

Fatigue of the wrist extensor muscles decreases palmar grip strength

Fadiga dos músculos extensores do punho diminui a força de preensão palmar

La fatiga de los músculos extensores de muñeca disminuye la fuerza de prensión palmar

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ABSTRACT | The objective of this study was to evaluate the effects of a wrist extensor muscles fatigue protocol at the handgrip and lateral pinch strength through dynamometry and surface electromyography (EMG). Forty male individuals were divided into two groups: handgrip and lateral pinch group. The fatigue protocol was based on the 1 Maximal Repetition (1-MR) test, followed by wrist extension movement repeated multiple times with a load of 75% of 1-MR. The volunteers performed hand grip and lateral pinch with a dynamometer. Surface EMG was performed by both groups to analyze the behavior of median frequency (MF) during a fatigue protocol. The muscles extensor *carpi radialis longus* and *brevis*, *extensor carpi ulnaris*, *extensor digitorum* and *flexor digitorum superficialis* were analyzed. The strength and EMG evaluations were carried out before and after the fatigue protocol in both groups. The fatigue protocol was effective on hand grip strength reduction (43.5±3.85 kgf in baseline and 36.50±5.1 kgf final) and lateral pinch strength reduction (10.26±1.01 kgf in baseline and 8.54±0.86 kgf final) ($p < 0.05$, 95% CI). At the EMG analysis, using median frequency, an ulnaris carpal extensor muscle fatigue at the handgrip group was evidenced. The findings indicate that wrist extensors fatigue can decrease the strength in functional activities such as handgrip, resulting in upper limb dysfunctions.

Keywords | Grip; Pinch Strength; Fatigue; Eletromiography; Dinamometria.

RESUMO | O objetivo deste estudo foi avaliar os efeitos de um protocolo de fadiga dos músculos extensores de punho na força de preensão e da pinça lateral através da dinamometria e eletromiografia de superfície (EMG). Foram selecionados 40 indivíduos do sexo masculino, divididos em dois grupos: preensão ou pinça lateral. O protocolo de fadiga foi baseado no teste de 1 Repetição Máxima (1-RM), seguido da realização do movimento de extensão de punho repetidas vezes com carga de 75% da 1-RM. Os voluntários realizaram as tarefas de preensão ou pinça lateral associadas à dinamometria. A EMG foi realizada para ambos os grupos, analisando o comportamento, segundo o protocolo, pela frequência mediana (FM) do extensor radial do carpo (ERC), do extensor ulnar do carpo (EUC) e do flexor superficial dos dedos (FD). A dinamometria de preensão ou pinça lateral e a EMG foram realizadas antes e após o protocolo de fadiga para ambos os grupos. O protocolo de fadiga foi eficaz na diminuição da força de preensão palmar (43,5±3,85 kgf inicial e 36,50±5,1 kgf final) e da pinça lateral (10,26±1,01 kgf inicial e 8,54±0,86 kgf final), bem como na diminuição da FM, sugerindo uma condição de fadiga do EUC no grupo preensão. Os achados do presente estudo possibilitam relacionar a fadiga dos extensores de punho à diminuição de força em atividades funcionais, como a preensão, o que pode implicar em disfunções musculoesqueléticas do membro superior.

Descritores | Força da Mão; Força de Pinça; Fadiga; Eletromiografia; Dinamometria.

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RESUMEN | En este estudio se evalúa los resultados de un protocolo de fatiga de los músculos extensores de muñeca en la fuerza de presión y de pinza empleando la dinamometría y la electromiografía de superficie (EMG). Se eligieron a cuarenta hombres, los cuales fueron divididos en dos grupos: el de presión y el de pinza lateral. Se basó el protocolo de fatiga en la prueba de 1 Repetición Máxima (1RM), y se realizó el movimiento de extensión de muñeca muchas veces con carga del 75% de la 1RM. Los participantes realizaron la tarea de prensión o de pinza lateral asociada a la de dinamometría. La EMG fue realizada por ambos grupos, en los que se evaluó el comportamiento ante el protocolo de la frecuencia mediana (Fm) del extensor radial del carpo (ERC), del extensor cubital del carpo (ECC) y del flexor superficial

de los dedos (FD). Se realizaron la dinamometría de presión o de pinza lateral y la EMG antes y después del protocolo de fatiga en ambos grupos. El protocolo de fatiga fue eficaz en la disminución de la fuerza de presión palmar ($43,5\pm 3,85$ kgf inicial y $36,50\pm 5,1$ kgf final) y de pinza lateral ($10,26\pm 1,01$ kgf inicial y $8,54\pm 0,86$ kgf final), así como en la disminución de la Fm, lo que demuestra una condición de fatiga del ECC en el grupo de presión. Los resultados de este estudio permiten relacionar la fatiga de los extensores de muñeca a la disminución de fuerza en las actividades funcionales, lo que puede causar trastornos musculoesqueléticos del miembro superior.

Palabras clave | Fuerza de la Mano; Fuerza de Pinza; Fatiga; Electromiografía; Dinamometría.

INTRODUCTION

In recent years, trauma-orthopedic injuries of the upper limb have been featuring in the scientific literature with the increased incidence of traumatic injuries^{1,2} and also of different pathologies related to musculoskeletal overload^{3,4}. In the evaluation of results of patients treated for upper limb disorders, various clinical parameters are used, among which we highlight the lateral pinch and palmar grip strength^{5,6}. Individuals with palmar grip and lateral pinch dysfunction present deficit in daily life activities, thus the return of strength to this body segment is necessary^{7,8}.

Sensory capacity combined with agility are essential to the daily performance of the distal segment movements of the upper limb. Muscles in this region are of the utmost importance because they enable the practice of movements, such as the lateral pinch and the grip, therefore, a set of muscle actions is necessary such as the wrist extensor muscles activation associated with contraction of finger flexors⁹⁻¹¹.

Bawa et al.¹² describe the synergy that exists between the wrist extensor muscle and finger flexor muscle. Extensor muscles act on stabilization of the wrist in extension during activities of grip and pinch. Studies that investigate this synergistic relationship in functional activities are important for the understanding of pathophysiology and also to outline prevention and treatment protocols in musculoskeletal dysfunctions such as lateral epicondylitis^{5,13}.

Caporrino et al.¹⁴, in a populational study of the palmar grip strength with Jamar[®] dynamometer for the Brazilian population, defined that the average of palmar grip strength in the dominant side is 44.2 ± 8.9 kgf for male individuals and 31.6 ± 7.5 kgf for female individuals. With the same goal, Araujo et al.¹⁵ conducted a populational study of pinch strength with pinch gauge[™] dynamometer and concluded that the strength of lateral pinch in the male gender presents an average of 9.9 ± 1.9 kgf and 6.7 ± 1.4 kgf in the female gender. Studies related to normative data for grip and pinch are presented in different countries and serve as a reference in clinical practice in order to compare possible changes of grip strength and pinch, arising from different lesions of the upper limb^{6,16}. Tang et al.¹⁷ describe that changes in biomechanical parameters of the wrist can be an important cause of diseases and dysfunctions. Alizadehkhayat et al.¹⁸ describe the fatigue as a possible etiology of wrist and elbow dysfunctions.

Muscle fatigue is commonly described as a gradual decrease, resulting from the activity on contractile function and thus reducing muscle capacity to generate force. It may present central or peripheral origin; in the latter, there is increase in the extracellular potassium, in the amount of inorganic phosphate, in the production of reactive oxygen species, in the lactate levels and in the concentration of hydrogen ions and inorganic phosphate. Due to energy consumption, levels of adenosine triphosphate (ATP) decrease because of substrate use in form of energy. The breakdown of ATP

results in adenosine diphosphate (ADP), which justifies the increase of its concentration during muscle fatigue¹⁹.

The electromyographic (EMG) assessment seeks to investigate parameters involving muscle action such as fatigue, conduction velocity, diagnosis of muscular diseases and the muscle recruitment pattern²⁰⁻²². Median frequency (MF) is the most reliable parameter for measuring the changes of EMG spectra, since this parameter is less sensitive to noises and more sensitive to physiological changes related to muscular fatigue such as the accumulation of lactate and extracellular potassium. This metabolic accumulation leads to reduction in the conduction velocity of the action potential, resulting in a decline in the MF values as the muscle becomes fatigued²³⁻²⁵. Studies demonstrate the difficulty in assessing the EMG of the forearm muscles due to proximity of the extensor and flexor compartments^{26,27}. Rota et al.²⁸ describe the influence of fatigue in muscular performance of tennis athletes, and report the importance of surface electromyography in the evaluation of activation and fatigue in the muscles of the upper limb in this population.

In this context, this study aimed to evaluate the pattern of surface EMG in a fatigue protocol of the wrist extensor muscles and the relationship of this protocol in the alteration of grip strength and lateral pinch.

METHODOLOGY

The study was characterized as randomized controlled, with a proposal for evaluation of individuals before and after the fatigue protocol of the wrist extensor muscles, having as outcomes the palmar grip strength, the lateral pinch and the electromyographic activity in different groups. It was approved by the Research Ethics Committee at Universidade Federal de Santa Catarina (UFSC) – 122645/2015 and all subjects recruited signed an informed consent form.

SUBJECTS

Forty male individuals were volunteers and included in the research, aged between 18 and 25 years, no regular physical activity practitioners, who were subdivided into two groups of 20 individuals: Handgrip Group or Lateral Pinch Group.

History of nerve damage associated with bone or joint complex multiple lesions, the presence of central nervous system injury, rheumatic diseases, leprosy and any disease in the upper limbs were considered criteria for non-recruitment.

Randomization to assemble groups was based on a sequence of random numbers generated by the Excel[®] program.

Evaluations were carried out in LARAL (Laboratory for Evaluation and Rehabilitation of the Locomotor System – UFSC/Araranguá) and divided into two phases: on the first day, maximal repetition (1-MR) was calculated for the wrist extensor muscles in the dominant upper limb and, after a week, the pre-fatigue evaluation was carried out (EMG associated with task of grip or lateral pinch, depending on the group), the extensor fatigue protocol and the post-fatigue evaluation (EMG associated with grip or lateral pinch task).

PROCEDURES

Fatigue Protocol

Participants were told not to perform moderate or vigorous physical activity 24 hours before data collection.

The load used for the fatigue protocol was based on the 1-MR test, which consisted in the biggest load the volunteer has achieved the full wrist extension, starting from full flexion.

The fatigue protocol consisted in the performance of flexion and extension movements of the wrist in the maximum range, with the elbow in extension (Figure 1), with 75% of 1-MR load, preset to every volunteer, associated with the use of a metronome with frequency of 50 bpm, being interrupted when the volunteer was unable to maintain the frequency in two consecutive or three alternate movements or failed to perform the maximum range^{29,30}.

For the calculation of MR and fatigue, shin guards were used (0.5; 1.0, 2.0 and 5.0 Kg) adapted to a chain and attached to a tether, which was positioned on the back of volunteers' wrist. Positioning the tether on the back of the hand aimed to avoid contraction of the flexor muscles of fingers during fatigue protocol, something that would happen if a halter was used to such proposal.

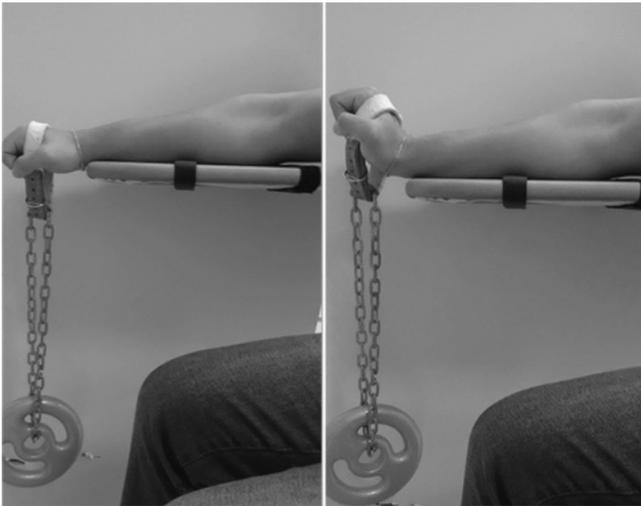


Figure 1. Positioning of the upper limb and resistance to implementation of the fatigue protocol of the wrist extensor muscles.

Grip or lateral pinch task associated with EMG

The tasks performed by the volunteers were: palmar grip using Jamar[®] dynamometer (Handgrip Group) or lateral pinch with the Pinch Gauge[®] (Lateral Pinch Group). The individual's positioning for evaluation followed the recommendation of ASHT (American Society of Hand Therapy), which is followed by SBTM (Brazilian Society of Therapy of the Hand and Upper Limb)³¹. Individuals were positioned comfortably on a chair without armrests, feet fully supported on the floor, the arm parallel to the body, elbow at 90° and forearm in neutral position. Evaluations occurred before and after the proposed fatigue protocol.

Muscle electrical signal was captured by the electromyograph Miotool 400 (Miotec[®], Porto Alegre, RS, Brazil), interfaced with the Miograph[®] software (Miotec[®]), with a 14-bit resolution analog-to-digital converter (A/D), acquisition amplified in 2000 Hz and 100dB common-mode rejection, with 10-500 Hz bandpass filter. Electrodes with bipolar contact Ag/AgCl (Silver/silver chloride) and 20 mm distance between poles – Medtrace[®] were positioned in the muscles: extensor carpi radialis (ECR) – longus and brevis –, extensor carpi ulnaris (ECU) and flexor digitorum superficialis (FD)³² (Figure 2). Three maximum voluntary isometric contractions (MVIC) maintained by six seconds were requested, with one minute rest interval between each task for both groups. The evaluations occurred before and after the fatigue protocol, with the reference electrode positioned over the acromion of the dominant member.



Figure 2: Positioning of electrodes for EMG signal capture of extensor carpi ulnaris (ECU), extensor carpi radialis (ECR) and flexor digitorum superficialis (FDS) muscles during the task of palmar grip strength and lateral pinch.

Data Analysis

The electromyography tracings were processed in the frequency domain, extracting the median frequency (MF) in Hertz; the time of exhaustion of fatigue protocol is calculated in seconds, and the measures of grip strength and lateral pinch are measured in Kgf.

Statistical analysis was performed by the program GraphPad Prism[™], version 6.0. Data normality was checked by the Shapiro-Wilk test, applying the One Way ANOVA test with Tukey's *post hoc* analysis, considering the significance of 5%.

RESULTS

Table 1 presents the anthropometric data and the age of the sample, which were homogeneous between the groups.

Table 1. Initial characteristics of the groups

| | Grip (n=20) | Lateral pinch (n=20) |
|------------------------------|---------------|----------------------|
| Age (SD) - years | 22.32 (±3.58) | 21.94 (±1.73) |
| Dominance (R/L) | 17/3 | 18/2 |
| BMI (SD) - kg/m ² | 24.75 (±2.15) | 25.11 (±3.02) |
| 1-MR (SD) - kg | 12.35 (±2.32) | 12.62 (±2.49) |

BMI: Body mass index; MR: Maximal repetition.

In the assessment of grip strength and lateral pinch, we can observe that there were significant differences when comparing assessments before and after fatigue protocol of the wrist extensor muscles, evidencing decreased strength in both groups (Figure 3).

In the evaluation of exhaust time (in seconds) during the fatigue protocol for both groups, we can observe that there was no statistical difference, as the average time was 33 and 35 seconds to handgrip group and lateral pinch group, respectively.

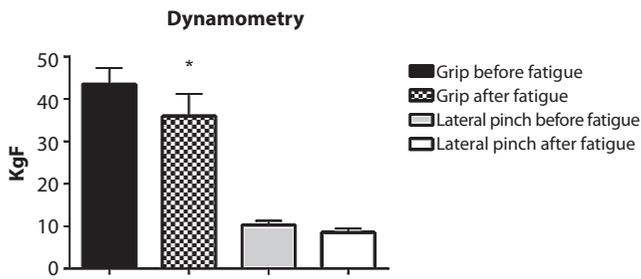


Figure 3. Average values (standard deviation) of force in kilogram-force of groups grip and lateral pinch in the moments before and after fatigue. * $p < 0.05$ - CI 95% grip before strength versus grip after strength

On the analysis of electromyography tracings from MF values, we can observe that it occurred more often in the ECU for both groups, in the initial assessment when compared with other muscles. It is worth mentioning that only the ECU of the Handgrip Group presented a significant decrease in the MF values when compared with initial and final assessment (Figure 4).

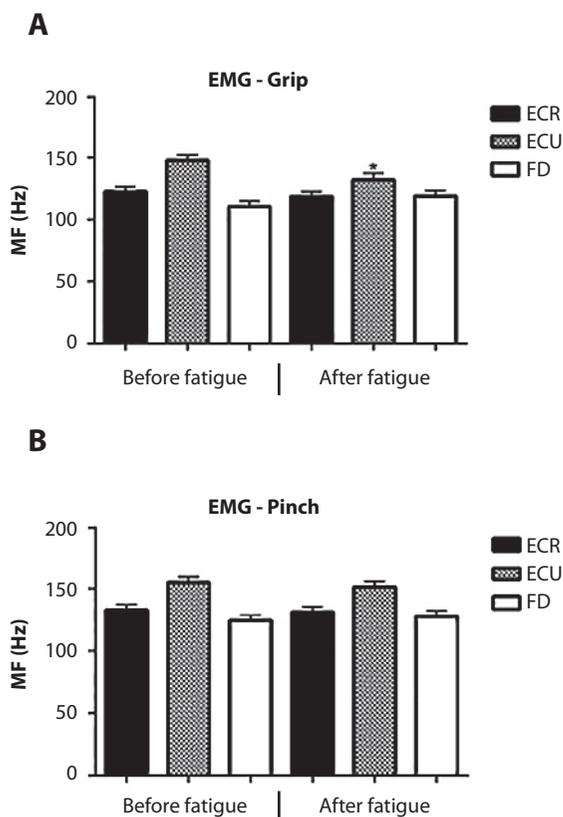


Figure 4. A - Average values of the median frequency (MF) of extensor carpi radialis (ECR), extensor carpi ulnaris (ECU) and flexor digitorum superficialis (FDS) muscles for the grip group. B - Average values of the median frequency (MF) of extensor carpi radialis (ECR), extensor carpi ulnaris (ECU) and flexor digitorum superficialis (FDS) muscles for the lateral pinch group. * $p < 0.05$ - CI 95% versus its respective before fatigue.

DISCUSSION

The assessment of palmar grip strength lateral pinch is widely used to evaluate upper limb disabilities as well as its ability to work. Manual tasks, such as palmar grip and lateral pinch, are study objects since the hand combines two different functions: strength and dexterity. In addition, palmar grip strength is predictive of future disabilities, morbidity and mortality, not only in older adults, but also in middle-aged and young people^{6,33-35}, which strengthens the importance of studies in this area.

The aim of this study was to evaluate the immediate effects of a fatigue protocol in the wrist extensor muscles and their relationship with the palmar grip strength and lateral pinch in different groups. Individuals accepted well the protocol, and no complaint occurred regarding the time of assessment. The protocol has proven to be effective in decreasing the strength of finger flexors, highlighting the synergistic effect between the wrist extensors and flexors of fingers. Corroborating this study, Danna-Dos Santos et al.³⁶ refer that fatigue changes muscle strength and coordination of the hand muscles.

Different studies seek to observe the biomechanical properties in the synergistic relationship between the wrist extensors and finger flexors in musculoskeletal dysfunctions. Studies sought to evaluate the function of the forearm muscles in professional tennis players with or without epicondylitis; among the findings, the authors report the need to evaluate activation and fatigue in wrist extensor muscle in an attempt to identify players more susceptible to development of lateral epicondylitis^{18,37}. This study sought to identify the relation of fatigue of the extensors in the changes of grip strength and lateral pinch in normal individuals, since the findings regarding grip indicate the need for future studies analyzing the pattern in individuals with elbow lateral epicondylitis, commonly observed in the population assisted by physical therapy.

The electromyographic assessment has been used for the evaluation of forearm muscles, in search of a recruitment pattern. Even with a wide variety of studies, we can observe that there is still no consensus on the positioning of electrodes and the influence of different wrist angles in the palmar grip task^{32,34,38,39}.

The muscular physiological processes can be analyzed by electromyographic signal during standardized activities. Thus, the range increase during sustained contractions has been attributed to an increase of

neuromuscular activation, due to increased recruitment of motor units to compensate for the saturation of fibers that are already fatigued, avoiding the immediate failure of the system²⁴. Our electromyographic findings showed a decrease of the ECU median frequency in both groups, with statistical difference for the Handgrip Group after the fatigue protocol. In the Handgrip Group evaluation, only the ECU presented decline in the MF, which suggests its fatigue after the protocol in week 2, when comparing before and after assessments of the wrist extensors fatigue.

Decline in the MF is also observed in the study of Da Silva et al.²⁵ in muscles of the lumbar region, when the authors sought to compare the parameters of fatigue in young and older people with chronic low back pain. Larivière et al.⁴⁰ showed the same change on the MF in the gluteus maximus muscle when they analyzed the specificity of an exercise about the “Roman Chair” in healthy people or people with low back pain. Da Silva et al.⁴¹ evaluated the reproducibility of MF in muscle fatigue located in the quadriceps venters and concluded that the MF is a reproducible and sensitive parameter for the characterization of muscle fatigue. Accordingly, Rota et al.²⁸ describe the influence of muscle fatigue of the pectoralis major muscle and the muscles of the forearm in decreasing the performance of tennis athletes.

This study demonstrates the importance of electromyographic evaluation of the wrist extensor muscles associated with the palmar grip strength or lateral pinch as indicative of muscle fatigue. Therefore, we suggest the incorporation of these analyses in clinical routines involving the evaluation and treatment of patients with upper limb dysfunctions, more specifically, of the wrist extensor muscles and finger flexors of individuals who perform resisted repeated movements of the wrist.

Among the study limitations, we considered the small follow-up time of volunteers, suggesting an effect in the short term and the need for comparison with other models associated with trauma-orthopedic pathologies in the upper limb.

CONCLUSION

In the sample and in the model used, we can conclude that the fatigue protocol of wrist extensor muscles was effective in decreasing palmar grip strength and lateral

pinch. In addition, the extensor carpi ulnaris muscle showed a decrease in the median frequency, suggesting fatigue of the muscle. The findings suggest that further studies with this methodology can bring contributions regarding synergistic assessment or agonist/antagonist relationship of these muscle groups, relating to the etiology and treatment of musculoskeletal dysfunctions of the forearms and wrist.

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