handle of the load cart during maximum isometric voluntary contraction, significant differences were found ($p = 0.006$) regarding the different joint positions of the upper limb, namely, 25.63 ± 6.10 kgf and 20.91 ± 3.80 kgf for WN-PF and WUD-NF positions, respectively.

The values of RMS for flexor and extensor muscles of wrists and fingers also had significant differences (Table 1) in both comparisons of intra-muscles (flexors in WUD-NF position *versus* flexors in WN-PF position and extensors in WUD-NF position *versus* extensors in WN-PF position) and inter-muscles (flexors in WUD-NF position *versus* extensors in WUD-NF position and flexors in WN-PF position *versus* extensors in WN-PF position), indicating a higher electromyographic activity in the WN-PF position (intra-muscles) and extensor muscles (inter-muscles). Table 2 shows the values of MF during maximum isometric contraction, with no statistical difference being observed in any of the comparisons (intra and inter-muscles).

With regard to the handgrip strength exerted on the handle of the load cart during its displacement along the trajectory (Table 3), one can find a decrease in the handgrip strength of the right upper limb in the WUD-NF and WN-PF positions (intra-position) during the last two phases of displacement compared to the initial phase. With regard to the left upper limb, such a difference was observed only between the initial and final phases of the trajectory. On the other hand, the inter-position analysis (WUD-NF *versus* WN-PF) for the same time intervals showed a decrease in the handgrip strength of the right upper limb in the WN-PF position during the initial phase. No significant difference was found between right and left upper limbs regarding the same interval and position.

With regard to the changes in RMS of the upper trapezius fibres, biceps, brachial triceps, and flexors and extensors of wrist and fingers during displacement of the load cart, a variation in the electromyographic activity at different joint positions was observed (Table 4). There was an increase in the electromyographic signal amplitude in the WN-PF position during the acceleration phase for upper

Table 1 Mean ± standard deviation of RMS (μV) for flexor and extensor muscles of wrist and fingers in the positions of wrists in neutral position with pronated forearm (WN-PF) or wrists in ulnar deviation with forearm in neutral position (WUD-NF) during maximum handgrip strength.

Muscle group	Position	
	WUD-NF	WN-PF
Flexors of wrist and fingers	83.15 ± 17.90[a]	191.60 ± 46.20
Extensors of wrist and fingers	169.26 ± 59.40[a,b]	369.43 ± 151.80[b]

[a] $p < 0.05$ intra-muscle; [b] $p < 0.05$ inter-muscle.

Table 2 Median (M) and interquartile amplitude (IQA) of MF (Hz) for flexor and extensor muscles of wrist and fingers in the positions of wrists in neutral position with pronated forearm (WN-PF) or wrists in ulnar deviation with forearm in neutral position (WUD-NF) during maximum handgrip strength.

Muscle group		Position	
		WUD-NF	WN-PF
Flexors of wrist and fingers	M	52.49	62.90
	IQA	30.60	20.10
Extensors of wrist and fingers	M	54.47	44.98
	IQA	24.20	4.60

No significant difference ($p > 0.05$) intra and inter-muscles.

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Table 3 Median (M) and interquartile amplitude (IQA) of handgrip strength (kgf) during the phases of displacement of the load cart (acceleration of 0–4″, curve of 5–11″ and deceleration of 12–17″) in the clock sense for the positions of wrists in neutral position with pronated forearm (WN-PF) or wrists in ulnar deviation with forearm in neutral position (WUD-NF).

Joint position		Trajectory phases					
		Upper right limb			Upper left limb		
		0–4″	5–11″	12–17″	0–4″	5–11″	12–17″
WUD-NF	M	3.41	3.32	$1.68^{a,b}$	1.55	3.01	0.67^{b}
	IQA	2.80	2.10	1.00	3.20	0.80	2.00
WN-PF	M	1.44^{c}	1.70	$1.01^{a,b,c}$	1.20	1.97	0.65^{b}
	IQA	1.10	0.90	1.10	1.80	0.6	1.60

$^{a}p < 0.05$ intra-position at 0–4″; $^{b}p < 0.05$ intra-position at 5–11″; $^{c}p < 0.05$ inter-position at the same interval.

trapezius fibres, brachial biceps, and extensors of wrist and fingers, whereas for the muscles brachial triceps and flexors of wrist and fingers there was an increase in the electromyographic signal amplitude in the WN-PF during the curve phase of the trajectory ($p < 0.05$).

When the wrist was positioned in ulnar deviation with forearm in neutral position (WUD-NF), statistical difference was observed in RMS ($p < 0.05$) for all muscles assessed during all phases of displacement of the load cart. Higher values of RMS were found in the upper trapezius fibres, brachial biceps, and extensors of wrist and fingers in the acceleration phase of the load cart as well as in the brachial triceps and flexors of wrist and fingers in the curve phase, keeping the same pattern in the WN-PF position. With regard to the different joint positions, the highest values of RMS were observed in all muscles in the WUD-NF position, except the brachial triceps, during the acceleration phase. The brachial biceps also had higher values of RMS in the deceleration phase compared to those in the WN-PF position.

Analysis of the median frequency in the WN-PF position showed statistical difference ($p < 0.05$) in all muscles assessed during the different phases of the trajectory (Table 4). Upper trapezius fibres, brachial biceps and extensors of wrist and fingers exhibited identical behaviour, with higher values of MF in the phases of acceleration and curve. Brachial triceps and flexors of wrist and fingers had higher values in the curve phase. Lower variation in MF was observed between the trajectory phases in the WUD-NF position, with higher values being observed for upper trapezius fibres and brachial biceps muscles in the acceleration phase and for triceps in the curve phase. The inter-position analysis showed differences in the phases of deceleration and curve for upper trapezius fibres and brachial biceps muscles, respectively.

Discussion

The maximum handgrip strength exerted by the dominant limb showed variations depending on the different positions of the upper limbs. Higher values of strength were found when the wrist was in neutral position with forearm pronated (WN-PF). These results corroborate the study by McGorry (2001), who observed a higher handgrip strength exerted by the wrist in neutral or slightly extended position as well as a decrease when the wrist was flexed or lateralised.

The capacity of generating hand strength is related to location and size of the object to be carried as this changes the position of wrists and fingers, resulting in alteration in the muscle and joint length of the upper limbs (Shih and Ou, 2005; Roman-Liu and Tokarski, 2005). Another factor influencing the wrist–hand relation is the task of maneuvering the load by using holders and handles. Studies have shown evidence that the angulation of holders or handles can cause deviation of the wrist (Chung and Wang, 2001; Wang et al., 2000), since each muscle has an optimal length in which a higher number of crossed bridges is formed to allow maximum production of force (Rassier et al., 1999).

Still within this context, the extrinsic and intrinsic muscle groups of the hand, except the thumb's extrinsic muscle, act together in order to provide stabilisation to the wrist joint and fine movement control to the hand. When one of the muscle groups does not work adequately, the other group is required to compensate the action. In fact, the major problem has to do with the wrist position, which may reduce the efficiency of the extrinsic muscles by making the small intrinsic muscles to have greater effort and consequently reducing the handgrip strength when the wrist is not in neutral position. Another issue to be considered is the diameter of the handle. Montanari et al. (2009) found that a diameter of approximately 50 mm for cylindrical handles seems to be biomechanically the most adequate, regardless of the activity being performed (handgrip, torque, traction). Montanari et al. (2009) found that a diameter of approximately 50 mm for cylindrical handles seems to be the most adequate as far as the biomechanics, regardless of the activity being performed (handgrip, torque, traction).

With regard to the analysis of the electromyographic signals during isometric handgrip of the dominant limb, the comparison between intra and inter-muscles showed significant difference in the RMS of flexors and extensors of wrist and fingers. These results are in accordance with the study by Dias et al. (2006), who found different levels of electromyographic activity between biomechanically similar exercises, reporting that the difference in the electromyographic values, despite the biomechanical similarity, may be related to the amount of isometric effort and certain characteristics of the exercise (e.g. muscle co-activation), which can favour the activation of a muscle in relation to another.

The results of this study have indicated a higher electromyographic activity for flexors and extensors of the wrists and fingers when the former is positioned in a neutral position and the forearm is pronated. This position also presented the highest level of strength during isometric handgrip. The increase in muscle contraction also raises the recruitment of motor units and the frequency of triggering each one of them until the individual potentials are added up and no longer recognised (Basmajian and De Luca, 1985). Therefore, the higher the muscle contraction the greater

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Table 4 Median (M) and interquartile amplitude (IQA) of root mean square (RMS) and median frequency (MF) of the muscles of dominant upper limb during the phases of displacement of the load cart (acceleration of 0–4″, curve of 5–11″ and deceleration of 12–17″) in the clock sense for the positions of wrists in neutral position with pronated forearm (WN-PF) or wrists in ulnar deviation with forearm in neutral position (WUD-NF).

EMG parameters	Position	Muscles														
		Upper trapezius fibres			Brachial biceps			Brachial triceps			Flexors of wrist and fingers			Extensors of wrist and fingers		
		0–4″	5–11″	12–17″	0–4″	5–11″	12–17″	0–4″	5–11″	12–17″	0–4″	5–11″	12–17″	0–4″	5–11″	12–17″
RMS (μv)	**WUD-NF**															
	M	46.45	29.20	$23.12^{a,b}$	71.29	25.63^{a}	20.35^{a}	19.37	52.45^{a}	29.02	40.85	61.36	$26.17^{a,b}$	52.83	45.52	$31.02^{a,b}$
	AIQ	26.31	78.08	12.49	66.13	10.25	7.43	10.50	36.55	24.58	39.46	41.92	21.65	43.90	33.46	17.65
	WN-PF															
	M	36.61^{c}	26.82	$16.12^{a,b}$	58.84^{c}	28.62	$15.44^{a,b,c}$	18.86	52.65^{a}	24.98^{b}	28.11^{c}	60.70^{a}	32.12^{b}	37.47^{c}	29.66	29.88^{a}
	IQA	20.54	19.57	12.90	59.25	14.09	8.60	14.71	23.96	46.33	11.79	44.49	22.84	24.68	21.42	37.41
MF (Hz)	**WUD-NF**															
	M	50.35	42.26	39.69^{a}	46.90	47.01	$34.86^{a,b}$	29.23	40.20^{a}	26.92	49.50	57.95	38.53	54.42	41.68	32.55
	IQA	39.36	24.73	16.31	16.74	9.17	14.85	20.77	35.29	25.57	26.23	32.15	44.53	40.13	65.14	52.90
	WN-PF															
	M	43.87	38.02	$25.57^{a,b,c}$	43.68	35.62^{c}	$24.53^{a,b}$	19.17	42.45^{a}	19.93^{b}	48.86	53.08^{a}	40.86^{b}	53.05	48.78	$41.11^{a,b}$
	IQA	28.53	14.25	15.40	10.41	14.99	12.12	19.42	23.82	3.77	30.83	19.09	41.41	42.18	39.21	32.35

$^{a}p < 0.05$ intra-position at 0–4″; $^{b}p < 0.05$ intra-position at 5–11″; $^{c}p < 0.05$ inter-position at the same interval.

the amount of motor units recruited, thus increasing the signal amplitude.

The handgrip movement promotes intense activity of flexor muscles of fingers and intrinsic muscles of the hand. In view of this, one can say that the handgrip movement involves the finger flexion performed by the flexor muscles (Hagg and Milerad, 1997). However, Bennie et al. (2002) also reported that extensor muscles are activated to oppose the flexion torque in order to keep the wrist in neutral position. Because it is known that handgrip requires the action of the flexor and extensor muscles of wrist and fingers, it is necessary to quantify the degree of electromyographic activity of each muscle group so that one can obtain an indication of the potential risk of musculoskeletal lesion, thus suggesting a causal relationship between labour activity and occupational diagnosis of lateral or medial epicondylitis.

For different positions of forearm and wrist, a similar behaviour was observed in the handgrip strength exerted on the handle of the load cart during its displacement along the trajectory, exhibiting higher values in the initial phase. Newton's First Law states that it is necessary to apply a force to make a body start moving as well as to keep it in motion, and this force was found to be reduced when the wrists were in neutral position with forearms pronated. These results support the findings reported by Montanari et al. (2009), who found that handles should be preferentially located in the horizontal position to minimise the handgrip strength needed. Considering that our results for isometric handgrip allowed more force to be produced in that position, including the electromyographic activity, due to the changes in the length–stress relationship of the muscles involved by making distant the origin and insertion points, we believe that a neutral position of the wrist with the forearm pronated should be used for labour activities, since the biomechanical conditions are more favourable.

The differences found between the values of RMS and MF regarding the electromyographic signals recorded from the brachial biceps compared to the brachial triceps during the phases of acceleration and curve can be related to the constitution of the muscle fibres of these muscles. Johnson et al. (1973) reported that the brachial biceps has a higher amount of fast-contraction fibres compared to the brachial triceps. Therefore, the greater amplitude of electromyographic signals found in the brachial biceps can be explained by the fact that this muscle has larger motor units compared to the muscle fibres of slow contraction.

The present study has the limitation of not having electromyographic activity collected bilaterally, differently from the handgrip strength during displacement of the load cart, which could demonstrate the muscle pattern in other situations. Furthermore, future studies including female subjects and taking into consideration the menstrual cycle as a variable that influences the use of strength are suggested.

Conclusion

In view of the results found, we conclude that muscle recruitment and handgrip strength vary depending on the position of forearm and wrist as well as on the trajectory of displacement of the load cart. These findings allow labour guidelines to be made regarding the most effective posture of the worker in order to reduce the overload on the upper limbs, in addition to indicating the potential risk of musculoskeletal lesions.

References

Bambaeichi, E., Reilly, T., Cable, N.T., et al., 2004. The isolated and combined effects of menstrual cycle phase and time-of-day on muscle strength of eumenorrheic females. Chronobiol. Int. 21 (4—5), 645—660.

Basmajian, J.V., Blumenstein, R., 1989. Electrode placement in electromyography biofeedback. In: Basmajian JV. Biofeedback: Principles and Practice for Clinicians, third ed. Williams & Wilkins, Baltimore, pp. 378—379.

Basmajian, J.V., De Luca, C.J., 1985. Muscle Alive: Their Function Revealed by Electromyography, fifth ed. Williams & Wilkins, Baltimore, p. 516.

Bennie, K.J., Ciriello, V.M., Johnson, P.W., et al., 2002. Electromyographic activity of the human extensor carpi ulnaris muscle changes with exposure to repetitive ulnar deviation. Eur. J. Appl. Physiol. 88 (1-2), 5—12.

Bridger, R.S., 2003. Introduction to Ergonomics, second ed. Taylor & Francis, London, p. 548.

Ciriello, V.M., Snook, S.,H., Hashemi, L., et al., 1999. Distributions of manual materials handling task parameters. Int. J. Ind. Ergon. 24 (4), 379—389.

Chung, H.C., Wang, M.J., 2001. The effects of container design and stair climbing on maximal acceptable lift weight, wrist posture, psychophysical, and physiological responses in wafer — handling taskes. Appl. Ergon. 32 (6), 593—598.

d'Errico, A., Caputo, P., Falcone, U., et al., 2010. Risk factors for upper extremity musculoskeletal symptoms among call center employees. J. Occup. Health 52 (2), 115—124.

Dias, E.M., Oliveira, A.S., Brum, D.P., et al., 2006. Avaliação Eletromiográfica de Músculos da Cintura Escapular e Braço Durante a Realização de Exercícios em Cadeia Cinética Fechada. In: XVII Reunião Anual da FeSBE. Curitiba, PR: Anais da XVII Reunião Anual da FeSBE.

Dick, F.D., Graveling, R.A., Munro, W., et al., 2011. Workplace management of upper limb disorders: a systematic review. Occup. Med. (Lond.) 61 (1), 19—25.

Dull, J., Weerdmeester, B., 2004. Ergonomia Prática, second ed. Editora Edgard Blücher, São Paulo.

Guirro, R.R.J., Forti, F., Bigaton, D.R., 2006. Proposal for electrical insulation of the electromyography signal acquisition module. Electromyogr. Clin. Neurophysiol. 46 (6), 355—363.

Hagg, G.M., Milerad, E., 1997. Forearm extensor and flexor muscle exertion during simulated gripping work - an electromyography study. Clin. Biomech. 12 (11), 39—43.

Hermens, H.J., Freriks, B., Disselhorst-Klug, C., et al., 2000. Development of recommendations for SEMG sensors and sensor placement procedures. J. Electromyogr. Kinesiol. 10 (5), 361—374.

Hermes, H.J., Freriks, B., Disslhorst-Klug, C., et al., 1999. European Recommendations for Surface Electromyography — Results of the SENIAM Project. Roessingh Resebiarch and Development, Enschede, The Netherlandes.

Herring, S., Hallbeck, M.S., 2007. The effects of distance and height on maximal isometric push and pull strength with reference to manual transmission truck drivers. Int. J. Ind. Ergon. 37 (8), 685—696.

Hintermeinster, R.A., Lange, G.W., Shultheis, J.M., et al., 1998. Electromyography active and applied load during shoulder rehabilitation exercises using elastic resistance. Am. J. Sports Med. 26 (2), 210—220.

Jeremy, M., Peter, K., 2003. The effects of posture on forearm muscle loading during gripping. Ergonomics 46 (9), 956—975.

Johnson, M.A., Polgar, J., Weightman, D., et al., 1973. Data on the distribution of the fiber types in thirty-six human muscles: an autopsy study. J. Neurol. Sci. 18 (1), 111—129.

Lehmkuhl, L.D., Smith, L.K., 1989. Brunnstrom. Cinesiologia Clínica, fourth ed. Manole, São Paulo.

McGorry, R.W., 2001. A system for the measurement of grip forces and applied moments during hand tool use. Appl. Ergon. 32 (3), 271—279.

Mircea, F., Shrawan, K., Yogesh, N., 2004. Measurement of angular wrist neutral zone and forearm muscle activity. Clin. Biomech. 19 (7), 671—677.

Montanari, M.R., Paschoarelli, L.C., Carmo, C.L., 2009. Forças manuais e o design de produtos: uma revisão. Rev. Tecnológica 18, 37—52.

Osha, 2007. Agência Européia para saúde e segurança no trabalho. Disponível no site: https://osha.europa.eu/en/topics/msds.

Padula, R.S., Souza, V.C., Gil Coury, H.J., 2006. Tipos de preensão e movimentos do punho durante atividade de manuseio de carga. Rev. Bras. Fisioter. 10 (1), 29—34.

Rassier, D.E., Macintosh, B.R., Herzog, W., 1999. Length dependence of active force production in skeletal muscle. J. Appl. Physiol. 86 (5), 1445—1457.

Roman-Liu, D., Tokarski, T., 2005. Upper limb strength in relation to upper limb posture. Int. J. Ind. Ergon. 35 (1), 19—31.

Shih, Y.C., Ou, Y.C., 2005. Influences of span and wrist posture on peak chuck pinch strength and time needed to reach peak strength. Int. J. Ind. Ergon. 35 (6), 527—536.

Straker, L.M., 1999. An overview of manual handling injury statistics in western Australia. Int. J. Ind. Ergon. 24 (4), 357—358.

Wang, M.J.J., Chung, H.C., Chen, H.C., 2000. The effect of handle angle on MAWL, wrist posture, RPE, and heart rate. Hum. Factors 42 (4), 553—565.

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