

Article

Provincial Differences in Cardiometabolic and Work-Related Health Among Professional Spanish Wildland Firefighters: An Age- and Sex-Adjusted Cross-Sectional Study

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Abstract

Professional wildland firefighters are exposed to substantial physical, thermal, respiratory, and psychosocial demands. This cross-sectional study examined whether cardiometabolic and work-related health indicators differed among the five provinces of Castilla-La Mancha after accounting for age and sex. The analytical sample comprised 757 salaried GEACAM wildland firefighters (663 men and 94 women). Outcomes were visceral fat level, device-derived metabolic age, metabolic age gap, the Work Ability Index (WAI), the 14-item Perceived Stress Scale (PSS-14), self-rated health, and anxiety problems. Province effects were tested using heteroscedasticity-robust linear models or logistic regression, with age and sex as covariates. Adjusted pairwise provincial contrasts were corrected using Holm's method. Province was associated with visceral fat level ($F(4, 687) = 3.21, p = 0.013$, partial $R^2 = 0.021$) and PSS-14 score ($F(4, 685) = 4.64, p = 0.001$, partial $R^2 = 0.029$). No adjusted provincial association was found for metabolic age, metabolic age gap, WAI, self-rated health, or anxiety problems. After Holm correction, PSS-14 scores were lower in Albacete than in Guadalajara (adjusted difference = -3.17 , 95% CI -5.18 to -1.16 ; $p_{\text{Holm}} = 0.018$) and Toledo (-3.54 , 95% CI -5.36 to -1.72 ; $p_{\text{Holm}} = 0.001$). Although the global province effect for visceral fat was significant, no individual pairwise contrast remained significant after Holm correction. Provincial heterogeneity was therefore modest and concentrated in perceived stress and, less conclusively, visceral fat. These findings support age- and sex-adjusted surveillance while precluding causal explanations based on terrain, fire exposure, workload, or recovery, none of which were measured.

Keywords: professional wildland firefighters; occupational health; visceral fat; perceived stress; work ability; metabolic age; occupational surveillance; cross-sectional study



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1. Introduction

Wildland firefighting constitutes a distinct occupational-health setting. Professional wildland firefighters perform prolonged work over irregular terrain under heat stress,

smoke exposure, extended shifts, and restricted recovery. These conditions impose cardiovascular strain, thermoregulatory stress, respiratory exposure, dehydration, fatigue, and musculoskeletal load across the fire season. Previous studies have reported adverse metabolic and cardiovascular changes associated with wildland firefighting activity [1,2], while repeated-measures exposure research has emphasised the need to monitor smoke-related and physiological health outcomes in this workforce [3,4].

Cardiometabolic health is central to surveillance because demanding fire-suppression work is undertaken by workers whose risk profiles vary with age, sex, body composition, physical conditioning, recovery, and accumulated exposure. Visceral adiposity is associated with insulin resistance, dyslipidaemia, systemic inflammation, and cardiovascular risk [5]. Device-derived metabolic age may provide a supplementary descriptive indicator, but it is not a validated measure of biological ageing. Work ability and psychosocial status should also be considered because the Work Ability Index captures the balance between job demands and workers' physical and mental resources [6], while cumulative psychosocial stress may affect health, recovery, and work functioning [7].

Provincial differences may be relevant for workforce surveillance, but province is an organisational and geographical grouping variable rather than a direct exposure. Differences in terrain, fire-season intensity, crew organisation, travel, smoke exposure, health behaviours, or recovery could contribute to geographical patterns; however, these factors require direct measurement and cannot be inferred from province alone. Previous wildland-firefighter research has documented variation in health behaviours across crews and fire-season contexts [8], sex-related differences in body composition [9], and associations of age, work experience, physical activity, and health with work ability [10–14].

The primary aim is to determine whether visceral fat, device-derived metabolic age, metabolic age gap, work ability, perceived stress, self-rated health, and anxiety differed among the five provinces of Castilla-La Mancha after adjustment for age and sex. We hypothesised that provincial differences would remain for selected cardiometabolic and psychosocial indicators, but expected their magnitude to be small because province is an indirect grouping variable. A secondary aim was to quantify adjusted pairwise provincial differences with confidence intervals and correction for multiple comparisons.

2. Materials and Methods

Study design

This observational, cross-sectional occupational-health study used the 2018 health-assessment records of professional GEACAM wildland firefighters in Castilla-La Mancha, Spain. Participants were grouped by work province: Albacete, Ciudad Real, Cuenca, Guadalajara, and Toledo. The report follows the STROBE recommendations for cross-sectional studies [15].

Participants

The analytical sample comprised 757 salaried GEACAM employees assigned to the regional wildfire-prevention and suppression service; volunteers were not included. The sample included 663 men and 94 women. Recorded summer and winter duties included forest specialist, crew leader, fire-engine or support-vehicle driver, helitack specialist, lookout, coordinator, and technical or administrative support. Province-specific demographic characteristics are presented in Table 1. Chronological age was available directly or was calculated from year of birth using the 2018 assessment year.

Before data collection, participants were informed about the aims and procedures of the occupational-health assessment. Participation was voluntary, and all data were anonymised before analysis to preserve confidentiality. The study was conducted in accordance with the Declaration of Helsinki and institutional requirements for research

involving anonymised occupational-health data. The project was reviewed and approved by the University Research Ethics Committee of Universidad Europea (approval code: CI 2024-499; 25 January 2024).

Table 1. Participant characteristics by province.

Province	<i>n</i>	Men, <i>n</i> (%)	Women, <i>n</i> (%)	Age Available, <i>n</i>	Age, Years
Albacete	137	132 (96.4)	5 (3.6)	132	45.31 ± 8.20
Ciudad Real	166	151 (91.0)	15 (9.0)	152	43.76 ± 8.99
Cuenca	156	129 (82.7)	27 (17.3)	152	44.09 ± 9.13
Guadalajara	109	89 (81.7)	20 (18.3)	106	40.27 ± 8.01
Toledo	189	162 (85.7)	27 (14.3)	178	43.20 ± 9.30
Total	757	663 (87.6)	94 (12.4)	720	43.46 ± 8.92

Age values are mean ± standard deviation. Percentages are calculated within province. Age was available for 720 participants.

Occupational-health assessment

The assessment included body-composition, work-ability, psychological, and perceived-health indicators. Visceral fat level and metabolic age were obtained by segmental bioelectrical impedance. The metabolic age gap was calculated as device-derived metabolic age minus chronological age. Work ability was assessed with the WAI, perceived stress with the PSS-14, anxiety with the corresponding EQ-5D-5L dimension, and self-rated health with the EQ visual analogue scale [16].

Body-composition measurements were obtained using the RD-545HR device (TANITA Europe) under the standard assessment protocol. Visceral fat level and metabolic age are proprietary estimates generated by the device. They were treated as surveillance indicators and not as direct measurements of visceral adipose tissue, clinical disease, or biological ageing.

Metabolic age differential

The metabolic age gap was defined as metabolic age minus chronological age. Positive values indicate that the device estimate exceeded chronological age; negative values indicate the opposite. This difference was analysed as a continuous device-derived measure and was not labelled as accelerated biological ageing.

Work ability and psychosocial variables

The WAI total score was reconstructed from the recorded seven-domain components using the standard scoring procedure [6,17]: current work ability; work ability in relation to physical and mental demands; physician-diagnosed diseases; estimated work impairment due to disease; sickness absence; personal prognosis of work ability; and mental resources. Scores range from 7 to 49 and are conventionally classified as poor (7–27), moderate (28–36), good (37–43), or excellent (44–49). The database field labelled ‘wai’ was not used because it contained a three-category code rather than the total WAI score. PSS-14 items were scored from 0 to 4, with items 4, 5, 6, 7, 9, 10, and 13 reverse-scored before summation; higher totals indicate greater perceived stress [18]. Self-rated health was expressed on the EQ visual analogue scale from 0 to 100, with higher values indicating better health [16]. Anxiety was dichotomised as no reported problem versus any reported problem because the higher severity categories were sparse.

Study variables

The main explanatory variable was province. Outcomes were visceral fat level, metabolic age, metabolic age gap, WAI total score, PSS-14 total score, EQ visual analogue scale, and the presence of any anxiety problem. Age and sex were prespecified covariates. Province was not treated as a causal exposure.

Age and sex were included because both are related to body composition and may differ across provincial workforces. The adjusted analysis therefore estimates provincial differences at a common age and sex distribution rather than comparing unadjusted provincial averages.

Statistical analysis

Analyses were conducted in Python 3.11 using NumPy, SciPy, and statsmodels. Continuous outcomes were analysed using linear regression with province as a categorical factor and age and sex as covariates. HC3 heteroscedasticity-robust standard errors were used because several outcomes were non-normally distributed and residual variance was not assumed to be constant. Anxiety was analysed with binomial logistic regression using the same predictors. The overall province effect was tested jointly across the four province coefficients. Effect size was expressed as partial R^2 for linear models and incremental McFadden pseudo- R^2 for the logistic model. Adjusted marginal means or predicted prevalences and 95% confidence intervals were calculated at the analytical-sample mean age and sex distribution. For outcomes with a significant overall province effect, all ten adjusted pairwise provincial contrasts were estimated and Holm-corrected within outcome. Complete-case analysis was used separately for each model. Of 757 participants, available values were: age, 720; visceral fat, 717; metabolic age, 717; metabolic age gap, 694; reconstructed WAI, 640; PSS-14, 715; self-rated health, 735; and anxiety, 738. Adjusted analytical samples were 694 for visceral fat, metabolic age, and metabolic age gap; 622 for WAI; 692 for PSS-14; 712 for self-rated health; and 715 for anxiety. Two-sided statistical significance was set at $p < 0.05$.

3. Results

The sample comprised 757 professional wildland firefighters from Albacete ($n = 137$), Ciudad Real ($n = 166$), Cuenca ($n = 156$), Guadalajara ($n = 109$), and Toledo ($n = 189$). There were 663 men and 94 women. Mean age among the 720 participants with age data was 43.46 ± 8.92 years. Participant characteristics by province are presented in Table 1.

Adjusted marginal estimates and overall province tests are presented in Table 2. Province was associated with visceral fat level ($F(4, 687) = 3.21$, $p = 0.013$, partial $R^2 = 0.021$) and PSS-14 score ($F(4, 685) = 4.64$, $p = 0.001$, partial $R^2 = 0.029$). The corresponding effect sizes were small. There was no adjusted province association for metabolic age ($p = 0.183$), metabolic age gap ($p = 0.183$), WAI ($p = 0.450$), self-rated health ($p = 0.768$), or anxiety problems ($p = 0.139$).

Table 2. Age- and sex-adjusted provincial estimates and overall province effects.

Outcome	<i>n</i>	Adjusted Provincial Estimate (95% CI)	Overall Province Effect
Visceral fat level	694	Albacete: 8.80 (8.02–9.57); Ciudad Real: 8.46 (7.98–8.94); Cuenca: 8.25 (7.81–8.70); Guadalajara: 7.43 (6.82–8.04); Toledo: 7.65 (7.18–8.13)	$p = 0.013$; partial $R^2 = 0.021$
Metabolic age, y	694	Albacete: 40.79 (38.80–42.79); Ciudad Real: 40.06 (38.16–41.95); Cuenca: 39.20 (37.53–40.87); Guadalajara: 37.67 (35.45–39.89); Toledo: 38.19 (36.54–39.85)	$p = 0.183$; partial $R^2 = 0.010$
Metabolic age gap, y	694	Albacete: -2.65 (-4.65 – -0.66); Ciudad Real: -3.39 (-5.28 – -1.49); Cuenca: -4.24 (-5.92 – -2.57); Guadalajara: -5.78 (-8.00 – -3.56); Toledo: -5.25 (-6.91 – -3.60)	$p = 0.183$; partial $R^2 = 0.010$

Table 2. Cont.

Outcome	<i>n</i>	Adjusted Provincial Estimate (95% CI)	Overall Province Effect
WAI total	622	Albacete: 43.84 (43.22–44.46); Ciudad Real: 44.12 (43.55–44.68); Cuenca: 43.84 (43.19–44.49); Guadalajara: 43.80 (43.22–44.38); Toledo: 43.40 (42.90–43.90)	$p = 0.450$; partial $R^2 = 0.006$
PSS-14	692	Albacete: 25.43 (23.90–26.97); Ciudad Real: 26.74 (25.37–28.10); Cuenca: 27.52 (26.43–28.61); Guadalajara: 28.61 (27.32–29.89); Toledo: 28.98 (28.05–29.91)	$p = 0.001$; partial $R^2 = 0.029$
Health VAS	712	Albacete: 81.98 (79.95–84.01); Ciudad Real: 81.21 (79.11–83.31); Cuenca: 81.54 (79.36–83.71); Guadalajara: 80.68 (78.38–82.98); Toledo: 82.58 (80.65–84.52)	$p = 0.768$; partial $R^2 = 0.003$
Any anxiety, %	715	Albacete: 5.3% (1.4–9.2); Ciudad Real: 7.8% (3.7–11.9); Cuenca: 4.2% (1.0–7.3); Guadalajara: 7.3% (2.3–12.3); Toledo: 11.2% (6.4–15.9)	$p = 0.139$; Δ McFadden $R^2 = 0.019$

Values are adjusted marginal means with 95% confidence intervals, except anxiety, which is the adjusted predicted prevalence. Partial R^2 quantifies the province contribution in linear models; incremental McFadden pseudo- R^2 is shown for anxiety.

All adjusted post hoc contrasts for visceral fat and PSS-14 are reported in Table 3. No individual visceral-fat contrast remained significant after Holm correction, despite the significant overall province test. PSS-14 scores were lower in Albacete than in Guadalajara (adjusted difference = -3.17 points, 95% CI -5.18 to -1.16 ; $p_{\text{Holm}} = 0.018$) and Toledo (-3.54 points, 95% CI -5.36 to -1.72 ; $p_{\text{Holm}} = 0.001$). No other PSS-14 contrast remained significant after correction.

Table 3. Adjusted pairwise provincial contrasts for outcomes with a significant overall province effect.

Outcome	Contrast	Adjusted Difference (95% CI)	<i>p</i> Values
Visceral fat	Albacete—Ciudad Real	0.34 (-0.58 to 1.25)	raw 0.471; Holm 1.000
Visceral fat	Albacete—Cuenca	0.54 (-0.35 to 1.43)	raw 0.232; Holm 0.927
Visceral fat	Albacete—Guadalajara	1.36 (0.36 to 2.37)	raw 0.008; Holm 0.078
Visceral fat	Albacete—Toledo	1.14 (0.22 to 2.06)	raw 0.015; Holm 0.119
Visceral fat	Ciudad Real—Cuenca	0.21 (-0.45 to 0.87)	raw 0.538; Holm 1.000
Visceral fat	Ciudad Real—Guadalajara	1.03 (0.25 to 1.81)	raw 0.010; Holm 0.089
Visceral fat	Ciudad Real—Toledo	0.81 (0.12 to 1.49)	raw 0.021; Holm 0.144
Visceral fat	Cuenca—Guadalajara	0.82 (0.06 to 1.58)	raw 0.034; Holm 0.204
Visceral fat	Cuenca—Toledo	0.60 (-0.05 to 1.25)	raw 0.070; Holm 0.352
Visceral fat	Guadalajara—Toledo	-0.22 (-0.98 to 0.54)	raw 0.571; Holm 1.000
PSS-14	Albacete—Ciudad Real	-1.30 (-3.35 to 0.75)	raw 0.214; Holm 0.824
PSS-14	Albacete—Cuenca	-2.09 (-3.99 to -0.19)	raw 0.031; Holm 0.217
PSS-14	Albacete—Guadalajara	-3.17 (-5.18 to -1.16)	raw 0.002; Holm 0.018
PSS-14	Albacete—Toledo	-3.54 (-5.36 to -1.72)	raw 0.000; Holm 0.001
PSS-14	Ciudad Real—Cuenca	-0.79 (-2.54 to 0.97)	raw 0.379; Holm 0.824
PSS-14	Ciudad Real—Guadalajara	-1.87 (-3.76 to 0.02)	raw 0.052; Holm 0.279
PSS-14	Ciudad Real—Toledo	-2.24 (-3.90 to -0.58)	raw 0.008; Holm 0.066
PSS-14	Cuenca—Guadalajara	-1.08 (-2.76 to 0.60)	raw 0.206; Holm 0.824
PSS-14	Cuenca—Toledo	-1.45 (-2.88 to -0.02)	raw 0.046; Holm 0.279
PSS-14	Guadalajara—Toledo	-0.37 (-1.92 to 1.18)	raw 0.641; Holm 0.824

Differences are first province minus second province. p_{Holm} values were corrected across the ten provincial contrasts within each outcome. CI: confidence interval.

The reconstructed WAI averaged 43.76 ± 3.30 points among 640 participants with complete component data; 24 participants (3.8%) had moderate, 231 (36.1%) good, and 385 (60.2%) excellent work ability, with no poor scores. The mean metabolic age gap was -4.01 ± 11.12 years among 694 participants, but this device-derived difference showed no adjusted provincial association.

Missingness was outcome-specific rather than concentrated in a single province. Because each adjusted model required age, sample sizes were lower than the number with the outcome alone. No imputation was performed, and the exact model sample is reported in Table 2.

4. Discussion

The principal finding was that age- and sex-adjusted provincial heterogeneity was limited. Province explained approximately 2.1% of residual variance in visceral fat and 2.9% in perceived stress, while no adjusted differences were detected for metabolic age, metabolic age gap, work ability, self-rated health, or anxiety. The adjusted analysis therefore materially changes the unadjusted interpretation: the lower metabolic-age values previously observed in Guadalajara were largely attributable to age and sex composition rather than an independent province association.

The attenuation of several unadjusted provincial differences after covariate adjustment is methodologically important. In a workforce with unequal age and sex distributions across provinces, crude means can overstate geographical variation and encourage explanations that are not supported by the data. The adjusted results indicate that province should be interpreted as a contextual marker for further investigation, not as an independent determinant of health.

The significant overall visceral-fat result should be interpreted cautiously. Adjusted means ranged from 7.43 in Guadalajara to 8.80 in Albacete, but none of the ten pairwise contrasts survived Holm correction. This pattern is compatible with a small distributed province effect rather than a clearly isolated high-risk province. Visceral adiposity remains relevant because of its established association with insulin resistance, dyslipidaemia, inflammation, and cardiovascular risk [5], and because wildland firefighting imposes substantial cardiovascular and thermal demands [1,2,19–21]. The present data, however, do not justify attributing the observed values to province-specific terrain, workload, smoke exposure, or recovery.

Perceived stress showed the clearest adjusted geographical pattern. Albacete had lower PSS-14 scores than Guadalajara and Toledo after correction for age, sex, and multiple pairwise testing. The absolute differences were modest, and the cross-sectional design does not identify their cause. Organisational climate, staffing, travel, fire-season activity, personal circumstances, and recovery may all influence stress, but none was measured. Previous reviews describe firefighter stress as a product of interacting individual, occupational, and environmental factors [7,19,20,22–24]. Provincial stress differences should therefore trigger more detailed assessment rather than assumptions about their origin.

The stress findings may nevertheless be relevant because psychosocial strain can affect sleep, recovery, musculoskeletal symptoms, and broader health in firefighters [7,19,20,22–24]. PSS-14 measures perceived stress rather than a specific occupational exposure, so the observed differences may reflect both working conditions and circumstances outside work. Repeated within-worker assessment across the fire season would help distinguish persistent organisational differences from temporary fluctuations in perceived demand.

Work ability was generally favourable and did not differ by province. This result is more credible after reconstruction of the standard 7–49 WAI total; the three-category

database field previously used in the manuscript was not a valid total score. The absence of a province association does not diminish the value of WAI, which integrates health, functional resources, sickness absence, and perceived capacity [6,10–13]. Similarly, metabolic age and the metabolic age gap should remain secondary descriptive measures. They are device-dependent estimates influenced by the bioimpedance algorithm and measurement conditions and cannot be interpreted as direct evidence of biological ageing.

The coexistence of favourable WAI scores with provincial differences in perceived stress and small differences in visceral fat also shows that these indicators are not interchangeable. WAI reflects the balance between health resources and job demands, whereas PSS-14 and visceral fat capture distinct psychosocial and cardiometabolic domains [5–7,10–13]. Occupational surveillance should therefore retain separate domain-specific measures rather than reducing workforce health to a single composite classification.

The findings also require placement within the broader carcinogenic-exposure context. IARC classifies occupational exposure as a firefighter as carcinogenic to humans (Group 1), with sufficient evidence for mesothelioma and bladder cancer and limited evidence for several other malignancies [25–29]. This study did not measure combustion products, dermal contamination, diesel exhaust, ultraviolet exposure, fire attendance, or cancer outcomes; its cardiometabolic and psychosocial indicators are not proxies for carcinogen dose or cancer risk. Their value lies in complementing, not replacing, exposure control and cancer-focused surveillance. Preventive programmes should combine documented exposure histories, contamination-control procedures, appropriate respiratory and dermal protection, medical follow-up, and the cardiometabolic, work-ability, and psychological assessments examined here.

Several limitations require emphasis. The cross-sectional design prevents causal inference. Province was an indirect grouping variable, and potentially explanatory factors such as fire exposure, task intensity, terrain, shift pattern, sleep, nutrition, physical fitness, medication, and recovery were not measured in the adjusted models. Missing data reduced the analytical sample to between 622 and 715 participants; complete-case estimates may be biased if missingness depended on unobserved health status. Metabolic age and visceral fat were device-derived. Anxiety was dichotomised because severe categories were sparse. The WAI was reconstructed from recorded component responses, although the standard scoring rules were applied explicitly. Finally, the study represents one regional professional workforce and should not be generalised to volunteers, structural firefighters, or other services without further evidence.

Practical Applications

The results support proportionate surveillance. Province-specific action is most defensible for investigating perceived-stress differences, while visceral-fat findings warrant workforce-wide cardiometabolic monitoring rather than labelling a single province. Repeated assessments should incorporate direct measures of smoke and heat exposure, fire attendance, shift duration, sleep, recovery, physical fitness, and cardiometabolic biomarkers. Longitudinal models could then determine whether changes in exposure or work organisation precede changes in health.

At an organisational level, standardised cardiometabolic, work-ability, and psychosocial assessments should be applied consistently across all provinces, while provinces with higher adjusted PSS-14 values should receive a structured review of staffing, shift organisation, travel burden, supervisory support, recovery opportunities, and recent fire-season activity. The objective is to identify modifiable conditions, not to classify a province or its personnel as intrinsically high-risk.

At the individual level, elevated visceral fat, high perceived stress, or declining WAI should prompt confidential occupational-health follow-up based on repeated measurements rather than a single assessment. Body-composition findings should be interpreted alongside blood pressure, lipid and glucose markers, physical fitness, sleep, symptoms, medication, and documented exposure history [3,4,8,16–21]. These measures should complement exposure control, decontamination, respiratory and dermal protection, and cancer-focused surveillance required by the Group 1 carcinogenic classification of occupational exposure as a firefighter [25,27].

5. Conclusions

In 757 professional GEACAM wildland firefighters, age- and sex-adjusted provincial differences were small and confined to perceived stress and the overall visceral-fat model. PSS-14 scores were lower in Albacete than in Guadalajara and Toledo, whereas no individual visceral-fat contrast remained significant after Holm correction. Metabolic age, metabolic age gap, WAI, self-rated health, and anxiety did not differ by province after adjustment. Province should therefore be used as a surveillance stratum, not as a causal explanation. Future longitudinal assessment must directly measure fire exposure, job demands, and recovery and should integrate cancer-exposure control with cardiometabolic, work-ability, and psychological surveillance.

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Informed Consent Statement: Before data collection, participants were informed about the aims and procedures of the occupational-health assessment. Participation was voluntary, and all data were anonymised before analysis to preserve confidentiality.

Data Availability Statement: The datasets analysed during the current study are not publicly available due to institutional and confidentiality restrictions related to occupational-health records. Anonymised data may be made available from the corresponding author upon reasonable request and subject to approval by the relevant institutional authorities.

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