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ANALYSIS OF THE ELECTROMYOGRAPHIC ACTIVITY, STRENGTH, AND HEART RATE VARIABILITY IN CAREGIVERS OF BEDRIDDEN PATIENTS BEFORE AND AFTER A WORKDAY: A CROSS-SECTIONAL OBSERVATIONAL STUDY

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Abstract

This study aims to analyze the electromyographic (EMG) signal and strength of the erector spinae muscles and heart rate variability (HRV) of caregivers before and after a workday. Twenty-four caregivers with low back pain were selected. EMG data (RMS (Root Mean Square) and F50) and erector spinae strength were collected from three maximal voluntary isometric contractions and recorded using an electromyograph (EMG System of Brazil 830C). HRV was collected using the POLAR H10 strap. For data analysis, GraphPad Prism (version 8.4; GraphPad Software, Inc.) was used, and the significance level was set at 5%. RMS significantly increased after a workday, but no significant drop was observed in the values of F50 and strength. Regarding HRV, a predominance of the sympathetic nervous system was observed to the detriment of the parasympathetic nervous system. The results suggest increased neuromuscular demand and autonomic alterations consistent with higher physiological stress at the end of the day.

Keywords: Electromyography. Low back pain. Work stress.

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1. Introduction

Demographic and epidemiological changes in Brazil over the last few decades have increased the demand for long-term care, mostly due to the chronification of disease and the aging of the population. This scenario has led governments to rethink the health care model and thus reclaim home as a therapeutic environment for care (Neves et al. 2019; Rajão and Martins 2020).

However, to shift care to the home and recognize it as a space for action and execution of health work, the figure of the caregiver becomes necessary. This person will play a fundamental role as the link

between the health team and the patient, taking on responsibilities that, in other settings, would be restricted to health professionals (Pereira 2016; Rajão and Martins 2020).

The actions that permeate the care of a bedridden patient are carried out routinely and repeatedly, with a high workload borne entirely by the caregiver (who often does not have help to share the care). In addition to this work, caregivers' lifestyle, age, and physical and mental health can become risk factors for the development of acute and chronic diseases, which can compromise their ability to work and make them as sick as the person being cared for (Pereira 2016; Skovlund et al. 2020).

Among the most common disorders in caregivers are musculoskeletal disorders and high levels of physiological stress (Barbosa and Gonçalves 2005; Cesario et al. 2017). One way to identify muscle fatigue is through the study of the activation and behavior of motor units, which are functional components of the neuromuscular system. This study analyzes the amplitude of the electromyographic (EMG) signal as a function of time (Root Mean Square – RMS) or the motor unit firing rate (Median Frequency – F50) (Koumantakis and Oldham 2021; Sun et al. 2022).

Santos et al. (2017) and Mendes et al. (2018) evaluated the EMG activity of the erector spinae before and after a workday in military police officers and welders, respectively. Santos et al. (2017) identified a decrease in the amplitude of the EMG signal, as well as possible muscle fatigue on the right side, where police officers usually carry their weapons. Mendes et al. (2018) showed increased pain and perceived exertion at the end of a workday, without changes in the strength and EMG activity of the erector spinae.

Given the continuous and indefinite nature of caregiving, caregivers must be physically and psychologically well to perform their role effectively. Several studies have been conducted on caregivers of elderly individuals (Alves et al. 2018; Oliveira et al. 2018; Nunes et al. 2019; Ceccon et al. 2021; Nemcikova et al. 2023; Brito and Santos 2025; Marzola et al. 2025), but none have evaluated the effect of the working hours of caregivers of bedridden patients. Therefore, this study aimed to analyze the EMG signal, the strength of the erector spinae muscles, and the heart rate variability (HRV) of caregivers from a Home Care Service before and after a workday.

This study is pioneering in evaluating and combining quantitative variables (EMG and HRV) in a population with a majority of informal caregivers. The results will provide objective data on the current physical and mental conditions of caregivers so that measures (psychosocial assistance projects and support for the caregiver, ergonomic guidelines, and awareness-raising for regular physical activity) can be designed and developed for this group to minimize the development and/or worsening of musculoskeletal disorders and psychological overload, avoiding their inability to care for bedridden patients.

2. Material and Methods

This observational study with repeated measures was approved by the Research Ethics Committee of the Universidade Federal de Uberlândia (number 5003332). It was conducted at the Home Care Service of the University Hospital of the Universidade Federal de Uberlândia (SAD-HC/UFU). This study was based on the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational studies (Von Elm et al. 2007).

The sample was defined by convenience, and caregivers with low back pain who had been caring for a patient for at least three months were eligible to participate in the study. In addition, caregivers' patients had to be totally dependent on activities of daily living (ADLs) for the same period. Only the main caregivers were included, defined as those responsible for caring for the patient most of the time. The presence of low back pain was determined by two criteria: first, a painful condition between the last costal arch and the pelvis, with at least one outbreak of pain lasting at least 24 h, which could be continuous or not; and second, the presence of at least two positive answers to the Roland-Morris Questionnaire (RMQ) (Goubert et al. 2017).

We excluded caregivers who did not consent to participate in the study; those who had undergone back surgery; those with any pathology or physical condition that compromised the performance of the tests; caregivers of patients who died before the tests were performed; and caregivers who shared the care of a patient with other caregivers (Figure 1). All participants signed an informed consent form in accordance with the rules for conducting research on human beings (CNS Resolution 466/12).

Participants were selected between November 2021 and March 2022. During this period, the SAD-HC/UFU monitored a total of 84 patients (and, consequently, the same number of caregivers). Of this total, 33 patients were bedridden and totally dependent on ADLs, and 24 caregivers met the criteria to participate in the study.

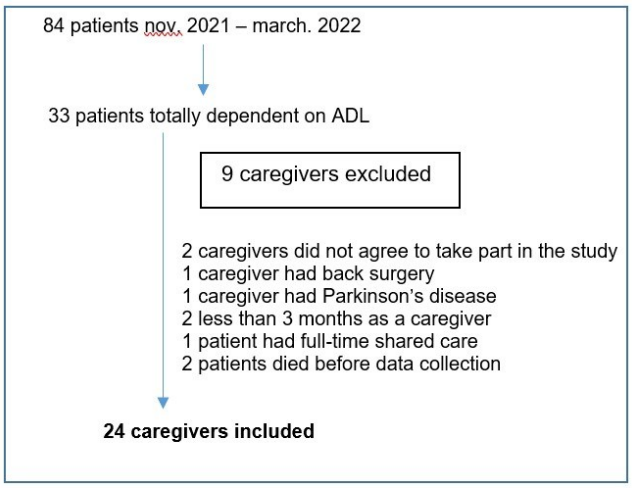

Figure 1. Study eligibility criteria.

Experimental Procedures

Data collection took place on two separate days at the caregiver's home, with days and times pre-established by mutual agreement. On the first visit, anthropometric data were measured, general information was collected (Table 1), and the RMQ was administered. On the second visit, heart rate variability (HRV), strength, and EMG data were collected. The data were collected at two different times: in the morning, before the caregiver started their routine care activities, and at the end of the workday, with an 8-hour break, thus simulating a usual workday. The main researcher conducted all the experiments (test-retest reliability) to minimize any variation between evaluators.

Heart Rate Variability

HRV was recorded using a POLAR® H10 chest strap, with a sampling rate of 1000 Hz connected via Bluetooth to the Kubios HRV® application for Android, version 1.1.9(23), which performed and stored HRV analysis. HRV was monitored for 5 min, with the caregiver at rest, lying supine, and breathing spontaneously. HRV analyses were performed using Kubios HRV 1.1.9 (Kuopio, Finland), as validated by Tarvainen et al. (2014) in the time domains.

Figure 2. Kubios HRV application with heart rate recording and subsequent HRV analysis.

Electromyography

To record the EMG signal, we used an EMG System do Brasil 830C computerized electromyograph with eight channels (EMG System do Brasil Ltda., São José dos Campos, SP, Brazil), which has an analog/digital converter with 16-bit resolution, 1000 times amplifier gain, Butterworth filters, and an integrated rechargeable battery. The sampling frequency was 2000 Hz per channel, and the signals were subjected to a 20 Hz high-pass filter and a 500 Hz low-pass filter.

To capture the EMG signal, surface electrodes consisting of two 10-mm Ag/AgCl discs (EMG System do Brasil) were used, to which disposable electrodes (3M 2223BRQ) were attached with an inter-electrode distance of 20 mm (center to center). The system consists of active bipolar electrodes with 20 times pre-amplification gain and a common mode rejection ratio >120 dB.

The participants underwent trichotomy and skin cleansing with 70% alcohol. A skin marker was used to mark the anatomical reference points for positioning the electrodes at the two test times. The electrodes were attached laterally to the spinous process of the first lumbar vertebra, at a distance of approximately 2 cm from it, on both antimeres (right erector spinae (RE) and left erector spinae (LE)) (Figure 2), and the reference electrode was positioned on the spinous process of the seventh cervical vertebra (SENIAM, 2022). The participants were instructed to sit relaxed and wait in this position for 3 min to achieve electrical stability of the electrode and assess possible interference in the signal.

Lumbar dynamometry

Maximum lumbar strength was quantified using the maximum voluntary isometric contraction test (MVIC) with a dynamometer (EMG System do Brasil Ltda.) with a maximum capacity of 200 kgf. The methodology described by Eichinger et al. (2016) was used to measure lumbar strength.

Participants stood on a platform with their hands placed in front of their thighs. The handle was adjusted using a chain to obtain 30° of lumbar spine flexion and 30° of knee flexion, measured using a goniometer (Marques 2003). Then, three maximum voluntary isometric spine extensions were requested against the resistance of the lumbar dynamometer (figure 3), lasting 5 s, with a rest period of 3 min between each extension to avoid fatigue (Santos et al., 2024a). This posture was chosen for the test to simulate as close as possible the position usually taken by caregivers in their day-to-day care of patients, as well as making it easier to standardize the measurements for all participants, since the collection was carried out in different homes.

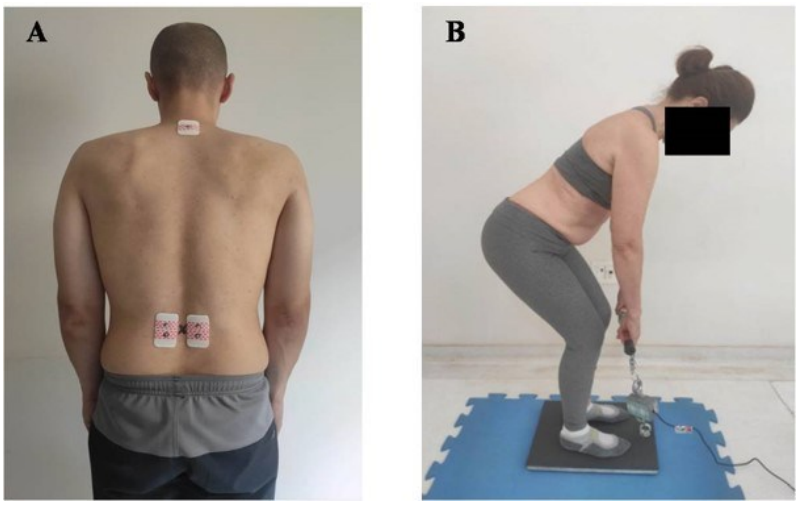

Figure 3. (A) Electrode positioning; (B) MVIC test.

Data Analysis

The EMG signals obtained in the MVIC were analyzed in the time (RMS) and frequency (F50) domains, using the Myosystem br1 software (version 3.5.6). To calculate the maximum values of force and electromyographic signal (F50, RMS), a one-second window was used at the moment of peak force.

A Fast Fourier Transform was performed to analyze the power spectrum of the EMG signal. The median frequency is the frequency bin where the cumulative EMG power spectrum reaches half of the total power, which means that the power below this frequency equals the power above it. The median frequency is more commonly used because it is less sensitive to noise and signal changes and is considered the parameter that best reflects the physiological changes in the muscle during sustained contractions, such as the conduction velocity of muscle fibers (De Luca 1997).

For normalization of EMG (RMS and F50) and strength (MVIC) data, the initial values, i.e., before the workday, were considered as 100%; thus, after the workday, the values measured represented the percentage of increase or reduction of variables.

Concerning HRV, the following parameters were analyzed and quantified in the time domain using Kubios HRV (version 3.5.3): parasympathetic nervous system index (PNS), sympathetic nervous system index (SNS), and Baevsky stress index (STI) (Lucio et al. 2025).

Statistical Analysis

Statistical analysis was performed using GraphPad Prism software (version 5.0; GraphPad Software, Inc.), and the data are presented as mean, standard error, and standard deviation. The Kolmogorov-Smirnov test was used to assess the normality of the data, and the unpaired t-test was used to compare the data between sexes (RMS, F50, and HRV).

The Student's t-test for paired samples was used to compare RMS, F50, strength, and HRV values (PNS index, SNS index, and STI) before and after the workday. The significance level was set at 5%, and the effect size (ES) was calculated using Cohen's description for interpretation (d = 0.2, small; d = 0.5, medium; and d = 0.8, large).

The values of the intraclass correlation coefficient (ICC) were calculated to verify the reproducibility between repetitions in the MVIC tests, following the criteria of Fleiss (1999): ICC > 0.75 = excellent replicability, ICC between 0.40 and 0.75 = average to good replicability, and ICC < 0.40 = poor replicability.

3. Results

General Characteristics

The sample consisted of 24 caregivers who met the inclusion and exclusion criteria. The majority of caregivers were women (75.00%), with daughters/sons representing the main family bond (37.50%), followed by mothers/fathers (20.83%). The average age of caregivers was 45 years, with the youngest participant being 19 and the oldest 70. Most participants did not exercise regularly (70.84%) and were overweight (BMI > 24.9). Almost half of the participants had visited a healthcare service in the last year because of low back pain. Sociodemographic, behavioral, and health profiles are shown in Table 1.

Electromyographic Signal and Strength

To verify the reproducibility between repetitions in the MVIC tests, ICC values were calculated and are described below:

- RMS: The ICC values obtained between the three repetitions of the MVIC tests for RE (0.84) and LE (0.76) demonstrated excellent replicability.
- F50: The ICC values obtained between the three repetitions of the MVIC tests for RE (0.85) and LE (0.67) demonstrated excellent replicability and medium to good replicability, respectively.
- Strength: The ICC values obtained between the three repetitions of the MVIC tests for strength (0.85) demonstrated excellent replicability.

Regarding the EMG signal and strength values, no significant differences were found between sexes (RMS – RE: p=0.772, LE: p=0.634; F50 – RE: p=0.625, LE: p=0.231; and strength: p=0.948).

RMS showed a significant increase after the workday compared to before the workday for both muscles (RE: 130.60 ± 13.13; p= 0.028; d= 0.26; LE: 123.40 ± 11.28; p= 0.049; d= 0.29)(Figure 4).

F50 of LE significantly increased after the workday compared to before the workday (109.10 ± 4.08; p=0.035; d= 0.64), whereas for the RE muscle, no significant difference was found (105.50 ± 3.91; p=0.173).

Regarding strength values, no significant differences were observed between before and after the workday (105.40 ± 4.35; p=0.231).

Table 1. Sociodemographic, behavioral, and health characteristics of SAD-UFU caregivers eligible for the study.

VARIABLES:	N	%
Sex		
Female	18	75.00%
Male	6	25.00%
Age (years)		
19-29	4	16.67%
30-39	4	16.67%
40-49	7	29.16%
50-59	4	16.67%
>60	5	20.83%
Bond of Care		
Formal	4	16.67%
Informal	20	83.33%
Kinship		
Mother/Father	5	20.83%
Daughter/Son	9	37.50%
Wife/Spouse	4	16.67%
Other (including informal caregiver)	6	25.00%
Length of time as a caregiver (years)		
<1	3	12.50%
1-5	10	41.67%
6-10	5	20.83%
>10	6	25.00%
Physical Activity		
Practice	7	29.16%
Not practiced	17	70.84%
Body Mass Index (BMI)		
Normal (18.5 - 24.9)	7	29.16%
Overweight (25 - 29.9)	10	41.67%
Obesity grade I (30 - 34.9)	5	20.83%
Obesity grade II (35 - 39.9)	2	8.34%
Have you sought health care in the last year because of low back pain?		
Yes	11	45.84%
No	13	54.16%

Heart Rate Variability

We collected HRV data from 21 caregivers only. No significant differences were found between sexes for any variable (PNS: *p*=0.325, SNS: *p*=0.447; STI: *p*=0.880).

Comparing the different times of the workday (Figure 5), significant differences were observed for the variables SNS (Pre=0.90 ± 0.32; Post= 1.58 ± 0.39: *p*=0.016; *d*= 0.41) and STI (Pre= 13.63 ± 1.28; Post= 15.83 ± 1.43: *p*= 0.041; *d*=0.35). Regarding PNS, no significant differences were observed between before and after the workday (Pre= -0.31 ± 0.29; Post= -0.71 ± 0.30: p=0.058).

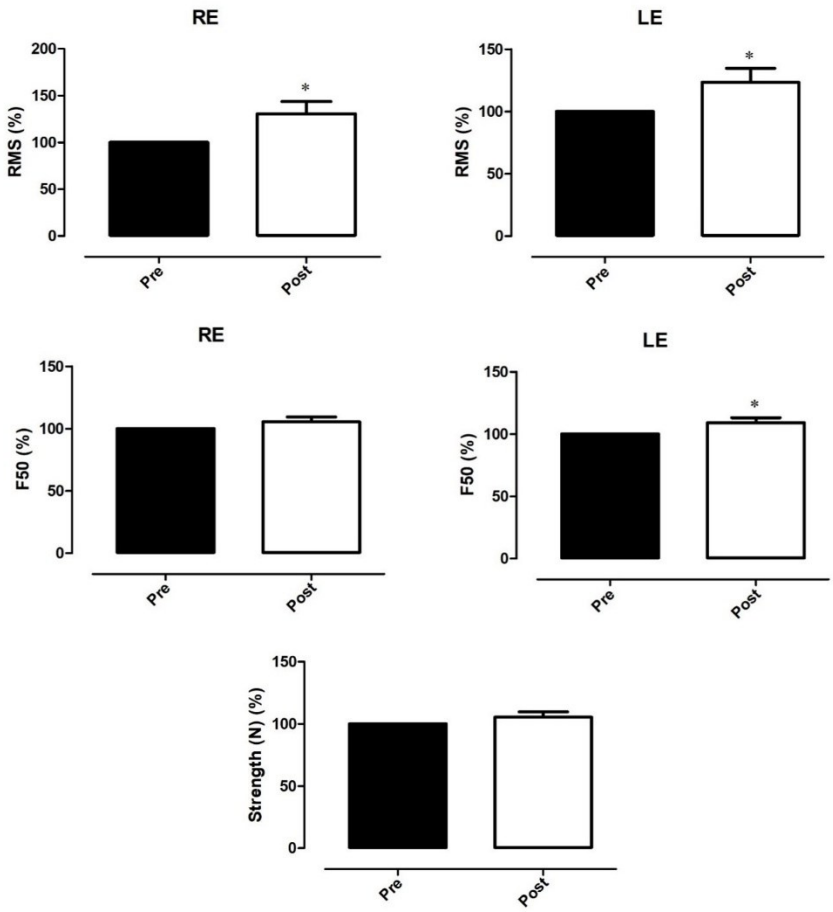

Figure 4. Comparison of normalized values (% Pre) of RMS, F50, and strength before and after the workday in caregivers of bedridden patients. Right erector spinae muscle (RE) and left erector spinae muscle (LE). Bars represent the mean and standard error. *significantly higher than before the workday.

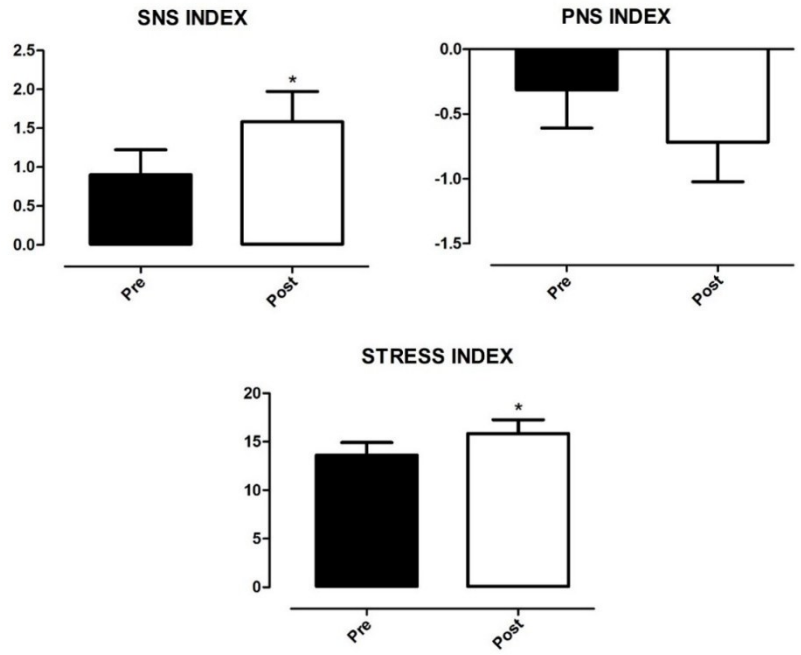

Figure 5. Comparison of the sympathetic nervous system index (SNS), parasympathetic nervous system index (PNS), and Baevsky stress index (STI) before and after the workday in caregivers. Bars represent the mean and standard error. * Significantly higher than before the workday.

4. Discussion

This study aimed to evaluate the EMG activity and strength of the erector spinae muscle in caregivers of a Home Care Service before and after a workday. We organized the results in this section into topics to evidence the main findings on the EMG signal and HRV.

Heart Rate Variability

A significant increase in SNS and STI was observed, related to the predominance of sympathetic activity of the Autonomic Nervous System, confirming the presence of physiological stress in caregivers at the end of the workday.

Most of the caregivers assessed in this study had informal work relationships (83.33%), reflecting the low purchasing power of the families to seek help from a formal caregiver, as they depend on a regulated salary. Therefore, the process of choosing who will care for a bedridden relative is potentially stressful, since it involves the entire family system and affects its economic, cultural, and social spheres. As pointed out earlier, the majority of caregivers were women (75.00%), who take on the responsibility of caring for a bedridden relative, bearing one more role in the domestic sphere, and who, in many cases, are also aging (Braz and Ciosak 2009; Williams et al. 2016). The pressure of needing to provide care for others, the lack of support, and the exposure to stress factors linked to the act of caring—such as the imposition of major responsibilities, work overload, multiple tasks, few hours of sleep, and lack of rest and leisure breaks—lead to physical and mental burden (Genuíno et al. 2009).

In addition, working for long periods without sufficient recovery from the fatigue and stress imposed by that work (returning to a normal or pre-stress level of functioning) is one of the most important factors influencing an individual's physical and mental condition. Without possibilities of recovery during or after work, the worker needs to make extra mental effort on the next workday. This repeated action is seen as the start of a vicious circle in which extra effort must be exerted at the start of each new work period to rebalance the suboptimal psychophysiological state to avoid a drop in performance (Jansen et al. 2002).

Therefore, individuals in occupations that provide assistance and are responsible for the care of others are the main ones affected by high levels of stress, as they are repeatedly and cumulatively exposed to the same stressor. This stress can intensify with each new and persistent factor and trigger negative reactions at the psychological, physiological, and behavioral levels, leading to the development of serious illnesses such as high blood pressure, diabetes, heart disease, immune system failure, or even collapse of the body, resulting in incapacity for work and poor quality of life.

Strength and EMG

RMS showed a significant increase after work in RE and LE, corroborating the results of Barbosa and Gonçalves (2005), who used the same variable to identify muscle fatigue. The increase in EMG activity occurs due to a higher rate and synchronization of motor unit firing as a strategy for maintaining strength levels as a consequence of muscle fatigue.

F50 significantly increased in LE between before and after the workday, while showing similar values for RE before and after the workday. However, a reduction in these values was expected, since muscle fatigue decreases the conduction velocity of action potentials due to the accumulation of metabolic by-products (lactate and K+), thus determining lower frequencies over time (Sun et al. 2022; Santos et al. 2024b; Yu et al. 2024).

In this study, caregivers with low back pain showed a similar pattern to individuals assessed by other studies. Suehiro et al. (2021) demonstrated that individuals with low back pain showed a delayed onset of activation in the transversus abdominis/internal oblique muscles during the active hip abduction test compared to the pain-free control, providing less stabilization and making the spine more susceptible to overload and microtraumas. In contrast, Varrecchia et al. (2022) demonstrated that individuals with low back pain showed greater activation and co-contraction of the global trunk muscles during lifting tasks under

fatigue, presenting increased trunk stiffness as a protective mechanism; however, this increased the risk of fatigue and spinal overload.

Due to this mechanism of delayed activation of the deep/local muscles and the greater overload of the global activation system, an evident change in neuromuscular control and spinal stabilization is observed in individuals with low back pain. Although this study assessed low back muscles instead of global trunk muscles, it is believed that the presence of low back pain in caregivers greatly activates the global muscles (erector spinae) at the end of the workday, because of greater muscle stiffness and hyperactivity triggered by the compensatory mechanism of deep muscle inhibition. Future studies should analyze the activity of local and global trunk muscles in caregivers of bedridden patients to better understand this mechanism and provide insights into preventive and rehabilitation measures.

Another possible explanation is that individuals with low back pain may redistribute activity between the lumbar extensor muscles as an adaptive strategy for changes in their muscle function (D'hooge et al. 2013). Some studies, such as those by Hodges and Danneels (2019) and Devecchi et al. (2021), have shown that a deficient activity of the erector spinae can be compensated by increased activation of other muscles in the spine or even in the lower limbs, generating a synergistic mechanism to ensure the necessary strength for a given action. Caregivers may have these adaptive compensations due to the length of time they have been involved in caregiving, their low back pain, and the type of work required to care for the bedridden individual (repetitive movement, posture, high load, etc.). Therefore, the activation of compensatory muscles ensured that muscle strength was maintained after the workday. However, the lack of EMG signal collection from other synergistic muscles is a limitation of the study. Future studies should analyze other muscle groups beyond the paravertebral muscles to better understand this compensation in caregivers.

In addition, caregivers are active in their work activities, and this might preserve their functional capacity, or part of it. This could minimize the atrophy of the lumbar musculature and probably maintain type I fibers, ensuring greater resistance during a sustained contraction and the maintenance of F50 values, since the spectrum of its power directly depends on the percentage area of this type of fiber (Mendes et al. 2018).

Hao et al. (2020), when comparing healthy individuals with those with low back pain, observed significantly greater asymmetries in EMG (RMS, F50) between the right and left sides of the erector spinae in the low back pain group, a situation observed in the present study regarding F50. The presence of F50 asymmetries may reveal unhealthy muscle function, indicating that the presence of pain produces a redistribution of activation behavior among the lumbar spine muscles and a greater imbalance of the erector spinae, which may be a detrimental factor in spinal stabilization.

Mendes et al. (2018) demonstrated similarities in strength values between pre- and post-shift moments in welders with chronic low back pain. In the present study, which used same MVIC protocols, similar results were observed in caregivers. Mendes et al. (2018) concluded that workers with low back pain who remained in their labor activities managed to maintain their functional capacity, justifying the maintenance of their muscle strength, a situation similar to the present study with caregivers.

Although almost half of the caregivers (45.84%) had accessed the healthcare system in the last year because of low back pain, 95.83% had not left their role. Even if this last figure is a consequence of the lack of choice in having another person to take on the role of caregiver, these results confirm that the fact that these caregivers were active in their activities, even in the presence of low back pain, preserved their functional capacity.

However, the intense overload to which these caregivers are exposed and the deprivation of self-care (70.84% of the caregivers in the survey were overweight or obese to some degree, and 70.84% did not exercise regularly) lead us to believe that they are always working close to their physiological limit, since almost half of the caregivers sought healthcare services in the last year. Therefore, it is not possible to determine the extent to which this ability to be active only in their work activities would preserve their functional capacity and prevent them from developing chronic injuries.

Another important factor is the MVIC extension test itself. Caregivers—who maintained their functional capacity, were predominantly female, and may have had a redistribution of muscle activity—may have developed adaptive compensation during the test. This is because the posture chosen for its execution—with 30° of trunk flexion and 30° of knee flexion, mimicking postures adopted by caregivers

during their activities with patients—may have generated muscle compensations to maintain the force level required to perform and sustain this posture, which would explain the lack of decrease in strength values and F50.

Final considerations and limitations of the study

The results of EMG and HRV show that the individualization of responsibility invisibly passed on by the healthcare services and the family to caregivers has a visible negative impact on their health and quality of life. Caring for the patient should be seen as a collective demand between healthcare services, the family, and the caregiver; however, most of the time, all responsibility for care ends up falling on just one caregiver.

Despite the significant differences in the RMS and F50 variables (LE), attention should be given to the small and medium effect sizes, which may be related to the sample characteristics. However, quantitative analyses in research with informal caregivers remain a challenging factor of great social relevance, as they can strengthen strategies of home health care, which are compatible with SUS's guidelines focused on integral care and support for the caregiver.

We must recognize the main problems faced by caregivers regarding the physical, organizational, and psychological aspects of care. The focus cannot only be on the patient's integrity and well-being. Caregivers also require care to avoid falling ill. Therefore, it is necessary to expand the actions and interventions aimed at this group and make them accessible to their routine, enabling them to continue to perform their role and be cared for. Future studies should explore the impact of longer interventions, the use of technological resources (such as telehealth) for remote monitoring, and the incorporation of psychosocial variables in monitoring therapeutic effects.

The study limitations include the use of a convenience sample, the absence of a control group, and variability in caregivers' daily tasks and home-based data collection. Furthermore, the sample size was constrained by the data collection period (COVID-19 pandemic) and caregivers' availability, which hindered the recruitment of a larger number of participants with and without low back pain. Consequently, the findings may only be representative of the specific populations studied.

Additionally, a limitation of HRV was the use of spontaneous breathing during collection. Since respiration can be a confounding factor in HRV assessment (Sazaki and Maruyama 2014), the absence of respiratory control may have caused variability in the results.

5. Conclusions

The EMG activity of the erector spinae in caregivers showed a significant increase in RMS after a workday, but no significant declines in the values of F50 and strength. Furthermore, a significant increase in the stress index was observed after a workday, accompanied by an increase in the SNS and a reduction in the PNS. These results suggest increased neuromuscular demand and autonomic alterations consistent with higher physiological stress at the end of a workday.

Authors' Contributions: SILVA, P.K., FIDALE,T.M. and LIZARDO, F.B.: conception and design, acquisition of data, analysis and interpretation of data, drafting the article, critical review of important intellectual content, 6) final approval of the version to be published; SOUZA, M. P.: analysis and interpretation of data, final approval of the version to be published; FACCIOLI, C.K., BORGES, E.F., SILVA, D.C.O. and JUNIOR, R.B.: drafting the article, critical review of important intellectual content, final approval of the version to be published.

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