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Objective Measures of Work and Non-Work Physical Behaviors Associated with Neck and Back Pain in Viticulture Workers

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Abstract: Musculoskeletal disorders are prevalent among agricultural workers, increasing the risk of work-related diseases due to manual labor, repetitive tasks, and prolonged postures. This study evaluates the association between physical behaviors during work and non-work, measured objectively, and musculoskeletal pain in the neck, upper back, and lower back in viticulture workers. A cross-sectional quantitative study was conducted with 75 viticulturists of both sexes aged 18 years or older. An accelerometer measured physical behaviors (lying down, sitting, standing, moving, walking, and sleeping) during work and non-work periods. Pain intensity was quantified using a 0–10 scale and categorized as "Low" and "High" pain intensity. Binary logistic regression tested the association between pain and time spent on physical behaviors. Results indicated a high prevalence of pain: 46.7% cervical, 52% upper back, and 60% lower back. Standing was the most common behavior during work, while lying and sitting were predominant during non-work. An increased sleeping time was associated with a decreased probability of experiencing high-intensity neck pain. Increased time spent lying down during non-work hours was associated with an increased probability of experiencing high-intensity upper back pain. No physical behavior was associated with high-intensity lower back pain. In conclusion, sedentary behaviors worsen upper back pain, and sleep reduces neck pain in viticulture workers.

Keywords: accelerometry; agriculture; ergonomics; musculoskeletal pain; occupational health

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1. Introduction

Musculoskeletal disorders (MSDs) are a prevalent issue among workers across various occupational sectors, with higher prevalence rates observed in manual laborers, particularly in agriculture, forestry, and fishing [1,2]. Musculoskeletal pain (MSP) often manifests as a continuous and recurrent condition exacerbated by occupational activities and environmental factors, contributing significantly to disability and social burden [3,4]. The neck, upper back, and lower back regions are most commonly affected, with each area presenting unique challenges in occupational health [2].

Neck pain (NP), upper back pain (UBP), and lower back pain (LBP) share commonalities in their association with occupational factors, yet they exhibit distinct characteristics. NP is particularly prevalent among manual laborers, with evidence suggesting a correlation between prolonged sitting and increased pain intensity [5–8]. UBP, while less common, is frequently associated with pain in other spinal regions and remains understudied, especially in manual labor contexts [9,10]. LBP stands out as the most prevalent musculoskeletal

disorder among workers, regardless of occupation type, with research indicating complex relationships between pain intensity and various postural behaviors such as sitting, static standing, and walking [11–13].

Agriculture, characterized by physically demanding activities, repetitive manual tasks, varied postures, and long working hours, is particularly prone to MSDs. Previous studies in agricultural populations have documented a high incidence of these disorders [14–16]. Brazil, ranking among the top five agricultural producers worldwide and being the third-largest fruit producer, has a significant stake in this issue, especially in regions like the São Francisco Valley, where viticulture is crucial for the local economy and employment [17–19].

The assessment of MSDs in agricultural settings has traditionally relied on self-reported measures, which are subject to individual interpretation and often lack sensitivity and specificity [20,21]. This highlights the need for direct measures to quantify behaviors adopted in work and non-work environments, providing a more accurate basis for associating these characteristics with neck and back pain. The use of objective measurement tools, such as accelerometers, offers a promising approach to overcoming the limitations of self-reported data and gaining deeper insights into the biomechanical demands of agricultural work.

Given the scarcity of studies focusing on agriculture using direct measures, the present research aims to evaluate the association between work and non-work behaviors (lying down, sitting, standing, moving, walking, and sleeping) and musculoskeletal pain in the neck, upper back, and lower back among viticulture workers. By employing objective measurement techniques, this study seeks to provide a more comprehensive understanding of the physical demands in viticulture and their impact on musculoskeletal health, ultimately contributing to developing more effective prevention and intervention strategies in this important agricultural sector.

2. Materials and Methods

2.1. Study Design and Participants

A cross-sectional quantitative study was conducted from April to July 2022, following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [22]. This design was chosen to assess the prevalence of musculoskeletal pain and its association with physical behaviors at a specific point in time among viticulture workers.

The study was conducted on table grape farms in the São Francisco Valley, Petrolina, Pernambuco, Brazil. Ninety-four viticulture workers (field and packing workers) aged 18 and older with formal employment contracts were recruited using convenience sampling. Inclusion criteria were: (1) age 18 years or older, (2) formal employment contract, and (3) working in field or packing roles. Exclusion criteria included: (1) allergy to adhesive tape, (2) fever at the time of evaluation, (3) pregnancy, and (4) refusal to sign the informed consent form.

Workers performing pruning, harvesting, thinning, tying, de-budding, clipping, and packing were evaluated. Except for packing, the other activities conducted by agricultural workers are done standing with arm elevation (above 90°) and repetitive manual activity (also requiring tools, such as scissors), in addition to being directly influenced by weather conditions. The packing activity is performed in a controlled environment, with workers standing in front of a bench, with the possibility of supporting their forearms. All workers in direct contact with grapes maintain an upright posture throughout the workday.

2.2. Ethical Considerations

This study was approved by the University's Ethics Committee (Approval No. 3.494.076). All participants were informed about the study's objectives and procedures and signed an informed consent form before enrollment.

2.3. Data Collection Instruments

2.3.1. Sociodemographic and Occupational Questionnaire

A Sociodemographic, Occupational, and Health Assessment Questionnaire was used to collect data on age, sex, height, weight, education, job role, working hours, seniority, self-reported health, and absenteeism. This questionnaire was developed specifically for this study based on previous literature [23].

2.3.2. Pain Assessment

Pain intensity in the neck, upper back, and lower back regions was self-reported using a 0–10 numerical rating scale for the past three months, specifically in response to the question: "In the past three months, have you experienced pain or discomfort in this body region? If yes, please rate the intensity of the pain on a scale from 0 to 10, where 0 means no pain and 10 means the worst pain possible" [24]. Pain was categorized as "Low" or "High" intensity based on previously established cut-off points (high neck pain ≥ 3, high upper and lower back pain ≥ 5). These cut-off points were chosen based on their clinical relevance and previous use in occupational health research [25].

2.3.3. Accelerometry

Physical behaviors were quantified using direct measurements with an accelerometer (ActivPAL4, PAL Technologies Ltd., Glasgow, UK) positioned on the right thigh of the participants, using previously described procedures adapted to real-world settings [26]. The accelerometer measures triaxial acceleration at 20 or 40 Hz with 10-bit precision and stores data in a 64 MB internal memory. The output includes periods spent in work and non-work activities, where non-work consists of all activities outside the work environment. This study used only the thigh position to analyze and classify activities into lying down, sitting, standing, moving, and walking.

The protocol involved recording direct measures for at least four consecutive days, including at least two workdays and two non-workdays (leisure) [23]. Work and non-work hours were cross-referenced with self-reported data collected via an activity diary provided to participants, which recorded routine activities such as waking up, starting and finishing work, and bedtime. To minimize the potential Hawthorne effect, participants were instructed to maintain their normal routines during the accelerometer wear period. The accelerometers were initialized for data recording and download using PAL Software Suite version 8 (PALconnect, PALbatch, and PALanalysis). Data was processed using ActiPASS software version 2024.06 (The National Research Centre for the Working Environment, Copenhagen, Denmark, and Occupational and Environmental Medicine, Department of Medical Sciences, Uppsala University, Sweden). This software identifies and classifies physical behaviors, differentiates physical activities and behaviors, and measures time spent in each position based on the inclination and maximum standard deviation of thigh accelerations. The data show excellent sensitivity ($\geq$93%) and specificity ($\geq$93%) for activities such as sitting, standing, moving, walking, climbing stairs, and cycling based on a semi-standardized protocol [27].

Direct measurement variables express participants' physical behaviors in absolute time (minutes) and relative time (percentage of a 24-h day) during work and non-working days. These variables include: 1. time lying down; 2. time sitting; 3. time standing; 4. time moving; 5. time walking; 6. and sleep time. These variables were categorized as "Low" and "High" based on their median.

2.4. Data Collection Procedure

After obtaining consent from the farms, workers were grouped at farm support points to receive information about the research. Workers who agreed to participate signed the informed consent form and completed the Sociodemographic, Occupational, and Health Assessment Questionnaire and Pain Assessment Self-Report.

Participants were then instructed on how to wear the accelerometer and fill out the activity diary. They were asked to wear the accelerometer continuously for at least four days, removing it only for water-based activities. Detailed written and verbal instructions were provided on properly attaching and removing the device and accurately recording their daily activities in the diary.

2.5. Statistical Analysis

The primary outcome was the association between physical activity and behavior exposure during work and non-work periods and neck, upper back, and lower back pain among viticulture workers. Binary logistic regression models were used to test the probability of a specific categorical outcome (high or low pain) based on explanatory variables (predictors). Given that a binary logistic regression was conducted, the sample was dichotomized into high and low pain categories to examine differences in specific physical behaviors.

Independent variables included categorized time spent in physical behaviors during work and non-work periods, sleep time, age, sex, and BMI. Multicollinearity assumptions were tested and found to be within acceptable ranges. Statistical analysis was performed using SPSS version 25.0 for Windows (SPSS Inc., Chicago, IL, USA), with a significance level set at 5% ($\alpha < 0.05$).

3. Results

3.1. Characteristics of the Sample

The sample consisted of 93 workers, with 18 excluded due to invalid accelerometry data, leaving 75 vineyard workers for analysis. Among them, 65.3% (n = 49) were female, 65.3% (n = 49) worked in the field, and the average age was 28.9 (±8.9) years. The average BMI was 26.3 (±5.1) kg/m^2, 95.9% (n = 71) were non-smokers, and 51.4% were alcohol consumers. Descriptive characteristics are shown in Table 1.

Table 1. Demographic Characteristics of the Sample.

Variable	Total Sample	Field	Packing
Age (years)–M (SD)	28.9 (±8.9)	30 (±9.7)	27.4 (±1.3)
Sex	-	-	-
Female–*n* (%)	49 (65.3%)	28 (37.3%)	21 (28%)
Male–*n* (%)	26 (34.7%)	21 (28%)	5 (6.7%)
BMI (kg/m^2)–M (SD)	26.3 (±5.1)	-	-
Underweight–*n* (%)	3 (4%)	1 (1.3%)	2 (2.7%)
Normal–*n* (%)	28 (37.3%)	20 (26.7%)	8 (10.6%)
Overweight–*n* (%)	44 (58.7%)	28 (37.3%)	16 (21.4%)
Function	-	-	-
Field–*n* (%)	49 (65.3%)	-	-
Packing–*n* (%)	26 (34.7%)	-	-
Non-smoker–*n* (%)	71 (95.9%)	45 (60.8%)	26 (35.1%)
Alcoholic consumer–*n* (%)	38 (51.4%)	25 (33.8%)	13 (17.6%)
Pain Intensity (0–10)	-	-	-
Neck–M (SD)	3.28 (±3.7)	3.3 (±3.8)	3.32 (±3.7)
Upper back–M (SD)	4.24 (±3.9)	4 (±3.9)	5 (±3.9)
Lower back–M (SD)	4.64 (±3.9)	4.3 (±3.9)	5.2 (±3.8)

M: Mean; SD: Standard Deviation; BMI: Body Mass Index.

Regarding pain, the lower back had the highest average pain intensity (4.64 ± 3.9) in the past three months, especially among packing workers (5 ± 3.9). The upper back had the second highest pain intensity (4 ± 3.9), and the neck had the lowest (3.3 ± 3.8). When pain was categorized as "Low" and "High" intensity, the prevalence of high-intensity pain was 46.7% for the neck, 52% for the upper back, and 60% for the lower back.

3.2. Characteristics of Total Times Obtained by Accelerometry

Data were obtained for 4.9 (±0.9) valid days during the "work" periods in the total sample (75 viticulture workers) and 1.6 (±0.5) valid days during "non-work" periods for 80% of the sample (60 viticulture workers). Among the valid "work" days, an average of 83.5 (±21) valid hours was obtained, while 38.1 (±12.7) valid hours were obtained on valid "non-work" days. The descriptive data of the objective measures for work and non-work periods, relative to the valid days and hours, are described in Table 2.

Table 2. Objective Measures for Work and Non-Work.

Variable	Work			Non-Work		
	***n* (%)**	**M**	**SD**	***n* (%)**	**M**	**SD**
Total valid days	75 (100)	4.9	0.9	60 (80)	1.6	0.5
Weekdays	74 (98.6)	2.9	0.9	3 (4)	1	0
Weekends	37 (49.3)	1.2	0.4	59 (78.6)	1.5	0.4
Total valid hours	75 (100)	83.5	21.0	60 (80)	38.1	12.7
Weekdays	74	69.7	22.8	3	20.4	3.1
Weekends	37	29.8	10.4	59	37.7	11.9
Valid hours/day awake	75	17.0	0.9	60	15.5	1.4
Valid hours/day sleeping	75	6.6	0.9	60	8.2	1.3

n: number; %: Percentage; M: Mean; SD: Standard Deviation.

3.3. Characteristics of Total Time Spent in Each Behavior

Workers' behaviors were measured both during work and non-work periods. The most common behavior during work was standing (199.2 ± 103.5 min) and sitting (119.8 ± 97.2 min). In non-work periods, the most prevalent behaviors were lying down (310.1 ± 150.4 min) and sitting (290.8 ± 100.4 min). Viticulture workers spent an average of 72.9 (±39) minutes walking during work and 68.5 (±31) minutes during non-work. Figure 1 and Table 3 show the average percentage of time spent in each behavior for both work and non-work periods in the total sample.

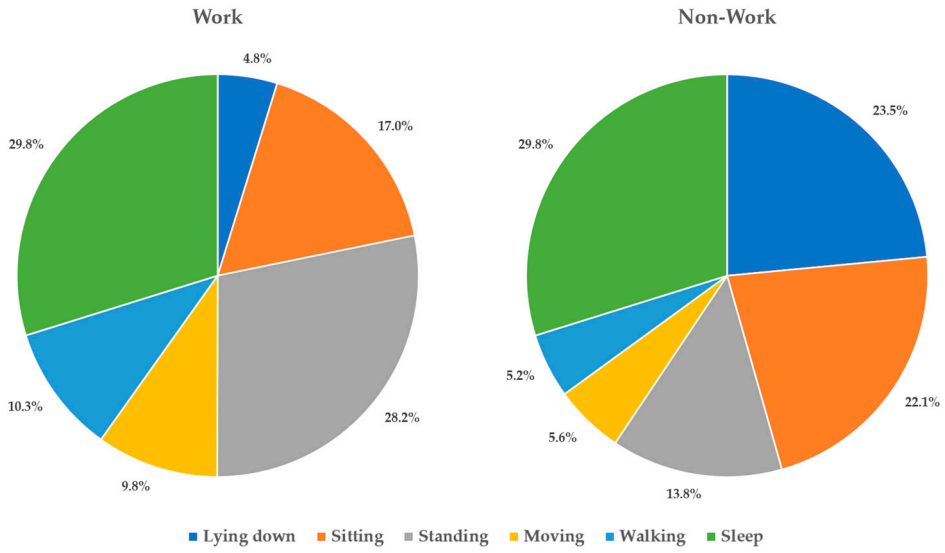


Figure 1. The total sample time spent on behaviors during the work and non-work periods (%).

Table 3. Characteristics of the total time spent on each behavior during work and non-work periods.

Variable	Total Sample	
	Min (M ± SD)	%
Work	-	-
Time Lying down	33.4 (±49.6)	4.8%
Time Sitting	119.8 (±97.2)	17.0%
Time Standing	199.2 (±103.5)	28.2%
Time Moving	69.5 (±34.8)	9.8%
Time Walking	72.9 (±39)	10.3%
Non-Work	-	-
Time Lying down	310.1 (±150.4)	23.5%
Time Sitting	290.8 (±100.4)	22.1%
Time Standing	182 (±76.4)	13.8%
Time Moving	74 (±37.7)	5.6%
Time Walking	68.54 (±31)	5.2%
Time Sleep	393.4 (±57.7)	29.8%

Min: minutes; M: Mean; %: Percentage; SD: Standard Deviation.

The main difference between the total sample during work and non-work periods lies in the behaviors of lying down, sitting, and standing. During the non-work period, the total sample spent significantly more time lying down (23.5%) compared to the work period (4.8%). Additionally, the total sample spends more time sitting during the non-work period (22.1%) than during the work period (17.0%). Conversely, during the work period, the sample spends more time standing (28.2%) than the non-work period (13.8%). Therefore, during the non-work period, individuals spend more time in sedentary behaviors (lying down and sitting) and less time standing compared to the work period. It is important to note that the results in the field and packing samples are similar in both work and non-work perspectives, with no significant differences between the job roles for all behaviors. Figure 2 illustrates the relationship between field and packing during work and non-work periods. Thus, subsequent analyses will not consider the differentiation between workers in the field and packing sectors.

Table 4 shows the results of the associations between high-intensity pain in the neck, upper back, and lower back and the independent variables related to physical behaviors at work and non-work, as well as age, sex, and BMI. The binary logistic regression models were significant for all three regions: neck [$X^2(3) = 16.90$; $p = 0.01$, R^2Nagelkerke = 0.35], upper back [$X^2(3) = 13.20$; $p = 0.01$, R^2Nagelkerke = 0.29], and lower back [$X^2(2) = 8.28$; $p = 0.01$, R^2Nagelkerke = 0.43].

Table 4. Binary logistic regression analysis between high-intensity pain in the neck, upper back, and lower back and independent variables.

Variable	β	OR	*p*	CI 95%
Neck	-	-	-	-
Moving Time at Work (High)	1.23	3.45	0.05	0.96–12.36
Sleep Time (High)	−1.50	0.22	0.02	0.06–0.79
Sex (female)	1.32	3.74	0.07	0.88–15.82
Upper back	-	-	-	-
Moving Time at Work (High)	2.26	9.63	0.01	1.46–63.55
Sleep Time (High)	2.14	8.54	0.03	1.21–60.03
Sex (female)	2.05	7.84	0.01	1.94–31.64
Lower back	-	-	-	-
Age	−0.85	0.91	0.01	0.85–0.98
Sex (female)	1.30	3.68	0.05	0.99–13.62

OR: Odds Ratio; CI: Confidence Interval.

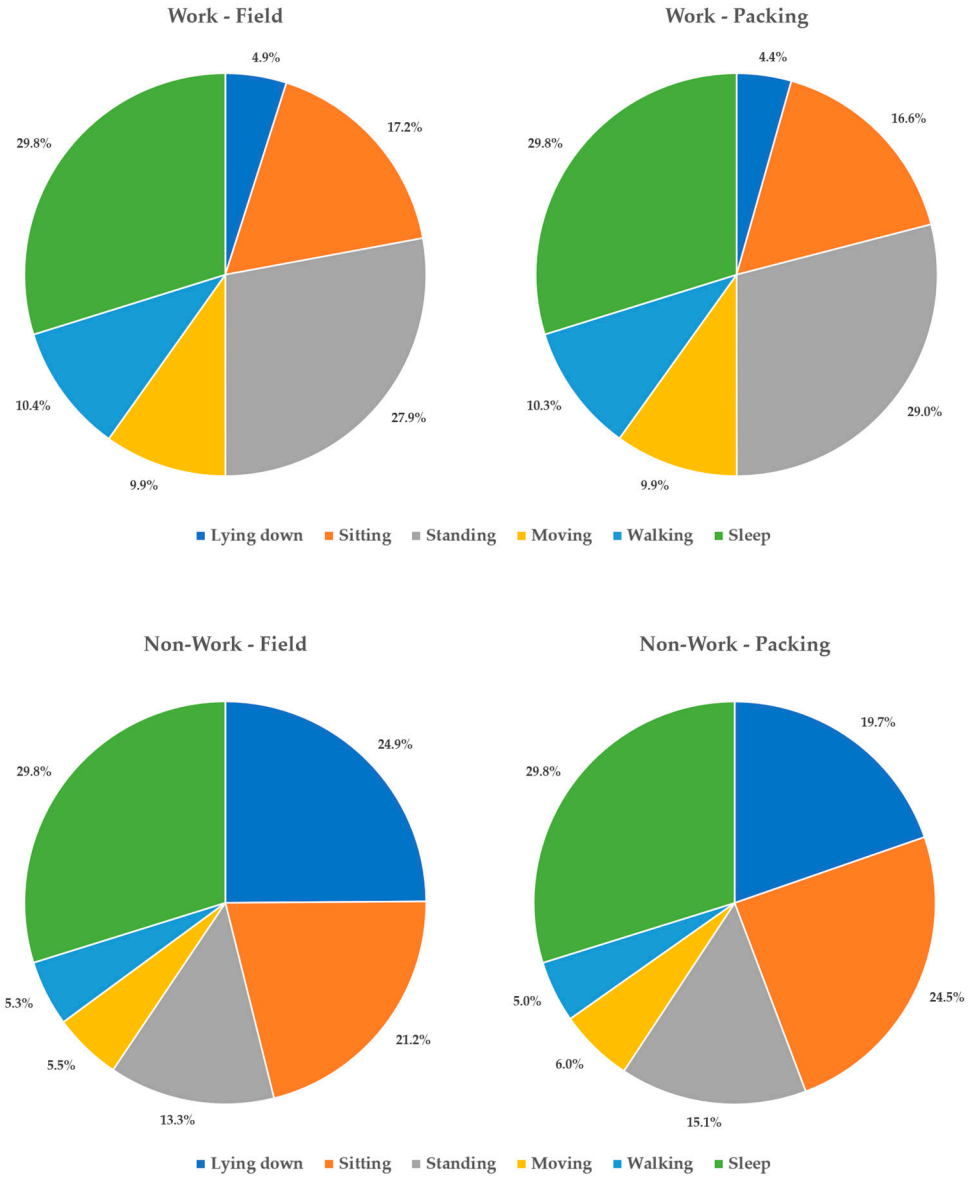


Figure 2. The total sample time spent on behaviors during the work and non-work periods (%) for field and packing.

The analysis demonstrated that high sleep time was associated with a decreased probability of experiencing high-intensity neck pain. Specifically, individuals with high sleep time were 78% less likely to report high-intensity neck pain compared to those with low sleep time (OR: 0.22, 95% CI: 0.06–0.79, $p = 0.02$). High time spent lying down during non-work hours was associated with an increased probability of experiencing high-intensity upper back pain. Individuals with high lying down time during non-work hours were 9.63 times more likely to report high-intensity upper back pain compared to those with low lying down time (OR: 9.63, 95% CI: 1.46–63.55, $p = 0.01$). High time spent standing during non-work hours was also associated with an increased probability of experiencing high-intensity upper back pain. Individuals with high standing time during non-work hours were 8.54 times more likely to report high-intensity upper back pain compared to those with low standing time (OR: 8.54, 95% CI: 1.21–60.03, $p = 0.03$). Being female was associated with an increased probability of experiencing high-intensity upper back pain. Women were 7.84 times more likely to report high-intensity upper back pain compared to men (OR: 7.84, 95% CI: 1.94–31.64, $p = 0.01$). The analysis did not reveal any statistically significant associations between the measured physical behaviors and the probability of

experiencing high-intensity lower back pain. However, age was significantly associated with the probability of experiencing high-intensity lower back pain. For each additional year of age, the odds of reporting high-intensity lower back pain increased (β: −0.85, 95% CI: 0.99–13.62, $p = 0.01$).

4. Discussion

This study revealed a high prevalence of pain among viticulture workers in the neck, upper back, and lower back. Additionally, it was observed that the predominant posture during work was standing, while sedentary behaviors, such as lying down and sitting, were more common during non-working periods. The analysis also indicated that sleep duration was negatively associated with neck pain, while sedentary behaviors were associated with increased pain in the upper back.

4.1. Prevalence and Intensity of Musculoskeletal Pain

Our study revealed a high prevalence of musculoskeletal pain among viticulture workers, with 60% reporting high-intensity lower back pain, 52% upper back pain, and 46.7% neck pain. These rates are generally higher than those reported in previous studies of blue-collar workers [8,9,12,13], suggesting that viticulture may pose unique challenges to musculoskeletal health.

The neck showed the lowest mean (3.28 ± 3.7) and the lowest prevalence of high-intensity pain (46.7%) compared to other areas. It was similar to Hallman et al., 2016 [8], which reported that 37.3% of a sample of blue-collar workers from various occupational sectors had a "high" pain intensity score (pain > 4).

For the upper back, the mean value was 4.24 ± 3.9, with a prevalence of 52% of high-intensity pain. It differs from Fouquet et al., 2015 [9], which found a 7–30% prevalence in men and 9–38% in women in a sample of workers from various occupational sectors, including industry and agriculture. Briggs et al., 2009, [28] in a literature review, found that the prevalence of thoracic pain varies by occupational sector and time period, ranging from 3 to 55%, with 30% being the median. Factors related to work (high load, high intensity, ergonomic problems), physical tasks (manual tasks, physical stress), and psychosocial aspects are associated with upper back pain in the adult working population [28].

The lower back had the highest mean intensity (4.8 ± 3.8) and the highest prevalence of high-intensity pain (60%), exceeding values from other studies on manual labor populations. In the study by Locks et al., 2018 [12] with blue-collar workers in the cleaning, transportation, and manufacturing sectors, the prevalence of high-intensity lumbar pain was 27.8%. Nielsen et al., 2017 [13] also reported a prevalence of 17% in a similar sample of workers [12,13].

4.2. Physical Behaviors During Work and Non-Work Periods

Contrary to expectations, our findings indicate that viticulture workers exhibit predominantly sedentary behaviors both during work and non-work periods. This contrasts with previous literature suggesting that blue-collar workers are typically more physically active [6,29]. The sedentary nature of viticulture work, as observed in our study, may contribute to the high prevalence of musculoskeletal pain and warrants further investigation.

4.3. Associations Between Physical Behaviors and Pain

4.3.1. Neck Pain

Few studies have directly measured and associated physical behaviors with neck pain. Hallman et al., 2015 [6,7] found no significant association between sitting posture during non-work hours and neck pain. However, prolonged sitting at work is associated with high neck pain, particularly among males, while shorter sitting periods reduce pain. Temporal patterns of sitting behavior at work showed mixed associations with neck pain in manual workers [6–8]. In developing countries, neck pain is often linked to poor work organization and forced postures [30]. Notably, a significant negative association between high-intensity

pain and sleep duration suggests sleep might reduce de probability of high-intensity neck pain. Despite extreme neck movements and repetitive tasks among viticulture workers, no studies corroborate this finding, indicating that sleep and rest could mitigate high-intensity neck pain. Other physical behaviors do not seem to influence neck pain.

Our finding of a negative association between sleep duration and high-intensity neck pain is novel and suggests that adequate sleep may be associated with a diminished probability of experiencing high-intensity neck pain. This highlights the importance of considering non-work behaviors in occupational health strategies. However, despite these findings suggesting a significant negative association, additional research is needed for validation. Longitudinal studies would be particularly valuable in confirming the potential relationship between sleep duration and reduced likelihood of neck pain, as well as in better understanding the complex interplay between sleep, physical behaviors, and musculoskeletal health.

While our cross-sectional study provides valuable insights, it is important to note that we cannot infer causality from these results. The observed association between longer sleep duration and lower probability of high-intensity neck pain could be influenced by various factors not captured in our current study design. Future research should aim to explore potential mechanisms underlying this relationship and consider other variables that might influence both sleep patterns and neck pain experiences.

Furthermore, it would be beneficial to investigate whether interventions aimed at improving sleep duration could lead to reductions in the incidence or severity of neck pain among vineyard workers. Such studies could provide more concrete evidence for the potential role of sleep in musculoskeletal health management strategies within occupational settings.

4.3.2. Upper Back Pain

The positive associations between high-intensity upper back pain and prolonged lying or moving during non-work hours, as well as female sex, align with some previous findings. Fouquet et al., 2014 [9] reported a higher prevalence of upper back pain among women in France, possibly due to biological predisposition and repetitive biomechanical restrictions. Although the highest prevalence of upper back pain was observed among white-collar workers, manual laborers also showed similar pain patterns compared to the lower back. This study found that prolonged moving and lying during non-work hours increase the likelihood of high-intensity upper back pain among viticulture workers. Holtermann et al., 2010 [31] discussed the paradox between occupational and leisure physical activity, suggesting that increased sedentary time can lead to more significant morbidity and absenteeism. While no studies directly link sedentary behavior with upper back pain, a similar relationship to that seen in the occupational-leisure paradox might be possible. These results underscore the complex relationship between occupational and leisure activities in musculoskeletal health.

4.3.3. Lower Back Pain

Interestingly, we found no significant associations between physical behaviors and high-intensity lower back pain, which differs from some previous studies [11–13]. Nielsen et al., 2016 [13] and Locks et al., 2018 [12], found no association between static standing and lower back pain but noted that walking was negatively associated with high lumbar pain. Gupta et al., 2015 [11] found a positive association between sitting time and lower back pain at work and leisure. This supports the theory that prolonged sedentary behavior is linked to musculoskeletal pain. Factors like baseline lower back pain, low work capacity, low BMI, and blue-collar work are predictors of chronic lumbar pain [32]. The diminished effect of older age against high-intensity lumbar pain is particularly intriguing and contradicts some existing literature [33]. This finding warrants further investigation into age-related factors in occupational health.

4.4. Limitations and Strengths

This study has some limitations that should be considered when interpreting the results. Firstly, the cross-sectional design limits our ability to establish causal relationships between physical behaviors and musculoskeletal pain. Longitudinal studies are needed to further elucidate these associations. Secondly, the relatively small sample size (n = 75) may limit the statistical power and generalizability of the findings and may not be representative of the broader viticulture worker population. Future studies with larger cohorts could provide more robust results. Our study did not assess psychosocial factors such as work stress or job satisfaction, which could influence musculoskeletal pain.

Recent research has demonstrated strong associations between psychosocial work factors and musculoskeletal disorders among various occupational groups [34,35]. For instance, job demands, job control, and social support have been identified as key psychosocial factors influencing the development and persistence of work-related musculoskeletal pain [36]. Future studies in this field should incorporate measures of psychosocial work factors to provide a more comprehensive understanding of the complex interplay between physical behaviors, psychosocial factors, and musculoskeletal health in viticulture workers.

Our study did not consider the potential impact of Long COVID, which could affect workers' physical behaviors and pain reports. Future studies should consider this factor, especially in research conducted during or after the COVID-19 pandemic. The binary categorization of pain intensity may have simplified the complex nature of pain experiences. Future analyses could consider using the full pain scale to provide more nuanced insights.

Despite these limitations, our study has several strengths. Using accelerometry to objectively measure physical behaviors provides more accurate and reliable data than self-reported measures. Including work and non-work periods allows a more comprehensive understanding of workers' behavior patterns. Examining pain in three distinct body regions (neck, upper back, and lower back) provides a more complete picture of workers' musculoskeletal health. The inclusion of demographic variables such as age, sex, and BMI in the analysis allows for a more nuanced understanding of factors influencing musculoskeletal pain. Finally, our study provides novel insights into the relationship between sedentary behaviors and musculoskeletal pain in viticulture workers, contributing to the existing literature on occupational health.

Furthermore, our study primarily focused on pain intensity as an outcome measure. We recognize that pain is a multidimensional experience, and future studies could benefit from including other dimensions of pain and pain-related behavioral factors to provide a more comprehensive understanding of the relationship between physical behaviors and musculoskeletal pain.

These strengths and limitations should be considered when interpreting our findings and planning future research in this area.

4.5. Implications for Occupational Health in Viticulture

Our findings have several implications for occupational health practices in viticulture:

1. The need for interventions targeting sedentary behaviors both during work and non-work periods.
2. The importance of promoting good sleep hygiene to potentially reduce neck pain.
3. The need for gender-specific interventions, particularly for upper back pain.
4. The potential for age-tailored approaches to lower back pain management.

Based on this data, implementing ergonomic tools and practices can significantly reduce physical strain and sedentary periods. Providing workers with ergonomically designed tools that minimize postural load and repetitive movements can enhance their physical activity levels and reduce sedentary behavior. Promoting sleep health by recognizing and incentivizing good sleep practices and implementing corrective measures, such as adjusting work shifts or providing sleep hygiene education, can enhance both worker well-being and economic outcomes.

5. Conclusions

This study provides novel insights into the relationships between physical behaviors and musculoskeletal pain among viticulture workers. Our findings challenge some existing assumptions about blue-collar work and highlight the complex interplay between work and non-work behaviors in occupational health. The lack of association between physical behaviors and lower back pain, coupled with the negative association between sleep on neck pain and the influence of non-work behaviors on upper back pain, suggests a need for holistic approaches to musculoskeletal health in this population.

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