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# Amateur Handball Athletes Present Delayed Muscle Recovery Index Compared to Non-Athletes

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## ABSTRACT

**Magalhães PMN, Silva CAN, Silva AKV, Sousa SP, Melo ALM, Barbosa BT, Leite Filho MAA, Barbosa EL, Montenegro RC, Borges LPNC.** Amateur Handball Athletes Present Delayed Muscle Recovery Index Compared to Non-Athletes. **JEPonline** 2018;21(2):19-29. The purpose of this study was to analyze the fatigue index and the rectus femoris (RF) and biceps femoris (BF) muscle recovery index of amateur handball athletes through the median ($f_{med}$) frequency of electromyogram ($EMG_S$). The sample consisted of 10 handball athletes ($G_{han}$) and 10 control individuals ($G_{con}$). The fatigue and muscle recovery protocol were performed with the subjects at 80% of their maximum voluntary isometric contraction. There was no statistical difference in the percentage of $f_{med}$ drop between $G_{han}$ and $G_{con}$ (RF: -30.86 ± 10.75% vs. -30.35 ± 12.57%, BF: -31.91 ± 10.55% vs. -28.22 ± 12.83%). The percentage of BF muscle recovery was significantly lower in $G_{han}$ compared to $G_{con}$ (54.64 ± 17.24% vs. 71.11 ± 14.61%, P=0.0156). The findings in the present study indicate that practicing amateur handball does not improve fatigue resistance in the thigh muscles, and is associated with a lower percentage of muscle recovery.

**Key Words:** Electromyography, Median Frequency, Muscular Fatigue, Muscular Recovery

## INTRODUCTION

Handball is commonly understood as being one of the easiest taught and learned sports (25). The movements of running, jumping, and throwing in handball are the most used elements in training and games (9). The moment of landing a throwing jump is the stage where the lower limbs collide against a fixed outer surface, where the body is overcome by a rapid deceleration force (i.e., impact generating forces) (22). These forces are able to act individually in each segment of the body that receives the impact, and such forces are dissipated by the musculoskeletal system, which is one of the main causes of injury in the lower limbs in handball athletes (4). In fact, handball players have a prevalence of lower limb injuries that range from 11.9% to 67%, and in upper limbs the range is 7.5% to 40% (20). In this context, Farina and Merletti (5) indicate it is important to point out that muscles are more susceptible to injuries when influenced by muscular fatigue that reduces and compromises muscle contraction, which causing an imbalance in the structure that surrounds the musculature.

Biomechanics is a branch of science that has used to study different concepts, instruments, and strategies to develop a broader understanding of fatigue. In particular, the surface electromyography ($EMG_S$) is used to better understand neuromuscular impulse patterns during and after exercise. This is possible because muscle fatigue generates changes in muscular activation parameters, and the study of the $EMG_S$ signal is of a considerable value in the evaluation process (1). This is especially the case with the assessment of changes due to muscle fatigue (17). To measure peripheral fatigue, the most commonly used indicator is the median frequency ($f_{med}$) of the $EMG_S$ frequency spectrum, since its application is based on greater scientific support. The finding that the phenomenon of localized muscle fatigue changes the frequency bands of the $EMG_S$ allows for the detection of fatigue through indicators related to the density of its frequency spectrum (19).

Considering the above, and taking into account the basis of the frequency spectrum evaluation of the $EMG_S$, the purpose of this study was to analyze the localized fatigue index and the muscle recovery index (MRI) of the biceps femoris (BF, a double-headed muscle on the back of the thigh) and the rectus femoris (RF, one of the 4 muscles of the quadriceps) muscles of amateur handball athletes through the $f_{med}$ of the $EMG_S$ frequency spectrum and compare them to healthy young individuals of the same age who were not practicing the sport.

## METHODS

### Subjects

The sample consisted of 20 males who were between 19 and 30 yrs of age. Ten were amateur handball athletes ($G_{han}$), and 10 were control subjects ($G_{con}$). Data collection was carried out at the Escola de Treinamento Resistido do Centro Universitário de João Pessoa (ETRES – UNIPÊ).

All subjects were informed about the methodological procedures, and they signed an informed consent form whereby the possible risks and the use of the obtained information were explained. In addition, the study adhered to the intervention procedures and ethical precepts for research involving human subjects as recommended by Resolution 466/2012 of the National Health Council. This study was approved by the Research Ethics Committee of UNIPÊ (CAAE: 61876216.2.0000.5176).

The subjects were invited and selected from the previously determined criteria: (a) no previous lesion of the musculoskeletal system; (b) no alcoholic beverage 48 hrs prior to the tests; (c) no use of any drugs that compromise neuromuscular function; and (d) a regular night's sleep with an average of 8 hrs the night before the tests were performed.

**Procedures**

A previously published protocol (18,21) was adapted to measure the fatigue index and muscle recovery index. The performed adaptation prolonged the isometric contraction time (60 sec to 80% of the Maximum Voluntary Isometric Contraction - MVIC), which involved the dominant leg muscles [i.e., biceps femoris (BF) and rectus femoris (RF)] that are involved in the throw landing. Each subject visited the resistance volunteer training school at three different moments: (a) 1st day, familiarization of the environment, clarification about the project, and collection of the informed consent form signature; (b) 2nd day, MVIC measurement of the lower limb muscles (BF and RF) with at least a 10-min rest interval between the measurements; and (c) 3rd day, measurement of fatigue index and muscle recovery index.

Fatigue testing was performed by instructing the subject to sustain an 80% isometric contraction of the MVIC for 60 sec while visual feedback of the performed force was monitored through a load cell. After a 1 min rest period, each subject was instructed to perform an isometric contraction, again at 80% of the MVIC for 10 sec to evaluate the muscle recovery index. For the assessment of the BF, the subject was placed in the ventral decubitus position with knee flexion at 80° and seated on a flexor table. For the RF muscle, the subject was positioned sitting in a flexor chair while maintaining knee flexion at 60º, which is consistent with the literature (15) that a 60º angle is where the quadriceps receive the greatest activation. In contrast, the angulation with greater activation of the BF muscle is at 80º (15). These angles provide the most reproducible parameters of the $EMG_S$ (10). In order to capture the MVIC, each subject performed three sustained contractions under strong verbal command for 5 sec each with a rest interval of 60 sec between each contraction. The MVIC was the largest of the trials. The electrode positioning protocol recommended by SENIAM was adopted in order to capture the electromyography of the BF and RF muscles.

Angulation measurements were performed using a CARCI5® goniometer SH5205. The force signal was measured using a BTS200PrimaxBalanças®load cell with a capacity up to 200 kgf attached to a chain, which in turn was attached to fasteners fixed to the wall of ETRES - UNIPÊ. A MiotecSuite® digital polygraph with 8 input channels, 16-bit A/D conversion, and a sample rate of 3000 samples·$sec^{-1}$ was used to capture the electromyographic signal. During recording of the electromyographic data, a high pass filter of 20 Hz and a low pass filter of 500 Hz were used. The data were amplified with a common mode rejection ratio of 126 db.

The captured $EMG_S$ signal was evaluated through Fast Fourier Transform (FFT), and from which the $f_{med}$ values were obtained. For the fatigue test, the first 3 sec and the last 3 sec of the total period of 60 sec of contraction were analyzed, given that they represented the initial median frequency ($f_{medi}$) and the final median frequency ($f_{medf}$), respectively. For the recovery test, the mean of the total period of 10 sec was evaluated, with the latter being called the median recovery frequency ($f_{medr}$). After analyzing the fmed values, they were used to calculate the muscle recovery index using the following equation (19,21):

$$MRI = \left(\frac{f_{medr} - f_{medf}}{f_{medi} - f_{medf}}\right) x\,100$$

Ag/AgCl electrodes (Skintact®) positioned 20 mm center-to-center were arranged in the direction of the muscle fibers. The reference electrode was positioned on the patella opposite the dominant limb for each analyzed muscle. Trichotomy and skin hygiene were performed with a gauze soaked with 70% alcohol before the electrode placement.

**Statistical Analyses**

The sample was tested for normality by the Shapiro-Wilk test. The $f_{med}$ drop data during the fatigue test were analyzed when there was significance for the paired *t*-test. The significance to evaluate the differences between the averages of the $f_{med}$ fall and the percentage of recovery was determined using the unpaired *t*-test. A significance level of $P<0.05$ was used for all statistical analyses. The data were analyzed using the Statistical Package for Social Science (SPSS) version 17.0 of which all findings were expressed as mean ± standard deviation.

## RESULTS

Table 1 presents the mean ± standard deviation for age, body mass, height, and strength of the subjects who participated in this study.

**Table 1. Anthropometric and Strength Data of 20 Subjects** (10 $G_{han}$ and 10 $G_{con}$).

| | **Age** (yrs) | | **Height** (cm) | | **Weight** (kg) | | **Force – MVIC** (kgf) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $G_{han}$ | $G_{con}$ | $G_{han}$ | $G_{con}$ | $G_{han}$ | $G_{con}$ | $G_{han}$ | | $G_{con}$ | |
| | | | | | | | Ext | Fle | Ext | Fle |
| **Mean** | 22.75 | 23.55 | 173.77 | 175.62 | 78.00 | 73.17 | 20.34 | 10.42 | 17.43 | 11.37 |
| **± SD** | 2.31 | 2.78 | 3.38 | 6.92 | 10.25 | 7.85 | 7.23 | 2.49 | 5.84 | 3.46 |

$\mathbf{G_{han}}$ = Group of Handball Athletes; $\mathbf{G_{con}}$ = Group of Control Subjects; **MVIC** = Maximum Voluntary Isometric Contraction; **Ext** = Extension of the Knee at 60º; **Fle** = Knee Flexion at 80º

Figure 1 (Panels A and B) shows the $EMG_S$ $f_{med}$ values during the initial 3 sec ($f_{medi}$) and the final 3 sec ($f_{medf}$) of the total period of 60 sec to 80% of the MVIC for both RF (Panel A) and BF (Panel B). The decrease in fmed values was significant in both groups ($G_{han}$ and $G_{con}$) when compared with fmed and fmedf, showing that the time and intensity of contraction that were used were effective in promoting alteration of the electromyographic estimator for fatigue (RF: $G_{han}$ 115.20 ± 13.80Hz vs. 79.76 ± 16.54Hz, P=0.0001, and $G_{con}$ 120.66 ± 11.29Hz vs. 83.44 ± 13.70Hz, P=0.0005; BF: $G_{han}$ 122.14 ± 26.26Hz vs. 81.44 ± 12.27Hz, P=0.0001, and $G_{con}$ 123.50 ± 25.45Hz vs. 87.01 ± 16.33Hz, P=0.0081).

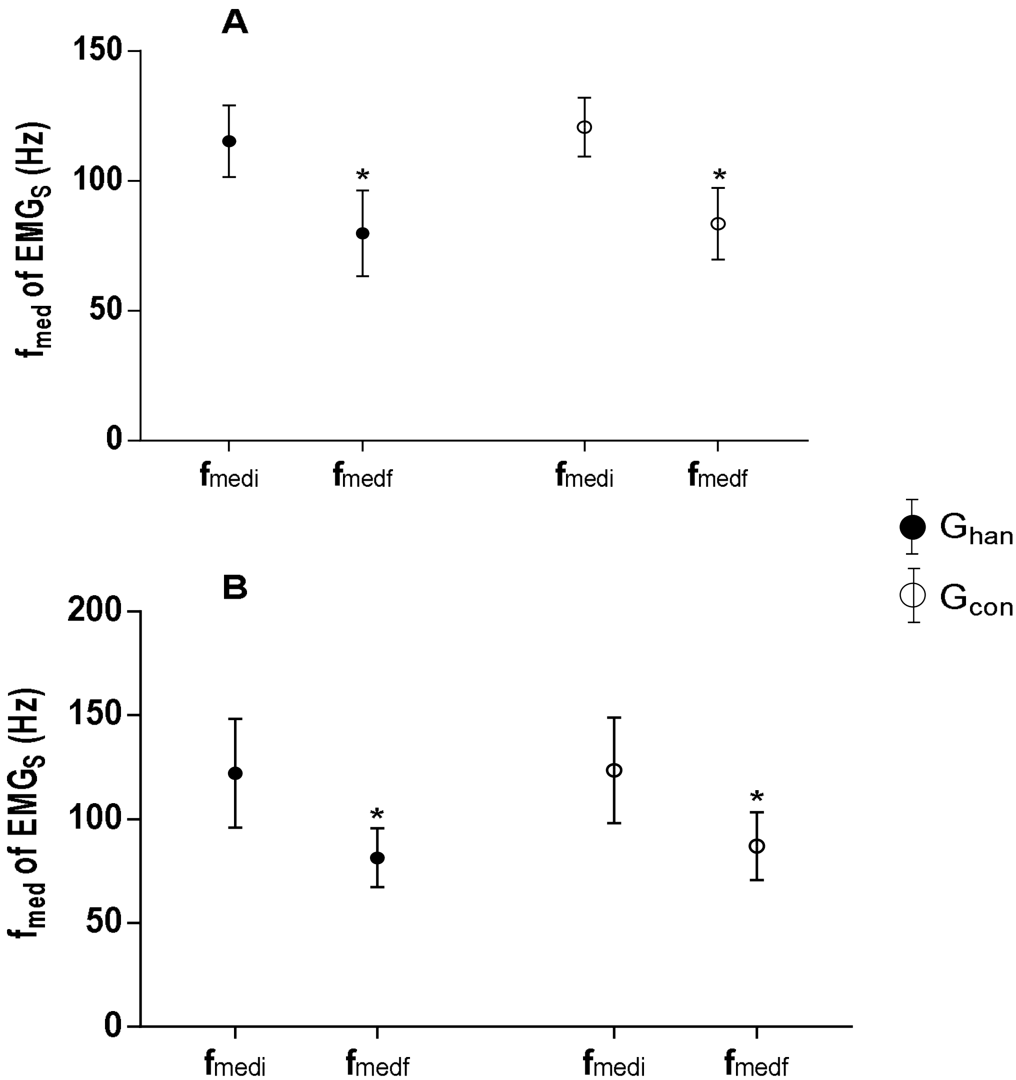


**Figure 1. Behavior of fmed over the Total Period of 60 sec for 80% of the Rectus Femoris Muscle MVIC (Panel A) and Biceps Femoris (Panel B). Ghan** = Handball Athletes; **Gcon** = Control Group. *Significant difference ($P<0.05$) with respect to the median value of the same group

For each muscle group for both $G_{han}$ and $G_{con}$, the percentages of fall magnitude of the $f_{med}$ were compared over the period of 60 sec to 80% of the MVIC. Statistical analysis showed no difference for the percentage of $f_{med}$ fall. In other words, both the RF (-30.86 ± 10.75% vs. -30.35 ± 12.57%, Figure 2, Panel A) and the BF (-31.91 ± 10.55% vs. -28.22 ± 12.83%, Figure 2, Panel B) of $G_{han}$ and $G_{con}$ showed the same rate of $f_{med}$ change.

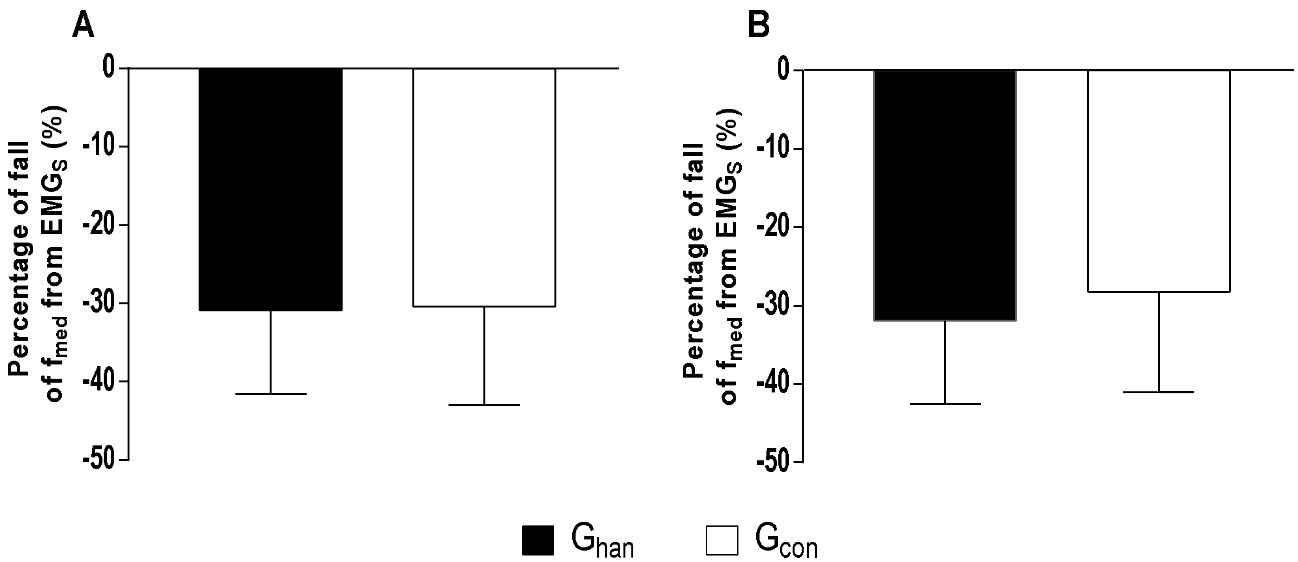


**Figure 2. Percentage of Fall Magnitude of the fmed Measured by the Initial 3 secs and the Final 3 secs of the Total Period of 60 sec for 80% of the Rectus Femoris Muscle MVIC (Panel A) and Biceps Femoris (Panel B). Ghan** = Handball Athletes; **Gcon** = Control Group.

Figure 3 shows the recovery percentage of fmed calculated 60 sec after the fatigue protocol for both the RF and BF of $G_{han}$ and $G_{con}$. There was no statistical difference for the percentage values of RF recovery (51.95 ± 17.57% vs. 62.04 ± 9.77%, $G_{han}$ vs. $G_{con}$). In contrast, statistical analysis showed a significant difference for BF recovery percentages with $G_{han}$ presenting a lower percentage of muscle recovery (54.64 ± 17.24% vs. 71.11 ± 14.61%, P=0.0156, $G_{han}$ vs. $G_{con}$).

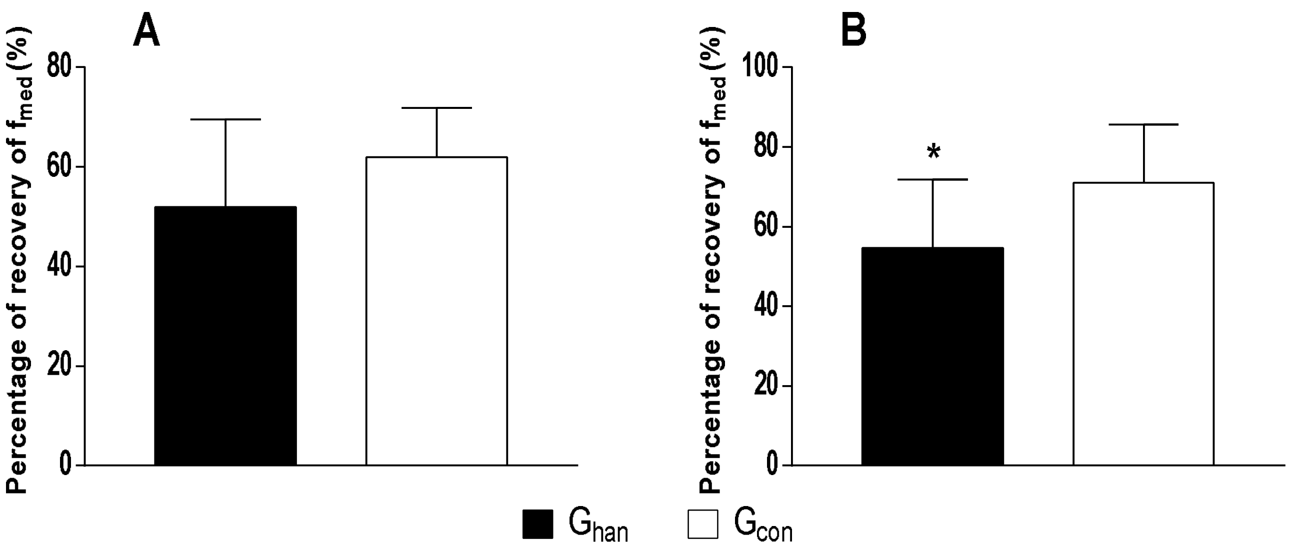


**Figure 3. Percentage of Recovery of fmed After a 60-sec Resting Period following the fatigue Protocol for Rectus Femoris Muscle (Panel A) and Biceps Femoris (Panel B).** *P<0.05 compared to $G_{con}$

**DISCUSSION**

The purpose of the present study was to analyze the levels of localized muscle fatigue by means of the electromyographic signal, as well as to use the $f_{med}$ to estimate the recovery rate of the rectus femoris and biceps femoris muscles that are constantly in use by handball players. This was done by comparing the handball players' responses with those of the control subjects not practicing the sport. The 80% contraction protocol of the MVIC for producing the subjects' fatigue was effective, reverberating in the significant fall between the $f_{medi}$ and $f_{medf}$ values in all the analyzed muscular groups in the $G_{han}$ as well as in the $G_{con}$. These significant decreases in $f_{med}$ values during the fatigue process have a direct relation with the accumulation of hydrogen ions, metabolites, and changes in sodium and potassium concentrations, given that these biochemical factors are characteristic of muscle fatigue (13).

When we refer to the percentage of $f_{med}$ drop, there was no significant difference for this parameter in the RF and BF muscles, with the fatigue estimator of the electromyographic signal changing in the same proportion for both athletes and control subjects. This statement was substantiated by observing the decrease in $f_{med}$ values in both groups. This decrease in $f_{med}$ is found in the literature as an indication that the muscle is in a state of fatigue (5). According to the literature, a trained individual should show a slower fall in $f_{med}$ during exercise when compared to an untrained individual (21). According to our results, the practice of amateur handball does not promote this fall retardation in $f_{med}$. Thus, based on the electromyographic fatigue estimator we can hypothesize that practicing amateur handball does not promote better fatigue resistance in its participants.

To reinforce our observation of the non-favoring of better resistance to fatigue by amateur handball athletes, we point out that Reckling et al. (16) characterizes handball as a sport with fast movements, numerous jumps, and abrupt decelerations with athletes being frequently subjected to a constant and intense training overload from practicing the sport modality itself (20). Thus, according to the literature (3), it can be inferred that anaerobic capacity is of great importance for handball athletes, since much of the predominant movement of handball players involves very intense and short duration efforts with the anaerobic condition having greater significance in the physical preparation of the handball player.

Regarding the percentage recovery being measured after 60 sec of rest that followed the fatigue that was induced by the isometric contraction at 80% of the MVIC, it was significantly lower for the BF muscle in the athletes when compared to the control subjects. Muscle fatigue is a result of post-exercise metabolic disorders, in which recovery depends on the restoration of muscle glycogen stores and other variables involving homeostasis, which usually occur within 24 hrs after exercise (24). However, in literature reviews encompassing $EMG_S$ this time period depends on the exercise, and it may be minutes, hours, and even days, although there is not a complete agreement on this point (11). According to De Luca (12), the ability of the muscle to present a $f_{med}$ value near resting after a fatigue test can basically be understood as a better muscle recovery index.

Fatigue is directly related to a decrease in contraction capacity and force generation, which may be associated with both the behavior of the nerve impulse patterns sent to the muscle and the physiological and biochemical events of the muscles in use. Thus, when one of these events are unbalanced, muscle recovery does not occur in a satisfactory manner (7). Clearly, the dynamics involved in muscle recovery area very important element in training. It is necessary to give equal importance to both training and recovery, because not paying attention to the time needed to repair the substrates used during exercise prevents the body from returning to its state of homeostasis, which decreases its muscular performance and increases the risk of injury (6).

The types of muscle fibers that are used during a specific physical exercise may be associated with the onset of fatigue. Muscle fibers can be characterized into two types: (a) red fibers; and (b) white fibers (23). Red fibers are known as type I fibers, and are characterized by greater use of the aerobic pathway, more mitochondria, and slower contraction, which allows the muscle to be used for sustaining resistance work. On the other hand, white fibers are known as type II fibers. They are characterized by the predominance of the anaerobic pathway, a smaller number of mitochondria, and a higher rate of contraction. Type II fibers are recruited more when the individual performs short duration and high intensity activities that are characteristic of the movements in handball.

Contessa et al. (2) indicate that the RF muscle has a predominance of type II muscle fibers with a large motor neuron that innervates a larger number of muscle fibers, but with low resistance to fatigue. On the other hand, according to Onishiet et al. (14), type 1 fibers are predominately found in the BF muscle, which allows the BF muscle to have a greater capacity to perform more sustained or repeated muscular contractions that require relatively lower tension. It is interesting that the observations of Contessa et al. (2) and Onishiet et al. (14) are not in line with our results, since both muscles presented the same percentage of $f_{med}$ fall for the control subjects when submitted to the fatigue protocol. Furthermore, when the muscular recovery index was evaluated, the RF muscle presented the same recovery percentage as was found in the control subjects, which was different from that observed in the BF muscle that presented a significantly lower recovery percentage.

Our results indicate that the anaerobic characteristics in the amateur handball athlete population are more evident in the BF muscle more so than in the RF muscle. We emphasize that the intense physical effort associated with an unsatisfactory muscular recovery makes the used muscles more susceptible to injuries (8). In addition, we call attention to the importance of developing the aerobic process that must be taken into account when training handball players. This is important since this population can maintain the characteristics of effort intensity throughout the game with probable higher efficiency in lactic acid removal and, consequently, a decrease in the state of fatigue and increase in muscle recovery patterns.

### Limitations in this Study

The present study is limited as follows: (a) the small sample size hinders the generalization of the results to all population; (b) the investigators did not analyze the real proportion of the types of muscle fibers in the athletes; and (c) the evaluation was made in a detraining period.

## CONCLUSION

Thus, based on the analysis of $EMG_S$ $f_{med}$ behavior patterns, the results of the present study make it possible to infer that amateur handball athletes have no advantage in fatigue strength of the thigh (with respect to the RF and the BF muscles) when compared to control subjects of the same age and non-practitioners of the sport. In addition, this study found that the BF muscle had a lower percentage of muscle recovery when compared to the control subjects. We start from the premise that a muscle that has no advantage in its resistance to fatigue plus a disadvantage in its recovery profile is more favorable to the appearance of injuries during intense practice of the sport modality.

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