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Renato Alexandre Da Costa-Machado , Ana Teresa Conceição , Fernando Rocha , Marco Branco *

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Assessment of Muscle Activity during a Deadlift Performed by Trained and Untrained Construction Workers

Renato Alexandre da Costa-Machado [1], Ana Conceição [2,3], Fernando Rocha [3,4] and Marco Branco [5,6]*

[1] Escola Superior de Desporto de Rio Maior, Instituto Politécnico de Santarém, Rio Maior, Portugal; renato.machado@esdrm.ipsantarem.pt
[2] Departamento de Treino Desportivo, Escola Superior de Desporto de Rio Maior, Instituto Politécnico de Santarém, Rio Maior, Portugal; anaconceicao@esdrm.ipsantarem.pt
[3] Research Centre in Sports of Health and Human Development (CIDESD), 5000-801 Vila Real, Portugal
[4] Education School, Polytechnic Institute of Setubal 2914-504 Setubal, Portugal; fernandopsrocha@gmail.com
[5] Departamento de Atividade Física e Saúde, Escola Superior de Desporto de Rio Maior, Instituto Politécnico de Santarém, Rio Maior, Portugal
[6] CIPER, Faculdade de Motricidade Humana, Universidade de Lisboa, Cruz Quebrada Dafundo, Portugal
* Correspondence: marcobranco@esdrm.ipsantarem.pt; Tel.: +351-243-999-280

Abstract: Construction work is physically demanding. The tasks involved in this professional occupation physically exhaust workers and put them at high risk of injury. This work aims to analyze muscle fatigue in civil construction workers, with and without physical activity historical practice. For this purpose, the muscle activity of the Biceps Femoris, Trapezius Transversalis, Erector Spinae Longissimus, was evaluated using surface electromyography. Eleven male civil construction workers aged 26 to 52 years (38.00 ± 9.60), of whom 7 were untrained (N =7) and 4 were trained (N=4) participated in this study. Each subject completed two assessments at two different times. At the first assessment moment, a questionnaire was completed, and the maximum repetition of the deadlift exercise was assessed. At the second assessment, the subjects were assessed while performing the deadlift in four different situations: 50%RM at rest, 80%RM at rest, 80%RM at fatigue, and 50%RM at fatigue. The trained construction workers have higher levels of muscle activity, and there are no significant differences in muscle activation between the fatigued and non-fatigued sets. There appears to be a strong influence of physical exercise on muscle activity and fatigue in civil construction workers.

Keywords: electromyography; deadlift construction workers; exercise

1. Introduction

Construction is the base for several industries, stimulating their activities by building facilities for various purposes, contributing significantly to the economy by maintaining and increasing industrial productivity [1]. There are several risk factors for construction workers (CWs), ranging from precarious working conditions, poor or inadequate safety equipment, repetitive movements, incorrect postures, high contact forces, long hours of exposure to adverse atmospheric conditions, among others [1–3]. These contribute to a high risk of injury and death, with a twofold higher risk of injury and a threefold higher risk of death when compared to other occupations [2,4–9]. According to Hulls, *et al.* [10], the construction industry is predominantly male, and male-dominated industries have a higher prevalence of risky health behaviors, and male habits may contribute to poorer health outcomes. The risk factors associated with this profession are exacerbated by the poor health habits of CWs, such as smoking, alcohol consumption, overweight and obesity [11–15]. As such a physically and psychologically demanding occupation, CWs are exposed to high levels of physical activity (PA) and subsequent fatigue on a daily basis, which promotes negative health outcomes [2,7,9,15,16]. As a result of the tasks performed by CWs, there are several associated health problems, such as musculoskeletal injuries, most commonly in the shoulder, knee, and lumbar regions [2,4,6,17].

Cardiovascular and metabolic problems, such as hypertension, diabetes, and cholesterol are also observed in this population as a consequence of their lifestyle and occupation [15,18].

According to the Magyari, *et al.* [19], physical exercise (PE) and PA are recommended for all apparently healthy adults, as well as the maintenance of PA levels, at a moderate intensity for at least 150 minutes per week, distributed over the days of the week. Although CWs have higher levels of PA, it appears to be more detrimental than beneficial given the low intensity and long hours of the task, highlighting the importance of structured and planned PE practice [8,20]. The tasks of this occupation appear to require high balance and postural muscle strength, with CWs carrying heavy equipment and materials on sloping floors and in some cases with reduced grip [2]. As these workers are exposed to several movements throughout the day, it was chosen to analyze the movement of "picking up an object from the ground", such as the deadlift (DL) exercise, which has a direct transfer to the daily life of these professionals [21], requiring a lot of strength and the use of postural muscles, such as the shoulder girdle and lower back. According to Amin, *et al.* [22], repetitive loading of spinal tissues, especially under high magnitude spinal loads, has been associated with a high risk of fatigue failure in spinal tissues. In addition, according to Ramirez, *et al.* [23], performing a deadlift while fatigued increases the trunk flexion and is likely to place greater mechanical demands on internal trunk tissues (muscles and ligaments) to ensure spinal balance and stability, ultimately leading to higher spinal loads. Moreover, according to Martin-Fuentes, *et al.* [24], the biceps femoris is the most studied muscle, when performing the DL exercise, but it is the erector spinae that shows the highest activation, and Ramirez, Bazrgari, Gao and Samaan [23] reported that the lift-off (initial part of the movement) is the lifting position associated with the greatest mechanical demand on the lumbar spine during the deadlift.

Therefore, the main objective of this study was to compare the muscle activity during the performance of the DL exercise by construction workers who practice physical exercise (CWPE) and construction workers who do not practice physical exercise (CWnPE). This was done to see if there were differences between the groups to understand if practicing PE benefits this population. The subjects performed four sets of deadlifts, two sets at 50% RM (maximum repetition) and two sets at 80%RM. The first two sets (50% RM and 80% RM) were performed at rest and the last two sets (80% RM and 50% RM) were performed at fatigue.

2. Results

Table 1 shows that the CWPE had higher muscle activation than the CWnPE, in every set and in every muscle. The CWnPE showed greater muscle activation in TTL and TTR in every set, with values between 20% and 37%, approximately. On the other hand, BFL, BFR, ESL and ESR had values below 20% in every set. The 80% RM set at post-fatigue was the set that had the greater activation in almost every muscle for these subjects. When comparing the sets in the pre-fatigue situation, almost all muscles reported a greater muscle activation in the 80% RM set, with the exception of BFR and ESL, which did not report this behavior. In the post-fatigue situation, the untrained subjects also reported higher values in almost all muscles, except for ESL and ESR in the 80%RM set. As in the case of CWnEP, the analysis of the CWPE group of workers showed that the muscles with greater muscular activation were the same, TTL and TTR.

Table 1. Comparison of Muscle Activity (RMS (%)) between Sets at 50%RM and 80%RM, at Pre-Fatigue and at Post-Fatigue, in Untrained and Trained Subjects.

			50%RM		80%RM		Z	≠	Effect Size
			Mean	Std dev	Mean	Std dev			
Untrained	Pre-Fatigue	BFL	6,59	3,00	11,80	6,96	-1,83	0,07	-
		BFR	13,66	17,73	12,88	18,43	-0,37	0,72	-
		TTL	**21,02**	12,15	**28,10**	9,14	-2,02	**0,04**	**-0,61**
		TTR	**19,91**	10,13	**30,70**	10,26	-2,02	**0,04**	**-0,61**
		ESL	9,44	7,96	8,06	1,68	-0,94	0,35	-
		ESR	11,28	8,80	15,78	8,85	-0,94	0,35	-

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		BFL	14,18	8,04	14,67	10,85	-0,73	0,47	-
		BFR	15,85	19,58	18,62	25,49	-0,73	0,47	-
	Post-Fatigue	TTL	25,46	18,33	32,31	25,87	-1,36	0,17	-
		TTR	35,06	22,86	36,69	29,61	0,00	1,00	-
		ESL	16,97	22,47	13,16	14,68	-0,73	0,46	-
		ESR	16,29	7,19	19,74	7,26	-0,94	0,35	-
Trained	**Pre-Fatigue**	BFL	13,52	10,47	20,64	20,89	-1,07	0,29	-
		BFR	16,02	5,06	24,12	6,64	-1,60	0,11	-
		TTL	28,42	9,26	50,45	24,88	-1,83	0,07	-
		TTR	28,05	28,56	52,57	45,09	-1,83	0,07	-
		ESL	9,89	1,91	20,75	15,60	-1,46	0,14	-
		ESR	16,27	5,68	35,87	24,14	-1,83	0,07	-
	Post-Fatigue	BFL	16,73	6,82	21,69	11,72	-1,83	0,07	-
		BFR	20,82	1,34	25,01	6,33	-1,07	0,29	-
		TTL	28,99	23,08	42,93	31,40	-1,10	0,27	-
		TTR	61,28	50,92	64,75	68,43	-0,37	0,72	-
		ESL	25,16	12,02	26,88	17,34	-0,37	0,72	-
		ESR	29,68	9,93	42,30	23,72	-1,46	0,14	-

RMS: Root Mean Square; BFL: Biceps Femoris Left; BFR: Biceps Femoris Right; TTL: Trapezius Transversalis Left; TTR: Trapezius Transversalis Right; ESL: Erector Spinae longissimus Left; ESR: Erector Spinae Longissimus Right.

Significant differences ($p \leq 0.05$) were found in CWnPE in the muscle activation value of TTL in the pre-fatigue situation between the 50%RM set (21.02 ± 12.15) and the 80%RM set (28.10 ± 9.14) ($z = -2.02$, $p = 0.04$) and in the muscle activation value of TTR in the pre-fatigue situation between the 50%RM set (19.91 ± 10.13) and the 80%RM set (30.70 ± 10.26) ($z = -2.02$, $p = 0.04$). In the post-fatigue situation, no significant differences were observed between the 50%RM and 80%RM sets, nor on either set of CWPE.

In Table 2, when comparing the same intensity values at pre-fatigue and post-fatigue, higher values of muscle activation were observed in the post-fatigue set at both 50%RM and 80% RM. Significant differences were found between the muscle activation values in TTL at pre-fatigue (21.02 ± 12.15) and post-fatigue (25.46 ± 18.33) ($z = -2.02$, $p = 0.04$), and in TTR at pre-fatigue (19.91 ± 10.13) and post-fatigue (35.06 ± 22.86) ($z = -2.02$, $p = 0.04$), both at 50% RM. There were also significant differences between TTR values in the 80%RM set when comparing the pre-fatigue and post-fatigue situations ($z = -2.02$, $p = 0.04$), with TTR showing greater muscle activation in the post-fatigue (36.69 ± 29.61) compared to pre-fatigue (30.70 ± 10.26). CWPE showed no significant differences between sets.

Table 2. Comparison of Muscle Activity (RMS (%)) between Sets at Pre-Fatigue and at Post-Fatigue, at 50%RM and 80%RM, in Untrained and Trained Subjects.

			Pre-Fatigue		**Post-Fatigue**		**Z**	**≠**	**Effect Size**
			Mean	**Std dev**	**Mean**	**Std dev**			
Un-trained	**50%RM**	BFL	6,59	3,00	14,18	8,04	-1,83	0,07	-
		BFR	13,66	17,73	15,85	19,58	-0,37	0,72	-
		TTL	**21,02**	12,15	**25,46**	18,33	-2,02	**0,04**	**-0,61**
		TTR	**19,91**	10,13	**35,06**	22,86	-2,02	**0,04**	**-0,61**
		ESL	9,44	7,96	16,97	22,47	-0,41	0,69	-
		ESR	11,28	8,80	16,29	7,19	-1,21	0,23	-
	80%RM	BFL	11,80	6,96	14,67	10,85	-1,10	0,27	-
		BFR	12,88	18,43	18,62	25,49	-1,10	0,27	-
		TTL	28,10	9,14	32,31	25,87	-0,14	0,89	-
		TTR	**30,70**	10,26	**36,69**	29,61	-2,02	**0,04**	**-0,61**
		ESL	8,06	1,68	13,16	14,68	-0,14	0,89	-

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		ESR	15,78	8,85	19,74	7,26	-1,48	0,14	-
Trained	50%RM	BFL	13,52	10,47	16,73	6,82	-1,60	0,11	-
		BFR	16,02	5,06	20,82	1,34	-1,60	0,11	-
		TTL	28,42	9,26	28,99	23,08	-0,37	0,72	-
		TTR	28,05	28,56	61,28	50,92	-1,83	0,07	-
		ESL	9,89	1,91	25,16	12,02	-1,46	0,14	-
		ESR	16,27	5,68	29,68	9,93	-1,83	0,07	-
	80%RM	BFL	20,64	20,89	21,69	11,72	0,00	1,00	-
		BFR	24,12	6,64	25,01	6,33	-1,07	0,29	-
		TTL	50,45	24,88	42,93	31,40	-0,37	0,72	-
		TTR	52,57	45,09	64,75	68,43	-0,73	0,47	-
		ESL	20,75	15,60	26,88	17,34	-1,83	0,07	-
		ESR	35,87	24,14	42,30	23,72	-1,83	0,07	-

RMS: Root Mean Square; BFL: Biceps Femoris Left; BFR: Biceps Femoris Right; TTL: Trapezius Transversalis Left; TTR: Trapezius Transversalis Right; ESL: Erector Spinae longissimus Left; ESR: Erector Spinae Longissimus Right.

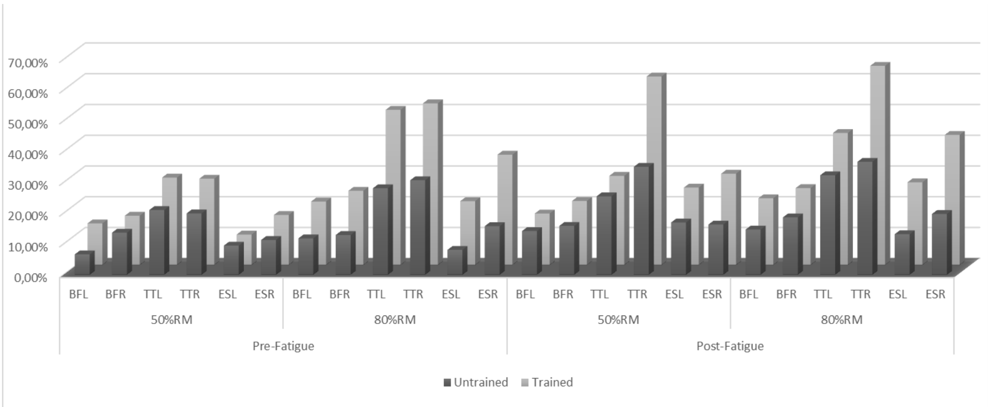

Figure 1. Comparison of Muscle Activation (RMS (%)) between 50%RM and 80%RM Sets, in a Pre-Fatigue and Post-Fatigue Situation, in Untrained and Trained Subjects. BFL: Biceps Femoris Left; BFR: Biceps Femoris Right; TTL: Trapezius Transversalis Left; TTR: Trapezius Transversalis Right; ESL: Erector Spinae longissimus Left; ESR: Erector Spinae Longissimus Right.

Table 3. Comparison of Muscle Activity (Mean Frequency) between Untrained and Trained Subjects, in Post-Fatigue Situation, in 50%RM and 80%RM sets.

		Trained		Untrained		Z	≠
Post-Fatigue		Mean	Std dev	Mean	Std dev		
50%RM	BFL	48,16	45,59	88,85	12,23	-1,51	0,13
	BFR	42,55	48,10	47,46	32,15	-0,19	0,85
	TTL	56,28	28,17	72,85	6,15	-0,94	0,34
	TTR	67,89	14,26	58,19	5,67	-1,51	0,13
	ESL	63,83	29,80	72,69	19,79	-0,19	0,85
	ESR	58,33	12,46	60,29	6,38	-0,38	0,71
80%RM	BFL	48,10	45,58	84,10	11,65	-1,13	0,26
	BFR	40,85	52,41	50,07	34,10	0,00	1,00
	TTL	59,00	28,33	68,68	5,50	0,00	1,00
	TTR	69,43	16,56	62,40	8,19	-0,76	0,45

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	ESL	62,95	29,99	74,27	21,73	-0,57	0,57
	ESR	61,05	13,10	57,70	7,70	-0,19	0,85

BFL: Biceps Femoris Left; BFR: Biceps Femoris Right; TTL: Trapezius Transversalis Left; TTR: Trapezius Transversalis Right; ESL: Erector Spinae longissimus Left; ESR: Erector Spinae Longissimus Right.

Significant differences between groups were tested and were not found for any of the variables. However, the mean values are mostly lower for trained subjects when compared to untrained subjects, and conversely, the standard deviation values are higher for trained subjects compared to untrained subjects.

Muscle asymmetries between the left and right sides were also tested and no significant differences were found for either group.

3. Discussion

The aim of this study was to evaluate and compare muscle activity between the CWPE and CWnPE. Differences were observed between subjects, with the untrained subjects showing significant differences in some values of muscle activation, while the trained subjects showed no significant differences in any parameter. However, significant differences were observed only in the TTL and TTR, which may reflect the low ability of the CWnPE to maintain shoulder girdle stability.

Since CWnPE showed significant differences between sets of different intensities and with induced fatigue, the results obtained in this work seem to be in line with the results presented in other studies [2,4,6,17]. This implies that the consequences of the tasks performed by CWs, caused by long working hours and high levels of PA, lead to several health problems, such as musculoskeletal injuries.

CWPE showed greater muscle activation when compared to the CWnPE, in every muscle and every set, which may reflect the influence of the exercise, which seems to be aligned with the findings of Viester, Verhagen, Bongers and van der Beek [5] who suggests that the lack of effect produced by the occupational PA may be related with the average high levels of baseline PA at work for CW, highlighting the importance of a structured and planed exercise schedule. Also as van den Berge, Van Oostrom, van der Molen, Robroek, Hulshof, van der Beek and Proper [15] claims, the worksite health promotion interventions should aimed at reducing occupational PA and improving leisure-time vigorous PA and reducing obesity can have beneficial health effects.

CWnPE showed greater muscle activation in TTL and TTR with peak values of 32% and 37%, respectively, and values below 20% in the other muscles. On the other hand, CWPE showed peak values of 50% and 65% for TTL and TTR, respectively, and values above 20% activation in all muscles except BFL and BFR at pre-fatigue.

In terms of muscle asymmetries, no significant differences were found between untrained and trained subjects, and no significant differences were observed between subjects in the fatigued condition, although CWnPE presented higher mean frequency values.

Contrary to the study by Martin-Fuentes, Oliva-Lozano and Muyor [24], the present results suggest that the muscle with the greatest activation during the DL is the TT, not the ES. However, this muscle was not analyzed by Martin-Fuentes, Oliva-Lozano and Muyor [24] and further research is needed on this issue.

As presented in this paper, the TT was the muscle with the highest values of RMs (%), which was also suggested by Manttari, Oksa, Lusa, Korkiakangas, Punakallio, Oksanen and Laitinen [2], who state that the tasks performed by CWs seem to require great balance capacity and strength of the postural muscles, as CWs have to support heavy equipment, sometimes on unstable surfaces.

Our results show a difference between the RM between CWPE and CWnPE, with the CWPE showing higher values. Those higher values were also perceived at younger individuals which is supported by Merkus, Lunde, Koch, Waersted, Knardahl and Veiersted [7].

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4. Materials and Methods

Sample

The sample consisted of 11 male CWs (N=11), aged 38.00 ± 9.60 years, with a body mass index (BMI) of 29.43 ± 2.60 g/m² (corresponding to overweight), and with professional practice times of 15.45 ± 10.80 years, divided into two distinct groups: i) CWPE (N=4); ii) CWnPE (N=7).

Some differences were observed between the groups in terms of age, in which the CWnPE presented a mean age of 41.14 ± 9.70 (years) and the CWPE presented a mean age of 32.70 ± 7.40 (years); in terms of professional practice time, the CWnPE presented a mean time of 18.43 ± 11.40 (years) and the CWPE presented a mean time of 10.25 ± 8.70 (years); and in the predicted values of 1RM, in which the CWnPE presented values between 75kg and 117kg (95.14 ± 19.60) and the CWPE presented values between 105kg and 150kg (123.00 ± 19.10). Regarding the time of PE practice, the CWPE have values between 3 and 7 years (5.00 ± 1.60) and the CWnPE have no record of PE practice. The BMI values were similar in both groups.

Procedures

This was a comparative study of two CWs populations, CWPE and CWnPE. There were two assessment moments. In the first moment, the subjects were informed about the nature and objectives of the study, as well as its procedure and that they could withdraw from the study at any time, after which an informed consent was signed.

They were then introduced to the technical movement they were going to perform and performed two sets of 10 repetitions of warm-up using only the Olympic barbell (20kg).

After the warm-up and the technical explanation of the exercise, the 1-RM prediction test was performed by indirect methods, where the practitioners performed several sets until the predicted 1RM value was found.

The 1RM prediction test began with a load that was expected to be performed for 8 to 12 repetitions. If the participant was able to complete 10 repetitions, a 2-minute rest period was provided. A 20% increase in the previous load was then applied, and the participant performed the test again. This procedure was repeated until the participant was unable to complete 10 repetitions, at which point an estimate of 1RM was used as described by Baechle and Groves [25]:

$$1RM = Workload(Kg) \times [(0.0375 \times Reps) + 0.978],$$

where 1RM is the maximum weight the person can perform, *workload* is the load used during the test and *Reps* is the number of repetitions performed with the indicated load.

At the second assessment moment, the EMG evaluation was performed. A warm-up of two sets of 10 repetitions was performed with a light load (barbell only).

After muscle activity was assessed on both sides of the body by surface electromyography (EMG), the skin under the electrode area was shaved, rubbed with sandpaper and cleaned with alcohol for each subject after warming up, so that the interelectrode resistance did not exceed 5 KOhm [26].

Electrode placement was performed according to SENIAM recommendations [27] for the following muscles: i) Biceps Femoris (BF), left (BFL) and right (BFR); ii) Trapezius Transversalis (TT), left (TTL) and right (TTR); iii) Erector Spinae Longissimus (ES), left (ESL) and right (ESR).

The first set was performed at a load of 50%RM and the participants were asked to complete 12 repetitions. A second set was performed after a 2-minute rest, this time at 80%RM, again with 12 repetitions. After the first two sets, a fatigue protocol was used in which the participants were asked to complete as many repetitions as possible at a load of 80%RM after a 2-minute rest. The third set was performed at a load of 80%RM after a 2-minute rest post-fatigue protocol, with 12 repetitions. The fourth set was performed at a load of 50%RM with a 2-minute rest with 12 repetitions.

The purpose of the fatigue protocol was to induce the physical fatigue, often experienced by CWs through exercise and to analyze how they behaved after reaching a high level of fatigue under various loads.

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The maximum contraction value was calculated using the maximum voluntary dynamic contraction (MVDC), as this method is preferable to isometric contractions for normalization purposes [28].

Figure 2. Deadlift Exercise Start and End Positions.

Data analysis

The data were collected using the MonitorPlux software (PLUX Biosignals, Portugal) and were recorded in a text file (.txt), then exported to MATLAB software (MathWorks Inc, Massachusetts) for data processing. A custom MATLAB routine was prepared to: 1) filter the raw EMG data with a forth-order Butterworth digital filter at 30-300 Hz, based on the power spectrum plot, in order to remove noise; 2) rectify the filtered data; 3) apply linear envelope [29]; 4) the normalization procedure was based on the maximum peak during task performance. Fatigue was determined according to Puce, *et al.* [30] using the mean frequency (MFREQ) of the EMG data and other values such as absolute and relative root mean square (RMS).

For statistical analysis, normality tests were performed and not assumed for all variables. Therefore, the Wilcoxon test was used to compare the pre- and post-fatigue tests, and to compare the 50%RM and 80%RM tests. The Mann-Whitney test was used to compare the CWPE and CWnPE groups. The level of statistical significance was defined as $p \leq 0.05$.

5. Conclusions

Significant differences were found in the muscle activation values of TTL and TTR in the CWnPE subjects. In addition, the CWPE subjects have greater muscle activity than the CWnPE subjects.

Increases in muscle activity values were observed in almost all muscles in both groups of subjects, in the 80%RM sets when compared to the 50%RM sets in the pre-fatigue and post-fatigue conditions, as well as in the same intensity sets, in the post-fatigue values compared to the pre-fatigue values.

Therefore, it appears that exercise practice has some influence on muscle activation during the deadlift exercise.

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Machado, Ana Conceição and Marco Branco; Visualization, Renato Costa-Machado, Ana Conceição and Marco Branco; Writing – original draft, Renato Costa-Machado, Ana Conceição and Marco Branco; Writing – review & editing, Renato Costa-Machado, Ana Conceição, Fernando Rocha and Marco Branco.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Polytechnic Institute of Santarém (protocol code 501 and November, 4th 2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Conflicts of Interest: The authors declare no conflict of interest.

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